Reprinted from the *Journal of Production Agriculture*
Volume 3, no. 4, October-December 1990
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In the dry-seeded, flooded rice (*Oryza sativa*, L.) production areas of the southern USA, a flood is normally maintained until shortly before harvest to minimize rice yield or milling quality reduction due to water deficits. Research conducted in Arkansas on Crowley (fine, montmorrillonitic, thermic Typic Albaqualfs) silt loam and Sharkey (very-fine, montmorillonitic, nonacid, thermic Vertic Haplaquepts) clay soils indicated no reduction in rough rice yields when flooding was ceased at heading, but effects of early cessation of flooding on rice milling quality were not assessed. The primary objective of this research was to determine if early cessation of flooding would reduce rice grain yield or milling quality. Field experiments were conducted at three Arkansas locations in 1987 and 1988. The experimental design was split-plot, randomized complete block. Main plot treatments were times of draining (TD) which were 0, 2, and 4 wk after the 50% heading date. Subplot treatments were times of harvest (TH) which were 3, 4, 5, and 6 wk after heading. Draining at 2 wk after heading did not reduce rough rice yields or head rice yields over draining at 4 wk after heading at any location in any year. On the Crowley soil, draining at heading reduced rough rice by 15 to 40 cwt/acre and head rice yields by 0 to 40% depending on year and TH. In 1987, draining at heading on the Sharkey soil reduced rough rice yields from 0 to 25 cwt/acre, and reduced head rice yields 0 to 30% depending on TH. Draining at heading decreased neither rough rice yields nor head rice yields on the Calhoun soil or in 1988 on the Sharkey soil. It appears that rice growers producing rice in the Mid-South on these or similar soils may safely cease flooding 2 wk after heading.

MOST SOILS used for extensive flooded rice production have a considerable ability to hold water after draining. In Arkansas, the recommended draining date is 25 d after the 50% heading date for most rice cultivars (Keisling et al., 1984). However, earlier-than-normal draining times for rice in the Southern USA have resulted in little or no reduction of rough rice yields (Ferguson et al., 1982; Wells and Shockley, 1978). These authors did not assess the effects of early cessation of flooding on rice milling quality. De Datta (1987) reported significant reduction in rough rice yields as a result of water deficits at heading; however, postheading water stress was not discussed.

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Published in J. Prod. Agric 3:436–445 (1990).

Yoshida (1981) concluded that maximum grain weights are achieved between 13 and 33 d after heading in most rice cultivars. Although plant stresses that occur during the grain filling period may cause significant decreases in both rough rice and head rice yields, stresses after this period are unlikely to cause significant reductions. The field drying process, however, may result in significant reduction in rice quality without reducing rough rice yield (Calderwood et al., 1980; Kunze et al., 1988; McNeal, 1950).

Rice quality is primarily determined by the head rice yield percentage, defined as the weight percentage of rough rice which remains as head rice throughout the milling process. Head rice is that portion of milled rice comprised of whole kernels which is defined as 75% or more of the original length of the kernel. Head rice yields are affected by several factors including maturity, moisture adsorption by dried kernels, and mechanical damage from combining and grain handling. Considerable research indicates that maximum head rice yields are usually obtained when rice is harvested between 16 and 23% moisture (wet basis) and between 22 and 36 d after heading (Calderwood et al., 1980; McNeal, 1950). Head rice yields may be greatly reduced by breakage of immature kernels if rice is harvested too early. After grain maturity, fissures in the rice grain may develop if dried kernels absorb moisture. Moisture adsorption has been shown to be a major reason for reduced head rice yields (Siebenmorgen and Jindal, 1986; Kunze et al., 1988). Kunze et al. (1988) state that management practices are likely to affect rice grain fissures only to the extent that they affect grain moisture content.

Three of the most important soils used for rice production in the Southern USA are the Crowley silt loam, the Sharkey clay, and the Calhoun silt loam (fine-silty, mixed, thermic Typic Glossaqualfs). These soils have significantly different physical characteristics that determine waterholding capacity following drainage. The Crowley soil has an impervious layer approximately 6 to 9 in. below the surface. Consequently, little water is lost from the Crowley soil by percolation. On this soil, most of the root mass after heading appears to be in the upper 8 in. of the soil profile (Beyrouty et al., 1988). The Sharkey soil lacks a distinct impervious layer in the profile, but percolation also is limited in this soil due to its fine texture. The Calhoun soil has poor internal drainage but lacks an impervious layer. All three soils have high waterholding capacities.

Important questions concerning the effect of early draining on rice yield and quality, and concerning possible interactions between time of harvest and time of draining were not addressed by earlier studies (Ferguson et al., 1982); Wells and Shockley, 1978). The questions concerning rough rice yield and quality addressed in this study are: (i) what are the effects of draining at 50% heading or draining at 2 wk after 50% heading over draining at 4 wk after 50% heading and (ii) what effect does time of harvest have on the effect of time of draining? The primary objective of this research was to determine the potential of early cessation of flooding for reducing rice grain yield or milling quality.

MATERIALS AND METHODS

Experiments were conducted on three soil types in the 1987 and 1988 growing seasons. These three soils were at different University of Arkansas facilities: Sharkey silty clay (pH 6.7) at the Northeast Research and Extension Center at Keiser; Calhoun silt loam soil (pH 7.0) at the Pine Tree Experiment Station at Colt; and Crowley silt loam soil (pH 6.1) at the Rice Research and Extension Center at Stuttgart.

Treatments were time of draining (TD=0,2,4 wk after heading), and time of harvest (TH=3,4,5,6 wk after heading). All of the 3-wk TH/4-wk TD plots and half of the 4-wk TH/4-wk TD plots were harvested while the plots were still flooded (Table 1). The experimental design was a split-plot, randomized complete block with TD as the main plot treatment and TH as the subplot treatment. Main plot dimensions at Keiser were 36 by 48 ft in 1987 and 36 by 50 ft in 1988; subplot dimensions were 6 by 48 and 6 by 50 ft in 1987 and 1988, respectively. Main plot dimensions at Stuttgart were 36 by 32 ft and subplot dimensions were 6 by 32 ft. Main plot dimensions at Pine Tree were 8 by 110 ft, and subplot dimensions were 8 by 25 ft with 2 ft borders between the ends of subplots. Plots at Pine tree were placed end to end while the plots at Keiser and Stuttgart were placed side by side. There were four replications in the experiments at Keiser and Stuttgart and three replications in the experiments at Pine Tree. The main plots at Keiser were divided by two levees to reduce or prevent lateral water movement between main plots. This precaution was necessary at Keiser because of the extreme shrinking and swelling of the soil. Sufficient borders between harvested areas and levees minimized or eliminated any seepage effects.

