

EXHIBIT 6

Evapotranspiration And Pollution Of Water By Water Hyacinth

C. E. TIMMER and L. W. WELDON

*Agricultural Research Technician and Research Agronomist, Crops Research
Division, Agricultural Research Service, U. S. Department of Agriculture,
Fort Lauderdale, Florida*

Water hyacinth is one of the most serious aquatic weed problems in the Southeastern United States and in the tropic and subtropic regions of the world. In Florida alone an estimated 90,000 of approximately 2,500,000 acres of fresh water are still covered with water hyacinth after decades of intensive control operations. This plant is also a major aquatic problem in parts of Africa, Australia, India, Ceylon and Java (3).

The problems created by water hyacinth are many and varied. First, it constitutes a health hazard by providing mosquito larvae with an ideal breeding place. Small fish that ordinarily feed on these larvae are kept from doing so by the thick mat of vegetation (3). Water hyacinth pollutes water supplies through growth and decomposition.

The oxygen-depleting pollutional load imposed by one acre of growing water hyacinth is estimated to equal the sewage created by 40 people (3). Second, fish are killed by oxygen starvation and pollution, and native aquatic plants are replaced in areas completely covered by water hyacinth. Third, it interferes with navigation. Fourth, dense growth limit water sports recreation. Fifth, water hyacinth obstructs drainage and flow of water in canals. Sixth, it utilizes water through evapotranspiration. More water can be lost through evapotranspiration from water hyacinth on large reservoirs, water conservation areas, and irrigation canals than is supplied for storage purposes.

Let us consider the use of water in irrigation. Irrigation projects vary in size from small single farm units to extensive areas of several hundred thousand acres. On large gravity-fed projects, supply works may include diversion dams, hundreds of miles of conveyance and control structures, and various additional works of a supplementary nature. Cost of water for irrigation of fruits, vegetables, and other crops may vary from \$1 to \$20 per acre (1,2).

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Expenditures depend primarily on the quantities of water required for effective irrigation, and on the cost of obtaining, conveying, and maintaining water. Irrigation project depends upon efficient use of water which can become impossible where water hyacinth reduces the flow of water up to 50% or more (8), and causes loss of water through evapotranspiration (5).

Transpiration is the evaporation of moisture from living cells through the surface of the plant. There are two modes of transpiration of water from a leaf. Stomatal transpiration is the loss of water through the stomates. Cuticular transpiration is loss through the leaves by direct evaporation from the epidermal cells through the cuticle.

Transpiration is essentially a modified form of the process of evaporation. When an open pan of water is exposed to the atmosphere, a few molecules of water absorb radiant energy, become excited, and attain sufficient momentum to overcome the attractive forces of the liquid to escape as vapor into the air. As the temperature of the water rises (due to irradiation from the sun), the rate of escaping molecules increases in proportion to the water temperature. Other environmental conditions such as humidity and wind influence the rate of evaporation. (4). However, most of the fluctuation in water temperature that occurs within a day is caused by heat from the sun (6). Several methods of measuring this energy have been devised. Langley units are widely used to measure solar energy. One langley equals 1 gram calorie/cm² (7).

Water hyacinth has a relatively large surface area that contributes to a high rate of transpiration. Evapotranspiration is the loss of water by both evaporation from soil or water surface and by transpiration from the plants therein.

We conducted this study to determine the amount of water lost through evapotranspiration from water hyacinth, and to correlate the loss with solar irradiation. A second objective was to determine the effects of 2,4-D on the evapotranspiration rate of water hyacinth. A third objective was to measure pollution and sediment caused by prolonged growth of water hyacinth and to compare the amount of sediment caused by the application of 2,4-D to the natural decaying of the plant tissue.

