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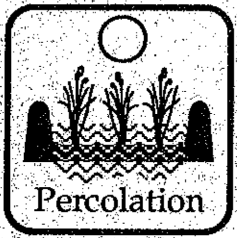

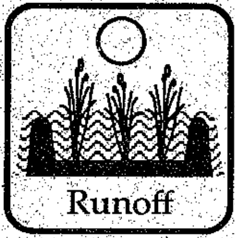

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Introduction

Water losses from an established flood in rice are evaporation, transpiration, deep percolation, levee seepage, and runoff.

Cooke and Callivet (1991) found that an average of 32 inches of water per acre (18 to 43-inch range) was pumped onto 19 rice fields in the Mississippi Delta. Earlier, a Texas group (McCauley et al., 1984-88) measured rainfall received, water pumped onto, and runoff from the main rice crop of 31 fields. Average amount of water pumped was 27 inches per acre with the range being 15 to 46 inches per acre. It appears that water conservation measures are needed when there is a difference of 25+ inches of water between the minimum and maximum amount of water being pumped.

Outside levee seepage losses typically have been measured in conjunction with runoff of excess water at the low end of a field. Runoff measured by McCauley et al. (1984-88) included seepage through levees, overflow from flushing, flood maintenance, rainfall, and end-of-season drainage. Losses ranged from 6 to 42 inches per acre and averaged 17 inches per acre.

Soil Conservation Service workers in Greenwood, Mississippi (Massey et al., 1989) measured 13.4 million gallons of seepage water over 56 days from 5,200 feet of levee on the lower end (permanent outside levees surrounded the remainder of the field) of two fields totalling 106 acres– an average of 4.8 inches per acre. Water depth was 4 to 5 inches against the levee. Outflow during the flood period on these two fields averaged 1.65 inches per acre. The cooperators managed their fields so that the only major water loss through the outlet gate was rainwater. This demonstration showed that seepage losses through outside levees could be a major component of water use in rice production.

In the Mississippi Delta, rice is grown on predominantly clay soils with a substantial percentage being on Sharkey clay (Vertic Haplaquepts). Deep percolation losses are minimal because of the low percolation or internal drainage rate of these soils when they are wet. This makes them suitable for establishing and holding a flood. However, the high shrink-swell characteristic (crack when dry) of these soils is not suitable for levees to hold a flood (USDA-SCS, 1970). Some producers have constructed permanent levees around their fields wide enough for vehicle traffic. Very little seepage has been observed when this practice is used.

When permanent levees are not feasible, construction of a nonpermanent outside levee is required. Seepage losses are present and methods for reducing these losses need to be developed (Figure 1).

The objectives of this study were to (1) determine differences in levee seepage between nonpermanent levees of different construction on a Sharkey clay over time, and (2) determine relationship of depth of flood to the quantity of seepage for a Sharkey clay and type of levee construction. This information will help develop levee construction criteria to reduce seepage losses.

Materials and Methods

The experiment was conducted using a randomized complete block design with four blocks and four treatments in 1990 and five blocks and four treatments in 1991. Soil type was Sharkey clay. Each experimental unit consisted of a 25- by 50-foot basin surrounded by levees. The levees to be tested were 50 feet long and

Figure 1. Example of seepage loss (right) occurring where a nonpermanent outside levee was constructed.

were constructed perpendicular to the main slope of the field so a constant water level could be maintained along its length. The construction method of the top and bottom levee of the basin was as defined by the treatment. Water was supplied to each basin by 6-inch gated pipe, and adjustable gates on the pipe were used to control the amount of water filling the basins. An overflow pipe in each basin provided an outlet for excess water. The overflow pipe was positioned at a height of 4.25 inches above the ground surface of the interior basin on the lowest end.

In 1990, a levee plow was used for constructing the basic levee of all four of the levee treatments (Figure 2). Treatments were (1) no packing, (2) packing with a levee packer, (3) packing with a dual-wheel tractor, or (4) no packing of a wider levee. The standard no-pack levee consisted of five passes with the levee plow. The levee packed with the levee packer ("Roll-a-Pak," made by Ironman Manufacturing, Dundee, MS) was packed after each of the last two passes with the levee plow (Figure 3). Bags of fertilizer were stacked on the deck of the levee packer for added weight. The levee packer weighed 4,295 pounds in 1990.

