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Fluridone - A New Aquatic Herbicide

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ABSTRACT

A new experimental herbicide 1-methyl-3-phenyl-5-(3-trifluoromethyl) phenyl)-4-(1H)-pyridinone (Fluridone) is active in aquatic systems at rates as low as 1.12 kg/ha. Effective conrol can be obtained using either surface or bottom application techniques. Fluridone is a safe, slow-acting, translocated herbicide that provides control of aquatic plants without affecting phytoplankton, zooplankton, benthic organisms or fish. Fluridone does not affect water quality and appears to increase the dissolved oxygen concentration within the water profile.

INTRODUCTION

Fluridone is a new herbicide that was first evaluated in aquatic systems by Lilly Research Laboratories. Results of early trials showed that fluridone provided effective control of various rooted aquatic vascular plants. Field trials were initiated to further evaluate the efficacy of fluridone in aquatic systems.

MATERIALS AND METHODS

Field experiments were established to evaluate the efficacy of fluridone on aquatic plants, and its impact on phytoplankton, zooplankton, benthic organisms and water quality parameters. Fluridone as an aqueous suspension (4 lb/gal) was applied at rates of 0.1, 0.2, 0.3, 0.4 and 1.0 ppm as surface or layered bottom acre foot treatment. Treated ponds ranged in size from 0.004 to 0.69 hectares with water depth varying from 0.69 to 1.3 meters. Fluridone was also evaluated using application rates based on the amount of active ingredient per surface area treated. Application was made as a layered bottom acre foot treatment at rates of 0.28, 0.56, 1.12 and 1.68 kg/ha. Ponds treated in this manner ranged in size from 0.07 to 0.8 hectares and had an average depth of 5.5 meters.

Surface applications were made with an airboat equipped with a conventional pump operated at 100 psi using a hand-help spray gun which delivered a volume of 421 l/ha. Bottom applications were made with an airboat equipped with a two-stage piston pump operated at 100 psi to deliver 449 l/ha through three weighted trailing hoses.

Dissolved oxygen, water temperature and pH were recorded in the field for both top and bottom of the water column prior to application and 1, 3, 7, 14, 21, 28 and 42 days following treatment. Laboratory analyses were conducted on water samples to determine alkalinity, ammonia, biological oxygen demand, color, dissolved solids, hardness, nitrate nitrogen, specific conductance, total phosphate, and turbidity. Samples of water, sediment, plankton, fish and vegetation were collected on the above schedule for chemical analysis and identification. Plankton samples were collected by passing three liter water samples taken from ten different locations throughout the pond through s standard Wisconsin plankton net (No. 30 bolting silk). Plankton numbers were counted in the laboratory using a compound microscope equipped with an ocular micrometer (Whipple) and Sedgewich-Raft counting cell. Results were expressed as numbers of plankton per liter.

Benthic samples were taken from three stations in each pond using an Ekman dredge. The samples were composited and washed through a large-diameter number 30 screen. The coarse vegetation and other organic matter were washed several times and discarded. Organisms were placed in a plastic bag with the remaining organic debris, preserved with 5% formalin, and transferred to the laboratory. The benthos were sorted by mechanical means since the particulate residue was not suitable for sorting by flotation or elutriation. The organisms were removed from the detritus and placed in 10 ml bottles for positive identification.

The weed populations were mapped prior to treatment and at timely intervals thereafter. Each treatment pond was observed by scuba diving to determine the efficacy of fluridone on regrowth of aquatic vegetation.

RESULTS AND DISCUSSION

The typical fluridone symptom on submerged aquatic vegetation such as hydrilla is chlorosis of new growth. The symptom on aquatic weeds begins to appear three to six days after treatment, but little control is noticed until two to four weeks after treatment. The mature vegetation begins to sink to the bottom and the percent open water gradually increases (Table 1). Fluridone at all rates resulted in an increase in open water 29 days after treatment, with the higher rates being more effective. Eighty-one days after treatment 100 percent open water was observed with the 1.12 kg/ha rate of fluridone.