Due to small differences in planting date and in rice development at the different locations and in different years, the treatments were applied on different dates (Table 1). Rainfall between heading and the last harvest date at each location was substantial (Table 2).

Table 1. Treatment applications for time of draining and time of harvest at three Arkansas locations in 2 yr.

Location	Year	Heading date†	Dates of time of draining (TD) 0	2	4	Dates of time of harvest (TH) 3	4	5	6
			Wk after heading						
Keiser	1987	8-14	8-14	8-28	9-11	9-2	9-9	9-16	9-23
	1988	8-26	8-26	9-9	9-23	9-13	9-20	9-27	10-3
Pine Tree	1987	7-29	7-29	8-13	8-27	8-19	8-26	9-2	9-9
	1988	8-15	8-15	8-29	9-12	9-6	9-13	9-20	9-27
Stuttgart	1987	8-5	8-5	8-19	9-2	8-26	9-2	9-9	9-16
	1988	8-7	8-7	8-21	9-4	8-30	9-6	9-13	9-20

† Heading is the 50% heading date as determined by visually rating the plots.

Table 2. Precipitation dates and amounts at three Arkansas locations in 1987 and 1988.

Keiser 1987 Date	Amt	Keiser 1988 Date	Amt	Pine Tree 1987 Date	Amt	Pine Tree 1988 Date	Amt	Stuttgart 1987 Date	Amt	Stuttgart 1988 Date	Amt
	in.		in.		in.		in.		in.		in.
8-18	0.20	8-28	0.63	8-10	0.51	9-11	0.73	8-5	0.05	8-11	0.06
8-19	0.25	9-2	0.01	8-11	0.41	9-19	0.35	8-10	0.04	8-18	0.02
8-25	0.02	9-3	0.02	8-18	0.45	9-26	0.76	8-12	0.41	8-20	0.42
8-28	0.12	9-4	0.65	9-8	1.45			8-19	0.04	8-24	0.04
9-8	0.95	9-12	0.16					8-28	1.75	9-4	0.43
9-11	0.40	9-17	0.20					9-1	0.13	9-11	0.20
9-16	0.88	9-19	0.26					9-8	0.02	9-12	0.34
9-17	0.08	9-20	0.01					9-11	0.35	9-17	4.30
9-19	0.02	9-24	1.95					9-12	0.04	9-18	0.34
		9-25	0.20					9-13	0.36	9-20	0.07
		9-29	0.03								
		9-30	0.17								
		10-1	2.16								
		10-2	0.07								
Sum	2.92		6.52						3.19		6.22
Long-term avg†	4.53		4.59		NA‡		NA		4.31		4.59

† The average of the sums of each of the previous 20 yr for the period beginning with the 50% heading date and ending with the 6 wk time of harvest.
‡ NA = not available.

'Lemont' rice (Bollich et al., 1985) was planted from late April to mid-May of each year in 7-in drill rows at seeding rates of approximately 47 seeds/sq ft. Weeds were controlled by preflood applications of propanil [N-(3,4-dichlorophenyl) propanamide], thiobencarb [S-(4-chlorophenyl)methyl diethylcarbamothioate], and by hand-weeding as necessary. Rice was fertilized with 120 lb N/acre at the 4- to 5-leaf stage and flooded within a day of fertilization. At the panicle differentiation stage of growth, plots were fertilized with 30 lb N/acre. A third application of 30 lb N/acre was made 7 to 14 d later.

Soil moisture tension was monitored by tensiometers for each main plot at Keiser and for each main plot in two replications at Pine Tree and Stuttgart. Following draining, and as conditions allowed, tensiometers were read 5 d/wk at Keiser and 3 d/wk at Pine Tree and Stuttgart. Tensiometers were placed at 9, 18, 27, and 36 in. below the soil surface at Keiser, and at 12 and 24 in. at Pine Tree and Stuttgart.

Plots were harvested by handcutting the standing crop on the mornings of the specified harvest dates. The unthreshed rice straw was placed overnight in an air-conditioned room with a temperature of approximately 72 °F. The harvested area in each subplot of each experiment (all locations and years) was 42 sq ft. The following day, rice was threshed with a Kubota[1] 1100 combine. The grain remaining in the grain augers was cleaned out with compressed air between plots and added to the grain sample of each respective plot. The grain was cleaned twice using a Clipper[1] seed-cleaner and weighed. Moisture content was determined using a Steinlite[1] moisture meter. Grain weights at harvest were calculated on a 12% moisture corrected (wet) basis (Grain moistures are presented as percentage on a wet basis.).

Two-pound samples were double-bagged using two Zip-loc[1] 1-gal. plastic bags. These bags were refrigerated at approximately 45° F until time of transport to Fayetteville to be milled. At various times during harvest, the refrigerated samples were transported to Fayetteville and placed in cold storage at approximately 35 °F. The samples were subsequently dried to 12 to 13% using a relative humidity and temperature control unit (Parameter Generation and Control, Inc, Model 300-AA[1]). Drying air temperature and relative humidity were maintained at approximately 68 °F and 62%, respectively. After drying, two 5.3-oz (150-g) samples of rough rice from each plot were milled. The milling procedure consisted of measuring the moisture content of the rough rice in triplicate in a Motomco Model 919A moisture meter, hulling the rice with a McGill huller, milling the brown rice for 30 s in a McGill No. 2 miller, and separating the white rice into head rice (kernels having 75% or more of the original kernel length) and brokens using a Seedburo[1] sizing machine with a No. 13 top screen and a No. 12 bottom screen. Head rice yield was expressed as the weight percentage of the original 5.3-oz. rough rice sample which remained as head rice.

Grain yields and moisture, and rice quality data (milled rice and head rice yields) were submitted to analysis of variance using the GLM procedure of SAS (SAS, 1982). Because units of time are continuous rather than discrete, an analysis of variance was done in which both linear and quadratic components of TD and TH and their interaction terms were analyzed. Because the principle factors affecting the rice grain responses, after physiological maturity, would be expected to be rainfall and relative humidity of the air, the analysis of linear and quadratic effects of TD and TH and their interactions did not facilitate a simplified discussion of the responses. Consequently, the data with interactions are discussed with comparisons made within and among levels of TD and TH. Comparisons within and among levels of TD and TH were determined to be significant using the LSMEANS routine of GLM (SAS, 1982).

