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PREDICTING CODLING MOTH SPRAY DATES WITH DEGREE-DAYS

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INTRODUCTION

The codling moth is one of the most important pests of apple and pear fruit of British Columbia's interior orchards. It's control in commercial orchards is essential to economic fruit production.

The sex pheromone trapping program has provided one method to increase the effectiveness of orchard control by showing where populations need spraying. The methods outlined in this pamphlet predict insect development based on the amount of heat during the season and can indicate the most effective timing for spraying. Used together the two systems can provide growers with information to increase the total effectiveness of their control programs.

The concept of using heat unit accumulation or degree days to explain codling moth activity originated in Illinois during the 1920's. A practical program using these principles was published in 1978 by Michigan State University and has been modified and used successfully in Washington State orchards since 1982. In British Columbia, tests of the Washington model during 1983-1985 have demonstrated its accuracy in predicting codling moth activity and spray dates under Okanagan weather conditions.

PROGRAM REQUIREMENTS

Temperatures - Orchardists using this program must be prepared to collect daily maximum and minimum temperatures from weather stations located in or near their orchard. The daily readings must begin on approximately March 1 of each year or when a "Biofix" (Table 4, see page 7) has been reached in moth trap captures. The temperature information is needed to:

1) Calculate daily degree-days from Table 1, page 5.
2) Provide a record of the accumulated degree-days needed to show the stages of moth development, and the amount of egg hatching, Table 3, page 7.

Pheromone Traps - Pheromone traps must be used as recommended in the pamphlet "Codling Moth Sex Pheromone Traps" but the traps must be:

1) Installed earlier, before or at the pink-bud stage of apples, and;
2) Examined every day or two until moth captures show "Biofix" has been reached (Table 4). Inspect traps weekly after Biofix has occurred.

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EQUIPMENT REQUIREMENTS

Thermometers - The reliability of the program is dependent upon accurate and reliable thermometers. Unfortunately a set of the standard calibrated weather station thermometers costs more than $100.00 while an accurate recording thermometer, or thermograph, costs in excess of $500.00.

Less accurate U-tube maximum/minimum thermometers costing, $30.00 to $50.00, are readily available and once calibrated should provide adequate temperature information. These thermometers must be checked annually by immersion in a stirred water and ice solution (0 degrees Celsius) to set their calibration.

Weather Shelters - The thermometers are best housed in a Stevenson screen shelter to protect them from the effects caused by sun and rain. Plans for the construction of these shelters are available from the B.C. Ministry of Environment, Kelowna. A "make-do" shelter, made from a wooden apple box painted with white exterior enamel, can be used as a temporary measure.

Locate the weather screen three to five rows inside the orchard border. A site between the trees may be used to avoid damage by equipment or wetting from sprinklers. If an apple box shelter is used, cover the opening while irrigating to prevent sprinklers wetting the thermometers.

Mount the shelter on a firm stand or post with the opening facing north. The base of the shelter should be approximately 1.25 meters (4 feet) above ground level. The maximum/minimum thermometer should be firmly attached inside, near the centre of the shelter.

Neighbouring orchardists who wish to share information from a common weather station must be sure their cooperative station is positioned in a location which reflects the temperatures of all their orchards. The "Biofix" requirements must be determined individually from pheromone traps located in each orchard (see Biofix below).

CALCULATING DEGREE-DAYS

Start-Up - The program has two start-up options, each will produce satisfactory results. Choose either one.

Option 1 - Begin degree-day calculations by March 1 and install your codling moth traps at or before pink-bud stage. When approximately 80 degree-days (^{O}D) have been accumulated check your traps every day or two until Biofix. After Biofix maintain the traps on a weekly basis.

Orchardists not using pheromone traps can use this option to indicate timing of the first cover-spray in a control program using scheduled spraying.

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Option 2 - Install your codling moth traps at the pink-bud stage and check them every day or two until Biofix. At Biofix, set the degree-day sum to 111°D and begin recording daily maximum/minimum temperatures. This option requires more pheromone trap inspections but fewer degree-day calculations.

