Effect of Rainfall and Temperature on Codling Moth Oviposition[1]

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ABSTRACT

Oviposition by 1st generation codling moth females was significantly affected by the average hourly temperature and the amount and duration of rainfall occurring between 5–11 PM. Oviposition by 2nd generation females during August and September was affected by temperature but not rainfall.

In a previous paper Hagley (1972b), showed that the establishment and survival of 1st instar larvae of the codling moth, *Laspeyresia pomonella* (L.), were adversely affected by rainfall. Oviposition by 1st generation females also appeared to be reduced by rainfall. The greater abundance of the codling moth in dry and hot rather than wet and cool seasons (Shelford 1927, Webster 1937, Putman 1963) may be due, therefore, not only to greater larval survival but also to increased oviposition. Consequently, further observations on the effect of rainfall and temperature on oviposition were made in two unsprayed orchards in Ontario from 1972–75. The results of these and earlier studies are reported here.

Materials and Methods

The study orchards have been previously described (Hagley 1970). Codling moth oviposition was determined by examining fruit clusters randomly selected fom the periphery of the tree canopy (Hagley 1972b). Samples were taken once or twice weekly and the total number of eggs observed related to the total number of fruit present (Geier 1963). The 'red ring' and 'black head' stages of embryonic development and 1st larval hatch occurred in about 3, 5, and 7 days in the Vineland orchard, and in 5, 7, and 9 days in the Meaford orchard and these periods were used to establish the actual date on which the eggs were deposited.

Rainfall was recorded with manual gauges which were checked soon after precipitation occurred or daily during extended wet periods. An automatic tipping bucket gauge (Weathermeasure Corp., Sacramento, Calif.) was used at Vineland in 1973 and at Meaford in 1974 and 1975, to determine the time and duration of precipitation. In 1972, rainfall occurring between 5–11 PM was recorded separately from a manual gauge. Temperature was recorded on thermohygrographs placed in Stevenson screens in the orchards. The average temperature between 5–11 PM =

$$\frac{\text{temperatures at each hr.}}{7}.$$

At Vineland, the 1st generation moths were regarded as occurring from the date of 1st female emergence to the 31st July, and the 2nd generation during August and the 1st week in September when sampling was terminated. At Meaford where a small partial 2nd generation of the moth occurs somewhat later than at Vineland oviposition was also related to the above-mentioned periods.

Multiple correlation and regression analyses were carried out on the data by computer.

Results and Discussion

At Vineland and Meaford, oviposition by females of the 1st generation was related to the average temperature between 5–11 PM when the moths are most active (Batiste et al. 1973) and total rainfall during the generation period (Table 1). The correlation coefficients for temperature were $r = 0.834$ and 0.982 and for rainfall $r = -0.846$ and -0.903 for Vineland and Meaford moths, respectively. The multiple correlation coefficients and regression equations are given below:

Meaford, $r = 0.989$, $P < .02$,

$$Y = -42.17 - 0.25x_1 + 3.14x_2 \qquad \text{(I)}$$

Vineland, $r = 0.834$, $P < .05$,

$$Y = 2.07 - 0.87x_1 + 1.42x_2 \qquad \text{(II)}$$

Where x_1 = rainfall (cm), x_2 = temperature (°C) and Y = no. eggs/ 100 fruit.

Oviposition was also adversely affected by rain falling between 5–11 PM (Table 2). As rainfall during this period was measured in only 3 yr at Meaford and one at Vineland, the data for both generations from the two locations were pooled for analysis. The correlation coefficients for temperature ($r = 0.831$) and rainfall ($r = -0.861$) were

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Table 1.—Relationship between total rainfall and temperature and oviposition by 1st generation codling moth females.

Orchard location	Year	Total rainfall (cm)	Avg. temp (°C) 5–11 PM	No. eggs/ 100 fruit
Vineland	1969	22.5	19.7±3.8	11.3
	1970	22.7	20.1±2.4	4.9
	1971	17.6	20.7±2.9	11.3
	1973	12.3	22.2±2.9	19.7
	1975	20.5	20.0±3.3	5.1
Meaford	1972	19.3	17.2±4.1	7.7
	1973	6.7	19.7±2.1	18.9
	1974	14.2	17.1±3.1	7.3
	1975	10.1	19.9±3.4	16.9

Table 3.—Relationships between average daily maximum temperature and total rainfall and oviposition by 1st generation codling moth females.

Orchard location	Year	Avg. daily maximum temperature (°C)	Total rainfall (cm)	No. eggs/ 100 fruit
Vineland	1969	22.9±3.8[a]	22.5	11.3
	1970	24.8±1.3	22.7	4.9
	1971	24.7±4.1	17.6	11.3
	1973	26.0±2.4	12.3	19.7
	1975	25.8±2.5	20.5	5.1
Meaford	1972	21.9±4.0	19.3	7.7
	1973	24.1±1.2	6.7	18.9
	1974	22.1±3.0	14.2	7.3
	1975	24.3±3.3	10.1	16.9

[a] Standard deviation.

significant ($P<.05$) and the multiple correlation coefficient and regression equation were:

$$r = 0.952\ (P<.02),$$
$$Y = -43.02 - 8.19x_1 + 4.52x_2 \qquad \text{(III)}$$

The regression coefficients for both rainfall and temperature are large and significant indicating that ovipositing females will respond to these factors acting over short time intervals.