RESULTS AND DISCUSSION

There were large and significant location effects on most of the variables; consequently, data from each location were analyzed separately.

SHARKEY SOIL

On the Sharkey silty clay soil at Keiser, all main effects (year, TD, TH) were significant (Table 3). The interactions were generally significant except for milled rice yields. There was a significant year by TH interaction for milled rice yields.

Table 3. Mean squares for rough rice yields, grain moisture, milled rice, and head rice yields from experiments conducted at Keiser, AR, in 1987 and 1988.

Source of variation	df	Mean squares: Rough rice	Grain moisture	Milled rice	Head rice
		cwt/acre	%		
Year	1†	4437**	243.6***	63*	943*
Rep/year	6	326***	2.3	9	66*
Time of draining (TD)	2‡	1134***	76.0***	43*	395**
Year × TD	2‡	372*	61.4***	9	190*
TD × rep/year	12	63	1.3	8	44
Time of harvest (TH)	3	1051***	198.9***	1657***	4455***
TD × TH	6	68**	3.0*	22	149***
Year × TH	3	673***	12.2***	209***	1107***
Year × TD × TH	6	94***	4.3**	20	135***
Error	54§	17	1.1	12	23
CV (%)		6.93	4.30	5.38	12.97

*,**,*** Significant at 0.05, 0.01, and 0.001 levels of probability, respectively.
† The error term for testing the "Year" effect was the "Rep/Year" mean square.
‡ The error term for testing the "TD" and "Year × TD" effects was the "TD × Rep/Year" mean square.
§ df for the error mean square for milled rice and head rice was 50 because of missing samples for those responses.

[1] The use of trade names in this publication does not imply endorsement by the University of Arkansas of the products named and does not imply their approval to the exclusion of other products that may be suitable.

In 1987, the TD effect on rough rice yields, grain moisture, and head rice yields depended on TH (Fig. 1). At the 3-wk TH, there was little difference among the three TD for any of the variables measured. However, 0-wk TD resulted in progressively lower rough rice yields over the next three TH, while yields for the 2- and 4-wk TD treatments increased between the 3- and 4-wk TH, after which yields changed little (Fig. 1a). The rough rice yields for the 2- and 4-wk TD treatments did not differ at any harvest date. Grain moisture was lower for the 0-wk TD treatment than the 2- and 4-wk TD treatments at all TH, and the 0-wk TD treatment decreased more in response to TH than did the 2- and 4-wk TD treatments (Fig. 1b). Milled rice yields tended to increase with later TH for all three TD treatments (Fig. 1c). Milled rice yields were lower for the 0- and 2-wk TD treatments than for the 4-wk TD treatment at the 3-wk TH, but there were not significant differences among the three TD treatments by the 6-wk TH. Head rice yields for the 2- and 4-wk TD treatments increased in two of the three TH intervals but decreased after the 4-wk TH for the 0-wk TD treatment (Fig. 1d). Soil moisture tension (SMT) for the 0-wk TD treatment increased over most of the period of observation and reached fairly large values before the 3-wk TH (Fig. 2).

Differences in rough rice yields, grain moistures, and head rice yields between the 0-wk TD and the 2- and 4-wk TD treatments may be related to differences in SMT. The 0-wk TD treatment increased in SMT over the period that the two other TD treatments were still flooded, exceeding 58 cbars (Fig. 2). As a consequence, grain moistures were possibly lower for the 0-wk TD than for the 2- and 4-wk TD. After the 3-wk TH, grain moisture in the 0-wk TD treatments decreased below 20% and subsequent rewetting, drying, and fissuring of some of the grains would be expected (Chau and Kunze, 1982). Consequently, the 0-wk TD decreased in head rice yield after the 4-wk TH while the 2- and 4-wk TD treatments stayed the same between the 4- and 5-wk TH and increased between the 5-and 6-wk TH.

In 1988 on the Sharkey soil, rough rice yields increased from 3-to 5-wk TH and leveled off with little difference among the three TD at any TH (Fig. 3a). Grain moisture decreased steadily over the four TH

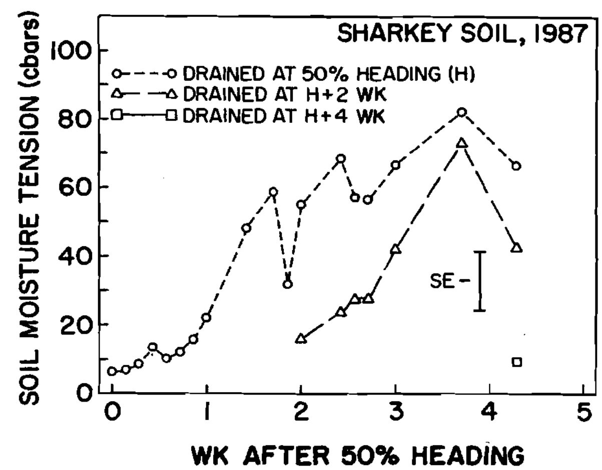

Fig. 2. Soil moisture tensions for three draining treatments from an experiment conducted at Keiser, AR, on a Sharkey silty clay soil in 1987.

