A COMPARISON OF WATER-SEEDED RICE MANAGEMENT SYSTEMS: POTENTIAL IMPROVEMENTS IN WATER QUALITY.

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ABSTRACT

Rice fields in southwest Louisiana are generally tilled under flooded conditions, a cultural practice referred to as 'mudding in.' This practice is very effective in controlling or suppressing red rice, a noxious rice biotype. A consequence of mudding in is the release of significant amounts of solids and nutrients once the field is drained after planting. These discharges have been associated with water quality degradation in surface waters that receive rice field effluent. A study was initiated in 1993 to compare the practice of mudding in with three alternative management practices: 1l no-till planting (into previous residue], 2) mudding in with floodwater retention (floodwater retained for 2 weeks to allow for settling), and 3) clear water planting (dry seedbed preparation). The three management practices were very effective in reducing levels of total suspended solids, total solids, and some dissolved elements during the initial drain. Five-day biological oxygen demand was significantly reduced in the no-till planting. Total dissolved solids were significantly reduced in the clear water and no-till plantings. Levels of suspended solids and most dissolved elements in the floodwater decreased over time. Stand density and grain yield were significantly reduced in the no-till planting, and maturity was delayed 5 to 7 days when compared with other planting methods. This study indicates the potential of alternative rice planting practices to mitigate problems associated with degradation of surface waters that receive rice field effluent. Stand establishment in no-till rice plantings appears to be the limiting factor in widespread adoption of this practice. Since evaluation of red rice in this study was limited to visual observation, the potential for these alternative management practices to control red rice needs further study.

INTRODUCTION

Water seeding is the most popular rice planting practice in Louisiana, especially in the southwest area. Rice fields are generally tilled under flooded conditions, a cultural practice referred to as 'mudding in.' This practice is very effective in controlling or suppressing red rice, a noxious rice biotype, and preparing a smooth and weedfree seedbed. Various types of mechanical operations are employed when fields are prepared in this manner. These puddling operations result in the release of significant amounts of solids and nutrients once the field is drained after planting, and rice field discharges have been associated with water quality degradation in receiving streams in the Mermentau River Basin (Cormier et al., 1990). These problems resulted in Bayou Queue de Tortue being selected for the United States Department of Agriculture Water Quality Initiative and the Louisiana Department of Environmental Quality Nonpoint Source Program.

A study conducted by Feagley, et al. (19921, compared mudding in with a number of rice management practices (MPs) developed by the Agricultural Stabilization and Conservation Service (ASCS), Soil Conservation Service ISCS), and research and extension personnel of the LSU Agricultural Center. These MPs were also offered to farmers in the Bayou Queue de Tortue drainage basin on a cost-share basis while being evaluated in cooperating farmers' fields and at the Rice Research Station in Crowley, LA.

Data in this study was collected from large, non-replicated plots in both the farmers' fields and at the Rice Research Station. All of the alternative MPs showed significant improvement in rice field effluent when compared with mudding in. Yield data were collected from the demonstration plots in farmers' fields only. There was also no evaluation made to determine the effectiveness of the alternative MPs in controlling or suppressing red rice. The objectives of this study were to 1) characterize rice field effluents from the various MPs, 2) compare stand establishment, grain yields, and other agronomic characteristics among MPs,

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and 31 assess the potential for controlling red rice in each MP.

MATERIALS AND METHODS

The experiment was conducted at the Rice Research Station in Crowley, Louisiana, on a Crowley silt loam (fine, montmorillonitic, thermic, Typic Albaqualfl. The test area was infested with red rice in 1991 and 1992 and allowed to reseed to establish a native population for this study.

Each MP was individually leveed, replicated three times, and arranged in a randomized complete block. Plots were 43 x 298 ft^2 (0.28 A) and were individually flooded and drained for water sample collection. Roundup (glyphosate) was applied to the no-till seedbed (MP1) at the rate of 1.0 lb ai/A 5 days prior to flooding. No soil-disturbing activities occurred after levee construction. The mudding in with water retention practice (MP2) was plowed dry, flooded, vibra-shanked, and smoothed with a drag. Rice field effluent was not released for 14 days to allow for settling. The clear water planting practice (MP3) consisted of dry seedbed preparation with no soil-disturbing activities occurring after flooding. The traditional mudding in practice (MP4) was prepared as described in MP2 and was drained 7 days after seedbed preparation. A 75-45-45 (N-P-K) fertilizer was preplant incorporated in MP3 at the time of dry seedbed preparation. Fertilizer was applied to the other MPs approximately 3 weeks after planting, All MPs received an application of 69 lb NIA at midseason.

