EVAPOTRANSPIRATION AND DEEP PERCOLATION LOSSES IN FLOODED RICE

H. C. (Lyle) Pringle, III
Delta Research and Extension Center
Stoneville, Mississippi

INTRODUCTION

Agriculture is the major consumer of water in the Mississippi Delta. The agricultural water demands have increased directly with the increase of irrigated crop acreage and catfish production over the past 10 to 15 years. Among the major field crops (cotton, soybeans, and rice) grown in the Mississippi Delta, rice production requires the most water.

Rice water use components are evapotranspiration (ET), percolation, seepage, and overpumpage along with excessive drainage associated with flushing and flood termination. Of these components, a rice producer does not actively control ET and deep percolation losses, the basis of minimum rice water requirements. There are, however, some conservation and management practices available to reduce seepage, overpumpage, and excessive drainage so that a producer can approach this minimum rice water use.

A three-year study is being conducted to determine minimum rice water requirements under this region's environmental conditions, varieties, and soils. The objectives of this study are to: 1) measure ET from several rice cultivars during flood; 2) measure deep percolation losses from several soils during the flood period of rice, and 3) model water use (ET & deep percolation losses) of rice from weather, variety, and soil data. This paper will present data from objectives 1 and 2.

MATERIALS AND METHODS

Potential evapotranspirometers (microlysimeters) designed by Tomar and O'Toole (1980a) were used to measure ET and deep percolation losses in research and production rice fields in the central Delta region of Mississippi. Rice was grown in microlysimeter containers (10 inch PVC pipe) with an open bottom to measure ET along with deep percolation losses. Microlysimeter containers with a covered top and open bottom were used to measure deep percolation losses only. A constant water level of approximately 2.5 inches was maintained in both microlysimeters types. As water was lost from each microlysimeter by ET and/or deep percolation, it was immediately replaced by water from the supply reservoir. Observations of the water level in the supply reservoir on a daily basis provided a measurement of daily water loss to ET and/or deep percolation. Water loss was recorded daily for the ET/deep percolation microlysimeters and bi-weekly for the deep percolation microlysimeters.

Maybelle, Rosemont, Lemont, and Newbonnet cultivars were selected for ET measurement due to their different growth characteristics. Newbonnet is tall and late maturing, Lemont has a short stature and late maturity, Maybelle is between Newbonnet and Lemont in height and is early maturing, and Rosemont has a short stature and early maturity. Lemont is widely grown throughout Mississippi, Arkansas, and Louisiana, whereas Newbonnet is a major cultivar in Arkansas and Mississippi.

The rice ET portion of this study was located at the Delta Research and Extension Center, Stoneville, Mississippi. Each cultivar was replicated four times in a randomized complete block design. Individual plots were 17 feet long and 15 feet wide on a Sharkey clay. A microlysimeter container was installed in each of the sixteen plots the day after planting. Also, four more microlysimeter containers were installed, one in each replication, to measure deep percolation losses only. Thinning or transplanting at flooding was required to allow the number of plants in each container to equal the average plant population outside the containers. The reservoirs for the microlysimeters were attached at the time of initial flooding. Measurements of ET + deep percolation losses were taken daily from initial flood to flood termination. An analysis of variance was performed for each year. Means were separated using Fisher's protected LSD. A combined analysis was performed and the year by variety interaction was found to be significant. Therefore, no main effect across years was determined. Biomass samples from each microlysimeter were hand harvested and dried after flood termination. Linear regression analysis was used to measure the biomass-to-ET relationship.

Using soil maps and county agents' knowledge of the producers in their county, soils from rice production fields in Washington, Bolivar, and Sunflower Counties were selected for deep percolation loss measurements. Five different soil series within a general area were selected when possible. The soil series selected were Sharkey, Alligator, Forestdale, Brittain, Pearson, and Dundee. There were four to five general areas. The Brittain and Pearson soils were found mostly in one general area around Merigold, Mississippi.

A microlysimeter container was installed after planting and before flood initiation for each soil series at each site. At this time, soil samples were taken from each site and sampled every 6 inches to a depth of 36 inches. Percentages of sand, silt, and clay were determined by the MCES soil testing laboratory and then were classified as to soil texture. Reservoirs for the microlysimeters were attached within two to three days after each flood was initiated. Measurements of deep percolation losses were taken one to three times a week during the flood period. Microlysimeter containers were retrieved after the flood was terminated. Regression analysis was used to measure soil texture-to-deep percolation loss relationships.