The tractor-packed levee (Figure 4) was packed with a dual-wheel IH 1466 tractor after each of the last two passes with the levee plow. The dual wheels of one side of the tractor passed down the center top of the levee. The loads applied to the levee and the respective tire sizes are given in Table 1.

Table 1. Tire size and load applied to the top of rice levees by the tractors packing the levees.

	Tire load and size			
	Single-wheel tractor		Dual-wheel tractor	
Tire location	(lb)	(in)	(lb)	(in)
Front	2,090	10.0 x 16	2,120	11.0 x 16
Inside rear	4,650	18.4 x 38	4,040	18.4 x 38
Outside rear			1,570	18.4 x 38

The wide no-pack levee was constructed by making three conventional passes with the levee plow, then a pass was made with the levee plow offset from the center by 2 feet, on each side, to pull soil from a wider area. Then, two more passes down the center with the levee plow resulted in a levee about 2 feet wider and slightly taller than the standard levee.

In 1991, the standard no-pack levee consisted of eight passes with the levee plow. A greater number of bags of fertilizer were stacked on the deck of the levee packer so that the unit weighed 6,010 pounds. Because of problems associated with building a wider levee with existing equipment, the no-pack wider levee was replaced with a packing treatment. This treatment was packed with a single-wheel tractor carrying the levee plow for added weight (Figure 5). One rear wheel of a Ford 9600 passed down the center of the top of the levee. The loads applied to the levee and the respective tire sizes are given in Table 1. All

Figure 2. Construction of a basic levee with a levee plow.

