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Impact of Integrated Aquatic Weed Management on Water Quality in A Citrus Grove[1]

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ABSTRACT

Between March and December 1980, water quality (pH, total alkalinity, specific conductance, chloride, potassium, magnesium, total iron, total phosphorus, total nitrogen, and chlorophyll *a*) was monitored in a south Florida citrus grove to determine if integrated chemical and biological aquatic weed management impacted grove water quality. Surface waters within the grove were alkaline, rich in dissolved salts, and highly eutrophic. Integrated chemical and biological control of hydrilla (*Hydrilla verticillata* Royle) and emergent weeds, primarily panicum (*Panicum repens* L.) had no measurable impact on grove water quality.

Key words: Hydrilla, Panicum, grass carp, mechanical, irrigation, drainage, endothall, copper, glyphosate.

INTRODUCTION

Florida's citrus sales at the farm level were over one billion dollars in 1980, thus making citrus Florida's major agricultural product (1). In south Florida a major producing area, citrus growers use a large number of canals and ditches to provide drainage and irrigation. South Florida's subtropical climate, however, is especially conducive to the growth and proliferation of aquatic plants which often interfere with grove drainage and irrigation. To prevent damage to citrus production, grove managers must establish some type of aquatic weed management program.

Early aquatic plant control programs relied on the manual and mechanical removal of aquatic weeds, but the development of effective herbicides led to a reliance on chemical management programs. The herbicide programs, however, are costly and require repeated application. In addition, there has been increased concern among some segments of the general public over possible adverse environmental impacts of chemical management programs. In recent years, biological control, especially the use of grass carp (*Ctenopharyngodon idella* Val.), has become an effective, low cost management technique (2,3,4,5,6,7). However, like mechanical or chemical techniques, there are limitations associated with the use of biological control. For this reason, it has been hypothesized that an integration of effective biological, chemical, and mechanical techniques should provide optimum aquatic plant management at reduced costs to agricultural producers. In 1980, a demonstration of integrated biological and chemical aquatic plant management was initiated at a commercial citrus grove in south Florida to test the integrated management hypothesis. The purpose of this study was to document impacts of chemical and biological treatments on surface water quality.

METHODS

The demonstration of integrated aquatic plant management was conducted in LaBelle, Florida at a 2428 ha commercial citrus grove operated by Congen Properties, Inc. The specific study area was a 283 ha tract located in the southeast portion of the grove. Irrigation water was obtained by pumping water from Townsend Canal, which is connected to the Caloosahatchee River, into a large Header Canal. Water from the Header Canal was pumped into a smaller header canal which delivered water to smaller feeder canals. Feeder canals were connected directly to lateral canals located between the citrus beds. Drainage from the lateral canals was via the feeder canals into a single discharge canal. Water levels in the grove were variable ranging from a few centimeters to over 2 m depending on rainfall and irrigation needs. Hydraulic flushing rates ranged from a few hours during irrigation and discharge after heavy rains to several days when water was not being moved. Within the study tract, canals were assigned to 8 treatments. Treatments tested included no treatment (controls), chemical treatment (Potassium salt of 7-oxabicyclo[2.2.1] heptane-2,3-dicarboxylic acid (endothall) at 14 kg a.e./ha plus copper triethanolamine (chelated copper) at 2 kg/ha for hydrilla and isopropylamine salt of N-(phosphonomethyl) glycine (glyphosate) at 5 kg a.e./ha for emergent vegetation), and biological treatment which consisted of stocking grass carp at densities of 25, 62, 124, 247, 556, and 618 fish/ha. Information pertaining to the experimental design, location of canals, and the effects of treatments on canal vegetation and fish population are given elsewhere (8).

Between March and December 1980, water samples were collected monthly from 34 lateral canals. Canals sampled and their associated treatments are listed in Table 1. Water samples were also collected from the Caloosahatchee River at State Road 29, Townsend Canal at State Road 80, Header

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TABLE 1. AREAS SAMPLED AND TREATMENTS APPLIED DURING STUDY PERIOD. ALL CANAL DESIGNATIONS ARE THOSE USED BY CONGEN PROPERTIES, INC., LABELLE, FLORIDA.

