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Efficacy of Early-Season Fluridone Treatment for Management of Watermeal, *Wolffia columbiana* Karst.

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ABSTRACT

Three fluridone formulations (4AS, 5P, and SRP) were applied at maximum label rates in mid- to late March and early April of 1988 and 1989 to evaluate early-season treatments for control of watermeal in ponds. The 4AS and 5P formulations effectively suppressed watermeal in 1988, and all three were effective in 1989. After treatment, watermeal continued to spread on all ponds until July and declined gradually thereafter. Treatment in early summer with 4AS either with or without a surfactant substantially suppressed growth by July, but some watermeal persisted until the end of the season. Hydraulic flushing during the first three weeks after treatment reduced efficacy in many ponds treated in 1989 and was solely responsible for the persistence of watermeal into the 1990 season in these ponds.

Key words: Timing of application, herbicide efficacy, aquatic weed control.

INTRODUCTION

More than 75,000 ponds have been constructed in North Carolina during the past 20 to 25 years, primarily for the purpose of irrigation of tobacco and other crops. Watermeal (*Wolffia columbiana* Karst.) is a common and very troublesome weed in many of these ponds and other small impoundments throughout the state. The small size, free-floating habit, and explosive growth rate of this plant prevent effective mechanical removal of this species. Although triploid sterile grass carp (*Ctenopharyngodon idella*) potentially will feed on watermeal (Thompson *et al.* 1988),

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biological control of this weed has not been consistent at the stocking rates of 25 to 50 fish per vegetated hectare recommended in North Carolina. Consequently, the management of watermeal usually requires herbicide treatments. Laboratory studies suggested that diquat {(6, 7-dihydrodipyrido [1,2-a:2′,1′-c] pyrazinediium dibromide} would be effective on watermeal (Karels and Lembi 1973), but this herbicide generally has not been effective on this weed under field conditions. Two currently-registered aquatic herbicides, simazine [2-chloro-4,6-bis(ethylamino)-*s*-triazine] and fluridone {1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1*H*)-pyridinone}, are effective on watermeal. Simazine may not be applied in ponds used either for irrigation or livestock watering, because of its persistence and label restrictions. Fluridone has no restriction for livestock watering and also may be used in irrigation ponds, provided that the water is not used for irrigation prior to 30 days after treatment. Irrigation of many crops cannot be withheld for 30 days during the growing season, however.

The objectives of this study were to determine whether or not early-season fluridone applications could be used to control watermeal prior to the irrigation season and to determine which formulations would provide best control.

MATERIALS AND METHODS

This study was conducted in small, non-irrigation ponds in Chatham and Wake Counties, North Carolina, during the 1988 and 1989 growing seasons. On March 14, 1988, three ponds were treated with fluridone 4AS, two with 5P, and one with SRP. The 4AS formulation was applied at 1.68 kg/ha in 20 l pond water. Both pellet formulations were applied at a rate of 1.12 kg/ha. The higher rate of 4AS was used because the average depths of the ponds receiving these treatments ranged from 1.67 to 1.92 m in comparison to 1.07 to 1.46 m in those treated with either 5P or SRP. The calculated initial fluridone concentrations averaged 94 ± 6 μg/l (range 88-100 μg/l) in the 4AS ponds, 91 (77-105) μg/l in the 5P ponds, and 82 μg/l in the SRP pond. During both years of the study, all formulations were applied at the maximum label rates for ponds within the average depth ranges specified on the label. This was done to simulate operational field applications. The liquid formulation was applied using a backpack sprayer to uniformly distribute the chemical over the water surface. No surfactant was used during early-season applications of the liquid formulation for three reasons: the watermeal still was associated largely with the hydrosoil because of negative buoyancy at low water temperatures (Ward and Whipple 1918); pellet formulations contain no surfactant; and a surfactant is not indicated as necessary on the label of the 4AS formulation. Pellet formulations were applied with a backpack pellet blower. Untreated ponds in the vicinity were observed as controls during both seasons of this study. Water temperatures on the date of treatment ranged from 6.7 to 7.8 C during 1988.