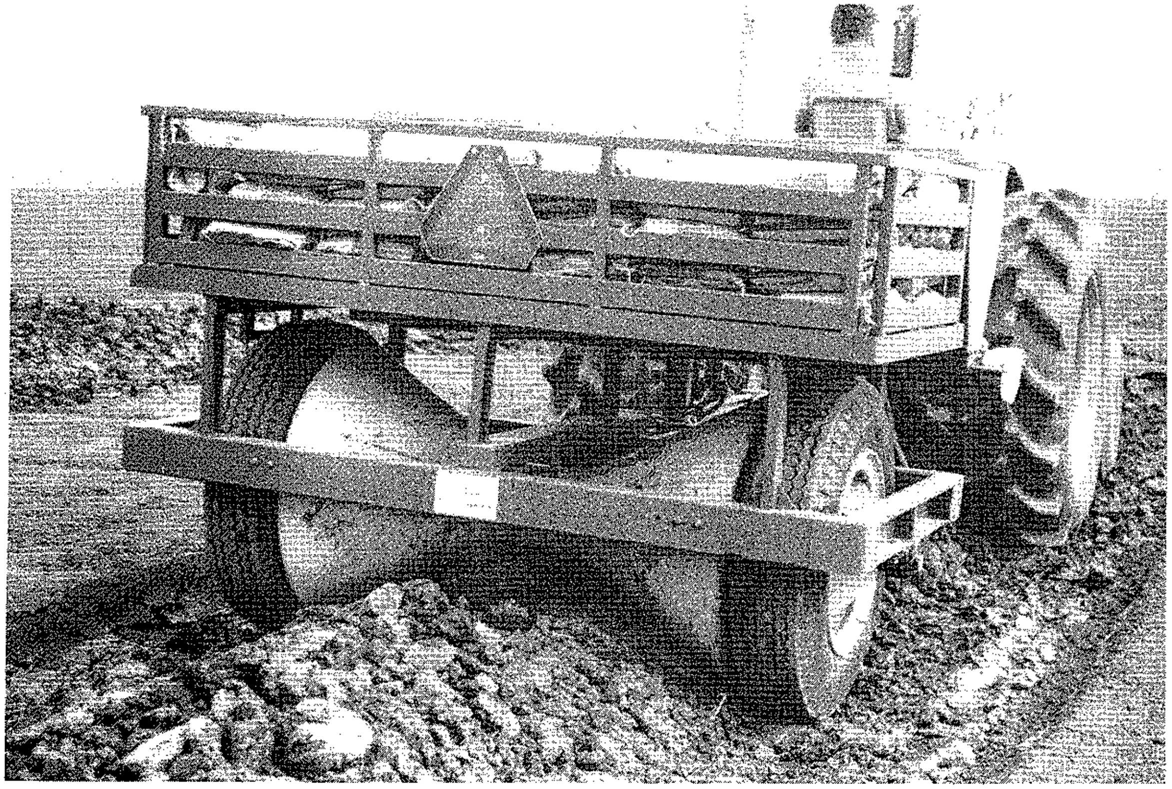

Figure 3. Levee packed with a commercially available levee packer.

Figure 4. Levee packed with a dual-wheel tractor.

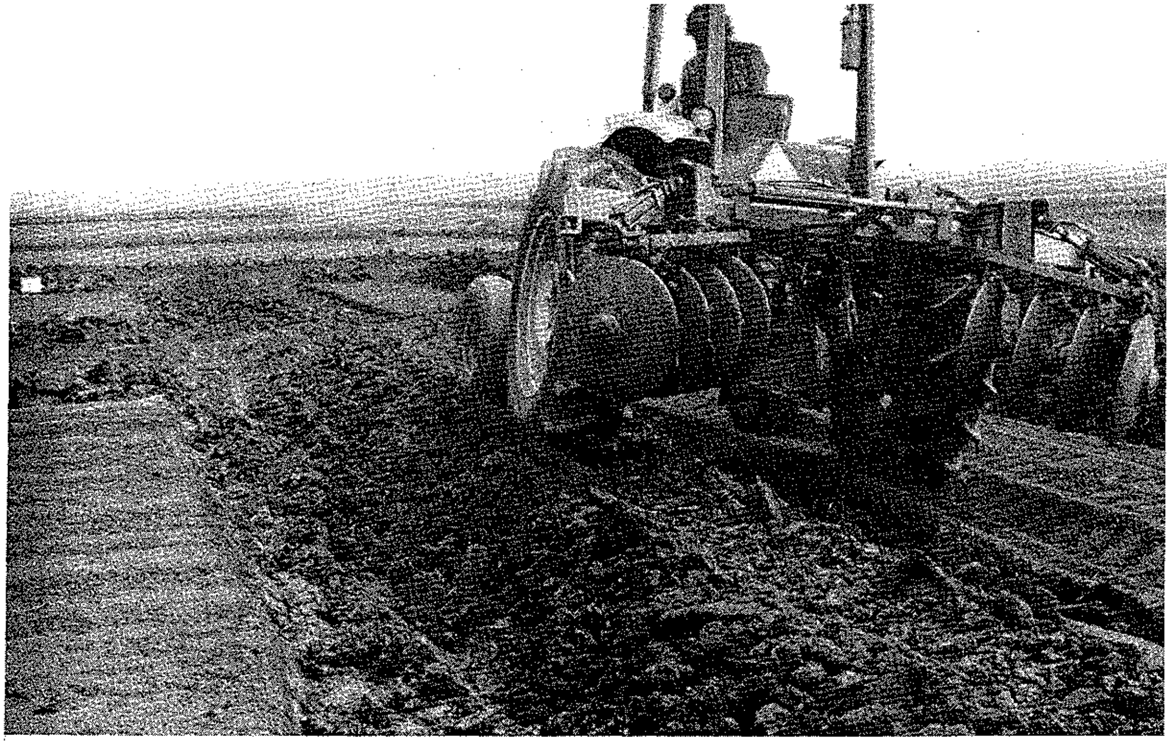

Figure 5. Levee packed with a single-wheel tractor carrying the levee plow for added weight.

Figure 6. Measurements of seepage over time were obtained by pumping seepage water occurring in a 10-foot section of the levee into adjacent containers.

packing treatments were made after each of the last two passes with the levee plow.

Each basin was filled with water daily throughout the test period. A constant flood depth was maintained starting the day before measurement was made in a given treatment. To maintain flood depth, water pumped into each basin was adjusted to account for all the losses occurring from ET (evapotranspiration), deep percolation, and levee seepage, plus a small amount of discharge through the overflow pipe. Measurements of depth of flood were recorded during each test run.