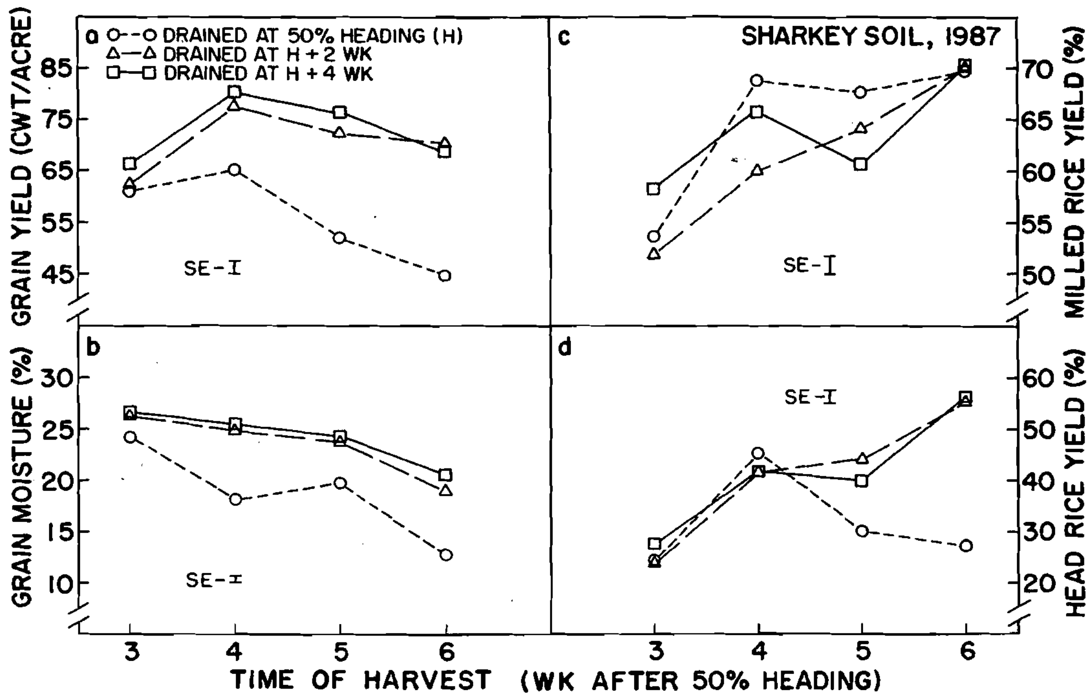

Fig. 1. Time of draining × time of harvest effects on rough rice yield, grain moisture, milled rice yield, and head rice yield from an experiment conducted at Keiser, AR, on a Sharkey silty clay soil in 1987.

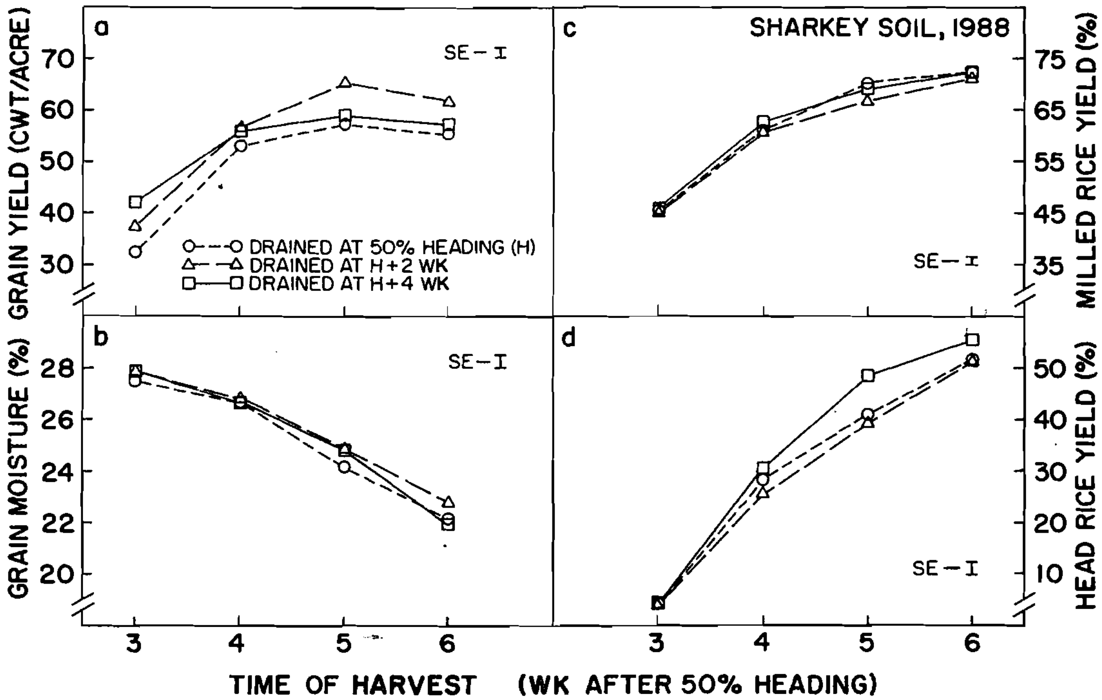

Fig. 3. Time of draining × time of harvest effects on rough rice yield, grain moisture, milled rice yield, and head rice yield from an experiment conducted at Keiser, AR, on a Sharkey silty clay soil in 1988.

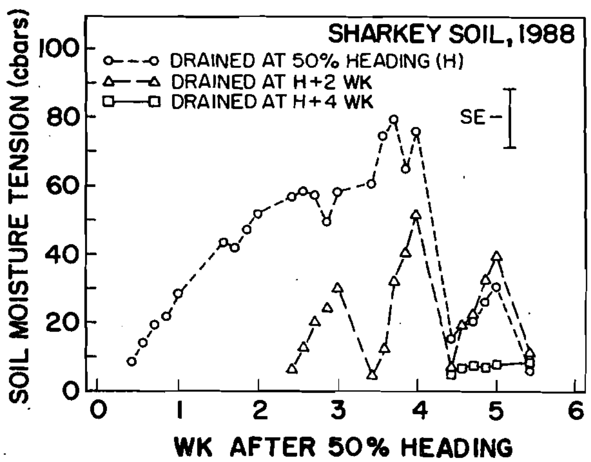

Fig. 4. Soil moisture tensions for three draining treatments from an experiment conducted at Keiser,AR, on a Sharkey silty clay soil in 1988.

for all TD with no differences among the TD (Fig. 3b). Milled rice yields increased or tended toward increasing over the four TH with no differences among the TD (Fig. 3c). Head rice yields increased over the four TH with no difference among the three TD treatments (Fig. 3d). The SMT reached 50 cbars for the 0-wk TD by the second TD (9 September), and almost reached 80 cbars before the soil was replenished with water by rainfall on 24 September, after which no soil moisture tension exceeded 40 cbars (Fig. 4).

On the Sharkey soil in 1988, the lack of response to TD may be related to the SMT in the 0-wk TD treatment before the two other TD treatments were drained. Although the maximum SMT observed in that period was almost as high in 1988 as in 1987 (47 vs. 58), the maximum was achieved earlier in 1987 (Fig. 2,4). Consequently, the 0-wk TD may not have undergone moisture stress for any substantial period as early as it did in 1987, and grain moistures among the three TD in 1988 did not differ. Since grain moistures did not differ among TD on the Sharkey soil in 1988, neither grain yield nor head rice yields were reduced by early (0-wk TD) draining. The 1987 and 1988 data at Keiser tend to confirm Kunze's hypothesis (Kunze et al., 1988) that head rice yields are likely to be affected by management practices only to the extent that management practices influence grain moisture content.