Station	Treatment
Canal E2, F4, G1, H4, I-N2, I-N11, K6, K14	Control
Canal E3, F3, I-N8	Chemical
Canal I-S2, I-S3, J1, J4	25 Grass Carp/ha
Canal G1, G3, G4, G5	62 Grass Carp/ha
Canal I-S5, J6, J7, J8	124 Grass Carp/ha
Canal I-S13, I-S15, I-S17	247 Grass Carp/ha
Canal I-S9, I-S12, J10, J14	556 Grass Carp/ha
Canal H1, H2, H3, H5	618 Grass Carp/ha
Header Canal Entrance and Discharge	None
Study Discharge Canal	None
Townsend Canal	None
Caloosahatchee River	None

Canal at the entrance and discharge points, and the study area discharge canal to determine water quality in the primary source and receiving waters (Table 1). In addition to the monthly samples, weekly samples were collected between March 12 and May 25 to determine if the initial herbicide application had a measurable effect on grove water quality.

At each sampling station, surface water samples were collected in acid-cleaned Nalgene bottles. Samples were iced and transported to the analytical laboratory at Gainesville, Florida. All analyses were intiated within 24 hrs of sample collection. At the laboratory, pH was measured by use of an Orion Model 601A pH meter and an Orion 91-105 combination pH probe. Total alkalinity was determined by titration (9). Specific conductance was measured by use of a Yellow Springs Instrument Company Model 31 conductivity bridge. Chloride concentrations were determined by titration with 0.0141 N mercuric nitrate and use of diphenylcarbazone for endpoint determination (9). Total iron concentrations were determined by using the ferrozine method (10). Total phosphorus concentrations were determined by the procedures of Murphy and Riley (11) with a persulfate digestion (12). Total nitrogen concentrations were determined by use of a modified Kjeldahl technique described by Nelson and Sommers (13). The concentration of plankton algae was determined by measuring chlorophyll *a* levels. A measured volume of water was filtered through a Gelman type A-E glass fiber filter. Filters were stored over dessicant and frozen until analyses could be completed (14,15). Chlorophyll *a* values were calculated by using the equations of Parsons and Strickland (16).

RESULTS AND DISCUSSION

Surface waters located within the citrus grove were generally alkaline, rich in dissolved salts, and highly eutrophic (Table 2). During this study, pH values averaged 7.6 and total alkalinity concentrations averaged 135 mg/l as $CaCO_3$. Mean specific conductance was 540 μmhos/cm and chloride concentrations averaged 76 mg/l. Calcium and magnesium concentrations averaged 57 and 13 mg/l, respectively. Total iron, total nitrogen, total phosphorus, and potassium concentrations averaged 460 μg/l, 2.5 mg/l, 230 μg/l and 13 mg/l respectively. Grove chlorophyll *a* values averaged 40 μg/l. Grove water quality, however, was similar to water quality in the Caloosahatchee River (Table 2), Townsend

TABLE 2. CHEMICAL CHARACTERISTICS OF WATER TAKEN FROM THE CITRUS GROVE, THE DISCHARGE CANAL, TOWNSEND CANAL AND THE CALOOSAHATCHEE RIVER BETWEEN MARCH AND DECEMBER 1980. SYMBOLS ARE $\bar{x}$ = MEAN; SE = STANDARD ERROR OF MEAN; R = RANGE OF OBSERVED VALUES; CV = COEFFICIENT OF VARITAION; AND N = NUMBER OF SAMPLES

Parameter		Grove	Discharge	Townsend Canal	Caloosahatchee River
pH	$\bar{x}$	7.6	7.7	7.7	7.8
	SE	0.02	0.03	0.04	0.07
	R	5.9-10.4	7.5-8.0	7.4-8.0	7.5-8.3
	CV	8	2	2	3
	N	626	17	17	15
Total Alkalinity (mg/l as $CaCO_3$)	$\bar{x}$	135	155	135	139
	SE	2	5	7	7
	R	11-271	130-199	108-189	110-186
	CV	31	13	20	19
	N	626	17	17	15
Specific Conductance (μmhos/cm)	$\bar{x}$	540	521	506	507
	SE	3	8	11	15
	R	370-1160	468-610	375-570	390-650
	CV	15	6	9	11
	N	630	17	17	15
Chloride (mg/l)	$\bar{x}$	76	69	70	73
	SE	0.4	2	2	3
	R	50-145	55-80	45-80	43-93
	CV	14	11	13	16
	N	630	17	17	15
Potassium (mg/l)	$\bar{x}$	13	5.6	4.8	5.2
	SE	0.4	0.4	0.2	0.2
	R	0.7-68	3.9-11	3.2-6.1	3.6-7.0
	CV	83	30	17	14
	N	630	17	17	15
Calcium (mg/l)	$\bar{x}$	57	60	51	50
	SE	0.8	4	4	4
	R	18-169	32-90	29-84	28-77
	CV	34	26	32	33
	N	593	16	16	14
Magnesium (mg/l)	$\bar{x}$	13	11	12	12
	SE	0.2	0.4	0.5	0.6
	R	3.4-72	8.3-14	7.7-15	7.5-15
	CV	29	15	17	18
	N	593	16	16	14
Total Iron (μg/l)	$\bar{x}$	460	330	160	130
	SE	33	26	27	30
	R	32-7800	205-578	60-480	50-510
	CV	180	32	68	95
	N	627	17	17	15
Total Phosphorus (μg/l)	$\bar{x}$	230	71	101	84
	SE	12	12	13	9
	R	0-2400	14-206	49-253	47-170
	CV	130	68	52	40
	N	627	17	17	15
Total Nitrogen (mg/l)	$\bar{x}$	2.5	1.2	1.2	1.3
	SE	0.1	0.1	0.1	0.1
	R	0.4-42	0.9-1.8	0.7-1.8	1.0-1.9
	CV	130	24	26	20
	N	618	16	17	15
Chlorophyll *a* (μg/l)	$\bar{x}$	40	5.4	10	17
	SE	4	1.4	4	6
	R	0-970	0.9-21	1.2-64	1.8-84
	CV	250	107	170	140
	N	621	17	17	15