Degree-Day Calculation - Read the thermometers to the nearest one-half degree before 10 o'clock each morning. Each daily maximum/minimum thermometer reading is converted to degree-days by using the table shown on page 5, Table 1.

For example, if the daily maximum temperature has been 17.5°C and the minimum 9.5°C, the degree-days accumulated for that day are 3.7°D (find the maximum temperature in the left side vertical margin, and the minimum in the temperature ranges shown on the top of the chart. These temperatures intersect at 3.7°D). No degree days can occur when the maximum daily temperature is below 10°C. See Table 2 for further examples and work-sheet format to use in recording temperatures calculating and the degree-days.

Daily maximum/minimum temperatures which have been missed or lost, can be substituted with those obtained from your nearest official Atmospheric Environment Service weather station by contacting your local Environment Canada weather office. This is a poor substitute for data from your specific orchard and should be avoided if possible.

Biofix - "Biofix" is a very important event in the program. The event occurs when significant moths have been captured (see Table 4) in the orchard. It is used to correct any errors in degree-day calculations for the early "start-up", and, it is used to signal the beginning of degree-day calculations for the "start-up, Option 2".

The examples shown in Table 2 shows how "Biofix" corrections can occur. The degree-day sum of 111°D is stalled or advanced when the "Biofix" event occurs.

SPRAY TIMING

Remember, the pheromone traps determine if the moth populations in the orchard need to be controlled, but the degree-day accumulations will show when to apply the spray. The program helps in second and third brood timing but its most important function is the timing of the first spray for first brood.

First Brood - Codling moth insecticides are most effective against the larval stages. Therefore sprays which protect the fruit should be applied when some of the eggs laid have hatched and a few larvae have just started to feed on the fruit.

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The first spray: the program predicts this event will occur when a total of 250°D has accumulated, see Table 3. At that time, over 50 percent of the over-wintered population will have emerged as moths, some will have mated and laid eggs, about 3 percent of these eggs will have hatched. Weather permitting, sprays should be applied the day when 250°D is reached.

If moth captures in the pheromone traps have been below the treatment level during the weeks between the "Biofix" (111°D) and the predicted spray date at 250°D, delay spraying until your moth captures have averaged two moths per trap for two consecutive weeks.

Second spray: if trap captures reach the treatment level again during the third and fourth weeks, in the fourth to fifth weeks or in any two week period after the first spray has been applied, a second insecticide spray will be needed to prevent fruit damage.

Second and Third Broods - A spray to control larvae from the second brood codling moths may be required at approximately 811°D. But since population levels can be very variable at this time, because of previous sprays and weather, use your trap capture results to determine the need for protection and the timing of the spray.

A partial third brood of moths may develop during the last half of August and early September if weather conditions are warmer than usual. Trap captures during this period may indicate treatment levels, but as weather conditions may change rapidly to temperature levels which would prevent any egg development, fruit should need protection only if a total of 1378°D have accumulated.

Forecasting Spray Dates - Orchardists using this program will notice in their calculations of daily degree-days that weather patterns will occur which produce fairly consistent daily degree-day totals. The recognition of these patterns will allow growers to predict spray timing several days in advance for orchards close to spraying.

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TABLE 1 Degree Days Calculated from Maximum and Minimum Temperatures in Degrees Celcius