At Meaford (Table 3) there was also a significant correlation between oviposition and the daily average maximum temperature ($r = 0.976$, $P<.02$) and total rainfall ($r = -.903$, $P<.05$). The multiple correlation coefficient and regression equation are:

$$r = 0.979,\ P<.02,$$
$$Y = -76.64 - .18x_1 + 3.97x_2 \qquad \text{(IV)}$$

At Vineland, although these factors were not individually related to oviposition, the multiple correlation coefficient was significant:

$$r = 0.975,\ P<.02,$$
$$Y = 118.4 - 1.72x_1 - 3.03x_2 \qquad \text{(V)}$$

Indeed, the negative regression coefficient ($r = -3.03$) for the relationship between average daily maximum temperature and oviposition suggests that egg deposition was adversely affected. As the average daily maximum temperature range (23.5–28.0°C) generally exceeded the optimum range of 23–25°C for oviposition (Hagley 1972a) in most years at Vineland this effect was not unexpected. Also, in the laboratory a reduction of 24%–38% in moth fecundity was observed at constant temperatures between 27 and 33°C compared to that at 24°C (unpubl.). At Meaford, average maximum temperatures (22.5–24.6°C) were just below or within the optimum range and hence changes of only a few degrees for short periods, particularly at the lower end of the range, would readily affect oviposition.

Oviposition by 2nd generation females in both areas was not correlated with total rainfall occurring either within the generation period (3.9–35.1 cm) or between 5–11 PM (0.0–24.1 cm). The numbers of eggs deposited by these females was largely related to temperature as shown by the r values in Table 4.

The observed egg deposition by 1st generation females and values predicted by using equations (I) and (II) (Table 5) are not significantly different ($P>.02$). These results indicate that the equations may be reliably used to estimate total oviposition by these females in the orchard. Also, equation (III) ($r^2 = 0.697$, based on partial correlation coefficient) would be useful in determining whether or not oviposition occurred.

The number of hours of precipitation between 5–11 PM and in the generation periods was also

Table 2.—Relationships between rainfall and temperature between 5–11 pm and oviposition by 1st and 2nd generation females.

Rainfall (cm)	Orchard location	Year	Codling moth generation	Avg. temp. (°C) 5–11 PM	No. eggs/ 100 fruit
3.5	Vineland	1973	1st	22.2±2.9	19.7
3.4	Meaford	1972	1st	17.2±4.1	7.7
4.9	Meaford	1974	1st	17.1±3.1	7.3
3.6	Meaford	1975	1st	19.9±3.4	16.9
0.0	Vineland	1973	2nd	24.5±4.7	77.4
4.0	Meaford	1972	2nd	17.0±2.4	9.2
9.5	Meaford	1974	2nd	17.5±2.4	16.5
0.2	Meaford	1975	2nd	19.7±3.0	35.3

Table 4.—Correlation coefficients ($P < .05$) for the relationships between temperature and codling moth egg deposition in the 2nd generation.

Temperature	Correlation coefficient Meaford	Vineland
Avg. hr. 5–11 PM	.936	.895
Avg. daily	*	.901
Avg. daily maximum	.897	*
Avg. daily maximum	*	.898

* Not significant.

Table 5.—Observed and predicted values for egg deposition (no. eggs/100 fruit) by 1st generation females.

Vineland		Meaford	
Observed	Predicted	Observed	Predicted
10.5±2.1[a]	10.8±2.1	12.7±3.0	12.5±3.1

[a] Standard error.

highly correlated with egg deposition (Table 6). The correlation coefficients and regression equations are given below:

5–11 PM, $r = -0.883$,

$$Y = 60.0 - 2.63x_1, P<.02 \quad \text{(VI)}$$

generation, $r = -0.810$,

$$Y = 54.9 - .68x_1, P<.05 \quad \text{(VII)}$$

Measurement of the duration of rainfall especially between 5–11 PM (equation (VI), $r^2 = 0.779$) would also prove of value in establishing the occurrence of oviposition.

The number of eggs deposited in a given orchard would, of course, be dependent on several other factors such as fecundity, number of females and fruit present, and mortality in each of the life stages involved. Estimates of these parameters, together with the effect of climatic factors on oviposition would enable estimates of the damage potential of the moth to be made. Correlating such estimates with pheromone trap catch data could provide a useful index for indicating the need to control moth populations in integrated pest management programs.

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Table 6.—Relationship between duration of precipitation between 5–11 pm and egg deposition by 1st and 2nd generation codling moth females.

Orchard location	Year	Codling moth generation	Duration of rainfall (hr)	No. eggs/100 fruit
Meaford	1974	1st	21	7.3
Meaford	1975	1st	13	16.9
Vineland	1973	1st	15	19.7
Meaford	1974	2nd	19	16.5
Meaford	1975	2nd	3	35.3
Vineland	1973	2nd	0	77.4

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