PROCEDURE

The experiment was initiated in March, 1966, in six growth pools. Each pool was 3 ft. wide, 2 ft. high, and 9 ft. long. Two layers of 6-mil, black, polythene plastic were inserted into each pool to contain canal water. Two pools were maintained without water hyacinth, to serve as a measurement of evaporation from a free water surface. Four of the pools were filled with water hyacinth, which was allowed to grow into a thick mat of vegetation approximately 30 inches tall. Fertilizer was added twice each month throughout the experiment at the rate of 3 ppm of nitrogen, 1.5 ppm of phosphorus, and 1.5 ppm of potassium per pool.

The water level was maintained weekly at a constant level in each pool. A ruler was placed permanently in each pool perpendicular to the earth to measure water fluctuation. At the termination of each 7-day interval, water was brought back to the original level. The difference in two water levels, plus the amount of precipitation that had occurred during the measured period, equalled the loss of water by evapotranspiration. A flow meter was also used for the first month, to record the gallons of water which had to be added to each pool after each 7-day inter-

val to maintain the appropriate level. The flow meter was used as a check of gallons per inch and a double check of the accuracy of measuring water level by the fixed rulers. The amount of water added was thereafter recorded by the fixed rulers. Because of heavy rain and other factors, readings were not continuous but each measurement recorded covered a 7-day period. Evaporation and evapotranspiration were recorded for 11 periods, each 7 days long, during April 23 to September 5. Daily hydrological data of precipitation, humidity, wind, temperature, solar energy, and pan evaporation were recorded.²

Two of the four pools containing water hyacinth were sprayed the first week in August with an amine salt of 2,4-dichlorophenoxyacetic acid at 4 lb/A. The spray application was made with a compressed-air sprayer that delivered a total spray volume of 200 gal/A. Constant pressure was maintained in the sprayer by a connected air tank regulated to maintain 42 psi. The experiment was terminated in September when the regrowth from the treated plots appeared large enough to influence the water level. Water samples were taken at the end of the experiment, to test turbidity of the water and to measure the decayed material in the bottom of the growth pools.

RESULTS

Evaporation of water from the growth pools was fairly comparable to the Class A aluminum pan, free water evaporation, a standard measurement used in hydrologic data (figure 1). There was some discrepancy in the amount of water loss, but these differences indicated generally that less water was lost in the pools than from the standard pan. The black plastic-lining and the greater volume of water to heat in the pools was probably the reason for this variance.

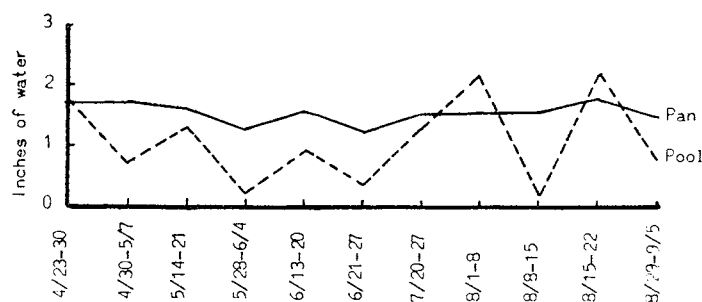


Figure 1. A comparison of the amount of water lost in the standard aluminum pan evaporation and from growth pool evaporation.

The average evapotranspiration rate of water hyacinth was 3.96 inches of water per week (Table 1). The average evaporation rate from open water was 1.08 inches per week. Evapotranspiration of water hyacinth under the conditions of this experiment was 3.7 times greater than evaporation, and at that rate would be greater than the evaporation by more than 6 acre-feet of water in a 6-month period. This correlated closely with the work in Louisiana by Penfound and Earle (5) who found that water lost from evapotranspiration of water hyacinth was 3.2 times greater than from evaporation.

²1966 Annual Report. Soil and Water Conservation Research Division, Southern Branch, ARS, U.S.D.A., Fort Lauderdale, Florida.

TABLE 1. COMPARISON OF HUMIDITY, AIR TEMPERATURE AND IRRADIATION ON EVAPOTRANSPIRATION OF WATER HYACINTH.