Seepage through a 10-foot section of levee was contained in the outside ditch made by the levee plow by blocking flow in or out of this section with metal barriers. Seepage occurring upstream of this section of levee was either pumped back into the basin or diverted down a drainage ditch. A battery-operated submersible pump with a float switch transferred the seepage water occurring in this 10-foot section into adjacent containers (Figure 6).

Two plastic containers were joined together by an overflow outlet so water would flow from one container to the other to collect this seepage for measurement. Two 44-gallon containers were used on the low side of the basin and a 32- and a 44-gallon container were used on the high side of the basin of each plot. Measurements were taken over approximately a 3-hour period or until the containers were nearly full, whichever occurred first.

There was a difference in depth of flood between the high and low side of each treatment because of the slope of the land and orientation of the basins. The high and low side of each treatment of one replication were measured simultaneously. Measurements were obtained from all five replications in 2 to 5 days. Measurements were obtained three different times during the season (early, mid, and late flood). An analysis was conducted combining all measurements as a split plot where season was a sub-unit stripped over the main unit treatments. A combined analysis across years was not performed because variability was not homogeneous.

Four basins were constructed for the depth-of-flood study. Levees were constructed, arbitrarily selecting the levee-packer method, as previously described. The overflow pipe for each of the basins was positioned either 2, 4, 6, or 8 inches above the soil surface. Water supply was the same as previously described. Measurements were taken from the high and low sides of each of the four basins.

In 1990, since there were only four basins, measurements were taken from three different 10-foot sections and one 20-foot section of each levee. The 20-foot section included all of one previously measured 10-foot section and part of another, plus a 6-foot section of the levee that had not been in a measurement.

In 1991, measurements were taken from four different 10-foot sections of each levee. Actual depth of flood was recorded. Regression analysis was used to measure seepage-to-depth relationships.

In 1990, levee construction was initiated May 30 but was delayed until June 11 by rain. A total of five passes were made with the levee plow to construct levees on May 30, and June 11, 12, and 13. Levees were allowed to air dry a minimum of 6 hours between passes with the levee plow. The appropriate levees were packed after each of the last two passes with the levee plow. After another rain delay, levees were butted and overflow pipes were put in place by June 26. Basins were flooded on June 28. The early, mid, and late season measurements were taken from July 5 to 6, July 17 to 20, and August 8 to 10, respectively. Measurements of the depth-of-flood study were taken on August 20, 21, and 23.

In 1991, levee construction was started June 18 and completed June 20. Levees were constructed using a total of eight passes with the levee plow, with seven passes occurring on June 18 and 19 and the last pass occurring June 20. Very little time was given for levees to air out between passes with the levee plow. Levees were packed for appropriate treatments after each of the last two passes with the levee plow. Levees were butted June 21. After two rain delays, the drainage system around the levees was completed and the overflow pipes were installed. Basins were flooded July 11. The early season measurements were taken on July 15, 16, 17, 18, and 25; midseason, August 5, 6, 7, 9, and 12; and late season, September 4, 5, 11, and 12. Depth-of-flood measurements were taken August 19, 20, and 26.

Results and Discussion

1990 Data

The amount of seepage collected [gallons per minute per foot (gpm/ft) of levee] averaged over all measurements by treatment for 1990 is given in Table 2. The dual-wheel tractor-packed levee had significantly less seepage ($P<0.05$) than the standard levee, the levee packed with the levee packer, and the wider levee in 1990. The dual-wheel tractor reduced seepage by an average of 62%. The mean depth of flood was 4.2 inches. Treatment by season was not significant.

Seepage losses on a Sharkey clay in 1990 for early, mid, and late season measurements averaged over all treatments are given in Table 3. No significant differences were found among early, mid, and late season measurements.

The relationship of flood depth to seepage losses in

Table 2. Effect of nonpermanent levee construction in rice fields on levee seepage losses.

