

# Uptake Of Diquat In Parrotfeather<sup>1</sup>

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## INTRODUCTION

Chemicals can provide an efficient and effective means of either eliminating or reducing the growth of undesirable aquatic plants. Because of the many uses placed on present water supplies, chemicals applied for the control of aquatic plants must not render the water unusable for other purposes.

The chemical 6,7-dihydrodipyrido [1,2-a:2',1'-c] pyrazidiinium salt (diquat) is particularly effective in alleviating problems in aquatic environments due to the excessive growth of certain plants (2, 8, 14, 15). This chemical has two characteristics which make it extremely valuable as a herbicide in an aquatic environment. Diquat has a low toxicity to fish and dissipates rapidly in water (3, 4, 12, 15).

This investigation was designed to evaluate the effect of diquat on growth and transpiration of emerged parrotfeather, *Myriophyllum brasiliense* Camb. and to determine the uptake of diquat-<sup>14</sup>C after foliar and root applications.

## METHODS AND MATERIALS

### Culture of parrotfeather

Emerged parrotfeather was obtained by vegetative propagation from greenhouse stock cultures (11). Plant age was the length of time the plants were grown in a growth chamber with a photoperiod of 1900 ft-c of light at the plant surface for 14 hr, followed by darkness for 10 hr. A temperature of 25° and 23° C was maintained for the light and dark periods, respectively. The plants were grown in one-half strength Hoagland's No. 1 nutrient solution (9), with Sequestrene 138 Fe as a source of iron. Plants of uniform shoot size were selected and treatments were applied according to a randomized block design.

### Effect of diquat on growth and transpiration.

Emerged plants were treated singly in aluminum foil-coated glass jars containing 350 ml of treatment solution. The top of the jar was covered with aluminum foil and the plant shoot was above the foil. The plant roots were submerged in the treatment solution by inserting them through a small hole in the foil. The roots of 1-week-old plants were placed in solutions containing diquat at concentrations of 2.00, 0.200, 0.020 and 0.002 ppmw cation. Diquat at 0.110, 0.020, 0.011 and 0.002 ppmw cation was used to treat the roots of 2-week-old plants. Each treat-

ment concentration and the control were replicated three times. Transpiration was determined by measuring the amount of one-half strength nutrient solution necessary to restore the original weight of the treatment containers. The containers were corrected for evaporation loss. Fresh and dry weight was determined 2 weeks after treatment of the 1-week-old plants. Shoot length was determined at weekly intervals and dry weight after 3 weeks for the 2-week-old plants treated with diquat.

### Uptake of diquat-<sup>14</sup>C.

Diquat labeled in the ethylene bridge of the molecule with carbon-14 (specific activity of 7.6  $\mu$ C/mg) was used to study the uptake of diquat in parrotfeather. Diquat-<sup>14</sup>C was mixed in 50% ethyl alcohol and 0.1% Tween 20 (containing polyoxyethylene sorbitan monolaurate) before foliar applications. Procedures for determining radioactivity in parrotfeather were described by Sutton and Bingham (11).

TABLE 1. EFFECT OF ROOT APPLICATIONS OF DIQUAT ON GROWTH AND TRANSPIRATION OF 1-WEEK-OLD EMERSED PARROTFEATHER.

Diquat cation (ppmw)	Weight (g) <sup>a</sup>				Transpiration (ml) <sup>a</sup>	
	Fresh		Dry		Weeks	
	Shoot	Root	Shoot	Root	1	2
2,000	0.2 a	0.4 a	0.09 a	0.05 a	38 a	1 a
0.200	3.0 c	0.8 ab	0.52 a	0.11 a	111 b	20 a
0.020	10.9 d	2.9 c	1.76 b	0.30 a	169 c	246 d
0.002	10.9 d	2.6 bc	1.33 b	0.24 a	163 c	245 d
Control	10.4 d	2.2 bc	1.38 b	0.23 a	167 c	214 d

<sup>a</sup>Values for fresh weight, dry weight, or transpiration followed by a common letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test. Mean of three replications.

The plants in experiment 1 were freeze-dried after treatment. In experiments 2 and 3 the plants were oven-dried at 70 C for 48 hrs after treatment.