Interval of measurement	Evapotranspiration of water hyacinth	Solar radiation total per week	Average weekly mean air temperature	Relative humidity
	Inches	Evaporation	Langley's	°F %
4/23-4/30	4.55	1.68	3,938	74 74
4/30-5/7	4.00	0.69	3,444	76 81
5/14-5/21	5.08	1.30	4,169	78 79
5/28-6/4	2.96	0.22	2,690	78 87
6/13-6/20	4.63	0.92	3,478	80 87
6/20-6/27	2.42	0.35	3,115	79 87
7/20-7/27	4.30	1.30	3,225	83 85
8/1-8/8	4.78	2.15	3,528	82 88
8/8-8/15	1.85	0.19	3,436	80 86
8/15-8/22	5.20	2.20	4,076	82 81
8/29-9/5	3.80	0.83	3,454	81 85
Total	43.57	11.83	38,553	873 920
Average per week	3.96	1.08	3,505	79.4 83.6

Solar energy is a major environmental factor influencing biological processes, and especially evapotranspiration. An accumulative graph was used to relate the influence of irradiation from the sun on evapotranspiration (Figure 2). The relationship is indicated by the similarity of the two factors measured during the course of the experiment. Any gap between the two lines indicates other processes affecting evapotranspiration or evaporation from solar energy data. An estimate of the acres of water hyacinth present with a measurement of solar energy could yield an estimate of the acre-feet of water lost each year by evapotranspiration through water hyacinth.

Wind or air movement, mean air temperature, and relative humidity affected evapotranspiration of water hyacinth under the conditions of this experiment (Figure

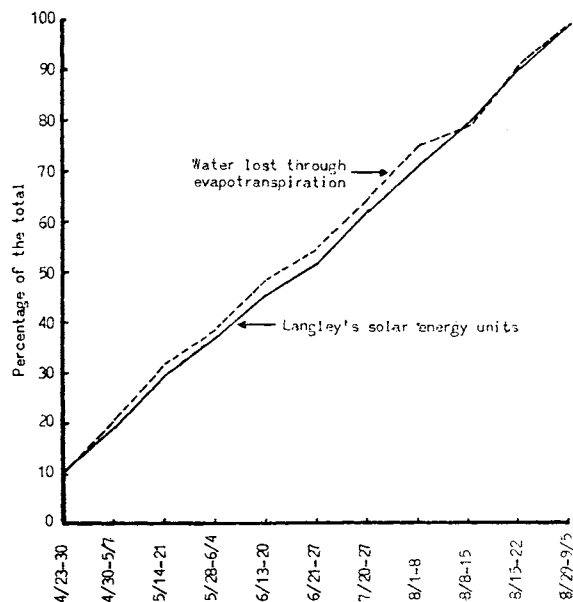


Figure 2. An accumulation of each individual factor based on percentage of the total recorded during the entire experiment.

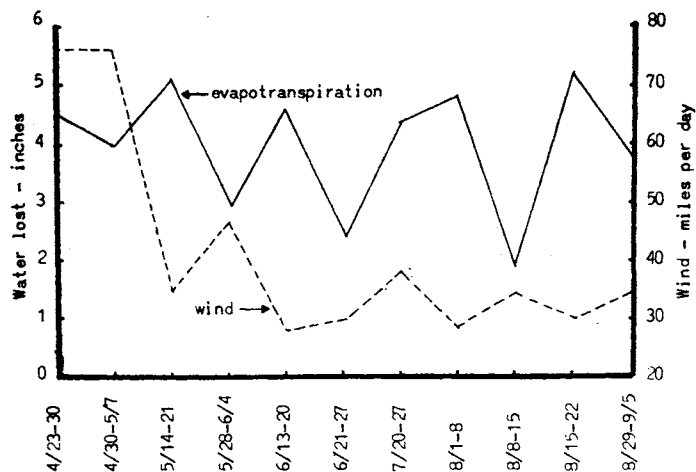


Figure 3. A comparison of evapotranspiration of water from water hyacinth to air movement.