Table 1. Percent open water following treatment with Fluridone.

Rate (kg/ha)	Days After Treatment			
	1	29	57	81
0.28	0	30	23	50
0.56	0	30	78	80
1.12	0	60	95	100
1.68	0	75	96	100

The effect of fluridone on the control of hydrilla from tuber formation is presented in Table 2. Seven months after treatment, fluridone at rates of 1.12 and 1.68 kg/ha provided 80 and 92 percent control, respectively. The tubers germinated and grew to a height of approximately 6 to 15 centimeters before control was achieved. In other trials where fluridone was applied, 100 percent control of hydrilla tubers was observed eleven months after treatment at rates of 0.2 ppm and above.

Table 2. Percent control of hydrilla tubers seven months after treatment with Fluridone.

Rate (kg/ha)	Percent Control
0.28	0
0.56	0
1.12	80
1.68	92
Control	0

Fluridone at 1.68 kg/ha also provided excellent control of common elodea, southern naiad, cattail, paragrass and other species as listed in Table 3. Fluridone symptoms on these weeds were similar as described for hydrilla and comparable control was obtained with either method of application.

Table 3. A list of plants mentioned in the text which were also effectively controlled with Fluridone.

Hydrilla	*Hydrilla verticillata* Royle.
Common elodea	*Elodea canadensis* (Michx.) Planchon.
Fanwort	*Cabomba caroliniana* Gray.
Southern naiad	*Najas guadalupensis* (Spreng.) Magnus
Cattail	*Typha* spp.
Maidencane	*Panicum hemitomon* Schult.
Paragrass	*Panicum purpurascens* Raddi.
Torpedograss	*Panicum repens* L.
Arrowhead	*Sagittaria* spp.
Pickerelweed	*Pontederia cordata* L.
Spatterdock	*Nuphar advena* Ait.

The response data for beneficial, semi-beneficial, and noxious phyotoplankton when treated with fluridone at 1.12 and 1.68 kg/ha, are presented in table 4 and 5, respectively. Plankton numbers were not substantially reduced after herbicidal treatments with fluridone at 1.12 kg/ha. The pond treated with fluridone at 1.68 kg/ha shows that the organisms classified as noxious phytoplankton were reduced 60 percent three days after treatment as compared to the organisms classified as beneficial phytoplankton (Table 5).

One pond treated at 1.0 ppm or 15 kg/ha showed that

TABLE 4. PHYTOPLANKTON COUNTS (No. /l X 10^5) BEFORE AND AFTER TREATMENT WITH FLURIDONE AT 1.12 KG/HA.

Organism[1]	Days After Treatment					
	0[2]	1	3	8	15	22
Beneficial	79	60	79	89	81	97
Semi-beneficial	2	1	3	1	0	2
Noxious	55	46	52	57	83	108

1 Organisms classified as beneficial were: *Ceratium, Cryptomonas, Asterionella, Fragilaria,* and *Synedra;* Semi-beneficials were: *Closterium* and *Staurastrum;* Noxious were: *Anabaena, Anacystis, Gomphosphaeria, Nostoc, Oscillatoria, Rivularia,* and *Oedogonium.*
2 0 is equal to the pretreatment observation.

TABLE 5. PHYTOPLANKTON COUNTS (No. /l X 10^5) BEFORE AND AFTER TREATMENT WITH FLURIDONE AT 1.68 KG/HA.

Organism[1]	Days After Treatment					
	0[2]	1	3	8	15	22
Beneficial	37	40	38	46	55	61
Semi-beneficial	34	20	23	16	13	6
Noxious	104	91	41	47	80	170

1 Organisms classified as beneficial were: *Ceratium, Cryptomonas, Asterionella, Fragilaria,* and *Synedra;* Semi-beneficials were: *Closterium* and *Staurastrum;* Noxious were: *Anabaena, Anacystis, Gomphosphosphaeria, Nostoc, Oscillatoria, Rivularia,* and *Oedogonium.*
2 0 is equal to the pretreatment observation.

fluridone did not reduce any groups of algae for prolonged periods (Table 6). The beneficial group of plankton was reduced by 77 percent three days after treatment while the noxious organisms were reduced by 74 percent. Eight days after treatment the beneficial plankton were reduced 55 percent while the noxious plankton were reduced 92 percent. The beneficial plankton appeared to develop faster in the system than the noxious group of plankton.

