

NOTE

Herbicide Inhibition of Grass Carp Feeding on Hydrilla

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INTRODUCTION

When herbicide application and grass carp (*Ctenopharyngodon idella* Val.) stocking are integrated for aquatic plant management, synergistic or antagonistic interactions between the methods may occur. At recommended field application rates, herbicides likely to be used in conjunction with grass carp are not acutely toxic to the fish (Tooby et al. 1980, Kracko 1989). However, grass carp stopped feeding after exposure to much lower than lethal concentrations of the herbicides (Tooby et al. 1980). The implications of this behavior on the level of control achieved when grass carp and herbicides are used together have not been evaluated.

The observed feeding inhibition could be due to changes in the vegetation which makes it unpalatable. Food quality of plants can affect preference by herbivores. Herbicides act by inhibiting chlorophyll function or by interfering with the photosynthesis process. Specifically, diquat (6,7-dihydrodipyrido [1,2-a:2',1'-C] pyrazinediium ion) inhibits photosynthesis by interfering with the electron transport process (Cassidy and Rodgers 1989). Fluridone (1-methyl-2-phenyl-5-[3 (trifluoromethyl) phenyl]-3(IH)-pyridone) inhibits the synthesis of carotenoid pigments which protect chlorophyll from photodegradation. Interference with photosynthesis or destruction of chlorophyll in a plant will affect carbohydrate production, and may lower the food quality of the plants (McCowen et al. 1979).

Grass carp exhibit definite feeding preferences which have been attributed to size of fish, water temperature and plant texture (Michewicz et al. 1972). Bonar et al. (1990) found that feeding rates were significantly affected by lake-to-lake variation in the mineral and cellulose composition of plant tissues. Consistent with optimal foraging theory (Pyke et al. 1977), nutrient content could also be involved.

Changes in palatability and food quality could affect grass carp feeding on hydrilla (*Hydrilla verticillata* (L.f.) Royle) which has been exposed to herbicide. We designed an experiment to test whether the fish feed preferentially on untreated vegetation when also offered plants treated

with diquat or fluridone. Untreated and treated plants were analyzed to determine nonstructural carbohydrate content.

MATERIAL AND METHODS

Hydrilla tubers were collected, planted in small pots containing sifted hydrosol, and placed in a shallow pool in the greenhouse. Rooted plants were fertilized when necessary with liquid plant food, and used in the fluridone experiment. Whole plants were collected for use in the diquat experiment. Plants were rinsed gently with tap water to remove debris and periphyton, and held in shallow plastic pools.

Because diquat can be removed from the water column by adsorption to sediments, plants used in the diquat experiments were not rooted in sediment. Five days before the plants were to be used in the experiment, pools containing hydrilla were treated with 2 ppm diquat. Eight days before the beginning of feeding experiments using fluridone, 1 g of Sonar 5P[®] pellets were applied to plants in 555 L pools, yielding a theoretical concentration of 90 µg/L active ingredient in water. Untreated plants used in the experiments were treated similar to treated plants, excepting herbicide treatment.

In the laboratory, ten 113 L (30 gal) glass aquaria were modified to allow equal amounts of treated and untreated hydrilla to be offered as food for each grass carp. Each aquarium had a vertical glass partition at the middle of one end, to form two equal compartments 25.4 cm deep. Styrofoam skimmers were placed at the top of the opening to hold floating vegetation on the proper side of the partition. Before each experiment the tanks were thoroughly cleaned, filled with unfiltered pond water, and mechanical filters were installed to maintain water quality. Filter intakes were screened to prevent removal of plant fragments from the tanks. A 12:12 light-dark cycle was maintained with fluorescent lighting. Air temperature in the laboratory was 24C for the majority of the experiments. Dissolved oxygen, water temperature, NH₄⁺-N, NO₂-N, and pH were monitored on alternate days.

Triploid grass carp, 200-300 mm total length (TL), were transported to the laboratory from local holding tanks at the beginning of each experiment. One fish was placed in each aquarium. The fish were allowed 5 days to acclimate, during which each fish was fed 40 g (blotted wet weight) of untreated hydrilla daily. Uneaten vegetation was left in the tanks until the end of acclimation to minimize disturbance of the fish.

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To establish baseline consumption, over the next 5 days each fish was fed 40 g of untreated vegetation daily, 20 g on each side of the partition. To reduce displacement of vegetation by the fish, whole plants were broken up before being placed behind the partitions. Uneaten vegetation was removed after 24 hours and weighed. Feeding rates during the experimental period were compared with baseline consumption, using each fish as its own control.

For the next 5 days, fish were offered 20 grams of untreated vegetation on one side of the partition, and 20 grams of treated vegetation on the other. Treated vegetation was randomly assigned to the right or left side of the partition daily. Uneaten plants were removed every 24 hours from behind the skimmers and weighed.

Paired t-tests were used to analyze the data. A two-sided t-test was calculated to determine if a fish fed differently in the baseline and experimental periods. One-sided t-tests were used to determine whether fish fed preferentially on untreated vegetation during the experimental period. A significance level of $P < 0.05$ was selected.

Treated and untreated plants were collected at the beginning of each experimental period for total nonstructural carbohydrate (TNC) analysis. A two-step procedure was used to extract TNC (Perkins and Sytsma 1982), and sugar content of each extraction was estimated using the phenol-sulfuric acid technique (Dubois et al. 1956). For each group of samples, a one-sided t-test was calculated to determine whether the TNC content of the treated plants was lower. Values of $P < 0.05$ were considered significant.