3, Table 1). However, all environmental factors are interrelated. Irradiation may raise air temperature, cause convection currents, and lower humidity. The evapotranspiration rate was generally lower when rainfall occurred every day in amounts of 0.5 inches or more per day. Small brief showers did not appear to have much effect. The environmental factors other than irradiation did not vary substantially during the course of the experiment, which probably accounts for the indicated lack of effect on rate of evapotranspiration.

The results of the application of 2,4-D made August 1, show that evapotranspiration of the treated water hyacinth was much less than that of the non-treated water hyacinth during the first week after treatment (Figure 4). The water in the treated pools was above the line to which they were filled in the second week following treatment indicating that evapotranspiration had not taken place. It is possible that the above-water leaves absorbed rainfall water, to raise the water level. By the third week the water hyacinth had formed a solid layer of decayed material on the surface of the water, and had reduced the rate of evaporation from the pools. It is apparent treatment of water hyacinth will reduce water loss.

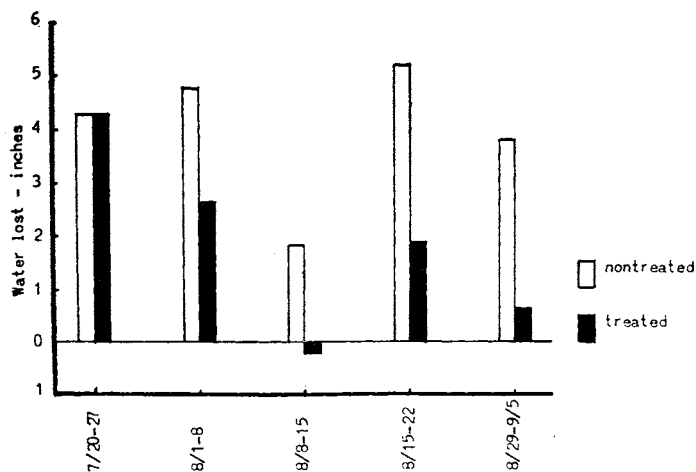


Figure 4. The effect of 2,4-D treatment on evapotranspiration of water hyacinth.

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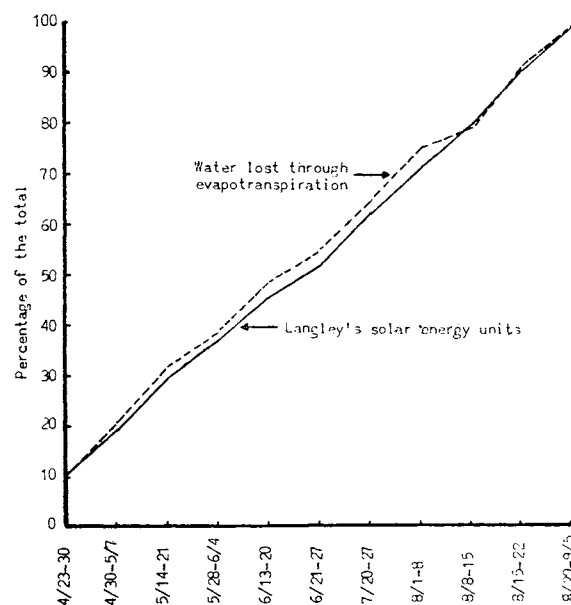


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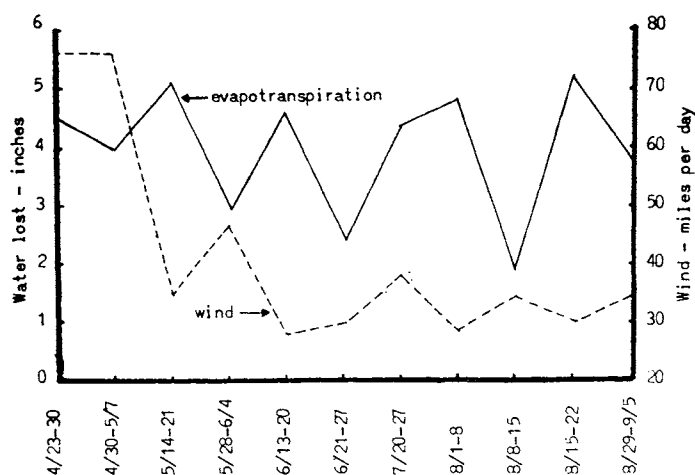


