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Thermal Requirements for Emergence of Overwintered Sorghum Midge (Diptera: Cecidomyiidae)

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Thermal Requirements for Emergence of Overwintered Sorghum Midge (Diptera: Cecidomyiidae)[1]

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ABSTRACT Emergence of overwintered sorghum midges, *Contarinia sorghicola* (Coquillett), was monitored during 1979, 1980, and 1981. Differences in emergence times and distributions among years was a function of soil temperature and rainfall. A heat unit accumulation model incorporating a rainfall adjustment factor was developed which described adult emergence in the spring. Adult midges initiated emergence after accumulating 431 centigrade heat units (based on mean daily 10-cm soil temperatures starting 1 April) above a threshold temperature of 14.8°C, whereas, 679 and 977 heat units were required for 50 and 95% emergence, respectively. Sorghum midges that overwintered in johnsongrass spikelets emerged after similar heat unit accumulations as midges that overwintered in sorghum spikelets. The time that midges initiated diapause one year had little effect on the timing or distribution of emergence the following spring. No midges terminated diapause and emerged as adults during the same season that diapause was initiated. Of the diapausing midges, 23% failed to emerge until the second spring and 2.6% emerged the third spring, but times and distributions of emergence were similar for all years.

The sorghum midge, *Contarinia sorghicola* (Coquillett) (Diptera: Cecidomyiidae), is a key insect pest of sorghum, *Sorghum bicolor* L. (Moench), in most regions of the world where the crop is grown (Young and Teetes 1977). Females deposit eggs in the flowering spikelets of grasses in the genus *Sorghum*. The immature stages develop cryptically within spikelets and larval feeding prevents normal kernel formation. Wild hosts such as johnsongrass, *Sorghum halespense* L., maintain early sorghum midge generations before flowering sorghum is available (Harding 1965).

In temperate regions, a variable proportion of sorghum midge larvae in each generation construct silken cocoons and enter a state of diapause within spikelets of the host plant (Walter 1941, Passlow 1965, Baxendale 1980). Typically, these spikelets fall to the ground and become covered with litter or are disked into the soil along with sorghum or johnsongrass residues. Harding (1965) reported that diapause termination and subsequent spring emergence of adult midges occurred in response to warm, moist soil conditions. However, few quantitative data were provided on the specific influence of these environmental factors. Baxendale and Teetes (1983) conducted laboratory studies on diapause termination in sorghum midges and found that diapausing larvae exposed to continuously moist conditions terminated diapause and emerged as adults when temperatures were in the range of 15 to 35°C. By using emergence rates within this range, they estimated an emergence threshold temperature of 14.8°C.

Baxendale (1980) reported that daily emergence of overwintered sorghum midges was greatly reduced on rainy days. However, in the first few clear days after a rainy period, increased midge emergence compensated for the reduction. A similar reduction and compensation in adult emergence was recorded for nondiapausing midges by Fisher and Teetes (1982). They concluded that rainfall played an important role in the population dynamics of the midge. Harding and Hogg (1966) showed that a few sorghum midge larvae remained in diapause for 2 or more years; however, the proportion of midges remaining in diapause for more than a single season was not reported. Walter (1941) suggested that midges entering diapause early in the season could terminate diapause later that same season under proper environmental conditions.

Control of sorghum midge is accomplished primarily through early regional uniform planting of sorghum to avoid high midge densities during the flowering period, and by multiple insecticide applications when the economic threshold of one adult midge per panicle is reached (Bottrell 1971, Young and Teetes 1977). Attempts to optimize the early uniform planting strategy have been complicated by lack of a sound understanding of the early-season population dynamics of the pest. Particularly important to this strategy are predictive data on the spring emergence of overwintered sorghum midges. Recently, considerable emphasis has been placed on the development of heat unit (degree-day) accumulation models that forecast the seasonal occurrence of insects (Sevacherian et al. 1977, Potter et al. 1981). In the present study, the adult emergence of overwintered midges was monitored during 1979, 1980, and 1981, and a predictive heat unit accumulation model was developed based on these 3 years of emergence data. In addition, the possibility of midges initiating and terminating diapause during the same season was investigated, and the proportion of midges remaining in diapause for more than 1 year was determined.