Canal (Table 2), and other surface waters in the LaBelle region (17,18). This suggests, similar to the findings of Canfield (17), that water quality within the grove is largely determined by regional geology and hydrology.

Although water quality (for the parameters measured) in the citrus grove is similar to that in the Caloosahatchee

River and Townsend Canal (the primary source for water), there were noticeable differences during this study. For example, measured values for specific conductance, potassium, total iron, total phosphorus, total nitrogen and chlorophyll *a* averaged higher within the grove (Table 2). With the exception of chloride, coefficients of variation for the measured parameters were consistently higher in the grove (Table 2). This suggested that there were factors operating within the grove that modify grove water quality. These factors could be associated with grove management (e.g., herbicide treatment, grove irrigation and drainage) or natural factors such as rainfall or shallow water-sediment interactions.

Prior to the stocking of grass carp, the whole study area was treated with herbicides to reduce the standing crop of hydrilla and emergent vegetation. Aerial applications of Endothall (14 kg a.e./ha) and chelated copper (2 kg/ha) were used to treat hydrilla, and glyphosate (5 kg a.e./ha) was used to treat emergent vegetation. With the exception of chloride, statistical analyses of the pretreatment and post-treatment weekly data failed to detect any significant ($P < 0.05$) change in the measured water quality parameters (Table 3). Chloride concentrations, however, rose from an average of 73 mg/l to 81 mg/l. The rise in chloride level, however, was most likely not due to the herbicide treatments but to an increase in chloride concentrations in the grove's main water supply, the Caloosahatchee River. During the pretreatment period, measured chloride concentrations averaged 70 mg/l in the river, but averaged 78 mg/l after treatment. Based on these data, it is concluded that the herbicide treatment did not impact any of the measured water quality parameters within the grove; thus, the whole-grove herbicide treatment was not an important factor modifying grove water quality.

Analysis of data collected after the grove was stocked with grass carp did, however, detect statistically significant ($P < 0.05$) treatment differences for some of the measured water quality parameters. This suggests grass carp might be an important factor modifying water quality within the grove (Table 4). For example, significant treatment differences were detected for pH, total alkalinity, chloride, potassium, and calcium. Examination of the data (Table 4), however, reveals that there was no consistent pattern with treatment. The lowest pH and total alkalinity values occurred for grass carp stockings of 62 and 618 fish/ha. Among the other water quality parameters, other treatments alternated in being significant thus suggesting the significant treatment differences were spurious and not the result of cause and effect relationships. Based on these data and the fact that no significant differences were detected for specific conductance, magnesium, total phosphorus, total nitrogen and chlorophyll *a*, it is concluded that the integrated chemical and biological treatments had no significant impact on water quality in the grove. Furthermore, comparison of the chemical characteristics of water in the study's discharge canal with water in the Caloosahatchee River and Townsend Canal (Table 2) reveals water quality entering and leaving the grove is basically unchanged.

During this study, it was not possible to demonstrate any major impact on water quality (pH, total alkalinity, specific conductance, chloride, potassium, magnesium, total iron, total phosphorus, total nitrogen, and chlorophyll *a*) by the tested chemical and biological treatments. Water

TABLE 3. MEAN VALUES FOR MEASURED WATER QUALITY PARAMETERS PRIOR TO AND AFTER THE INITIAL HERBICIDE APPLICATION. MEANS ARE BASED ON SAMPLES COLLECTED AT ALL STATIONS EXCEPT THE CALOOSAHATCHEE RIVER, TOWNSEND CANAL, AND THE HEADER CANAL WHICH WERE NOT TREATED.