Daily Minimum Temperature

DAILY MAX TEMP	26 to 24.5	24 to 22.5	22 to 20.5	20 to 18.5	18 to 16.5	16 to 14.5	14 to 12.5	12 to 10.5	10 to 08.5	08 to 06.5	06 to 04.5	04 to 02.5	02 to 01.5	00 to -1.5	-2 to -3.5	-4 to -5.5	-6 to -7.5	-8 to -9.5
								DEGREE-DAYS										
43.5	18.3	18.3	18.3	18.3	18.3	18.3	18.3	17.6	16.6									
43.0	18.3	18.3	18.3	18.3	18.3	18.3	18.3	17.4	16.4									
42.5	18.3	18.3	18.3	18.3	18.3	18.3	18.1	17.1	16.1	15.4								
42.0	18.3	18.3	18.3	18.3	18.3	18.3	17.9	16.9	15.9	15.1								
41.5	18.3	18.3	18.3	18.3	18.3	18.3	17.6	16.6	15.6	14.9								
41.0	18.3	18.3	18.3	18.3	18.3	18.3	17.4	16.4	15.4	14.6								
40.5	18.3	18.3	18.3	18.3	18.3	18.1	17.1	16.1	15.1	14.4	13.8							
40.0	18.3	18.3	18.3	18.3	18.3	17.9	16.9	15.9	14.9	14.1	13.5							
39.5	18.3	18.3	18.3	18.3	18.3	17.6	16.6	15.6	14.6	13.9	13.3							
39.0	18.3	18.3	18.3	18.3	18.3	17.4	16.4	15.4	14.4	13.6	13.0							
38.5	18.3	18.3	18.3	18.3	18.1	17.1	16.1	15.1	14.1	13.4	12.8	12.3						
38.0	18.3	18.3	18.3	18.3	17.9	16.9	15.9	14.9	13.9	13.1	12.5	12.0						
37.5	18.3	18.3	18.3	18.3	17.6	16.6	15.6	14.6	13.6	12.9	12.3	11.8						
37.0	18.3	18.3	18.3	18.3	17.4	16.4	15.4	14.4	13.4	12.7	12.1	11.6						
36.5	18.3	18.3	18.3	18.1	17.1	16.1	15.1	14.1	13.1	12.4	11.8	11.3	10.9					
36.0	18.3	18.3	18.3	17.9	16.9	15.9	14.9	13.9	12.9	12.2	11.6	11.1	10.6					
35.5	18.3	18.3	18.3	17.6	16.6	15.6	14.6	13.6	12.6	11.9	11.3	10.8	10.4					
35.0	18.3	18.3	18.3	17.4	16.4	15.4	14.4	13.4	12.4	11.7	11.1	10.6	10.2					
34.5	18.3	18.3	18.1	17.1	16.1	15.1	14.1	13.1	12.1	11.4	10.8	10.4	9.9	9.6				
34.0	18.3	18.3	17.9	16.9	15.9	14.9	13.9	12.9	11.9	11.2	10.6	10.1	9.7	9.3				
33.5	18.3	18.3	17.6	16.6	15.6	14.6	13.6	12.6	11.6	10.9	10.4	9.9	9.5	9.1				
33.0	18.3	18.3	17.4	16.4	15.4	14.4	13.4	12.4	11.4	10.7	10.1	9.6	9.2	8.9				
32.5	18.3	18.1	17.1	16.1	15.1	14.1	13.1	12.1	11.1	10.4	9.9	9.4	9.0	8.6	8.3			
32.0	18.3	17.9	16.9	15.9	14.9	13.9	12.9	11.9	10.9	10.2	9.6	9.2	8.8	8.4	8.1			
31.5	18.3	17.6	16.6	15.6	14.6	13.6	12.6	11.6	10.6	9.9	9.4	8.9	8.5	8.2	7.9			
31.0	18.3	17.4	16.4	15.4	14.4	13.4	12.4	11.4	10.4	9.7	9.1	8.7	8.3	8.0	7.7			
30.5	18.1	17.1	16.1	15.1	14.1	13.1	12.1	11.1	10.1	9.4	8.9	8.4	8.1	7.7	7.4	7.2		
30.0	17.9	16.9	15.9	14.9	13.9	12.9	11.9	10.9	9.9	9.2	8.7	8.2	7.8	7.5	7.2	7.0		
29.5	17.6	16.6	15.6	14.6	13.6	12.6	11.6	10.6	9.6	8.9	8.4	8.0	7.6	7.3	7.0	6.8		
29.0	17.4	16.4	15.4	14.4	13.4	12.4	11.4	10.4	9.4	8.7	8.2	7.7	7.4	7.1	6.8	6.5		
28.5	17.1	16.1	15.1	14.1	13.1	12.1	11.1	10.1	9.2	8.5	7.9	7.5	7.1	6.8	6.6	6.3	6.1	
28.0	16.9	15.9	14.9	13.9	12.9	11.9	10.9	9.9	8.9	8.2	7.7	7.3	6.9	6.6	6.3	6.1	5.9	
27.5	16.6	15.6	14.6	13.6	12.6	11.6	10.6	9.6	8.7	8.0	7.4	7.0	6.7	6.4	6.1	5.9	5.7	
27.0	16.4	15.4	14.4	13.4	12.4	11.4	10.4	9.4	8.4	7.7	7.2	6.8	6.5	6.2	5.9	5.7	5.5	