CALHOUN SOIL

On the Calhoun silt loam soil at Pine Tree, rough rice yields, grain moisture, head rice yields, and milled rice yields were significantly affected by TH (Table 4). Grain moisture and head rice yields had significant year × TH interactions. There were significant TD and year × TD effects on head rice yields.

On the Calhoun soil in 1987, rough rice yields did not differ among the three TD treatments but increased between the 3- and 4-wk TH across TD (Fig. 5a). Grain moisture decreased with TH (Fig. 5b). The 4-wk TD treatment had greater grain moisture than the 0-wk TD treatment at the 4- and 5-wk TH. The 4-wk TD treatment had greater grain moisture than the 2-wk TD treatment at the 4-wk TH but not before or after. Milled rice yields increased slightly over the

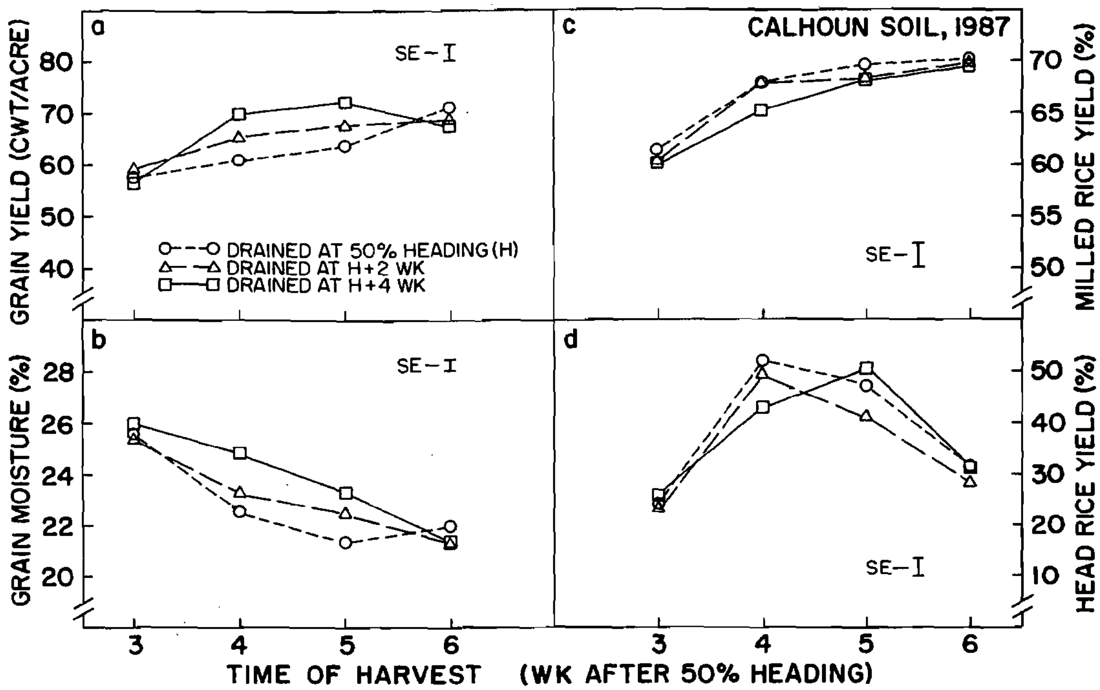

Fig. 5. Time of draining × time of harvest effects on rough rice yield, grain moisture, milled rice yield, and head rice yield from an experiment conducted at Pine Tree, AR, on a Calhoun silt loam soil in 1987.

course of the experiment and did not differ among TD treatments (Fig. 5c). Head rice increased between the 3- and 4-wk TH and decreased between the 5- and 6-wk TH for all TD but did not differ among the three TD treatments (Fig. 5d). Soil moisture tension did not exceed 60 cbars for any TD treatment (Fig. 6). Increases in SMT occurred after the 3-wk TH.

On the Calhoun soil in 1988, rough rice yields did not differ among TD treatments and increased slightly over the four TH (Fig. 7a). Grain moistures decreased gradually over the four TH to a low at the 6-wk TH; however, grain moistures were greater than 20% for all treatment combinations (Fig. 7b). Milled rice and head rice yields increased until the 5-wk TH after which they leveled off (Fig. 7 c, d). Head rice yields were greater for the 0- and 2-wk TD than for the 4-wk TD. Soil moisture tension exceeded 40 cbars for the 0-wk TD treatment during the 2 wk after draining but did not exceed 30 cbars again during the experiment, nor did the 2- and 4-wk TD treatments exceed 20 cbars (Fig. 8).

The SMT for these experiments appears to have been small enough to allow the plants in all treatments to extract adequate water for the plants' needs. The grain moisture contents were not less than 20% for any treatment combination on the Calhoun soil. The reduced head rice yields after the 5-wk drain time on

Table 4. Mean squares for rough rice yields, grain moisture, milled rice, and head rice yields from experiments conducted at Pine Tree, AR, in 1987 and 1988.

		Mean squares			
Source of variation	df	Rough rice	Grain moisture	Milled rice	Head rice
		cwt/acre	%		
Year	1†	6736**	8.9	92	16
Rep/year	4	262***	4.4***	46	100
Time of draining (TD)	2‡	100	8.0	47	182*
Year × TD	2‡	9	0.3	12	163*
TD × rep/year	8	115	2.4	23	27
Time of harvest (TH)	3	390***	82.1***	593***	2395***
TD × TH	6	42	0.9	17	61
Year × TH	3	8	4.4**	55	895***
Year × TD × TH	6	38	1.0	22	37
Error	36	37	0.7	20	53
CV (%)		10.96	3.56	6.82	19.28

*,**,*** Significant at 0.05, 0.01, and 0.001 levels of probability, respectively.
† The error term for testing the "Year" effect was the "Rep/Year" mean square.
‡ The error term for testing the "TD" and "Year × TD" effects was the "TD × Rep/Year" mean square.