TABLE 6. PHYTOPLANKTON COUNTS (No. /l X 10^5) BEFORE AND AFTER TREATMENT WITH FLURIDONE AT 1.0 PPM.

Organism[1]	Days After Treatment						
	0[2]	1	3	8	15	22	28
Beneficial	9	5	2	4	2	3	7
Semi-beneficial	2	1	1	4	1	0	0
Noxious	131	108	34	11	13	28	83

1 Organisms classified as beneficial were: *Ceratium, Cryptomonas, Peridinium, Asterionella, Fragilaria, Navicula* and *Synedra;* Semi-beneficials were: *Closterium, Cosmarium, Pediastrum* and *Staurastrum;* Noxious were: *Anabaena, Anacystis, Gomphosphaeria, Nostoc, Oscillatoria, Rivularia, Micrasterias, Microspora, Oedogonium, Spirogyra, Gonium* and *Volvox.*
2 0 is equal to the pretreatment observation.

Zooplankton populations following fluridone treatments are presented in Tables 7 and 8. Observations made on the pond treated with 1.12 kg/ha indicated that fluridone did not affect zooplankton in this pond. In the pond treated with 1.68 kg/ha, the data indicated a slight reduction in the *Copepoda* population. This reduction followed the same trends as observed in the reduction of the blue-green phytoplankton.

The benthic organisms changed very little in the 0.3 ppm treated pond, whereas the 1.0 ppm treatment did have an effect on the total number of organisms (data not shown). The pond receiving 1.0 ppm had an equivalent rate on a surface area basis of 15 kg/ha. At this rate, fluridone appeared to have indirect toxicity on the amphipod, *Hyalella azteca.* When rates of 1.12 to 1.68 kg/ha were applied, the numbers of benthic organisms changed very little (Table 9). A control pond sampled in the same sequence as the treated ponds indicates the amount of variability that was associated with collecting the benthic organisms.

TABLE 7. ZOOPLANKTON COUNTS (No /l X 10^5) BEFORE AND AFTER TREATMENT WITH FLOURIDONE AT 1.12 KG/HA.

Organism	Days After Treatment						
	0[1]	1	3	8	15	22	43
Rotifera	3	2	2	3	4	5	9
Copepoda	29	31	24	26	33	28	33
Cladocera	8	7	5	3	5	6	8
Ostracoda	1	—	1	1	2	3	2
Total	41	40	42	33	44	42	52

1 0 is equal to the pretreatment observation.

TABLE 8. ZOOPLANKTON COUNTS (No. /l X 10^5) BEFORE AND AFTER TREATMENT WITH FLURIDONE AT 1.68 KG/HA.

Organism	Days After Treatment						
	0[1]	1	3	8	15	22	43
Rotifera	5	3	1	—	2	11	14
Copepoda	43	44	17	14	19	26	39
Cladocera	12	18	11	9	11	19	24
Ostracoda	2	3	—	1	—	4	2
Total	62	68	29	24	32	60	79

1 0 is equal to the pretreatment observation.

TABLE 9. TOTAL BENTHIC ORGANISMS (No. /M^2) FROM PONDS TREATED WITH FLURIDONE.[1]

Rate (kg/ha)	Days After Treatment							
	0	1	3	8	15	22	28	43
1.12	36	27	34	22	22	29	39	35
1.68	54	40	26	23	36	20	28	35
Control	58	39	37	61	43	45	45	49

1 Benthic organisms present in these studies include *Hyalella, Callibaetis, Brachycerus, Caenis, Libellulidae, Coenagrionipag, Tendipes, Tenipendinae, Metriocnemus* and *Chaoborus.*

Fluridone did not change water quality as measured by the variables evaluated such as dissolved oxygen, pH, BOD, color, dissolved solids, hardness, nitrate nitrogen, specific conductance, total phosphates and turbidity.