RESULTS AND DISCUSSION

During both experiments, only one fish ate significantly different amounts of hydrilla in the baseline and experimental periods. This fish showed no preference for untreated plants during the experimental period.

After hydrilla was treated with diquat, five fish consumed significantly less treated vegetation. Consumption of untreated hydrilla by these five fish was an average of 2.8 g per day more than that of treated plants. Overall, there was significantly less feeding on hydrilla which had been exposed to diquat (Table 1).

In the experiment using hydrilla treated with fluridone, three fish consumed significantly less treated vegetation. Their average daily discrepancies were 5.7 g, 1.1 g and 5.6 g. Pooled data for all 10 fish indicated significantly less consumption of treated plants (Table 1).

Nonstructural carbohydrates were lower in treated plants which had been exposed to either herbicide than in

TABLE 1. CONSUMPTION (GRAMS FRESH WEIGHT/DAY) OF UNTREATED AND TREATED HYDRILLA BY GRASS CARP. VALUES REPRESENT MEAN CONSUMPTION BY TEN FISH OVER A 5 DAY PERIOD. TWENTY GRAMS OF TREATED AND UNTREATED VEGETATION WERE OFFERED DAILY.

Herbicide	Consumption		t
	Untreated	Treated	
Diquat	19.7	17.9	2.70 (9 df)*
Fluridone	19.5	17.7	2.63 (9 df)*

* Indicates significant differences at the 0.05 confidence level.

untreated plants. Exposure of hydrilla to diquat resulted in a 40% decrease in TNC levels, while plants treated with fluridone displayed nonstructural carbohydrate levels 20% lower than those in untreated plants.

These experiments indicate that interaction between control methods does occur. Treatment of hydrilla with either diquat or fluridone produced a significant reduction in consumption by grass carp. Reduced feeding activity could be caused by changes in plant food quality or palatability resulting from exposure of plants to herbicides.

Herbicide residues may persist in the water, plant tissues and sediments long after application of the chemicals (Carpentier et al. 1988). Diquat can be removed from the water column quickly by adsorption to particulates (Langeland and Warner 1986), however detectable levels of diquat in water have been reported 28 days after treatment (Grzenda et al. 1966). Studies have reported detectable levels of fluridone persisting in sediments up to 86 weeks from date of treatment (Schmitz et al. 1987). Regrowth of many submerged plant species is from vegetative reproductive parts in sediments such as rhizomes or tubers. When these plant parts are not killed by herbicide application, they may be affected by residues in the sediments or water.

In our experiments, TNC levels were lower in plants exposed to herbicides than in untreated plants. Woodward et al. (1974) measured changes in the content of phenolic acids (which are synthesized from carbohydrates) in hydrilla regrowth after treatment of the plants with diquat. Levels of one phenolic acid decreased by over 50% and required almost four months to return to pre-treatment levels. Treatment of plants with herbicides could result in long-term effects on plant food quality if this observed decrease in products synthesized from carbohydrates was related to lower levels of carbohydrates.

Hydrilla is a highly preferred plant species, therefore effects of herbicides on the food quality of this plant may affect grass carp feeding. Results from these feeding trials may explain some of the mixed effects of integrated control reported previously. Almost all previous studies have been done in systems where hydrilla was the target plant species. Two instances where hydrilla control was successful using an initial herbicide application followed by stocking low numbers of fish were in irrigation canals (Sutton 1974) and drainage ditches of citrus groves (Canfield 1983). In both cases, the systems could be flushed with water to remove herbicide residues before the fish were stocked.

Our results may have been influenced by seasonal and temperature effects. The experiments did not begin until late July, when hydrilla was flowering. Effects of herbicide treatment on the plants and effects on consumption by grass carp may not have been as great as if experiments were conducted earlier in the growing season. Grass carp feed most actively at water temperatures ranging from 18.3 to 29.4C (Kilambi and Robison 1979). Our average water temperature was 23.1C, well within the range of active grass carp feeding. However, unseasonably cold temperatures during the last 5 days of the hydrilla / diquat experiment caused water temperatures to drop to between 15.0 and 17.0C. This experiment also resulted in the high-

est number of fish which showed a preference for untreated plants. Lower water temperatures and associated lower consumption rates could have caused the fish to feed more selectively.

Ammonia, nitrite and pH were monitored because pilot experiments showed that fish stopped feeding when ammonia levels were high (> 1.0 mg/L). The amount of vegetation which could be offered daily to the fish was limited to 40 g wet weight (approximately 20% of fish weight), so that ammonia could be maintained at acceptable levels. Fish up to 3 kg in size and in water temperatures between 22 and 29C can consume 100% of their body weight of vegetation per day (Kilambi and Robison 1979). If the fish could have been fed *ad lib*, more feeding preferences may have been expressed. Many of the fish ate over 95% of the food which was offered. Fish which did show a preference for untreated plants were often fish which consumed less than 75% of food which was offered.

Results obtained from these experiments may have implications for aquatic plant management using these two methods together. Exposure of hydrilla to herbicides or herbicide residues may affect food quality or palatability, and result in reduced consumption of this plant species by the grass carp.

Field experiments should be conducted to determine whether the food preferences observed in these laboratory experiments are expressed under natural conditions. Edwards (1973) cautioned against predicting feeding behavior of fish in the field based solely on data obtained from laboratory experiments. Seasonal effects of herbicides on carbohydrate content of hydrilla should also be examined.

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