The test area was aerially seeded with presprouted rice (cv Maybelle) at a rate of 150 lb/A. All MPs were drained 3 days after seeding to encourage seedling anchorage. The study was reflooded 7 days later. Water samples were collected from each plot during the drainage procedure and immediately refrigerated. Total N was determined with a Wescan Ammonia Analyzer. Anions were analyzed with an ion chromatograph. Metals were analyzed by inductively coupled plasma spectroscopy. Water pH was determined on a filtered sample in the laboratory (Page, 1982). Electrical conductivity (EC) was determined using an EC bridge (Page, 1982). Total suspended solids (TSS) (non- filterable residue) and total dissolved solids (TDS) (filterable residue) were determined gravimetrically (EPA, 1983). The biological O_2 demand at 5 days (BOD5) was determined using EPA method 405.1 and DO was measured with an Orion portable O_2 meter.

Water quality parameters were determined at the initial drain, once at midseason, and at harvest drain. The BOD5 was not determined at midseason. Stand density was measured 3 weeks after planting. Plant height, days to 50% heading, grain yield, and milling quality were determined. Due to non-uniform establishment of red rice, only visual observations were noted.

Table 1. Influence of management practices on agronomic performance of water-seeded Maybelle rice. Rice Research Station, South Unit, Crowley, LA. 1993.

Management Practice[1]	Stand density	Days to 50% heading	Plant height	Grain yield at 12% moisture	% Milling yield
	-(ft^2)-		(in)	-(lb/A)-	(head-total1
MP1	9	76	37	4376	56-67
MP2	35	71	39	5449	57-69
MP3	41	69	37	5594	54-69
MP4	41	70	35	5243	51-69
C.V., %	22.35	1.06	5.52	5.43	3.3-1.4
LSD (0.05)	14	1	ns	560	4-ns

[1] MP1 = No till; MP2 = mudding in with floodwater retention; MP3 = clear water planting; MP4 = traditional mudding in.

Table 2. Influence of management practices on water quality of rice field floodwater (initial drain) from water-seeded rice. Rice Research Station, South Unit, Crowley, LA. **1993.**[1,2]

Parameter	MP1	MP2	MP3	MP4	LSD (0.05)
BOD5 (mg/L)	7.3	18.6	18.1	14.0	4.4
pH	7.8	7.7	8.2	7.4	0.4
EC (dS/m)	0.55	0.38	0.48	0.35	0.05
TSS (mg/L)	7	100	74	300	14
TDS (mg/L)	436	2000	325	3887	2036
TS (mg/L)	453	4207	520	8800	2776
Fe (mg/L)	0.05	1.35	0.02	11.31	7.08
Mn (mg/L)	0.001	0.009	0.001	0.021	ns
Ni (mg/L)	0.03	0.03	0.03	0.04	ns
Al (mg/L)	0.03	3.51	0.06	28.68	18.0
Cd (mg/L)	0.002	0.002	0.002	0.003	ns
Cu (mg/L)	0.004	0.005	0.003	0.010	0.005
As (mg/L)	0.020	0.033	0.023	0.070	ns
B (mg/L)	0.087	0.050	0.100	0.070	ns
Cr (mg/L)	0.004	0.004	0.004	0.023	ns
Si (mg/L)	15.5	13.5	7.7	55.2	30.5
P (mg/L)	0.28	0.17	0.15	0.41	ns
Pb (mg/L)	0.050	0.050	0.050	0.053	ns
Zn (mg/L)	0.018	0.015	0.010	0.052	.027
Mg (mg/L)	24.8	14.2	22.5	10.4	6.4
K (mg/L)	8.2	4.6	5.7	5.5	1.3
S (mg/L)	0.94	2.28	1.09	2.75	0.64
Na (mg/L)	80.2	61.5	95.6	67.6	ns
Ca (mg/L)	40.9	23.4	31.7	13.9	11.4
F^- (mg/L)	0.56	0.72	0.74	0.70	ns
Cl^- (mg/L)	42.0	40.8	50.1	48.3	ns
Br^- (mg/L)	0.07	0.15	0.13	0.20	ns
NO_2^- (mg/L)	<0.10	<0.10	<0.10	<0.10	ns
NO_3^- (mg/L)	0.28	0.53	0.25	0.90	ns
PO_4^{3-} (mg/L)	<0.2	<0.2	<0.2	<0.2	ns
SO_4^{2-} (mg/L)	1.10	4.43	1.81	5.98	1.64

[1] MP1 = No till; MP2 = mudding in with floodwater retention; MP3 = clear water planting; MP4 = traditional mudding in.

[2] < may indicate no measured amount at the detection limits for that particular variable.

RESULTS AND DISCUSSION

Agronomic characteristics of the MPs are shown in Table 1. Maybelle emerged 5 to 6 days after planting in MP2, MP3. and MP4 (water-seeded rice is considered emerged when 75% of the seedlings have a shoot 3/4 of an inch in length). Emergence in MP1 occurred 7 days later. Loss of seedlings and poor rooting were observed in this MP. These problems appeared to have been associated with poor floodwater quality that resulted from decomposition of terminated vegetation. Stand establishment in water-seeded, no-till rice has been a problem in previous studies (Bollich, 1992) and also in commercial fields. As a result, stand density was significantly reduced in MP1. Stand densities were similar for the other MPs.