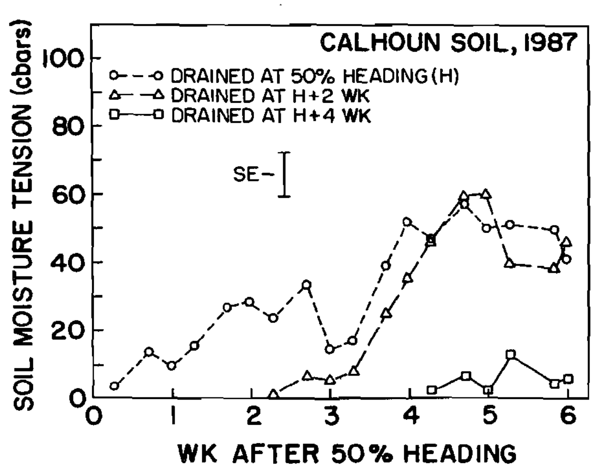

Fig. 6. Soil moisture tensions for three draining treatments from an experiment conducted at Pine Tree, AR, on a Calhoun silt loam soil in 1987.

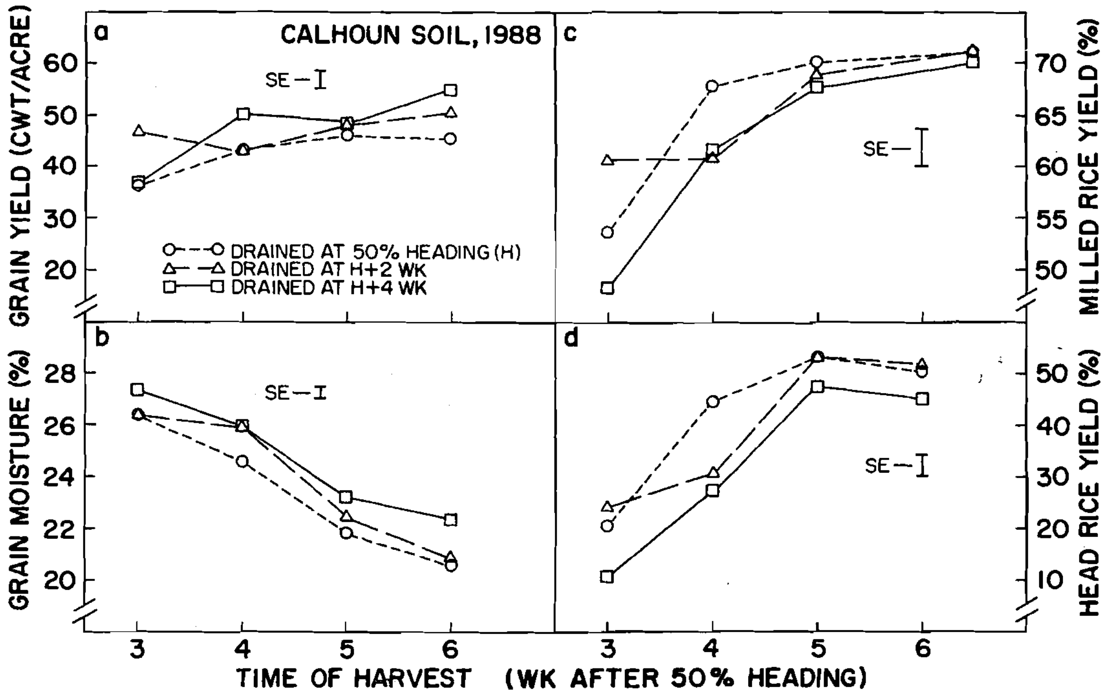

Fig. 7. Time of draining × time of harvest effects on rough rice yield, grain moisture, milled rice yield, and head rice yield from an experiment conducted at Pine Tree, AR, on a Calhoun silt loam soil in 1988.

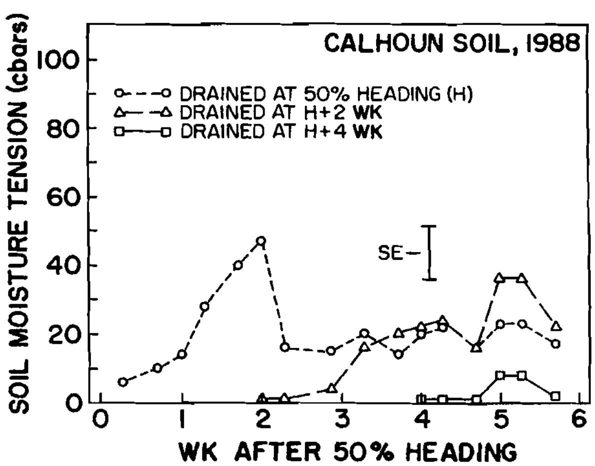

Fig. 8. Soil moisture tensions for three draining treatments from an experiment conducted at Pine Tree, AR, on a Calhoun silt loam soil in 1988.

the Calhoun soil may be related to rewetting and drying of mature grain (Chau and Kunze, 1982; Siebenmorgen and Jindal, 1986). The data suggest that draining as early as heading on the Calhoun soil may not reduce rice yield or quality.

CROWLEY SOIL

On the Crowley silt loam soil at Stuttgart, main effects were generally significant except for TH for rough rice yields and TD for milled rice yields (Table 5). In addition, interactions between year, TD, and TH were numerous.

On the Crowley soil in 1987, rough rice yields were less for the 0-wk TD treatment than for the 2- and 4-wk TD treatments at all TH (Fig. 9a). Rough rice yields changed little with TH within TD but the 0-wk TD was lower than the 2- and 4-TD treatments at all TH. Grain moisture decreased from 26 to 21% at the 2- and 4-wk TD treatments over the four TH (Fig. 9b). Grain moisture for the 0-wk TD treatment decreased from 20 to 14% in the first three TH and increased 3% in the next week indicating a considerable amount of rewetting of grain between the 5-wk and 6-wk TH. Milled rice yields changed little over the course of the experiment (Fig. 9c). Head rice yields increased gradually with TH for the 2- and 4-wk TD treatments and decreased gradually with TH for the 0-wk TD treatments (Fig. 9d). The SMT at 12 in. increased slightly for the 0-wk TD during the first 3 wk after heading. After 27 August, SMT for the 2-wk TD treatment exceeded the 0-wk TD treatment (Fig. 10).