The roots of 1-week-old plants were placed in a 1.0 ppmw diquat-<sup>14</sup>C cation solution for 3, 12, 48, and 192 hr in experiment 1. Two plants were placed in 350 ml of treatment solution. Control plants received only nutrient solution.

For experiment 2, 2.0  $\mu$ g diquat-<sup>14</sup>C cation in 10  $\mu$ l were placed on mature leaves in the shoot center of 17-day-old plants and immediately placed in the dark at 23 C for 48 and 72 hrs. After the dark period the plants were placed in the growth chamber for 4 days. Controls, plants which did not receive a dark period after treatment, remained in the growth chamber for 6 days. Each treatment was duplicated.

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TABLE 2. EFFECT OF ROOT APPLICATIONS OF DIQUAT ON GROWTH AND TRANSPIRATION OF 2-WEEK-OLD EMERSED PARROTFEATHER.

Diquat cation (ppmw)	Dry weight (g) <sup>a</sup>		Shoot length (cm) <sup>a</sup>			Transpiration (ml) <sup>a</sup>		
	Shoot	Root	Weeks			Weeks		
			1	2	3	1	2	3
0.110	0.40 a	0.09 a	34 a	35 a	35 a	54 a	16 a	24 a
0.020	1.10 b	0.21 a	52 ab	62 ab	87 bcd	144 b	132 b	172 bc
0.011	1.86 c	0.23 a	77 abc	108 bcd	148 e	216 bcde	277 def	339 f
0.002	1.54 c	0.19 a	50 ab	78 abc	119 cde	170 bc	250 cdef	309 ef
Control	1.62 c	0.33 a	58 ab	89 bcd	129 de	186 bcd	268 cdef	318 f

<sup>a</sup>Values for dry weight, shoot length, or transpiration followed by a common letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test. Mean of three replications.

In experiment 3, the roots of 2-week-old plants were placed in solutions containing 0.02 ppmw diquat-<sup>14</sup>C and 10<sup>-3</sup>, 10<sup>-4</sup>, or 10<sup>-5</sup> M dinitrophenol (DNP). Control plants received no DNP, only diquat-<sup>14</sup>C and nutrient solution. Two plants were placed in 350 ml of solution with each treatment concentration duplicated. The plants were removed from the solutions after 48 hrs.

**RESULTS**

**Effect of diquat on growth and transpiration.**

There was a reduction in shoot weight 2 weeks after the roots of 1-week-old emerged parrotfeather were placed in a solution of 0.2 ppmw diquat. Transpiration of plants 1 week after treatment with 2.0 ppmw was lower than the controls. After 2 weeks transpiration was reduced by the same concentration of diquat that reduced plant weight.

Shoot length of the 2-week-old plants was reduced by 0.11 ppmw diquat 3 weeks after treatment; shoot weight, however, was reduced by 0.02 ppmw (Table 2). Tran-

spiration was lower after 1 and 2 weeks for those plants whose roots were in solutions containing 0.11 ppmw diquat, but 3 weeks after treatment transpiration was reduced by the 0.02 ppmw concentration.

There was an interaction between time and transpiration during treatment of the 1-week-old plants. No interaction was observed between time and either transpiration or shoot length during treatment of the 2-week-old plants.

**Uptake of diquat-<sup>14</sup>C.**

Radioactivity was not detected in the shoots of plants whose roots were treated with 1.0 ppmw diquat-<sup>14</sup>C. However, there was a rapid increase of radioactivity in the roots for 48 hr followed by a more gradual increase for 192 hr (Figure 1).

There was no radioactivity in the shoot top or in the shoot below the leaves treated with 2.0 µg diquat-<sup>14</sup>C for 6 days. The treated sections of the plants contained an average of 218 cpm per mg of dry tissue. The plants placed in the darkness for 48 and 72 hr contained an average of 509 and 376 cpm per mg dry tissue, respectively in the treated sections. No radioactivity was detected above or below the treated leaves of the plants placed in darkness after treatment.

The DNP did not cause diquat-<sup>14</sup>C to move to the shoots from the roots. The plants whose roots were placed in 1.0 ppmw diquat-<sup>14</sup>C contained 339 cpm/mg dry weight of root tissue 48 hr after treatment. The roots of those plants in solutions containing diquat-<sup>14</sup>C and 10<sup>-3</sup>, 10<sup>-4</sup>, or 10<sup>-5</sup> M DNP contained 310, 339, and 345 cpm/mg dry weight, respectively.