During the second year of this study, each formulation was applied to three ponds during the period March 30 to April 4. Three more ponds were treated on June 14 with 4AS to compare the efficacy of early-season treatments with aplications made during the normal time of the growing season. Many applicators have indicated that fluridone is more effective on watermeal when X-77® surfactant is used. To test this hypothesis, three additional ponds were treated on June 14 with 4AS plus one percent X-77® surfactant. Application rate for all formulations was 1.12 kg/ha in 1989, as the average depths of the ponds all were within the range of 1.07 to 1.52 m. The calculated initial fluridone concentrations in these ponds on the dates of treatment averaged 82 ± 8 μg/l (range 74 to 105 μg/l). Water temperatures on the dates of treatment in the 1989 test ranged from 14 to 19 C in the early-season treatment and 26 to 31 C in June.

The effects of fluridone treatments were evaluated periodically throughout the growing season by visually estimating the percent pond coverage by watermeal. Effects on other plants also were noted. All ponds were observed carefully for signs of water outflow during the study, especially during the 1989 season when unusually heavy rainfall continued through July. The ponds treated in 1988 also were observed during the 1989 growing season for regrowth. A final evaluation of regrowth was made on May 7, 1990 on all ponds treated during 1989. Means were calculated for percent pond coverage at each observation date. Data from the 1989 study were subjected to an analysis of variance and means were separated using the Duncan's Multiple Range procedure (Steele and Torrie 1960). Due to incomplete replication, the data from the 1988 study were not subjected to statistical analysis.

RESULTS AND DISCUSSION

The effects of late-winter fluridone applications on watermeal were not apparent until early summer in either the 1988 or 1989 growing seasons Table 1). Very little watermeal (less than 1% surface coverage) was present on the dates of treatment at any of the locations. In 1988, approximately one month after treatment, slight chlorosis was present on the new growth budding from the parent plants. The watermeal was spreading on all ponds, and only a slight reduction in coverage was apparent in any treated ponds, in comparison to the controls. Watermeal in all ponds treated with fluridone continued to spread through early summer in both 1988 and 1989. The first evidence that early season treatments had been effective was observed on the July 1, 1988 evaluation date. Surface coverage varied from approximately 20 to 35% in the 4AS ponds, 10 to 50% in the 5P ponds, and 70% in the SRP pond, in comparison to 100% coverage in the controls. By early August, watermeal coverage had decreased to less than 5 percent in all ponds treated with either 4AS or 5P. Control ponds and the SRP pond had 100% and 50% coverage, respectively. Watermeal coverage decreased to less than 0.5% in all 4AS and 5P ponds and to approximately 10% in the SRP pond by mid-September. The watermeal remaining in all the 4AS and 5P ponds was almost totally chlorotic at this time, whereas that in the SRP pond showed little sign of chlorosis. Control ponds still were totally covered with green, healthy watermeal. During the 1989 growing season, all of the 4AS and 5P ponds treated in 1988 remained free of watermeal. Watermeal

TABLE 1. EFFECTS OF THREE FLURIDONE FORMULATIONS APPLIED AT MAXIMUM LABELLED RATES FOR WATERMEAL CONTROL IN PONDS DURING 1988 AND 1989. DATA SHOWN ARE MEANS (n = 3) OF PERCENT COVERAGE EVALUATED VISUALLY AT DIFFERENT TIMES AFTER TREATMENT.