RESULTS AND DISCUSSION

Evapotranspiration

An average of daily ET during flood and the average total flood ET was calculated for each variety. The date when 50% of the panicle had turned brown was used to calculate flood lengths for each variety. Flood lengths, average daily ET, flood ET, and vegetative biomass for 1991 are given in Table 1. The average daily ET from Maybelle and Rosemont, the earlier maturing cultivars, was significantly higher than Newbonnet, a later maturing cultivar. Lemont was significantly lower than Maybelle. There were, however, no significant differences among the cultivars in flood ET and vegetative biomass.

Flood lengths, average daily ET, flood ET, and vegetative biomass for 1993 are given in Table 2. The later maturing cultivars Lemont and Newbonnet had significantly higher average daily ET, flood ET, and vegetative biomass than Rosemont, an earlier maturing cultivar. Maybelle had significantly lower flood ET and vegetative biomass than Lemont and it had significantly lower vegetative biomass than Newbonnet. Lemont was not significantly different from Newbonnet.

Differences in results within 1991 and 1993 appear to be due largely to the differences in vegetative biomass. In 1991 when there were no differences in vegetative biomass, there were no differences in flood ET among cultivars and average daily ET from earlier maturing cultivars was greater than that from later maturing cultivars. The opposite was found in 1993. Earlier maturing cultivars had significantly less vegetative biomass than the later maturing cultivars, there were differences in flood ET among cultivars, and the average daily ET from later maturing cultivars was greater than that from earlier maturing cultivars. Daily ET and flood ET were higher in 1993 than 1991 when comparing cultivars with approximately equal vegetative biomass.

Logically, one might surmise that there would be differences in biomass among rice cultivars due to different growth characteristics. Review of literature provides mixed results on this subject. Lemont and Newbonnet were among the twenty-five cultivars tested by Brunson (1989), and they had significant differences in straw biomass within and between years. Kwon et al. (1992) found no significant difference in above-ground biomass of Lemont and Newbonnet throughout the growing season when each was thinned to equal plant populations. Data from this present study show no differences in biomass one year, yet does show differences another year though plant populations were equal at flooding.

Seasonal ET from Lebonnet has been shown to be linearly related to total biomass and grain yield (Shih et al. 1983). The results of a linear regression analysis of flood ET and vegetative biomass among cultivars for 1991 and 1993 are listed in Table 3. Although observations are limited, Maybelle, Rosemont, Lemont, and Newbonnet all showed a linear relationship between the two, with r-square values of 0.97, 0.65, 0.86, and .083, respectively.

Deep Percolation

It was assumed that weather was not a major factor in deep percolation losses, so the results are given for combined data from 1991-1993. Daily average deep percolation losses were determined along with the average total deep percolation losses for an 80-day flood and are listed with the number of sites measured in Table 4. For comparison purposes, an 80-day flood was chosen as the approximate average flood on rice in Mississippi. Typical rice soils, Sharkey, Alligator, Forestdale, and Brittain, had losses of 1.2, 1.2, 3.3, and 3.6 inches of water during an 80-day flood, respectively. Dundee and Pearson soils are not usually found throughout an entire field but in small portions on the top side of a field. They had average deep percolation losses of 3.1 and 4.7 inches of water over the 80-day period.

Sharkey and Alligator soils were very uniform among locations. Their deep percolation losses ranged from 0.6 to 3.3 inches of water for an 80-day flood. There was more variation in texture profiles among locations within the Forestdale, Brittain, Pearson, and Dundee sites. Along with this variation in texture profiles, there were greater ranges in deep percolation losses (0.6 - 8.3 inches of water). Due to these variations, there was a need to evaluate these losses with a more concise description of the soil than the soil series.

The soil texture profile was investigated as a means of predicting deep percolation losses. The majority of these soils are composed of predominantly silt and then clay. Soil textural analysis show that most of the soil layers were classified as silty clay, silty clay loam, or silt loam. There were a few soil layers classified as loam, sandy loam, and loamy sand. Deep percolation losses under flooded conditions should be governed largely by the dryness of the soil profile at initial flood, the depth to the layer of soil that is the most restrictive to water movement, and its rate of water loss when saturated. The layer that is the most restrictive should be the one with the most clay in it. Since clay particles are the smallest, they can fill voids and these then swell when wet. The layer of soil in a soil profile that has the maximum percentage clay was selected to evaluate the deep percolation losses.