26.5	16.1	15.1	14.1	13.1	12.1	11.1	10.1	9.1	8.2	7.5	7.0	6.6	6.2	5.9	5.7	5.5	5.3	5.1
26.0	15.9	14.9	13.9	12.9	11.9	10.9	9.9	8.9	7.9	7.2	6.7	6.3	6.0	5.7	5.5	5.3	5.1	4.9
25.5	15.6	14.6	13.6	12.6	11.6	10.6	9.6	8.6	7.7	7.0	6.5	6.1	5.8	5.5	5.3	5.1	4.9	4.7
25.0	15.4	14.4	13.4	12.4	11.4	10.4	9.4	8.4	7.4	6.7	6.2	5.9	5.5	5.3	5.0	4.8	4.7	4.5
24.5	15.1	14.1	13.1	12.1	11.1	10.1	9.1	8.1	7.2	6.5	6.0	5.6	5.3	5.1	4.8	4.6	4.5	4.3
24.0		13.9	12.9	11.9	10.9	9.9	8.9	7.9	6.9	6.2	5.8	5.4	5.1	4.8	4.6	4.4	4.3	4.1
23.5		13.6	12.6	11.6	10.6	9.6	8.6	7.6	6.7	6.0	5.5	5.2	4.9	4.6	4.4	4.2	4.1	3.9
23.0		13.4	12.4	11.4	10.4	9.4	8.4	7.4	6.4	5.8	5.3	4.9	4.7	4.4	4.2	4.0	3.9	3.7
22.5		13.1	12.1	11.1	10.1	9.1	8.1	7.1	6.2	5.5	5.1	4.7	4.4	4.2	4.0	3.8	3.7	3.5
22.0			11.9	10.9	9.9	8.9	7.9	6.9	5.9	5.3	4.8	4.5	4.2	4.0	3.8	3.6	3.5	3.4
21.5			11.6	10.6	9.6	8.6	7.6	6.6	5.7	5.0	4.6	4.3	4.0	3.8	3.6	3.4	3.3	3.2
21.0			11.4	10.4	9.4	8.4	7.4	6.4	5.4	4.8	4.4	4.0	3.8	3.6	3.4	3.2	3.1	3.0
20.5			11.1	10.1	9.1	8.1	7.1	6.1	5.2	4.5	4.1	3.8	3.6	3.4	3.2	3.0	2.9	2.8
20.0				9.9	8.9	7.9	6.9	5.9	4.9	4.3	3.9	3.6	3.4	3.2	3.0	2.9	2.7	2.6
19.5				9.6	8.6	7.6	6.6	5.6	4.7	4.1	3.7	3.4	3.1	3.0	2.8	2.7	2.6	2.5
19.0				9.4	8.4	7.4	6.4	5.4	4.4	3.8	3.4	3.2	2.9	2.8	2.6	2.5	2.4	2.3
18.5				9.1	8.1	7.1	6.1	5.1	4.2	3.6	3.2	2.9	2.7	2.6	2.4	2.3	2.2	2.1
18.0					7.9	6.9	5.9	4.9	3.9	3.3	3.0	2.7	2.5	2.4	2.2	2.1	2.0	1.9
17.5					7.6	6.6	5.6	4.6	3.7	3.1	2.8	2.5	2.3	2.2	2.0	1.9	1.9	1.8
17.0					7.4	6.4	5.4	4.4	3.4	2.9	2.5	2.3	2.1	2.0	1.9	1.8	1.7	1.6
16.5					7.1	6.1	5.1	4.1	3.2	2.6	2.3	2.1	1.9	1.8	1.7	1.6	1.5	1.5
16.0						5.9	4.9	3.9	2.9	2.4	2.1	1.9	1.7	1.6	1.5	1.4	1.4	1.3
15.5						5.6	4.6	3.6	2.7	2.2	1.9	1.7	1.5	1.4	1.3	1.3	1.2	1.2
15.0						5.4	4.4	3.4	2.4	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.1	1.0
14.5						5.1	4.1	3.1	2.2	1.7	1.5	1.3	1.2	1.1	1.0	1.0	0.9	0.9
14.0							3.9	2.9	1.9	1.5	1.3	1.1	1.0	0.9	0.9	0.8	0.8	0.7
13.5							3.6	2.6	1.7	1.3	1.1	0.9	0.8	0.8	0.7	0.7	0.6	0.6
13.0							3.4	2.4	1.4	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5
12.5							3.1	2.1	1.2	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4
12.0								1.9	0.9	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3
11.5								1.6	0.7	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2
11.0								1.4	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
10.5								1.1	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
10.0									0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Modified From -- Brunner, Hoyt and Wright, 1982: Washington State University, College of Agriculture, Extension Bull. 1072. and Reidl and Croft, 1978: Res. Rep. Mich. St. Univ. Agric. Exp. Stn. (Farm Sci.) 337. 18 pp.