Parameter	Pretreatment					Posttreatment				
	3/13/80	3/20/80	3/27/80	4/3/80	4/10/80	4/24/80	5/1/80	5/8/80	5/15/80	5/22/80
pH	9.5	7.8	7.5	7.5	7.8	7.1	7.5	7.7	7.5	7.4
Total alkalinity (mg/l as $CaCO_3$)	120	139	127	130	118	125	127	130	134	145
Specific conductance (μmhos/cm)	665	577	486	546	548	650	553	545	509	534
Chloride (mg/l)	74	77	73	74	67	87	79	83	82	76
Potassium (mg/l)	24	19	6.8	14	15	20	5.7	9.1	7.1	11
Calcium (mg/l)	78	71	49	53	—	66	45	43	37	40
Magnesium (mg/l)	15	14	13	12	—	17	13	13	11	13
Total iron (μg/l)	537	468	375	1100	535	1000	380	218	486	621
Total phosphorus (μg/l)	410	295	79	179	193	308	143	167	161	401
Total nitrogen (mg/l)	6.2	2.5	1.8	2.8	2.6	2.6	1.6	1.7	1.4	1.9
Chlorophyll *a* (μg/l)	19	29	16	70	50	150	11	25	8.6	18

TABLE 4. MEAN WATER QUALITY VALUES FOR THE TESTED AQUATIC PLANT MANAGEMENT TREATMENTS. VALUES ARE CALCULATED ON DATA COLLECTED AFTER JUNE 1, 1980. VALUES FOLLOWED BY THE SAME LETTER ARE NOT SIGNIFICANTLY ($P < 0.05$) DIFFERENT AS DETERMINED BY USE OF DUNCAN'S MULTIPLE RANGE TEST.

			Treatment Biological (No. Grass Carp/ha)						
Parameter	Control	Chemical	25	62	124	247	555	618	None
pH	7.62ab	7.65ab	7.63ab	7.42bc	7.63ab	7.89a	7.62ab	7.11c	7.71ab
Total alkalinity (mg/l as $CaCO_3$)	144a	142a	142a	109b	162a	161a	160a	93b	160a
Specific conductance (μmhos/cm)	527a	525a	49a	491a	527a	524a	532a	511a	505a
Chloride (mg/l)	78ab	78ab	74abc	75abc	72bc	76abc	75abc	81a	70c
Potassium (mg/l)	15ab	11bc	13b	15ab	11bc	7.2cd	12bc	18ab	5.0d
Calcium (mg/l)	60abc	61abc	61abc	55bc	67a	65ab	67a	52c	66a
Magnesium (mg/l)	14a	13ab	13ab	13ab	13ab	12ab	13ab	14a	12b
Total iron (μg/l)	474a	308a	235a	580a	129a	148a	447a	330a	231a
Total phosphorus (μg/l)	305a	212a	239a	397a	280a	144a	286a	175a	102a
Total nitrogen (mg/l)	3.3a	3.1ab	2.4ab	2.4a	2.4ab	1.8ab	2.5ab	2.1ab	1.2b
Chlorophyll *a* (μg/l)	51a	91a	56a	32a	67a	40a	54a	25a	18a

entering and leaving the grove was of similar quality. The higher average values and coefficients of variation recorded within the grove (Table 2) and the significant changes in water quality associated with treatment (Table 4) result because the canals are generally shallow and have variable hydraulic flushing rates. For example, during periods of low rainfall and irrigation, water depths in the lateral canals range from a few centimeters to less than 1 m. This brings the water into close contact with the sediments which contributes to higher concentrations of dissolved salts and nutrients. Water quality, however, can change rapidly when heavy rains or irrigation occur. Rainwater being low in dissolved salts lowers chemical concentrations in the canals through dilution and increased hydraulic flushing. Irrigation can flood the canals with water from Townsend Canal within a few hours. Rainfall and irrigation thus contribute to the observed variability and cause differences among canals. For example, total phosphorus concentrations in canal I-S 9 averaged 52 μg/l but phosphorus concentrations in I-S 12 averaged 184 μg/l despite the fact that both canals received similar treatments and were located near each other. Based on the data collected in this study, it should be possible to use the tested chemical and biological treatments either alone or in an integrated management program without affecting major water quality parameters in agricultural waterways.

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