Table 3. Influence of management practices on water quality of rice field floodwater (midseason drain) from water-seeded rice. Rice Research Station, South Unit, Crowley, LA. 1993.[1,2]

Parameter	MP1	MP2	MP3	MP4	LSD (0.05)
BOD5 (mg/L)[3]					
pH	7.8	7.8	7.8	7.7	ns
EC (dS/m)	221	167	185	160	13
TSS (mg/L)	8.67	4.33	5.67	7.67	ns
TDS (mg/L)	156	127	144	117	19
TS (mg/L)	158	114	125	113	15
Fe (mg/L)	0.57	0.94	1.21	1.40	ns
Mn (mg/L)	<0.001	<0.001	0.001	0.002	.001
Ni (mg/L)	0.001	0.004	0.004	0.000	ns
Al (mg/L)	0.017	0.047	0.033	0.043	ns
Cd (mg/L)	<0.002	<0.002	<0.002	<0.002	ns
Cu (mg/L)	0.003	0.003	0.004	0.002	ns
As (mg/L)	0.028	0.044	0.037	0.039	ns
B (mg/L)	0.037	0.033	0.033	0.033	ns
Cr (mg/L)	0.000	0.004	0.000	0.000	ns
Si (mg/L)	3.53	3.03	2.97	2.93	.29
P (mg/L)	0.30	0.28	0.19	0.24	ns
Pb (mg/L)	0.087	0.117	0.090	0.083	ns
Zn (mg/L)	0.002	0.012	0.005	0.005	ns
Mg (mg/L)	7.99	6.25	6.89	6.10	0.55
K (mg/L)	1.01	1.23	1.41	1.56	ns
S (mg/L)	0.44	0.38	0.35	0.37	0.05
Na (mg/L)	21.6	16.9	18.7	16.5	1.9
Ca (mg/L)	21.7	14.1	15.8	12.8	1.4
F^- (mg/L)	0.21	0.20	0.18	0.19	0.02
Cl^- (mg/L)	11.3	8.6	9.3	8.4	ns
Br (mg/L)	0.056	0.058	0.051	0.054	ns
NO; (mg/L)	<0.10	<0.10	0.10	0.432	0.230
NO, (mg/L)	1.29	0.48	0.34	0.05	0.35
PO_4^{3-} (mg/L)	<0.2	<0.2	<0.2	<0.2	ns
SO_4^{2-} (mg/L)	0.40	0.38	0.36	0.39	ns

[1] MP1 = No till; MP2 = mudding in with floodwater retention; MP3 = clear water planting; MP4 = traditional mudding in.
[2] < may indicate no measured amount at the detection limits for that particular variable.
[3] BOD5 was not determined on the midseason drain samples.

Stand establishment difficulty in MP1 also delayed maturity. Time to 50% heading was increased 5 to 7 days in MP1 when compared with the other MPs. Earliness is an important consideration in southwest Louisiana where ratoon cropping is practiced extensively, and delayed maturity of the main crop is a serious disadvantage. Plant height was similar in each MP.

Grain yield was significantly reduced in MP1. When compared with MP2, MP3, and MP4, yield of MP1 was reduced 20, 22, and 16%. respectively.

Table 4. Influence of management practices on water quality of rice field floodwater (harvest drain) from water-seeded rice. Rice Research Station, South Unit, Crowley, LA. 1993.[1,2]