		Percent Watermeal Coverage				
		Early-Season Treatments			June Treatments	
Date Evaluated	Control	4AS	5P	SRP	4AS	4AS/X-77
1988 Test[1]						
03-14-88	<1	<1	<1	<1	ND[2]	ND
04-20-88	80	27	30	70	ND	ND
07-01-88	100	<1	3	50	ND	ND
08-05-88	100	<1	<1	10	ND	ND
09-19-88	100	<1	<1	5	ND	ND
10-09-88	100	0	0	100	ND	ND
1989 Test[3]						
05-02-89	18a	5b	13ab	4b	ND	ND
05-30-89	48abc	12c	17bc	18bc	53ab	78a
07-03-89	80a	9b	9b	48ab	43ab	20b
08-23-89	87a	5b	<1b	4b	<1b	24b
10-09-89	100a	9bc	<1c	2c	<1c	50b[4]
05-07-90	47a	<1b	3b	<1b	3b	14b

[1]All ponds were treated on March 14, 1988. Statistics are not shown due to incomplete replication in the 5P (n = 2) and SRP (n = 1) ponds. No significant outflow occurred from any of these ponds during the first four months after treatment.
[2]ND = no data.
[3]Early season treatments were applied on March 30, and April 3, 1989. Mid-season treatments were applied on June 14. Means in a row followed by the same letter are not significantly different at alpha = 0.05 according to Duncan's New Multiple Range Procedure. Only slight outflow occurred during the first three weeks after the early-season treatments, but substantial outflow did occur in several of these ponds during May and in early June.
[4]One pond was flushed by 7.5 cm of rainfall 3 days after treatment; average coverage on this date without this pond < 1%.

had regrown and covered the entire surface of the 1988 SRP pond by the end of 1989.

The initial response of watermeal treated early in the 1989 growing season with each of the three fluridone formulations was similar to that observed in the first year of the study. Very little watermeal existed on the surface of any of these ponds at the time of treatment. Chlorosis of the new buds appeared approximately one month after treatment with all formulations, and coverage increased until July in all ponds receiving the early-season treatments. The continuation of the growth of watermeal for at least two months following fluridone treatment probably was the result of photosynthate transport from green tissues into the chlorotic new buds. Fluridone inhibits synthesis of carotenoid pigments, which prevent photodegradation of chlorophyll, but does not have an immediate effect on the older chlorophyllous tissues (Bartels and Watson 1978). Ponds treated in June with 4AS (either with or without the surfactant) were nearly covered with watermeal on the date of treatment, but most were almost clear by August. Observations during May 1990 revealed that very small amounts of watermeal still persisted in several of the ponds treated in 1989. All ponds which received early-season applications of 5P or June applications of 4AS without the surfactant were essentially clear at this time.

The 1988 and 1989 growing seasons were strikingly different with respect to rainfall. Essentially no outflow occurred in any of the ponds treated in 1988 due to a severe drought, which continued through August. Unusually heavy rainfall began in the spring of 1989 and continued through the end of July, however. This resulted in substantial hydraulic flushing on several occasions during 1989. Although there was no substantial outflow from any of the ponds at the time of treatment, the amount of watermeal remaining in a given pond at the end of the season and its persistence into the following growing season apparently was related to the date of occurrence and intensity of rainfall in the watershed (no data collected). One pond each treated in early spring with 4AS, 5P, or SRP had slow, but continuous outflow beginning within two weeks after application. A small amount of watermeal persisted in each of these ponds into 1990. One of the ponds treated in June with 4AS without the surfactant did not receive any rainfall during the first four weeks after application. The watermeal in this pond was totally eliminated by the end of August. Another pond treated in June with 4AS plus surfactant received 7.5 cm of rainfall only three days after application. This pond was the shallowest (average depth 1.07 m) and had the highest initial fluridone concentration (5 μg/1) of any of the ponds treated in 1989. This pond contained a heavy infestation of duckweed (*Spirodela oligorrhiza*) as well as watermeal. The duckweed was totally eliminated by July 3, but watermeal completely covered this pond by mid-summer and persisted through the end of 1989 and into the 1990 season. One pond treated early in 1989 with 5P also contained duckweed. No observable outflow occurred from this pond until late May. The duckweed was entirely gone from this pond by May 2, but the watermeal continued to spread until mid-summer before declining and disappearing entirely by the end of the season. Hydraulic flushing clearly explains the inconsistent control in ponds treated in June with 4AS plus surfactant as well as the lack of total watermeal elimination in the other ponds treated in 1989 in which the weed persisted into the subsequent growing season. The incidental observations on duckweed suggest that it may be substantially more sensitive to fluridone than watermeal and potentially could be used as a bioassay for fluridone in pond water. The sensitivity of duckweed to fluridone also was noted by McCowen *et al*, (1979).

