Degree-Day & Phenological Models

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Road map for today's talk

1. Degree-day DD models give an idea when an insect emerges; best time to use pesticides.
2. Need good scouting from multiple sources.
3. Phenological models easier, less infrastructure to use.
4. Microhabitat: use tape to monitor for crawlers.

What are degree-days?

To effectively control pest populations, pest managers need to be familiar with:

*The host plant; its life cycle, vulnerable stage of development, cultural needs, symptoms of stress and common pest problems.

*Pests; their life cycle, vulnerable stages of development, cultural needs, and natural enemies.

*Economic threshold of damage.

What are degree-days?

A degree-day is a measure of the amount of heat that accumulates above a specified base temperature during a 24-hour period.

The lower temperature threshold for development is used as the base temperature for calculating degree-days.

Experience has shown that 50°F is a reasonable base temperature for many species. Although other temperatures such as 32° and 42°F are also sometimes used.

Examples

D. A. Orton & T. L. Green. 1989. COINCIDE, The Orton System of Pest Management. Plantsmen's Publications

Pest	Life Stage	DD50	Silver maple, *Acer saccharinum*	Serviceberry, *Amelanchier laevis*
European pine shoot moth	Larvae	50-100		Floral buds
Spruce gall adelgid	Adult Female	50-100	First leaves	Floral buds

Examples

D. A. Orton & T. L. Green. 1989. COINCIDE, The Orton System of Pest Management. Plantsmen's Publications

Pest	Life Stage	DD50	Silver maple, *Acer saccharinum*	Serviceberry, *Amelanchier laevis*
Cankerworms	Larvae	100-200		Bloom
European pine sawfly	Larvae	100-200		Bloom
Spruce budworm	Larvae	100-200		Bloom
Eastern tent caterpillar	Lavae	100-200	Leaf 1-2	Bloom

Examples

D. A. Orton & T. L. Green. 1989. COINCIDE, The Orton System of Pest Management. Plantsmen's Publications

Pest	Life Stage	DD50	Silver maple, *Acer saccharinum*	Serviceberry, *Amelan chierlaevis*
Birch leafminer		275-500	Seeds	
Lilac borer	Larvae	275-500	Seed ripe	
Bronze birch borer	Larvae	400-600		
Elm leaf beetle	Larvae	400-600		
Bagworm	Larvae	700-800		Fruit ripe

Calculating degree-days

There are a number of ways to calculate degree-days, ranging from quite simple to those so complex that a computer is required. All three methods calculate degree-days from the daily minimum and maximum temperature, and a specified base temperature.

1. **Average Method**
2. **Modified Average Method**
3. **Modified Sine Wave Method**

Calculating degree-days

During a typical 24-hour day, the minimum temperature is usually reached just before dawn and the maximum temperature during mid-afternoon.

Daily temperature data can be obtained from a thermometer that records maximum and minimum temperatures, or from a nearby weather station.

Calculating degree-days

Degree-days = [(max temp + min temp) / 2] – base temp

Using this method, 5 degree-days accumulated during the day when temperatures ranged from 45 to 65
[(65 + 45) / 2] – 50 = 5 degree-days

If the maximum temperature for the day never rises above the base temperature, then no development occurs, and zero degree-days accumulate.

Using degree-days to predict insect and plant development

Cumulative degree-days = total number of degree-days that have accumulated since a designated starting date, and they are calculated simply by adding the number of degree-days that accumulate each day.

Any date can be used as the starting-date, but January 1 is used most commonly because many overwintering plants and insects do not resume development until they are first exposed to a period of cold.

Using degree-days to predict insect and plant development

Construct a degree-day model by monitoring a phenological event from one year to the and by noting the total number of degree-days that have accumulated.

For example, monitor adult emergence of bronze birch borer and flowering of crabapple. Record the cumulative degree-days or the total number of degree-days that have accumulated since by adding the number of degree-days that accumulate each day.

Using degree-days to predict insect and plant development

The number of degree-days required for a particular phenological event varies yearly. In Wooster, Ohio emergence of bronze birch borer adults first occurred at

475 degree-days in 1997
519 degree-days in 1998
654 degree-days in 1999
559 degree-days in 2000
526 degree-days in 2001
547 degree-days (5-year average)

Using plant phenology to predict insect activity

The critical assumption in the use of plant phenology to predict pest activity is that the phenological sequence (the order in which phenological events occur) remains constant from year to year even when weather patterns differ greatly.

Using plant phenology to predict insect activity

The dramatic variation in weather resulted in differences of up to four weeks in the dates on which these events occurred from year to year.

However, the order in which the phenological events occurred remained quite consistent from year to year.

Using plant phenology to predict insect activity

Phenological sequences can be used very effectively for scheduling pest management activities.

For example, when common lilac is blooming, a glance at the calendar would reveal that it was still too early to monitor for bronze birch borer emergence. Conversely, once black locust has bloomed, the calendar would show that it was too late to control the first generation of pine needle scale.