Parameter	MP1	MP2	MP3	MP4	LSD (0.05)
BOD5 (mg/L)	2.6	3.6	5.3	2.4	ns
pH	8.0	8.0	7.9	7.9	0.1
EC (dS/m)	282	292	283	277	ns
TSS (mg/L)	2.0	7.3	9.0	10.7	3.1
TDS (mg/L)	197	202	207	204	ns
TS (mg/L)	200	218	208	212	ns
Fe (mg/L)	1.0	0.1	1.2	1.2	0.7
Mn (mg/L)	<0.001	<0.001	<0.001	<0.001	ns
Ni (mg/L)	0.020	0.017	0.021	0.023	ns
Al (mg/L)	0.027	0.020	0.013	0.003	ns
Cd (mg/L)	0.003	0.002	<0.002	<0.002	ns
Cu (mg/L)	0.003	0.002	0.002	0.001	ns
As (mg/L)	0.034	0.012	0.016	0.023	ns
B (mg/L)	0.080	0.080	0.067	0.073	ns
Cr (mg/L)	0.009	0.003	0.003	0.002	0.005
Si (mg/L)	7.2	9.1	11.2	8.2	1.5
P (mg/L)	0.117	0.100	0.070	0.087	ns
Pb (mg/L)	0.063	<0.05	<0.05	<0.05	ns
Zn (mg/L)	0.001	0.001	0.002	0.003	ns
Mg (mg/L)	12.0	12.4	12.2	11.8	ns
K (mg/L)	3.1	6.2	7.8	6.3	1.5
S (mg/L)	0.34	0.39	1.23	0.46	ns
Na (mg/L)	30.8	32.9	30.5	30.6	ns
Ca (mg/L)	23.1	19.6	20.0	17.5	3.7
F (mg/L)	0.24	0.25	0.22	0.26	0.01
Cl^- (mg/L)	22.2	28.0	28.7	29.8	4.5
Br^- (mg/L)	0.15	0.25	0.24	0.23	0.02
NO_3^- (mg/L)	<0.10	0.38	0.77	0.51	ns
NO_2^- (mg/L)	<0.05	<0.05	<0.05	<0.05	ns
PO_4^{3-} (mg/L)	0.053	0.122	0.144	0.081	ns
SO_4^{2-} (mg/L)	0.18	0.37	0.43	0.40	0.11

[1] MP1 = No till; MP2 = mudding in with floodwater retention; MP3 = clear water planting; MP4 = traditional mudding in.

[2] < may indicate no measured amount at the detection limits for that particular variable.

The yield reduction was associated with inadequate stand density. Red rice stand density was not determined because of very nonuniform establishment in the test area. By visual estimation, the amount of red rice established among treatments was in the following order: clear water < mudding in = mudding in with floodwater retention < no-till. Grain samples were collected at harvest in each treatment to determine whether milling, grade, or quality was affected by red rice.

Head rice (whole grain) yield was significantly lower in MP4 but was due to severe lodging rather than red rice. Head rice was similar for the other MPs, and the total (whole grains + brokens) was unaffected.

The BOD5 was significantly lower in MP1 during the initial drain (Table 2). Values were similar in the other MPs. In MP2, BOD5 was significantly higher than in MP4. The pH was highest in MP3 and lowest in MP4. Both MP2 and MP4 were similar in EC, while EC was significantly higher in MP1 and MP3. Levels of TSS were significantly lower in MPl, followed by MP3, MP2, and MP4. Levels of TDS and TS were similar for MP1 and MP3. There was no difference in TDS between MP2 and MP4, but TS was significantly lower when the floodwater was retained for 2 weeks in MP2.

There were no differences among MPs in concentration of most of the nutrients. metals, and anions. Concentrations of Fe, Al, Cu, Si, Zn, Mg, S, Ca, and SO_4^{2-} were similar for MP1 and MP3, and in most instances, lower than levels found in MP2 and MP4. A higher concentration of K was released from MPl. Levels of most dissolved elements were similar for MP2 and MP4, with the exception of Fe, Al, Cu, and Si. These elements were decreased in MP2.

At midseason, EC increased in all MPs (Table **3).** This parameter was similar in MP2 and MP4, and significantly higher in MP1 and MP3. This is due to evaporation and additions of water to maintain flood depth. There were no differences in TSS among MPs, and although there were differences in **TDS** and TS, levels in all MPs were much lower than during the initial drain, indicating that sediment had settled overtime.

Concentrations of Si, Mg, S, Na, Ca, NO_3^{2-}, and PO_4^{3-} were significantly higher in MPl. Level of NO; was highest in MP4 with none being detected in MP1 or MP2.

With the exception of EC, Na, and Cl^-, values for most parameters were further reduced at harvest drain (Table 4). The increase in EC is most likely resulting from the increase in Na and Cl^-. Concentrations of most dissolved elements and metals, BOD5, EC, TDS, TS, NO; NO; and PO_4^{3-} were similar for all MPs. The TSS was significantly lower in MP1 but overall values were quite low. Concentrations of Fe and Cr were lowest and highest, respectively, in MP1. Concentration of Si was highest in MP2 and MP3, while K, Br^-, Cl^-, and SO_4^{2-} were lowest in MP1.

Rice planting practices do have a significant impact on effluent parameters when floodwater is released, especially during the initial drain. The quality of most effluent parameters improves over time, and while differences among MPs are detected at midseason and during harvest drain, most of the problems associated with degraded water in receiving streams occur during the initial drain. These alternative MPs have all been shown to be effective in improving rice field effluent. Stand establishment in MP1 is a serious concern, especially when grain yield is reduced to the extent measured in this study. Rice variety suitability, preplant vegetation manipulation, and floodwater management need to be addressed in order to minimize stand problems to make no-till planting more attractive to widespread commercial application. Greater emphasis also needs to be placed on red rice control, since red rice is the primary reason for culturing rice in the traditional mudding in system.

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