Treatment	Seepage Mean flow 1990*	Seepage Mean flow 1991**
	(gpm/ft)	(gpm/ft)
Standard	0.0416a	0.0653a
Standard + Levee Packer	0.0410a	0.0643a
Standard + Tractor Pack (Dual-wheel)	0.0149b	0.0478b
Wider Standard	0.0344a	
Standard + Tractor Pack (Single-wheel)		0.0613a
LSD (0.05)	0.0123	NS
LSD (0.10)	0.0099	0.0112

* Means in a column followed by the same letter are not significantly diferent at the 5% level by the LSD test.

** Means in a column followed bly the same letter are not significantly different at the 10% level by the LSD test.

1990 is given in Figure 7. Seepage losses increased linearly ($R^2=0.64$) with flood depth of 2 to 8 inches through levees packed with the levee packer.

1991 Data

The amount of seepage collected averaged over all measurements by treatment in 1991 is given in Table 2. The dual-wheel tractor-packed levee had significantly less seepage ($P<0.10$) than the standard levee, the levee packed with the levee packer, and the levee packed with the single-wheel tractor. The dual-wheel tractor reduced seepage by an average of 25%. Average depth of flood was 5.1 inches. Treatment by season was not significant.

Early, mid, and late season seepage losses on Sharkey clay averaged over all treatments in 1991 are given in Table 3. Significantly more seepage (45%) occurred in the early season than in mid and late season ($P<0.05$).

Seepage losses in relation to flood depth in 1991 are given in Figure 7. Seepage losses increased linearly ($R^2=0.43$) with flood depth of 2 to 8 inches through levees constructed with the levee packer.

Table 3. Effect of flood duration in rice on levee seepage losses.

	Weeks after initial flood	Seepage Mean flow 1990	Seepage Mean flow 1991*
		(gpm/ft)	(gpm/ft)
Early Season	1st	0.0339	0.0752a
Midseason	4th	0.0346	0.0535b
Late Season	7th	0.0304	0.0503b
LSD (0.05)		NS	0.0064

* Means in a column followed by the same letter are not significantly different at the 5% level by the LSD test.

Results and Conclusions

Seepage losses increased by an average of 55% from 1990 to 1991. This could possibly be related to a combination of the following factors.

(1) Rain that occurred in 1990 after the first pass with the levee plow may have reduced seepage by reducing the size of some larger clods, with loosened material settling into large cracks.

(2) The practice of letting the soil air out between passes with the levee plow may have reduced seepage. This practice gives the outer surface of the clods time to dry so that the subsequent pass with the levee plow will separate the dry material from the wet clod. This material will then fill voids in the levee.

(3) The slightly greater mean depth of flood maintained during measurements in 1991 could have had an increasing effect on seepage losses.

(4) Five more days were needed in 1991 than in 1990 to complete the setup between the completion of the levees and the flooding of the basins. This may have had an increasing effect on seepage losses if the levee dried enough to begin cracking.

Amount of seepage was different between years. Further research is needed to define optimum timing and technique of constructing levees under varying environmental conditions. Although seepage measurements were much higher (55%) in 1991 than in 1990, levees packed with the dual-wheel tractor had significantly less seepage than the standard levee and the levee packed with the levee packer.

The hypothesis that Sharkey clay levees seal with time appeared to be true in 1991, but not in 1990. This is associated with seepage losses being much greater in 1991 than in 1990. It appears that significant sealing of levees occurs when levees are constructed under less than optimum conditions in which excessive amounts of seepage occur in early season than in late season. The higher the initial seepage loss, the greater the chance of a significant reduction in later seepage losses because of levee sealing.

In both years, seepage losses increased linearly with flood depth of 2 to 8 inches through levees constructed with the levee packer. R-square values of the linear equation fitted to the 1990 and 1991 data were 0.64 and 0.43, respectively. A better regression coefficient (R^2) was found with 1990 data in which the seepage amounts were smaller where less variation occurred.