In general, a deep percolation loss curve should show a short but rapidly declining water loss rate period during the initial flooding of the soil followed by a slowly declining period after the soil becomes saturated at a restrictive layer. The deep percolation loss data were separated into this rapidly changing component and the slowly declining component. Figure 1 shows the relationship between deep percolation losses during the slowly declining period and the maximum clay layer (%) found in each of the 36-inch profiles sampled for 1991-1993:

$$Perc = 0.3125 + 1061.1/ (\%\ Clay)^{\wedge}2$$

$$R^2 = 0.49$$

The rapidly changing component of deep percolation losses ranged from 0-3 inches of water as governed by how dry the soil was initially and the depth to the soil layers most restrictive to downward water movement.

It is important to note that there were a few instances in which it appeared that very high deep percolation losses occurred. Usually these were found in deep, coarse textured soils in close proximity to streams where horizontal movement of water to the streams was possible. Accurate measurement of these losses were not obtained due to equipment problems.

CONCLUSIONS

1. Total flood ET of rice is related to vegetative biomass.

2. Average daily ET rates differ by cultivar (0.17-0.26 in/day).

3. Predominantly silty clay or silty clay loam soil texture profiles, Sharkey and Alligator, have the lowest average deep percolation losses (1.2 in/80-day flood).

4. Deep percolation losses are related to the soil layer with the highest percentage of clay when this layer becomes wet following the initial, rapidly declining phase of water movement downward through the soil.

REFERENCES

Brunson, M. W. 1989. Evaluation of rice varieties for double cropping crawfish and rice in southwest Louisiana. Bulletin Louisiana Agricultural Experiment Station, 812:17.

Kwon, S. L., R. J. Smith, Jr., and R. E. Talbert. 1992. Comparative growth and development of red rice (*Oryza sativa*) and rice (*O. sativa*). Weed Science. 40:57-62.

Shih, S. F., G. S. Rahi, G. H. Snyder, D. S. Harrison, and A. G. Smajstrla. 1983. Rice yield, biomass, and leaf area related to evapotranspiration. Transactions of American Society of Agricultural Engineers, 26 (5):1458-1464.

Tomar, V. S. and J. C. O'Toole. 1980. Design and testing of a microlysimeter for wetland rice. Agronomy Journal. 72:689-692.

Table 1. **Daily and total flood ET from four rice varieties, their respective flood length, and biomass in 1991 at Stoneville, Mississippi.**

Cultivar	Flood Length	Avg.[1] Daily ET	Total[1] Flood ET	Vegetative[1] Biomass
	(days)	------(inches)-------	(grams/container)	
Maybelle	65	0.23	14.8	43.5
Rosemont	72	0.21	14.9	42.8
Lemont	80	0.19	15.2	39.5
Newbonnet	84	0.17	14.1	40.0
Mean	75	0.20	14.7	41.4
LSD (0.05)		0.037	2.6	10.8

[1]Average Daily ET and Total Flood ET calculated from measurements made on days of no rain.

Table 2. **Daily and total flood ET of four rice varieties, their respective flood length, and biomass in 1993 at Stoneville, Mississippi.**

Cultivar	Flood Length	Avg.[1] Daily ET	Total[1] Flood ET	Vegetative[1] Biomass
	(days)	------(inches)-------	(grams/container)	
Maybelle	57	0.22	12.7	29.8
Rosemont	65	0.17	10.7	24.0
Lemont	71	0.26	18.2	48.6
Newbonnet	70	0.24	17.2	42.6
Mean	66	0.22	14.7	36.2
LSD (0.05)		0.065	4.6	11.3

[1]Average Daily ET and Total Flood ET calculated from measurements made on days of no rain.

Table 3. Linear regression analysis of flood ET and vegetative dry biomass for four rice varieties in 1991 and 1993 at Stoneville, Mississippi.