On the Crowley soil in 1988, rough rice yields were again lower for the 0-wk TD treatment than the 2- and 4-wk TD treatments at all 4 TH (Fig. 11a). There was no effect of TH on rough rice yields for the 2- and 4-wk TD, but there was reduction in rough rice yields between the 5- and the 6-wk TH at the 0-wk TD. Grain moisture was less for the 0-wk TD than for the 2- and 4-wk TD at all four TH (Fig. 11b). Grain moisture decreased gradually with TH for the 2- and 4-wk TD treatments but decreased only between the 3- and 4-wk TH for the 0-wk TD treatment. Milled rice yields increased gradually with TH for the 2- and 4-wk TD treatment and changed little with TH at the 0-wk TD treatment until the 6-wk TH when milled rice yields decreased (Fig. 11c). Head rice yields increased with TH through the 5-wk TH for the 2- and 4-wk TD, after

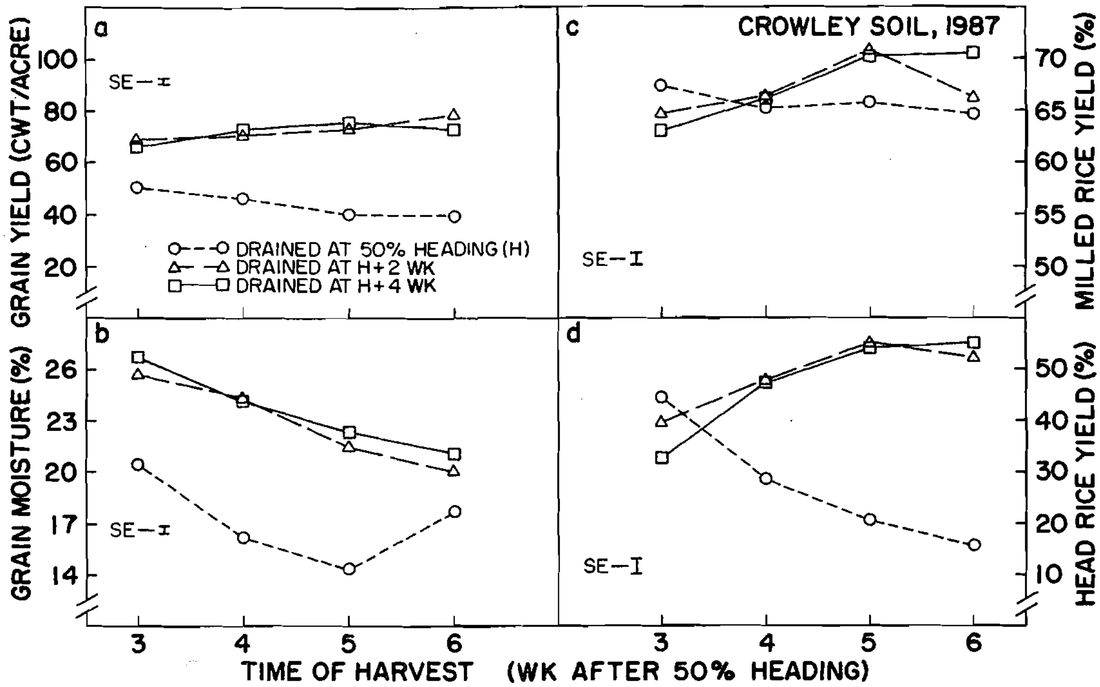

Fig. 9. Time of draining × time of harvest effects on rough rice yield, grain moisture, milled rice yield, and head rice yield from an experiment conducted at Stuttgart, AR, on a Crowley silt loam soil in 1987.

which they remained the same (Fig. 11d). At the 0-wk TD treatment, head rice yields decreased after the 4-wk TH. The SMT increased steadily over the course of the 1988 experiment until the 5-wk TH when rainfall replenished soil moisture (Fig. 12). The tensiometer readings on the Crowley soil probably were below the impervious layer; therefore, the readings may not relate to plant moisture availability.

On the Crowley soil, draining at 50% heading (0-wk TD) reduced rough rice yields and grain moisture contents at all TH in both years of the study. Head rice yields were reduced by early draining in both years at the later TH. The grain moistures for the 0-wk TD treatment indicate significant rewetting and drying at the later TH. Milled rice yields for the 0-wk TD treatment were reduced marginally by TH after the 4-wk TH.

Table 5. Mean squares for rough rice yields, grain moisture, milled rice, and head rice yields from experiments conducted at Stuttgart, AR, in 1987 and 1988.

Source of variation	df	Mean squares: Rough rice	Grain moisture	Milled rice	Head rice
		cwt/acre	%		
Year	1†	86	0.02	24	983**
Rep/year	6	63*	2.8**	9	72
Time of draining (TD)	2‡	5626***	267.1***	17	1862***
Year × TD	2‡	395	11.4**	1	575**
TD × rep/year	12	116	1.5	9	60
Time of harvest (TH)	3	29	150.2***	83***	152**
TD × TH	6	98**	12.8***	33**	743***
Year × TH	3	21	8.3***	8	23
Year × TD × TH	6	70*	1.0	7	103*
Error	54§	27	0.8	8	39
CV (%)		8.17	4.25	4.06	14.04

*,**,*** Significant at 0.05, 0.01, and 0.001 levels of probability, respectively.
† The error term for testing the "Year" effect was the "Rep/Year" mean square.
‡ The error term for testing the "TD" and "Year × TD" effects was the "TD × Rep/Year" mean square.
§ df for the error mean square for milled rice and head rice was 53 because of a missing sample for those responses.

REVIEW

Draining at 2 wk after heading did not reduce rough rice yields or head rice yields over draining at 4 wk after heading at any location in any year. On the Crowley soil, draining at heading reduced rough rice by 15 to 40 cwt/acre and head rice yields by 0 to 40% depending on year and TH. In 1987, draining at heading on the Sharkey soil reduced rough rice yields from 0

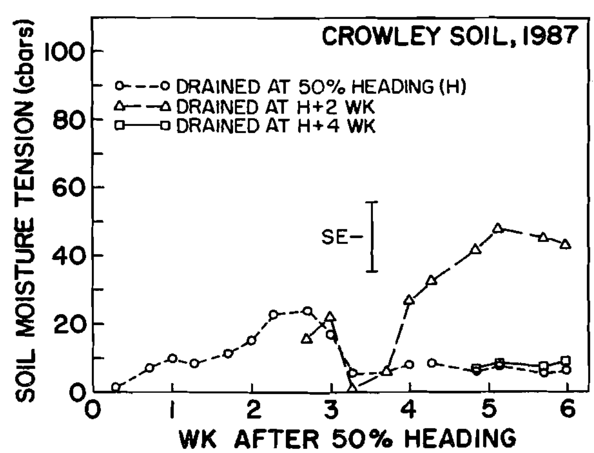

Fig. 10. Soil moisture tensions for three draining treatments from an experiment conducted at Stuttgart,AR, on a Crowley silt loam soil in 1987.

