OBSERVATIONS ON THE METEOROLOGICAL-MOSQUITO POPULATION RELATIONSHIP AT STONEVILLE, MISS., 1959–1960

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For mosquito production in the mid-South, free-standing water and warm temperatures are two basic conditions that occur frequently in the humid Delta area of Mississippi. However, factors associated with population variations from year to year, and during different parts of the same year, are very complex. It would be highly beneficial in mosquito control programs if a simple mathematical correlation could be developed so that weather conditions could be used to forecast mosquito incidence. The complexity of the relation and the indirect methods by which the necessary weather variables are estimated preclude this possibility.

Over the years, various moisture-accounting systems have been used to estimate irrigation requirements. For example, estimation of the moisture deficit has been calculated by (1) rainfall records only, (2) rainfall balanced by a calculated value of evaporation, and (3) rainfall balanced by a measured evaporation value from a standard evaporation pan or other evaporimeters. The third technique, more properly termed a rainfall-evaporation balance, was coupled with soil-temperature measurements and applied in this study. By this method, rainfall accumulation is balanced with evaporation to give an estimate of available surface water.

The entire Delta region where these experiments took place is characterized by flat topography, and the first major assumption in this study was that all rainfall either remained on the surface or soaked into the soil; hence runoff was assumed to be zero. Evaporation was measured once a day from an open-vat standard tank 4 ft. in diameter, and was assumed to be representative of the entire area from which the mosquitoes for the experiment were derived.

The soil of the area is mostly heavy clay and was estimated to have a capacity of (or absorb) 3 in. of available water. When the accounting system indicated that a 3-in. soil-moisture deficit had been reached, no further moisture depletion was assumed. The rate of percolation to replenish the soil moisture was variable. Some areas of pasture were compact and held water as if underlaid by a layer impervious to penetration of water. This condition was especially evident in the fall season, and occasionally small puddles remained long enough to produce mosquitoes, even though repeated rains did not occur.

Daily temperatures were measured by maximum-and-minimum soil thermometers at a 2-in. depth and by maximum-and-minimum air thermometers. A continuously recording soil thermometer was used during four 7-day periods to establish the water-soil temperature relationship. Variations of a few degrees undoubtedly occurred within a given pasture, depending on such factors as depth or surface area of water, emergent vegetation, and amount of shade.

As indicated, several very critical assumptions are associated with the present technique. Most of them appeared to be valid for the pastures of the Delta Branch

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Experiment Station; but the assumption of no runoff restricts use of the technique to flat areas or, at least, to areas that are not effectively drained. The method could be applied, with various modifications, to a wide area served by a single evaporation station. Rainfall, however, would have to be measured in some detail in specific locations. In a determination, evaporation is considered a more constant element than rainfall, and if adjustments were made for the different degrees of protection from wind and sun at specific locations in an area of 150 to 200 miles in diameter, it is likely that the corrected readings would be within reasonable limits for most of the area.

Adult mosquito densities were estimated by use of standardized New Jersey light traps, operated for 12-hr. periods at intervals of 3 to 5 nights, in pastures of the Delta Branch Experiment Station. Figure 1 presents the mosquito counts and the weather data in graph form. Peaks of mosquito abundance were primarily represented by *Psorophora confinnis* (Lynch-Arribalzaga), associated with temporary pools. Larval densities were estimated by standard dipping practices, and larval development was observed in representative ponds in the pastures. Time required for development of larvae during the 1960 season varied from 5½ to 12 days, depending on temperature of the water in the pools.

As an example of the way moisture-balance information was recorded, weather data in tabular form for the period May 21 through June 20, 1959 are presented in Table 1. Column 2 gives the moisture