Using plant phenology to predict insect activity

The dates of "first bloom" and "full bloom" recorded. "First bloom" is defined as the date on which the first flower bud on the plant opens revealing pistils and/or stamens, and "full bloom" as the date on which 95% of the flower buds have opened (i.e., one bud out of twenty has yet to open).

For each event, both the date of occurrence and the number of cumulative degree-days (using a starting date of January 1, and a base temperature of 50°F) was recorded.

Krischik, V and J. Davidson. 2004. IPM of Midwest Landscapes. University of Minnesota Experiment Station, 335pp. $45

Chapter degree days and plant phenology to predict pest activity

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Red : Wooster, Ohio
Blue: Dow Gardens, Michigan

Plant or Pest Species	Phenolog Event	Average Date	Cum DD
Silver Maple	first bloom	24-Mar	11
Silver Maple	full bloom	4-Apr	30
Corneliancherry Dogwood	first bloom	7-Apr	46
Eastern Tent Caterpillar	egg hatch	8-Apr	47
European Pine Sawfly	egg hatch	10-Apr	144
Red Maple	first bloom	9-Apr	49
Red Maple	full bloom	13-Apr	67
Border Forsythia	first bloom	15-Apr	71
Corneliancherry Dogwood	full bloom	16-Apr	75

Plant or Pest Species	Phenolog Event	Average Date	Cum DD
Corneliancherry Dogwood	full bloom	16-Apr	75
Star Magnolia	first bloom	17-Apr	83
Korean Rhododendron	first bloom	18-Apr	85
Manchu Cherry	first bloom	22-Apr	93
Border Forsythia	full bloom	22-Apr	97
Norway Maple	first bloom	22-Apr	103
White Pine Weevil	adult emergence	25-Apr	110
Pine Engraver	adult emergence	25-Apr	112

Plant or Pest Species	Phenolog Event	Average Date	Cum DD
PJM Rhododendron	first bloom	26-Apr	131
Manchu Cherry	full bloom	27-Apr	131
Bradford Callery Pear	first bloom	27-Apr	132
Gypsy Moth	egg hatch	28-Apr	148
Gypsy Moth	egg hatch	23-Apr	192
Apple Serviceberry	first bloom	29-Apr	153
Norway Maple	full bloom	29-Apr	154
Weeping Higan Cherry	full bloom	1-May	155

Plant or Pest Species	Phenolog Event	Average Date	Cum DD
Common Flowering quince	first bloom	29-Apr	155
Spruce Spider Mite	egg hatch	13-Apr	162
PJM Rhododendron	full bloom	3-May	172

Plant or Pest Species	Phenolog Event	Average Date	Cum DD
Koreanspice Viburnum	first bloom	5-May	189
Birch Leafminer	adult emergence	5-May	189
Birch Leafminer	adult emergence	26 Apr	215
Japanese Flowering Crab	first bloom	6-May	200
Snowdrift Crabapple	first bloom	6-May	205
Common Lilac	first bloom	7-May	207
Common Flowering quince	full bloom	7-May	208
Azalea Lace Bug	egg hatch	23-Apr	206
Sargent Crabapple	first bloom	7-May	213

Plant or Pest Species	Phenolog Event	Average Date	Cum DD
Snowdrift Crabapple	full bloom	11-May	255
Tatarian Honeysuckle	first bloom	12-May	259
Common Horsechestnut	first bloom	12-May	260
Japanese Flowering Crab	full bloom	12-May	267
Pine Needle Scale	egg hatch - 1st generation	13-May	277
Pine Needle Scale	egg hatch - 1st generation	8-May	305
Sargent Crabapple	full bloom	14-May	282

Plant or Pest Species	Phenolog Event	Average Date	Cum DD
Sargent Crabapple	full bloom	14-May	282
Cooley Spruce Gall Adelgid	egg hatch	13-May	283
Cooley Spruce Gall Adelgid	egg hatch	8-May	308
Eastern Spruce Gall Adelgid	egg hatch	13-May	283
Eastern Spruce Gall Adelgid	egg hatch	8-May	308
Wayfaringtree Viburnum	full bloom	14-May	287

Plant or Pest Species	Phenolog Event	Average Date	Cum DD
Common Lilac	full bloom	17-May	323
Lilac Borer	adult emergence	16-May	324
Vanhoutte Spirea	first bloom	17-May	329
Ohio Buckeye	full bloom	18-May	342
Common Horsechestnut	full bloom	18-May	344
Lesser Peach Tree Borer	adult emergence	20-May	362
Oystershell Scale	egg hatch	19-May	363
Blackhaw Viburnum	full bloom	20-May	370
Pagoda Dogwood	first bloom	20-May	376