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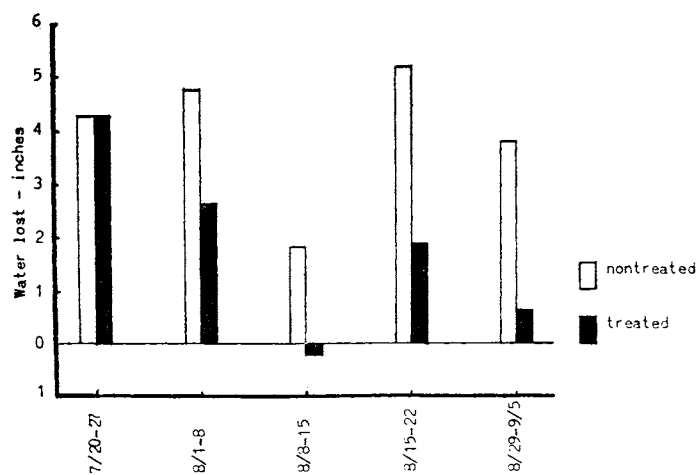


Figure 4. The effect of 2,4-D treatment on evapotranspiration of water hyacinth.

Water hyacinth is known, as previously indicated, to contribute to pollution of water. The depletion of oxygen by decaying vegetation is well known. However, the effect on other criteria of water quality is less well documented. We observed that the water in the evaporation pools was extremely clear, while the water in pools containing water hyacinth was very turbid. The visibility was limited to about 2 ft. in the pools containing water hyacinth. The water was analyzed by different methods to indicate the effect of decaying water hyacinth on water (Table 2). Decayed plant matter was present in the pools with both non-treated water hyacinth and treated water hyacinth. The pools contained 7 and 12 inches, respectively, of "sludge". Leaves and roots are constantly decaying and being replaced in actively growing water hyacinth, whether treated or not. Dense stands of water hyacinth have a pronounced effect on the natural quality of the water.

TABLE 2. WATER ANALYSIS AT THE TERMINATION OF EVAPOTRANSPIRATION STUDY.

	Open water	Water hyacinth	
		Untreated	Treated
Optical density	0.00	0.05	0.08
Percent transmittance of light	100	90	83
Turbidity (silica standard)	0	5	10
Color (APHA Platinum-Cobalt Standard)	0	260	390
Tannin and lignin (ppm)	0.1	5.5	7.0
Depth of decayed plant material (inches)	0	7	12

The natural decaying of untreated water hyacinth is constantly building up a residue on the canal or lake bottom. When an area is allowed to become completely covered with water hyacinth before treatment, even larger amounts of plant residue may be deposited on the bottom. Water hyacinth should be treated when only a small fraction of the water is covered to prevent the buildup of plant residue from natural growth and to minimize the deposition of decadent vegetation. This will also result in a water with less coloring from the decaying vegetation.

CONCLUSIONS

Water loss through evapotranspiration from water hyacinth was 3.7 times that from open water. Solar radiation was found to be a factor which can be measured to give an accurate prediction of the amount of water lost through evapotranspiration.

Natural growths of water hyacinth added plant debris and allowed water coloring chemicals to leach into the water. The clarity of the water was greatly influenced by the growth of water hyacinth.

ACKNOWLEDGMENTS

We wish to acknowledge the suggestions and data on environmental conditions supplied by Mr. William Speir of Soil and Water Conservation Division, Agricultural Research Service, U. S. Department of Agriculture, Fort Lauderdale, Florida.

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