Materials and Methods

The emergence of overwintered sorghum midges was monitored at the Texas A&M University plantation in Burleson County, using pyramid-shaped traps constructed of wooden frames covered with fine-mesh, saran screening. Each trap covered a 1-m^2 area. Adult midges,

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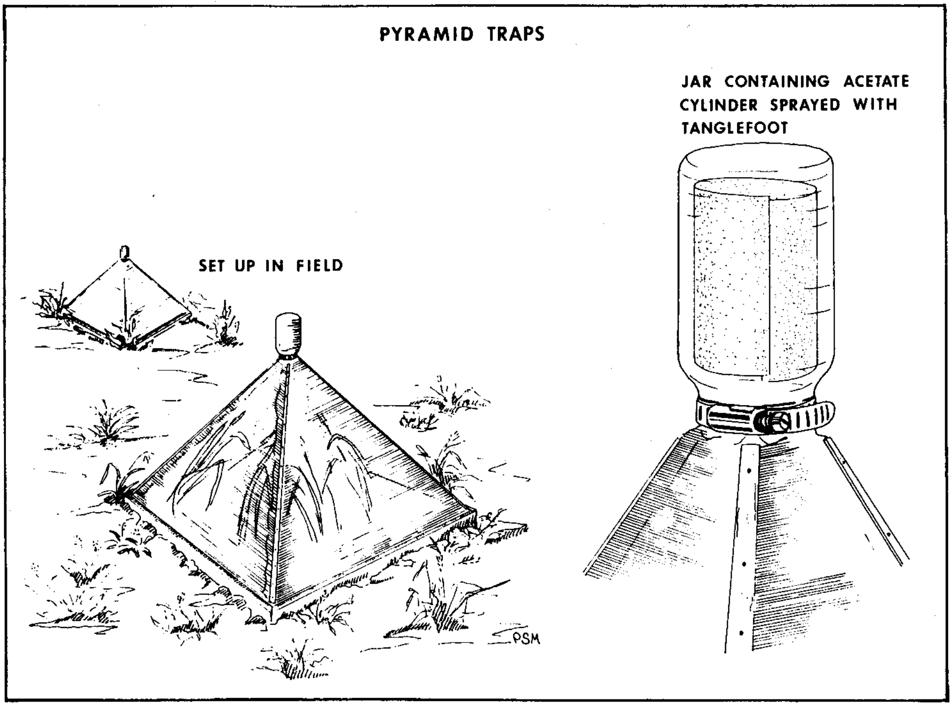

FIG. 1. Pyramid traps used to monitor the field emergence of overwintered sorghum midges.