An observation made during the 1988 study suggested that the 30-day waiting period indicated on the label may be insufficient, if fluridone is applied as early-season treatments to ponds intended for irrigation. On July 1, fluridone symptoms were present on corn in a vegetable garden adjacent to one of the ponds treated in March with the 4AS formulation. These symptoms were not present at the previous evaluation period. The corn had been irrigated the first week of June, approximately 11 weeks after pond treatment. In this case, the corn was not severely injured and produced a normal crop.

The persistence and rate of dissipation of fluridone depend largely upon photolytic reactions (Saunders and Mosier 1983). The water temperatures during the early-season treatments were lower than those occurring later in the season (e.g., June) when fluridone usually is applied.

Since chemical and biochemical reactions all are influenced significantly by temperature, it is a logical deduction that the rate of uptake of fluridone by the watermeal, the rates of dissipation from the treated ponds, and the time required to elicit a physiological response all would have been inhibited by the cooler water temperatures. This hypothesis is strongly supported by the results of this study and adequately explains the problem which occurred when corn was irrigated nearly three months after a late-winter pond treatment with fluridone. Therefore, even though early-season applications of fluridone will provide good control of watermeal, there may be little or no advantage gained with respect to avoiding the irrigation season. Also, as more rainfall generally occurs during the spring, more difficulties probably will be encountered due to outflow and loss of herbicide when early-season treatments are used.

Based on the results of this study, early-season applications of both the 4AS and 5P formulations of fluridone should provide effective control of watermeal if no substantial outflow occurs during the first two to three weeks following pond treatment. The SRP formulation also may be effective, although there was no satisfactory explanation for its failure during the 1988 season. No conclusion was possible regarding the effects of the surfactant on efficacy of the 4AS formulation. Early-season treatment with fluridone probably will not circumvent problems associated with irrigation of crops during the spring and early summer, however. Additional research is needed to address the seasonal aspects of fluridone dissipation in ponds, to determine the relative efficacies of all three fluridone formulations when applied during different seasons of the year, to determine whether or not adding a surfactant improves the efficacy of the 4AS formulation, and to find windows of application for sensitive irrigated crops. Split application also should be investigated as a potential method for maintaining adequate herbicide concentrations in ponds subject to frequent hydraulic flushing.

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LITERATURE CITED

Bartels, P. G. and C. W. Watson. 1978. Inhibition of carotenoid synthesis by fluridone and norflurazon. Weed Sci. 26:198-203.

Karels, L. A. and C. A. Lembi. 1973. Studies on the life history and control of watermeal (*Wolffia* sp.). Abstract, Proc. North Central Weed Contr. Conf. 28:107.

McCowen, M. C., C. L. Young, S. D. West, S. J. Parka, and W. R. Arnold. 1979. Fluridone, a new herbicide for aquatic plant management. J Aquat. Plant Manage. 17:27-30.

Saunders, G. G. and J. W. Mosier. 1983. Photolysis of the aquatic herbicide fluridone in aqueous solution. J. Agric. Food Chem. 31:237-241.

Steele, R. G. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York, 481 p.

Thompson, B. Z., J. L. Underwood, and R. S. Hestand III. 1988. Utilization of triploid grass carp in sewage-retention ponds for control of floating vegetation. Fla. Sci. 51:115-119.

Ward, H. B. and G. C. Whipple. 1918. Fresh-Water Biology. John Wiley and Sons, New York, 1111 p.