**DISCUSSION**

It appeared that the older parrotfeather were more susceptible to the phytotoxic effect of diquat than were the younger plants. Growth of the 2-week-old plants was reduced by 0.02 ppmw diquat, while a concentration of 0.2 ppmw was necessary to inhibit growth of the 1-week-old plants. The interaction of time with transpiration measurements suggests that other factors in addition to plant age may have contributed to this difference of phytotoxic effect.

There was no translocation of labeled material after foliar or root applications of diquat-<sup>14</sup>C in parrotfeather. Other workers (1, 13) have found that diquat moved in the apoplast of some plants. It appears that plant species differ in the translocation of diquat. For example, some plants do not translocate 2,4-dichlorophenoxyacetic acid (2,4-D) to the same extent after root applications (5).

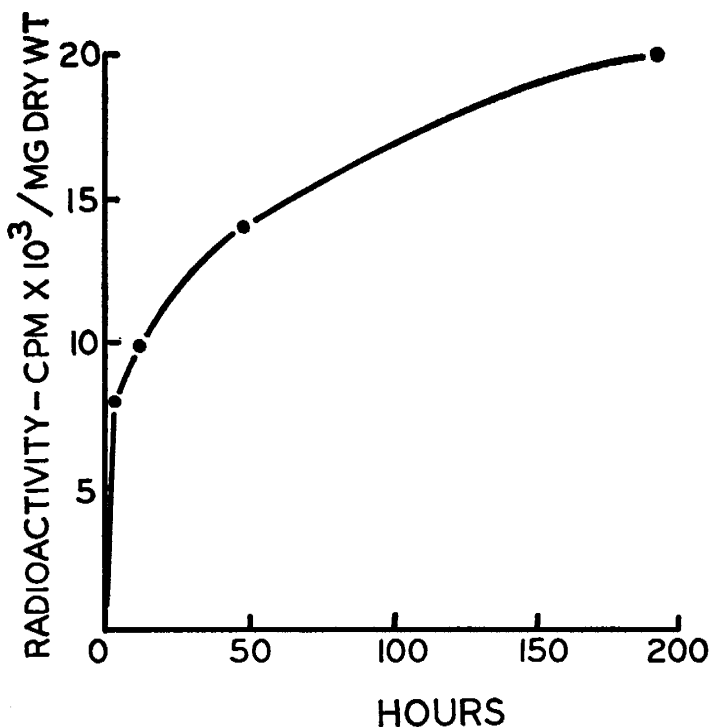


Figure 1. Uptake of diquat-<sup>14</sup>C by the roots of emerged parrotfeather.

Although darkness has been found to increase the absorption of diquat with subsequent translocation of the herbicide (10), this environmental condition did not enhance translocation of diquat-<sup>14</sup>C after foliar applications to parrotfeather. Since parrotfeather has a strong transpiration stream, apparently diquat did not enter the xylem of the plant where translocation of diquat could occur.

Metabolic accumulation was reported as one of the mechanisms involved in the long term uptake of diquat-<sup>14</sup>C in elodea *Elodea canadensis* Michx (6).

It appeared that metabolic energy was not involved in the uptake of diquat-<sup>14</sup>C after root applications to parrotfeather when DNP was used to reduce metabolic energy in the root cells. A reduction of energy in the root cells did not result in the movement of diquat-<sup>14</sup>C to the shoot by the transpiration stream. The diquat-<sup>14</sup>C was taken up very rapidly by the roots due to forces which did not involve metabolic energy. Uptake of diquat-<sup>14</sup>C by the roots of parrotfeather appeared to be a passive adsorption process. Since no degradation products have been found after treatment of diquat to plants (1, 7), it is assumed that the uptake of diquat by the roots of parrotfeather was the intact molecule.

### SUMMARY

Growth of emerged parrotfeather was inhibited by root applications of 0.02 ppmw diquat in nutrient culture in controlled environment conditions. Older plants appeared to be more susceptible to the phytotoxic effect of diquat. Diquat-<sup>14</sup>C was not translocated after it was applied to the foliage of emerged parrotfeather. The metabolic inhibitor, dinitrophenol, did not affect uptake of diquat by the

roots or cause translocation of diquat out of the root zone.

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