Water Use by Flooded Rice in Puerto Rico[1,2]

Servando Silva and José Vicente-Chandler[3]

ABSTRACT

Evapotranspiration with flooded, well-established rice averaged 0.61 cm/day, with a range from 0.31 to 0.84 cm/day. These variations resulted largely from climatic changes since they were closely related to evaporation losses from an open pan. The equation $Y = 0.2691 + 0.4696\ X\ (r = 0.97^{**})$ describes the relationship between evapotranspiration with rice and open pan evaporation, which averaged 0.55 cm/day during the experiment. Percolation losses in Toa soil (Mollisol) averaged only 0.20 mm/day after the first 2 weeks of flooding.

INTRODUCTION

Evapotranspiration with rice is generally not much different from that with other well-irrigated crops after they have reached full canopy cover. However, total water requirements (transpiration plus evaporation losses and percolation into the soil) of flooded rice have been found to range from 0.6 to 1.6 cm/day, with an average of 0.9 cm (3). Kung et al. (4), in a survey in southeast Asia, obtained the following values for total water use (in centimeters) with flooded rice: evaporation, 18–33; transpiration, 20–25; and percolation and seepage 20–70. No data have been published on the water requirements of rice in Puerto Rico.

Puerto Rico is developing a rice industry, starting in the lowlands of the north coast. Vicente-Chandler et al. (6) calculated that there are 20,000 ha of land suited to rice production in Puerto Rico with sufficient water for producing two crops yearly, if planted continuously. Only 50 to 60% of the land would actually be irrigated at a given time.

In this study, carried out under conditions typical of the north coast lowlands, the water requirement of flooded rice was determined over an 8-week period from 6 weeks after seeding until 3 weeks before harvesting.

MATERIALS AND METHODS

The experiment was carried out just north of Highway No. 2 in the Cibuco river basin near Vega Baja. Elevation is 6 m above sea level, mean annual temperature is about 25° C, mean annual rainfall is about 1600 mm, solar radiation is about 450 langleys/day, and open pan evaporation is about 0.6 cm/day.

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[2] This paper covers research conducted cooperatively by Agricultural Research Service, USDA and the Agricultural Experiment Station, Mayagüez Campus, University of Puerto Rico, Río Piedras, P.R.

[3] Research Technician and Project Leader-Soil Scientist, Agricultural Research, USDA, respectively.

The soil is Toa, a Fluventic Hapludolls (Mollisol). Eight core samples were taken at the 0–8 and 15–23 cm soil depths; and bulk density, percent macropores and particle size distribution were determined.

The experimental area was near the middle of a 10-ha rice field. The field was leveled, levees were constructed at 30-m interval, and the land was flooded. Rice of the Brazos variety was seeded aerially and the flood water was drained off after the seedlings rooted. About 300 kg of 10-5-15 fertilizer was applied/ha before seeding and 200 kg of ammonium sulphate was applied/ha about 7 weeks after planting. Propanil,[4] a herbicide, was applied about 4 weeks after planting, and the field was then flooded permanently. The rice was harvested about 4 months after planting.

Four sites about 30 m apart were selected in the center of the field for the water use measurements. Three sections of PVC pipe 30 cm in diameter and 45 cm long with a sharpened edge were driven into the soil to a depth of 30 cm at each of the four sites. In addition, a bucket filled with soil to within 15 cm of the edge was buried in the soil at each site.

At each site, one of the pipes and the bucket of soil were planted with rice and treated as part of the 10-ha planting. The remaining two pipes at each location were kept free of vegetation and covered tightly to prevent entrance of or loss of moisture from above. In one pipe a depth of 15 cm of water was maintained; in the other, an extra length of pipe was added and a depth of 30 cm of water was maintained. Except as noted, all the pipes and buckets were kept flooded to a depth of about 15 cm to simulate conditions in the rice field.

A standard rainfall gage and a class A evaporation pan equipped with a still well were installed near the center of the experimental site.

On Monday, Wednesday and Friday of each week, the water level was carefully measured in both the evaporation pan and the rainfall gage. Rainfall was measured directly and evaporation was determined by changes in the water levels corrected for the recorded rainfall. Water levels also were measured at these times in all the pipes and buckets, and water was added to restore the original water level.