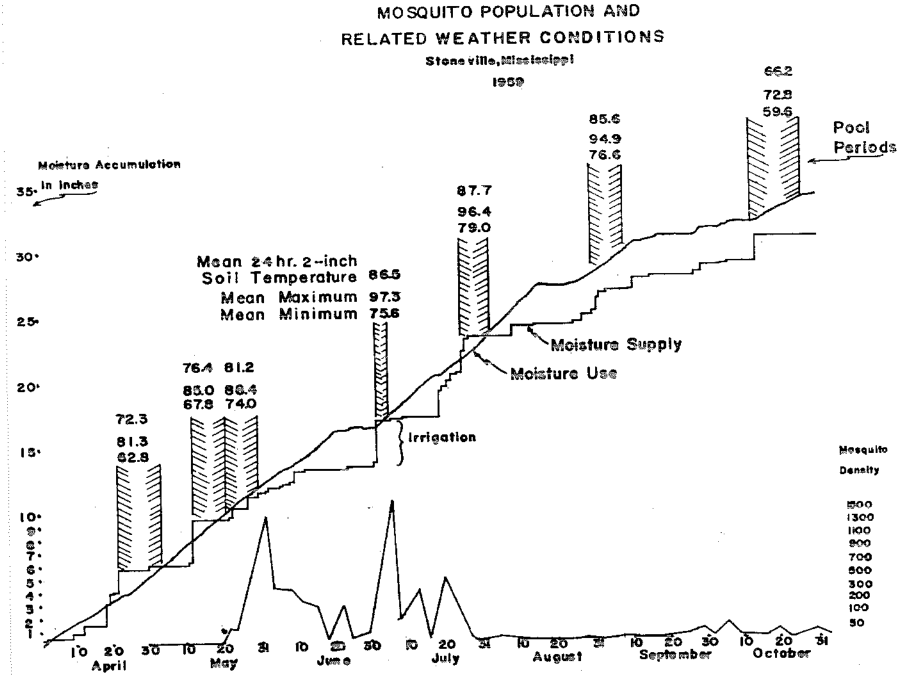

FIGURE 1.

TABLE 1.—Moisture balance in inches in the pastures of the Delta Branch Experiment Station, May 21–June 20, 1959.

Date of measurements	Moisture		24-hr. period		Moisture content
	Supply	Use	Rain	Evaporation	
May					
21	....	9.99	....	0.25	2.58
22	9.86	10.27	0.29	0.28	2.59
23	10.43	10.50	0.57	0.23	2.93
24	....	10.74	....	0.24	2.69
25	....	10.97	....	0.23	2.46
26	....	11.15	....	0.18	2.28
27	11.10	11.33	0.67	0.18	2.77
28	11.35	11.52	0.25	0.19	2.83
29	....	11.74	....	0.22	2.61
30	11.52	11.99	0.17	0.25	2.53
31	....	12.10	....	0.11	2.42
June					
1	11.66	12.31	0.14	0.21	2.35
2	11.94	12.50	0.28	0.19	2.44
3	....	12.66	....	0.16	2.28
4	....	12.82	....	0.16	2.12
5	12.00	13.03	0.06	0.21	1.97
6	12.05	13.10	0.05	0.07	1.95
7	....	13.31	....	0.21	1.74
8	12.17	13.56	0.12	0.25	1.61
9	13.23	13.62	1.06	0.06	2.61
10	....	13.83	....	0.21	2.40
11	....	14.00	....	0.17	2.23
12	13.35	14.16	0.12	0.16	2.19
13	....	14.31	....	0.15	2.04
14	....	14.60	....	0.29	1.75
15	....	14.89	....	0.29	1.46
16	....	15.11	....	0.22	1.25
17	....	15.43	....	0.32	0.92
18	....	15.14	....	0.31	0.61
19	....	16.10	....	0.36	0.25
20	....	16.35	....	0.32	0

supply or accumulation of rainfall dating from April 1. Column 3 gives the moisture use (loss) or cumulative evaporation, except for the periods during which the soil moisture showed a deficit of 3 in. For this reason, values in column 3 can exceed those in column 2 by a maximum of only 3 in. In the example, this condition does not occur. Columns 4 and 5 indicate the rainfall and evaporation for a 24-hr. period ending at 8 a.m. on the day of record.

The intervals in which moisture supply (column 2) was greater than the moisture use (column 3) are indicative of a saturated-soil profile in addition to standing surface water. During the period August 30 through September 8, 1959, small puddles developed on land surfaces in isolated areas of compact soil, even though the soil profile was not saturated. The moisture-supply curve rose irregularly during this period and was indicative of frequent small showers that were sufficient to replenish the puddles. In contrast, the moist period in mid-October resulted from a single rain of 1.84 in. and, although puddles were formed, they disappeared more rapidly for lack of replenishing showers.

Soil and water temperatures at the 2-in. depth demonstrated consistent graph patterns, as illustrated in Figure 2. Dry-soil maximum temperatures exceeded water temperatures and showed a variation of 10° to 15° F. between 1 and 4 p.m. daily.