Example of Degree-Day Work Sheet (Celsius)

Orchard Smith - Blk. A No. traps inside orchard 4

Example 1

Date	Max. Temp.	Min. Temp.	Degree Days	Degree-Days Sum to Date	No. Moths Trapped	Notes
May 15	20.5	10.5	6.1	108.8	0	
May 16	22.5	11.5	7.1	111.0*	-	
May 17	19.0	11.5	5.4	111.0*	1	
May 18	24.0	10.0	6.9	111.0*	-	
May 19	25.0	12	8.4	111.0 (+8.4)	2	Biofix
May 20	23.0	11.0	7.4	126.8	Check traps weekly	

Example 2

May 15	19.5	6.0	3.7	72.9	0	
May 16	20.0	7.0	4.3	77.2	-	
May 17	22.5	10.0	6.2	83.4	1	
May 18	22.5	11.0	7.1	90.5	-	
May 19	23.0	11.5	7.4	111.0** (+7.4)	2	Biofix
May 20	24.5	12.0	8.1	126	Check traps weekly	

*Stalled at 111°D, until enough moths trapped for Biofix

**Advanced to 111°D with Biofix

Table 3

Degree-Day Accumulations and Codling Moth Development

Degree-Day (^{o}D) Sum	Brood	Egg Hatch	Notes
Pink bud stage of apples			Set out traps in the orchard
80^{o}D	1st		Check traps every two days until Biofix.
111^{o}D	1st	0%	BIOFIX. As soon as Biofix from pheromone traps inside the orchard is reached, re-set the degree-day sum for the orchard to 111^{o}D.
250^{o}D	1st	3%	First spray for first brood codling moth larvae if traps have shown treatment needed.
678^{o}D	1st/2nd	100%	End first brood egg hatch: second brood moth emergence started.
811^{o}D	2nd	7%	(First spray to second brood larvae if pheromone traps are not being used)
1300^{o}D	2nd/3rd	100%	End second brood egg hatch; third brood moth emergence started.
1378^{o}D	3rd	7%	Third brood larvae hatching.

Table 4

Biofix Determination

No. Traps Inside Orchard	Orchard Size	Total No. Moths Captured in Two Days Inside Orchard
2	2 ha	1 moth
4	4 ha	2 moths or two moths in any trap
6	6 ha	3 moths or two moths in any trap
8	8 ha	4 moths or two moths in any trap
10	10 ha	5 moths or two moths in any trap
20	20 ha	10 moths or two moths in any trap

<u>Degree-Day Work Sheet (Celcius)</u>

Orchard ______________________ No. of traps inside orchard ______

Date	Max. Temp.	Min. Temp.	Degree Days	Degree-Days Sum to Date	No. Moths Trapped	Notes