The decreases in water level in the covered pipes were taken to represent water lost by percolation through the soil profile. The decrease in water level in the pipes in which rice was growing, minus percolation losses in the covered pipes and corrected for rainfall, was considered a measure of evapotranspiration. Changes in the water level in the buckets in which rice was growing, corrected for rainfall, were also taken to represent evapotranspiration.

[4] Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico or ARS USDA, nor is this mention a statement of preference over other equipment or materials.

Yields of rough rice were determined by harvesting two 1-m^2 areas near each site and drying the rice to 12% moisture.

RESULTS AND DISCUSSION

Bulk density of the soil at the experimental site was 1.2 g/cm^3 for cores taken at both depths, and macroporosity[5] was 4.3 and 4.1% for the 0- to 8-cm and 15- to 23-cm depths, respectively. The sand, silt and clay percentages were 27, 43, and 30 for the 0- to 8-cm depth and 22, 53, and 25 for the 15- to 23-cm depth.

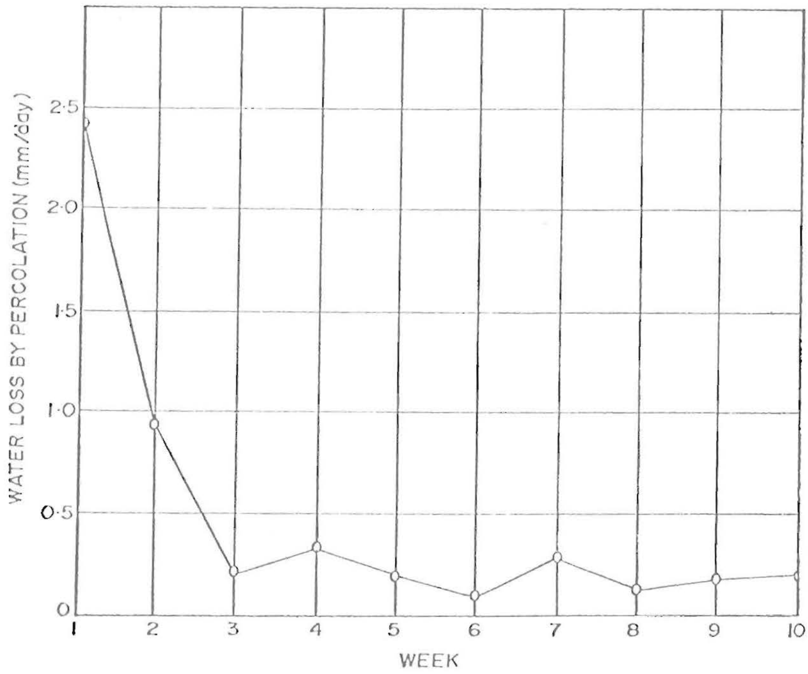

FIG. 1.—Loss of water due to percolation in a field of flooded rice over a 10-week period.

Yields of rough rice at the four experimental sites averaged 5,100 kg/ha, which were similar to yields obtained previously in numerous large plantings and experiments (6).

Percolation losses during the first week of permanent flooding averaged 2.4 mm daily, then dropped to 0.9 mm/day during the second week and to an average of only 0.2 mm/day during the final 8 weeks (fig. 1). This very low percolation rate, once the soil was saturated and premanently flooded, might have been due to disintegration of the soil aggregates and

[5] Volume of pores drained when saturated cores were subjected to a tension of 60 cm of water for 15 minutes.

clogging of the soil pores with microbial wastes as shown by Allison (1). Increasing the head of water in the pipes from 15 to 30 cm increased percolation from an average of 0.20 to 0.37 mm/day.

When necessary, percolation rates of even very porous soils can be sharply reduced by puddling and continuous cropping to rice. For example, Bodman and Rubin (2) found that 90 to 100 % of the volume occupied