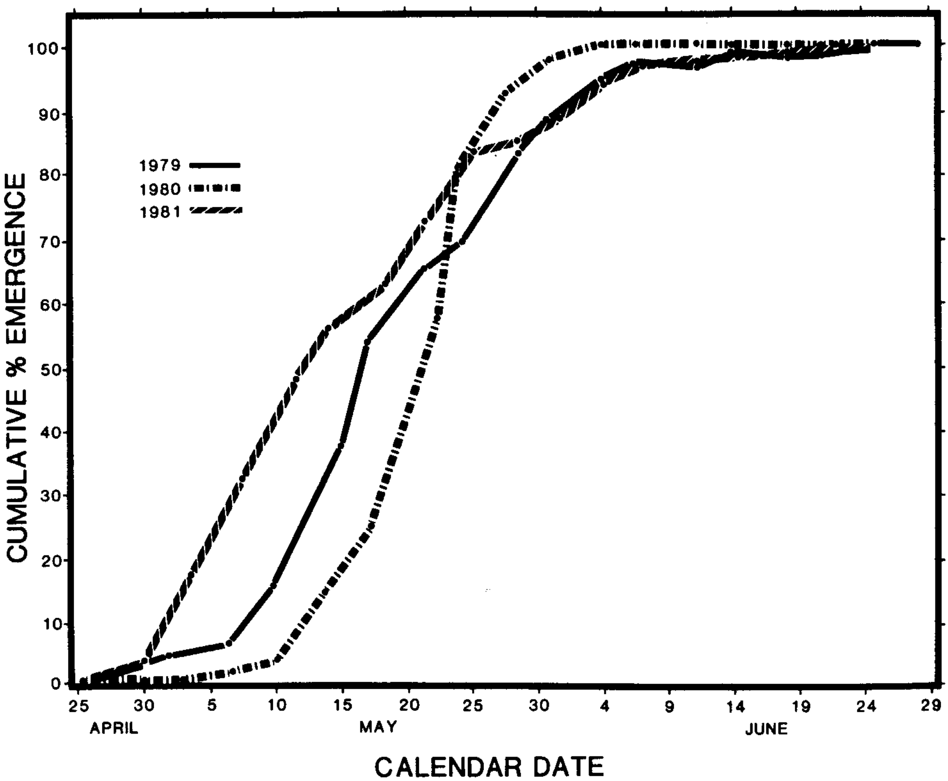

FIG. 2. Spring emergence of overwintered sorghum midges during 1979, 1980, and 1981.

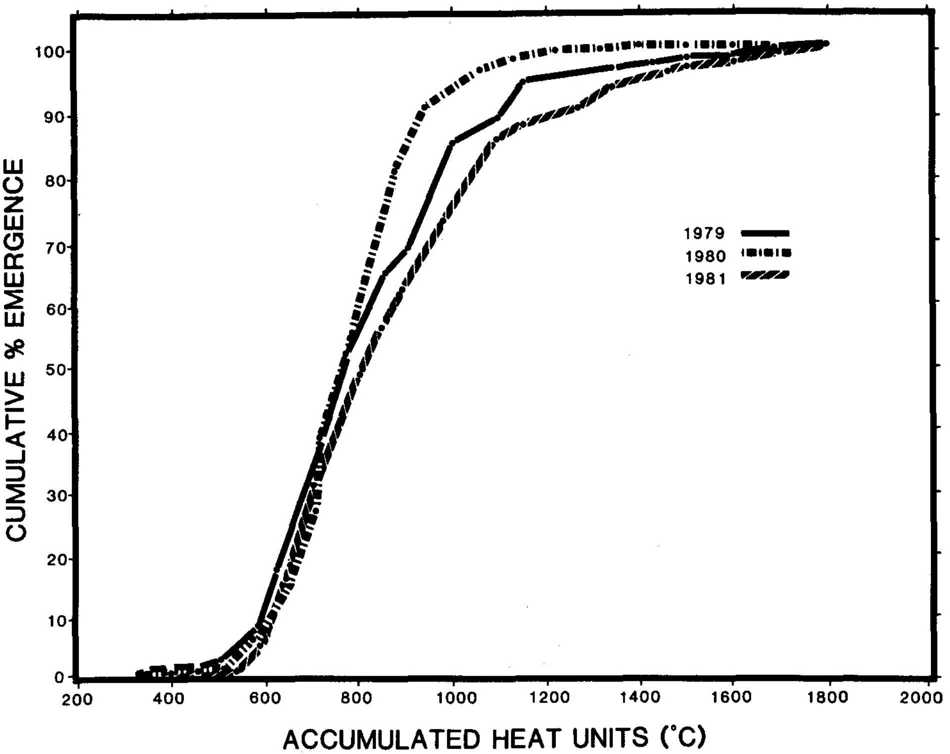

FIG. 3. Spring emergence of overwintered sorghum midges on a scale of accumulated heat units above a soil temperature of 14.8°C starting 1 April 1979, 1980, and 1981.

emerging from spikelets in the soil, were collected on Tree Tanglefoot-coated, acetate cylinders held within 437-ml Mason jars atop each pyramid (Fig. 1). Acetate cylinders were collected twice each week, and the number of adult sorghum midges was recorded. Soil temperatures and rainfall data were recorded throughout the growing season at the emergence site. Temperature was measured continuously at the 10-cm soil depth by using thermographs, and daily means were calculated as the average of 12 2-h readings. All emerged midges were the result of natural field populations.