The linear equations have similar slopes but different intercepts (Figure 7) since more seepage occurred in 1991 than in 1990. Thus, the shallower the flood depth, the less seepage loss. Shallow floods can be

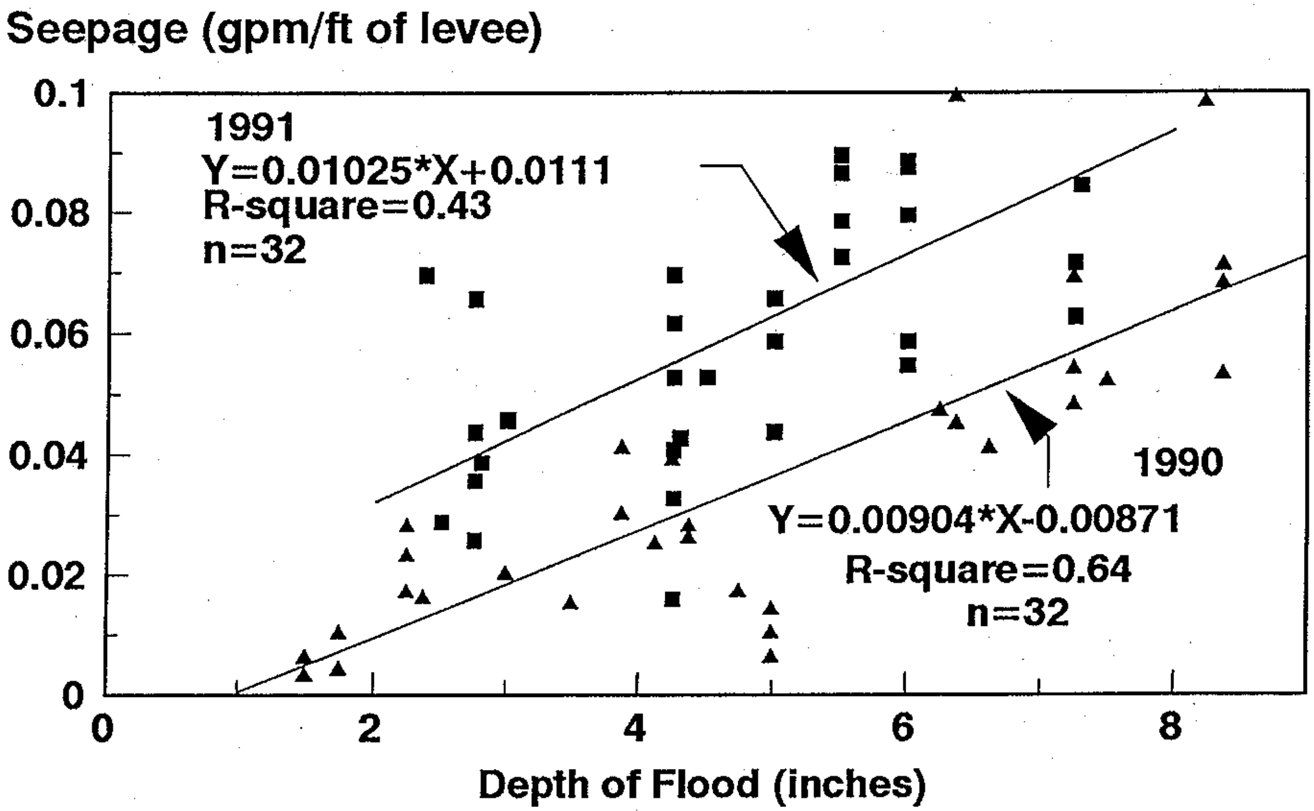

Figure 7. Effect of flood depth on seepage losses through a levee packed with a levee packer at the Delta Branch Experiment Station, Stoneville, MS.

achieved by intensified management, land forming, utilizing multiple inlets, and reducing levee spacing (McCauley, 1991).

Obviously, seepage losses can be reduced by shortening the flood period. The fewer days the field is flooded, the less time for seepage to occur. A reduced flood period can be accomplished by selecting early maturing varieties and by terminating flood earlier when a ratoon crop is not desired. Counce et al. (1990) found no significant differences in rough rice yield or head rice yield when fields were drained 2 weeks after 50% heading compared to the normal recommendation of draining 23 to 25 days after 50% heading.

Although maintaining a shallower flood, selecting early maturing varieties, or terminating the flood earlier may help reduce seepage losses, these practices should be evaluated to determine if they are economical and practical to fit an individual producer's operation.

Acknowledgments

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