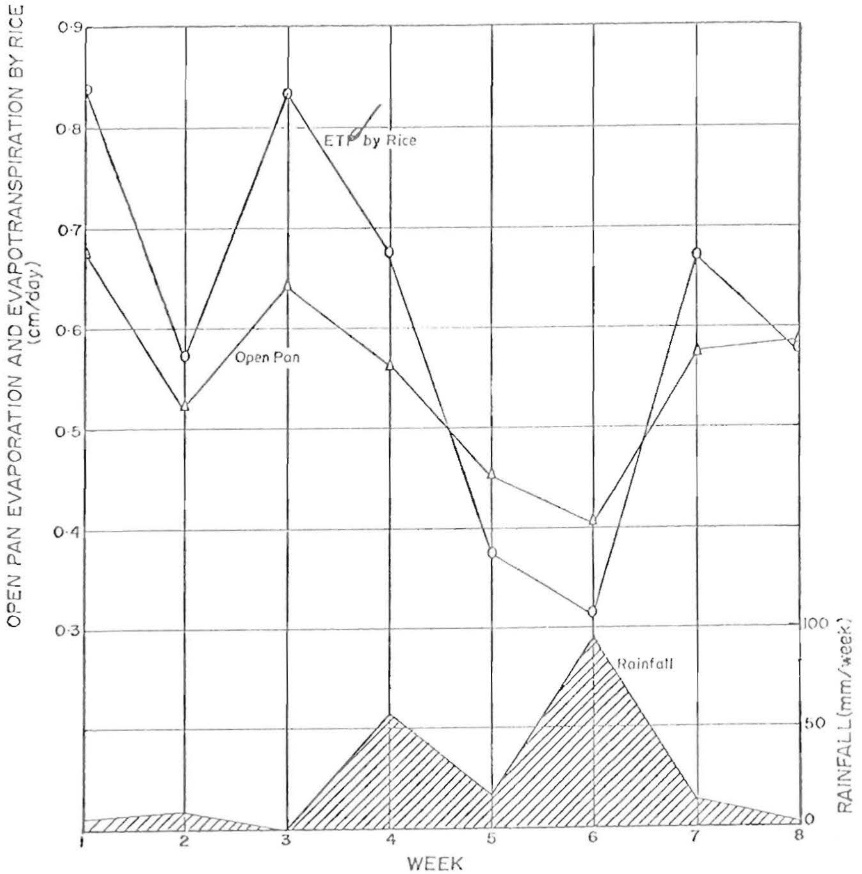

FIG. 2.—Average daily evapotranspiration with rice and open pan evaporation over an 8-week period with well-established flooded rice.

by noncapillary pores was destroyed by puddling a silt loam. Mikkelson and Patrick (5) reported that in certain very permeable California soils, percolation rates decreased to about one-fourth of the original value after being planted to rice continuously.

Figure 2 shows daily evapotranspiration with rice as related to open pan evaporation during the 8-week period of fast growth followed by heading. Evapotranspiration losses averaged 0.61 cm daily, and ranged from 0.84 cm to 0.31 cm. These variations were caused mainly by climatic factors since open pan evaporation, which integrates all these factors, closely followed evapotranspiration (fig. 2). Figure 3 shows the close correlation between open pan evaporation and evapotranspiration with rice. Open pan evaporation averaged 0.55 mm/day, about 90% of evapotranspiration with rice.

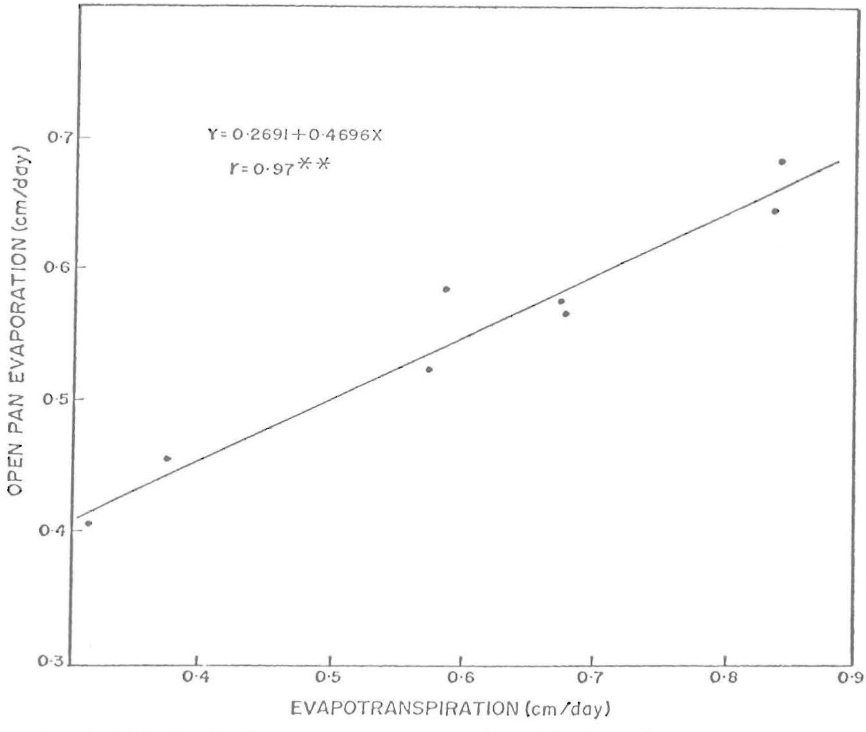

FIG. 3.—Relationship between evapotranspiration with rice and open pan evaporation over an 8-week period.