During February of 1979, 1980, and 1981, 25 pyramid traps were randomly placed in plots where midge-infested sorghum had been grown, shredded, and disked the previous season. Adult emergence of overwintered midges was recorded during the spring and summer of each year. In 1980, 10 additional traps were placed in johnsongrass plots to monitor midge emergence from this host. Five of the pyramid traps set out in 1979 were left in the field, and adult emergence continued to be monitored through 1980 and 1981.

In the spring and summer of 1979, four successive plantings of sorghum were made at monthly intervals. In each planting, the date of 50% flower was recorded. This date served to approximate the average diapause initiation data for sorghum midges diapausing in sorghum spikelets of that planting. Forty days after sorghum in each planting was in 50% flower, 50 randomly selected panicles were cut, buried under ca. 10 cm of soil, and covered with a pyramid trap. The 40-day interval ensured there were no nondiapausing midges remaining in the panicle spikelets. Adult emergence was monitored during the remainder of the 1979 season and throughout the spring and summer of 1980.

Results and Discussion

In all years (1979, 1980, 1981), emergence of adult sorghum midges began in the last week of April and was completed during the final 2 weeks of June (Fig. 2). However, there was considerable temporal variability within emergence periods among years. This variability in emergence was primarily a function of soil temperatures and rainfall experienced during the emergence period. In 1980, soil temperatures during April and early May were relatively cool (1 April to 7 May: mean = 16.2°C), but warmed rapidly as the season progressed. Only 16.6 cm of rain fell during the emergence period, so delays in emergence due to precipitation were negligible. By contrast, 1981 soil temperatures were relatively warm during April and early May (1 April to 7 May: mean = 19.2°C). However, 44.9 cm of rain (concentrated in late May and June) fell during the emergence period. This combination of warm soil temperatures and extensive rainfall resulted in earlier emergence but at a slower rate than experienced in 1980. The spring of 1979 represented intermediate conditions of soil temperature (1 April to 7 May: mean = 17.3°C) and rainfall (28.2 cm), and the cumulative percent emer-