The dissolved oxygen content was slightly reduced initially at the surface in certain studies from a high of 8 ppm to a low concentration of 4 to 6 ppm. This reduction could have been associated with time of sample collection rather than the influence of the fluridone treatment. As previously discussed, fluridone causes submerged plants to slowly sink to the hydrosoil without rapid decomposition. The mature plant continues photosynthesis, thus increasing the dissolved oxygen within the water profile (Table 10). The dissolved oxygen concentration at the bottom of the water column was increased from a low of 0.1 ppm before

TABLE 10. DISSOLVED OXYGEN AND TEMPERATURE PROFILE OF POND TREATED WITH FLURIDONE AT 1.68 KG/HA BEFORE (0), AND 50 DAYS AFTER TREATMENT.

Depth (M)	0		50	
	C	0.0	C	D.O.
0.3	25.7	5.1	24.3	5.9
0.6	25.4	5.0	23.3	5.8
0.9	25.2	4.8	23.0	5.7
1.2	24.8	3.5	22.7	5.6
1.5	24.5	2.1	22.5	5.4
1.8	23.8	1.9	22.3	5.1
2.1	23.5	0.2	22.0	3.8
2.4	23.3	0.2	22.0	2.6
2.7	23.3	0.2	22.0	2.8
3.0	23.2	0.2	21.8	3.2
3.3	23.3	0.1	21.8	3.2
3.6	23.2	0.1	21.8	3.2

TABLE 11. FLURIDONE CONTENT (PPM) OF WATER AND HYDROSOIL.

Days After Treatment	1.12 kg/ha		1.67 kg/ha	
	Water	Hydrosoil	Water	Hydrosoil
3	0.041	0.039	0.052	0.026
8	0.053	0.025	0.081	0.032
15	0.025	0.040	0.030	0.077
29	0.016	0.086	0.036	0.034
58	0.021	0.083	0.045	0.078
82	0.010	0.034	0.014	0.020
119	0.010	0.039	0.011	0.011
187	0.003	0.021	0.011	0.031

treatment to 3.2 ppm 50 days after treatment. The lake was thermally stratified throughout the interval, thus the increase in dissolved oxygen is apparently a result of the fluridone treatment.

TABLE 12. FLURIDONE CONTENT (PPM) IN BLUEGILL SUNFISH.

Days After Treatment	1.12 kg/ha			1.68 kg/ha		
	Head	Body	Entrails	Head	Body	Entrails
3	0.019	NDR	NDR	0.034	NDR	NDR
8	NDR*	NDR	NDR	NDR	NDR	NDR
15	0.015	0.023	NDR	NDR	0.023	NDR
29	0.022	0.027	NDR	0.031	NDR	NDR
58	NDR	NDR	NDR	NDR	NDR	NDR
82	NDR	NDR	NDR	NDR	NDR	NDR
119	NDR	NDR	NDR	NDR	NDR	NDR
187	0.013	NDR	0.014	<0.010	<0.010	<0.053

* NDR = No Detectable Residue.

Observations of other aquatic life, including crayfish, bass, bluegill, catfish, long neck soft shell turtles, frogs, common water snake species and water fowl were made in the ponds before and during the studies. No adverse effects were observed on these species from any application. A variety of water fowl and shore birds continued to feed from the treatment ponds. Water, hydrosoil and fish samples were analyzed for fluridone content. The results indicate that fluridone dissipates from the water into the hydrosoil (Table 11). The dissipation apparently includes uptake by aquatic plants, photodegradation, and absorption onto hydrosoil particles. Fluridone did not accumulate in fish (Table 12). It was found in the bodies of bluegills 15 days after treatment, but at no time did the amount in the head or body exceed the concentration in the water.