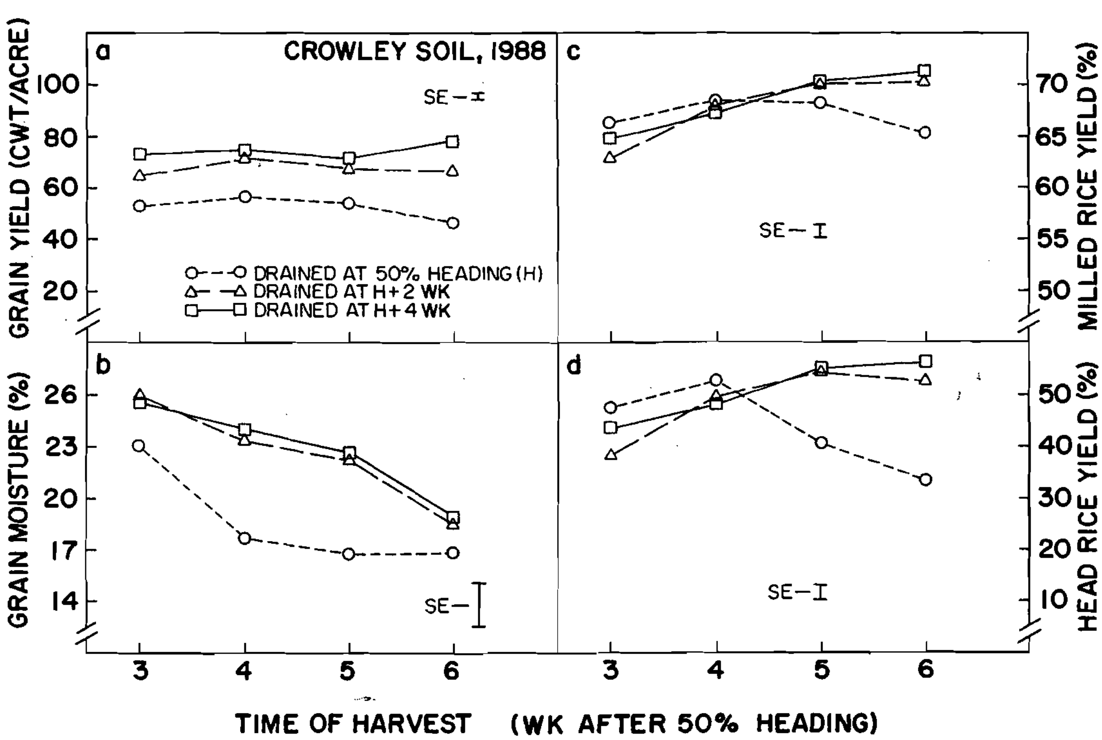

Fig. 11. Time of draining × time of harvest effects on rough rice yield, grain moisture, milled rice yield, and head rice yield from an experiment conducted at Stuttgart, AR, on a Crowley silt loam soil in 1988.

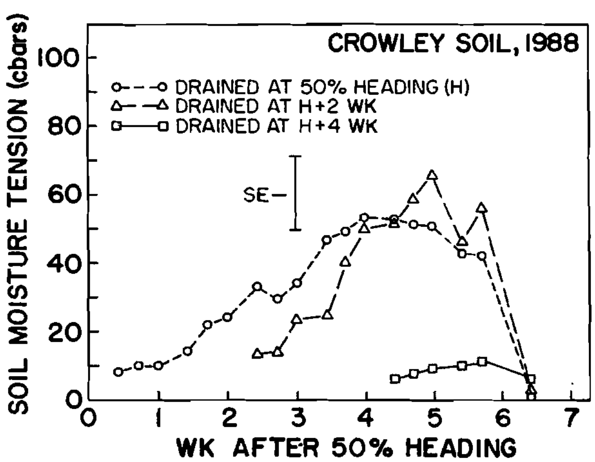

Fig. 12. Soil moisture tensions for three draining treatments from an experiment conducted at Stuttgart, AR, on a Crowley silt loam soil in 1988.

to 25 cwt/acre, and reduced head rice yields 0 to 30% depending on TH. Draining at heading decreased neither rough rice yields nor head rice yields on the Calhoun soil or in 1988 on the Sharkey soil.

Rough rice yields were less affected by TH on the Crowley soil than on the Sharkey or the Calhoun soil. The difference in the response to TH may have been due to slightly different meteorological conditions at Stuttgart than at Keiser or Pine Tree during the time of the study. The mature rice plants may have developed differently on the Crowley than on the Sharkey and Calhoun soils due to the more restrictive pan on the Crowley soil. Consistent with Calderwood et al. (1980), maximum head rice yields usually were obtained at the fourth through the sixth week after heading. Reductions in head rice and rough rice yields were found most often when the grain moisture at harvest was less than 20%.

The hypothesis that management practices are likely to influence head rice yields only to the extent that management influences harvest moisture (Kunze et al., 1988) can be tested using this data. Harvest moisture should account for a substantial amount of variation in head rice yields in this study, irrespective of other treatments. Equations for head rice yields with linear and quadratic moisture components accounted for greater than 70, 63, and 57% of the variation in head rice yields on the Sharkey, Calhoun, and Crowley soils, respectively. A quadratic equation for all locations combined accounted for 59.8% of the variation in head rice yields. In all four equations, both the linear and quadratic moisture components were highly significant ($P < 0.01$), and the optimum harvest moisture for the entire study was determined to be 20.5%.

INTERPRETATIVE SUMMARY

In the dry-seeded, flooded rice production areas of the Southern USA, a flood is normally maintained until shortly before harvest to minimize reductions in rice yield or quality due to water deficits. Based on the results of this study, it would be appropriate to change the recommendation for draining to applying no additional irrigation water to flooded rice after 2 wk past heading, followed by draining at the DD50 drain date (25 d after heading for most cultivars). Such a practice would save water and would not be likely to decrease rough rice yields or reduce rice quality. A less conservative approach would be to cease flooding shortly after heading, followed by draining 2 wk after heading. In view of this and earlier studies, such an approach is also reasonable. Maintaining the flood until 25 d after heading appears to be overly conservative.

ACKNOWLEDGMENTS

Excellent technical assistance throughout this study was provided by Dale Cox, Ray Rudisill, Mark Poag, Rodney Wright, Mike Banaszek, Cynthia Moore, William Johnson, P.A. Shockley, and Roger Eason. The advice of Drs. Bob Wells and Jim Ferguson during the planning of the study was also extremely helpful.

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