Cultivar	Obs.	R^2	Biomass X coefficient	Constant
Maybelle	8	.97*	0.160	7.938
Rosemont	8	.65**	0.175	6.974
Lemont	8	.86*	0.285	4.115
Newbonnet	8	.83*	0.468	-3.678

* Significant at the 1% level.
** Significant at the 5% level.

Table 4. Average deep percolation losses for rice soils in Mississippi Delta 1991 through 1993.

Soil Type	Sites	Deep Percolation Losses Daily Avg. (inch/day)	Average Total (inch/80 day flood)
Sharkey	16	0.015	1.2
Alligator	11	0.015	1.2
Forestdale	17	0.041	3.3
Brittain	8	0.045	3.6
Pearson	9	0.058	4.7
Dundee	9	0.039	3.1

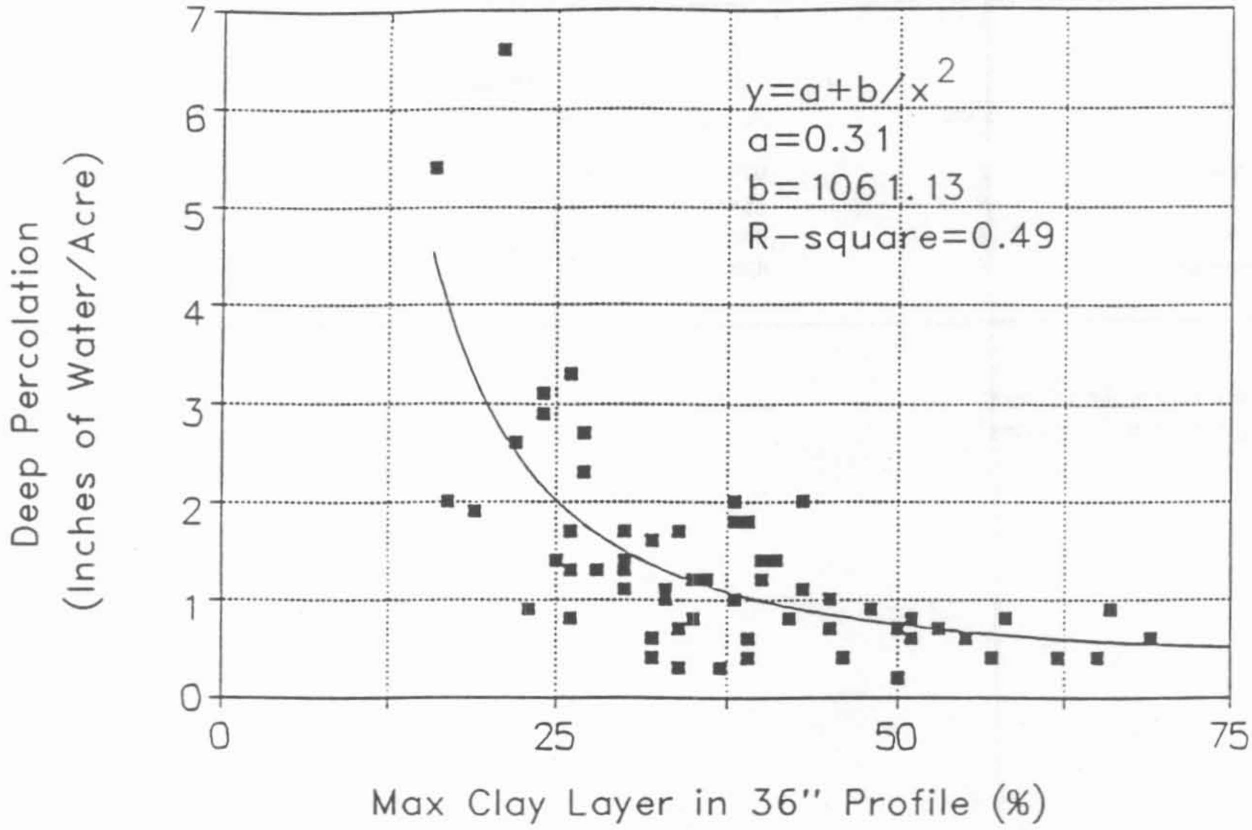

Figure 1. Relationship of deep percolation losses occurring after the initial flooding of the soil for an 80-day flood duration to the maximum 6-inch thick clay layer in a 36-inch soil profile, 1991-1993 data.