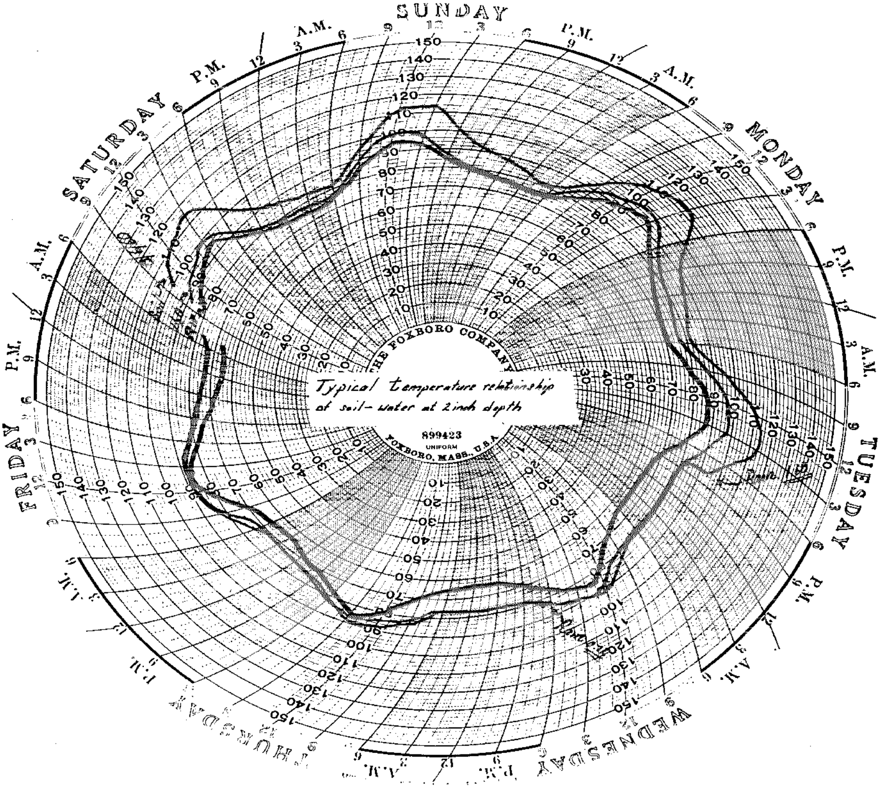

FIGURE 2.

Minimum differences of 2° to 4° F. occurred between 6:30 and 9 a.m. In a typical 24-hr. period, the mean dry-soil temperature exceeded the mean water temperature by 8¾° F., or a cumulative difference of 210 degree-hours F. per day. During periods when the soil contained moisture, water and soil temperatures were nearly identical. Water temperature exceeded air temperature by only 2° to 8° F. under dry conditions, but when the ground contained moisture the water-air relationship was more variable.

In a comparison of the cumulative totals of moisture and evaporation, four primary and three secondary periods of temporary pool water are indicated by the moisture-balance values (Fig. 1). The primary periods of moisture on the ground covered the intervals April 18–May 4, May 12–19, July 2–3 (due to irrigation), and July 25–August 1. The secondary periods occurred May 19–June 2, August 30–September 8, and October 14–27. The mean of the 2-in. soil temperature for each pool period is indicated by the top figure of the series located immediately above the pool dates. All temperatures are Fahrenheit scale. The figure of 86.5° for July 2–3 was taken in unirrigated soil, and undoubtedly the reading in the irrigated pasture would have been a few degrees lower, as indicated by the water-soil relationship data example in Figure 2.

The data obtained during the 1959–1960 seasons would appear to establish that the moisture requirements conform to theory; that is, intermittent periods of standing water are a prerequisite to a rapid buildup of mosquito populations in the Delta area. At least, our trap records showed an increase of mosquito adults during and immediately after certain of the excess-moisture periods. The mean 2-in. soil temperature of 72.3° F. is apparently too low for production of large populations without an extended pool period. A mean of 87.7° F. would appear to be too high for optimum productivity. An empirical interpolation between the cutoff points would suggest the most favorable range to be 75° to 85° F.

Only two of the pool periods in 1959 produced large numbers of mosquitoes, although larvae were observed in the pastures each time standing water occurred. Complete development of the larvae was apparently dependent upon a water temperature-pool period relationship that did not occur over a large land area after early July, and thus some broods did not survive to become adults. In our observations, the minimum time required to complete the immature portion of the cycle was 5½ to 6 days in August, when the temperature mean was over 85° F. In April, even a period of 15 days at a mean soil temperature of 72.3° F. did not allow a large brood to mature. The moisture use exceeded the supply during August; thus, little water was available for mosquito production.

As noted above, our field observations provided approximate data on the temperature-growth relationship for larvae, but it is probable (and desirable) that a reasonably accurate mathematical relationship could be established for *Psorophora* under laboratory conditions, as Huffaker (1944), Hurlbut (1943), or Kramer (1915) did with other species. Although the general pool period for the July irrigation is represented as being only about 4 days, tail waters formed a ditch pool that was probably the primary source of the adult flight. Apparently the period May 12–June 2 provided the most satisfactory temperature-water relationship for the production of *Psorophora.*

For the periods of observation, the readings of soil temperature conform to accepted levels of optimum air-temperature requirements. The authors believe soil temperatures would be a better measure of the true temperature of the mosquito habitat, especially during years of extremes of alternating wet and dry weather. Our data show that soil temperatures are more sensitive to local variation of sunshine and soil moisture than are air temperatures.

References Cited

Huffaker, C. B. 1944. The temperature relations of the immature stages of the malarial mosquito, *Anopheles quadrimaculatus* Say, with a comparison of the developmental power of constant and variable temperatures in insect metabolism. Ann. Ent. Soc. Amer. 37:1–27.

Hurlbut, H. S. 1943. The rate of growth of *Anopheles quadrimaculatus* in relation to temperature. Jour. Parasit. 29:107–113.

Kramer, S. D. 1915. The effect of temperature on the life cycle of *Musca domestica* and *Culex pipiens.* Science 41:874–877.