Values of evapotranspiration as determined from pipes planted to rice after discounting percolation losses determined from the covered pipes were similar to those from buckets filled with soil and planted to rice. Average values were 0.61 and 0.65 cm/day with these methods, respectively.

It is of interest to calculate the total water requirement to produce a rice crop (120 days from seeding to harvest). After planting, two irrigations of 10 cm each are generally required, plus an additional 30 cm to flood the rice field permanently at 3 weeks, for a total of 50 cm. An average of 0.9 cm/day is then required for evapotranspiration, percolation and some seepage (assuming most is recycled) during 80 days, after which no more water is applied since the flood water provides sufficient water for the rice to mature. Thus, a total of about 120 cm of water is required to produce a rice crop. If rice is planted continuously throughout the year, producing 2 crops yearly, as proposed in Puerto Rico, only 50-60% of the land will actually be irrigated at a given time. Therefore, the 240 cm required yearly by two rice crops will be equivalent to 0.66 cm or 68,000 liters of water/ha daily or a water supply capable of delivering about 47 liters/min for each ha. This is equivalent to about 5 gal/min for each acre confirming the calculations of Vicente-Chandler et al. (6) on which figures Puerto Rico's land and water potential for rice production was estimated.

RESUMEN

Se determinó el uso de agua por arroz inundado durante 8 semanas, cubriendo el período de crecimiento más rápido y el espigado, bajo condiciones típicas de las llanuras de la costa norte de Puerto Rico.

El suelo Toa (Mollisol) tenía 25% de arena, 27% de arcilla y 48% de limo, una densidad de 1.2 y 4.2% de poros de mayor tamaño. La producción fue de 5,100 kg de arroz seco en cáscara/ha. Las pérdidas de agua por percolación en el suelo alcanzaron 2.4 mm/día durante la primera semana después de inundarse el terreno, 0.9 mm/día durante la segunda y un promedio de sólo .20 mm/día durante las últimas 8 semanas.

La evapotranspiración alcanzó un promedio de 0.61 cm/día, variando de un mínimo de 0.31 cm a un máximo de 0.84 cm/día. Estas variaciones se debieron a factores climáticos, ya que la evapotranspiración correlacionó muy bien con las pérdidas de agua por evaporación de una superficie de agua (evaporímetro) el cual integra el efecto de todos estos factores.

La evapotranspiración del arrozal correlacionó muy bien (r=.97**) con la evaporación del evaporímetro, que en promedio alcanzó 0.55 cm/día, equivalente a 90% de la evapotranspiración.

Se calcula que producir una cosecha de arroz en 120 días requiere un total de 120 cm de agua de riego. Si se siembran 2 cosechas al año en forma continua, sólo el 50-60% del terreno estaría regado en un momento dado, y requiriría una fuente de agua que provea unos 47 litros de agua por minuto y ha, equivalente a 5 galones por minuto y acre o cuerda.

LITERATURE CITED

1. Allison, L. E., 1947. Effects of microorganisms on the permeability of soil under prolonged submergence, Soil Sci. 63: 439-50.

2. Bodman, S. B. and Rubin, J., 1948. Soil Puddling, SSSA Proc. 13: 27–36.
3. IRRI 1963–73 Annual Reports, Los Baños, Philippines.
4. Kung, P. C., Atthoyaddon, C. and Kruthabandhi, J., 1965. Determining water requirements of rice by field measurements in Thailand, Int. Rice Comm. News. 19 (4): 5–18.
5. Mikkleson, D. S. and Patrick, W. H., 1968. Fertilizer use in rice. Changing Patterns in Fertilizer Use, SSSA, Madison, Wis. p. 403–432.
6. Vicente-Chandler, J., Abruña, F., Lozano, J., Silva, S., Rodríguez, A., and Ramírez, C. T., 1977. Cultivo intensivo y perspectivas del arroz en Puerto Rico, Bol. 250, Esta. Exp. Agric., Univ. P.R., Río Piedras, P.R.