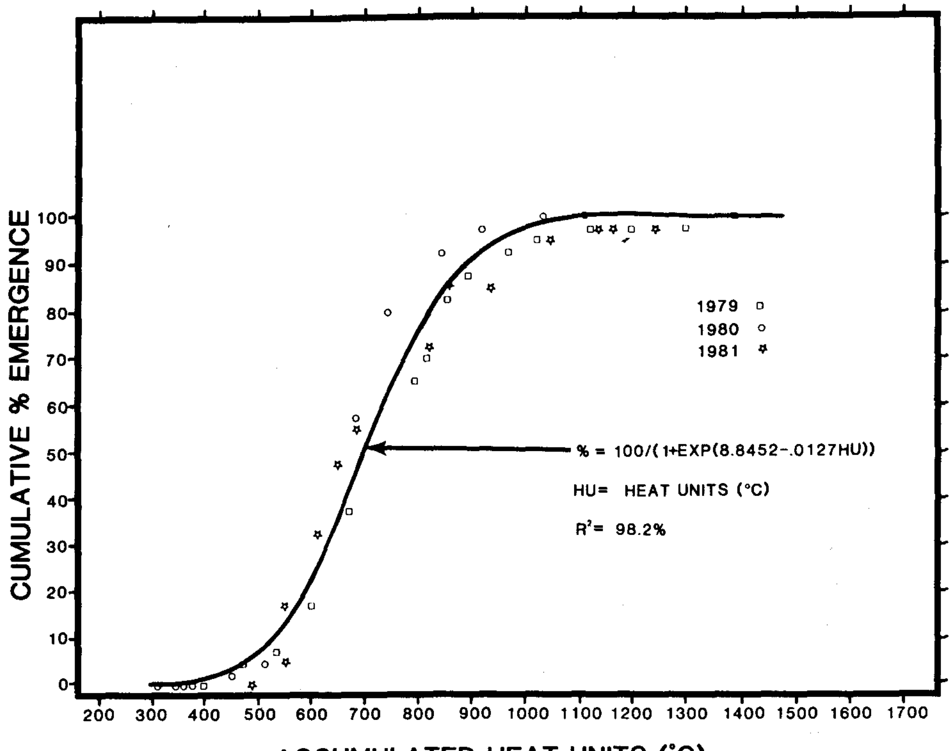

FIG. 4. Spring emergence of overwintered sorghum midges on a scale of accumulated heat units above a soil temperature of 14.8°C starting 1 April 1979, 1980, and 1981, including a rainfall adjustment factor.

gence curve fell between those of the two other years.

The strong influence of soil temperature on emergence of overwintered sorghum midges suggested that spring emergence could be described by using a heat unit accumulation model. Heat units were accumulated beginning 1 April, using mean daily 10-cm soil temperatures above a threshold of 14.8°C (Baxendale and Teetes 1983). The starting date for the model was 1 April, since few mean daily soil temperatures exceeded the threshold temperatures before this time. When the emergence of overwintered sorghum midges was placed on a physiological time scale of accumulated heat units, cumulative percent emergence curves for all 3 years were similar in shape and showed a considerable degree of overlap particularly during the earlier portions of emergence periods (Fig. 3). If development times had been solely a function of soil temperature, all emergence curves should have been nearly superimposed. However, due to the delaying effects of rainfall on emergence, an overall decrease in the rate of emergence (increase in accumulated heat units) occurred during the wetter years. Thus, in 1980 with only 16.6 cm of rain, fewer heat units were accumulated and the slope of the cumulative percent emergence curve was steeper than that of 1981 with 44.9 cm of rain.

The predictive capabilities of the model were improved by adjusting heat unit accumulations to reflect daily rainfall totals during the emergence period. On days when 1.27 to 2.54 cm of rain fell, heat units were not accumulated for that day. When the daily rainfall total was greater than 2.54 cm, no heat units were accumulated for a 2-day period, and no adjustments were made when there was less than 1.27 cm of rain. By using these rainfall adjustments, mean heat unit accumulations (mean ± SE) required for 1, 5, 10, 25, 50, 75, and 95% emergence were 431.7 ± 29.2, 510.0 ± 24.3, 545.8 ± 9.4, 607.5 ± 9.7, 679.3 ± 13.9, 801.3 ± 45.9, and 977.3 ± 57.1, respectively, for the 3 years. Heat unit accumulations (adjusted for rainfall) from all 3 years were combined, and a nonlinear regression procedure was used to fit a logistic model (Fig. 4). This model will provide more accurate predictions of spring emergence and will be extremely useful for scheduling sampling procedures and monitoring the early-season dynamics of midge generations in the field.

Additional studies on the emergence of overwintered sorghum midges indicated that midges overwintered in johnsongrass spikelets emerged during the same period in the spring with similar heat unit accumulations as midges that had overwintered in sorghum spikelets. Further, the time that diapause was initiated one year had little effect on the timing or distribution of emergence the following spring. In the four successive sorghum plantings made during 1979, 50% flower (and approximate diapause initiation dates for midges infesting these plantings) occurred on 7 July, 21 July, 21 August, and 15 September. No midges terminated diapause and emerged as adults before the following spring, and at that time, emergence times and distributions were nearly identical regardless of diapause initiation date.

Only 74.4% of the sorghum midges that initiated diapause during the 1978 growing season emerged as adults the following spring, whereas, 23 and 2.6% emerged during the second and third springs, respectively. The time and distribution of emergence, however, was similar for all midges during all 3 years.

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