Plant or Pest Species	Phenolog Event	Average Date	Cum DD
Pagoda Dogwood	full bloom	29-May	488
Common Ninebark	first bloom	30-May	507
White Fringetree	full bloom	31-May	528
Bronze Birch Borer	adult emergence	2-Jun	550
Black Locust	full bloom	3-Jun	564
Beautybush	full bloom	3-Jun	565
Greater Peach Tree Borer	adult emergence	3-Jun	573
Euonymus Scale	egg hatch - 1st generation	3-Jun	575
Golden Oak Scale	egg hatch	6-Jun	625
Common Ninebark	full bloom	7-Jun	636

Plant or Pest Species	Phenolog Event	Average Date	Cum DD
Japanese Tree Lilac	full bloom	20-Jun	860
American Elder	first bloom	21-Jun	870
Fletcher Scale	egg hatch	20-Jun	884
Cottony Maple Scale	egg hatch	23-Jun	930
Northern Catalpa	full bloom	24-Jun	937
Greenspire Littleleaf Linden	full bloom	26-Jun	985
American Elder	full bloom	28-Jun	1019
Black Pineleaf Scale	egg hatch	29-Jun	1068
European Fruit Lecanium Scale	egg hatch	29-Jun	1073
Panicled Goldenraintree	first bloom	3-Jul	1137

To tape or not to tape: Degree-days, confirming model predictions, and microhabitats

Using degree-days to predict insect development

http://www.nysipm.cornell.edu/factsheets/treefruit/pests/cmb/cmb_fig9.html

Tape trap for monitoring Comstock mealybug and San Jose scale crawlers

San Jose Scale recommendations from Arkansas, California, Illinois, Indiana, Kentucky, Minnesota, New York, Vermont, Virginia

San Jose Scale & Grape Scale - crawlers May 15.

May 7 was the time to start inspecting limbs for crawlers. One sampling method is to place several strips of either double sticky Scotch tape or scotch tape (sticky side out) around infested limbs.

Weekly, use a hand lens to look for small yellow crawlers on tape; 1/32" long. Keep trees protected as long as crawlers emerge (caught on tapes) in May (2 to 3 weeks).

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Damage:

California red scale attacks twigs, leaves, branches, and fruit by sucking on the plant tissue with their long, filamentous mouthparts.

Tree damage is most likely to occur in late summer and early fall when scale populations are highest and moisture stress on the tree is greatest.

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Damage:

Severe infestations cause leaf yellowing and drop, dieback of twigs and limbs, and occasionally death of the tree.

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Life history:

California red scale can be found on the wood as well as on fruit and leaves.

When mature, they produce 100 to 150 eggs. Crawlers hatch and emerge from under the female cover at a rate of two to three per day.

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Life history:

Crawlers move around to find a suitable place to settle and can be spread about by wind, birds, or picking crews.

They settle in small depressions on twigs, fruits, or leaves and start feeding; soon after, circular, waxy covers form over their bodies.

Degree day models for California red scale

Life history:

With each molt the female cover develops a concentric ring center.

Degree day models for California red scale

Life history:

Males form elongated covers while the female covers remains circular.

Degree day models for California red scale

Biological control: *Comperiella bifasciata*

Comperiella bifasciata **play a an important role in controlling California red scale but their effectiveness depends on careful monitoring and use of selective insecticides for other pests.**

Degree day models for California red scale

Biological control: *Aphytis melinus*

Aphytis melinus **attacks armored scales including California red scale, latania scale, San Jose scale, and oleander scale.**

Degree day models for California red scale

Biological control: *Aphytis sp.*

Pupa of a scale parasite, *Aphytis* sp., with black meconia and remains of the parasitized female San Jose scale.

Degree day models for California red scale

Biological control: *Aphytis*

Parasitized California red scale showing *Aphytis* exit hole.

Degree day models for California red scale

Biological control

Augmentative releases of *Aphytis melinus* has been shown to be effective in controlling red scale, but this approach requires that the use of broad spectrum pesticides be minimized.

Avoid multiple applications of organophosphate or carbamate insecticides by using *Bacillus thuringiensis* for the control of orangeworms and abamectin or spinosad to control citrus thrips.

Degree day models for California red scale

Biological control: *Rhyzobius lophanthae*

Several insect predators also feed on California red scale including the lady beetle *Rhyzobius* (=*Lindorus*) *lophanthae*.

Degree day models for California red scale

Biological control: *Chilocorus orbus*

Several insect predators also feed on California red scale including this adult lady beetle, *Chilocorus orbus*.

Degree day models for California red scale

Biological control: *Chilocorus orbus*

***Chilocorus orbus* larvae**

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Biological Control:

To enhance the effectiveness of all natural enemies, use pesticides only when their need is indicated by careful monitoring, use the most selective insecticides available, and treat only portions of the orchard where red scale populations exceed the threshold.

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Organophosphates and carbamates:

The most reliable method of timing organophosphate or carbamate treatments is to monitor for crawlers by wrapping sticky tape around 1-year-old branches (about 0.5 inch diameter) that have both grey and green wood and are infested with live female scales.

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Organophosphates and carbamates:

Time organophosphate and carbamate insecticide sprays to treat the crawler stage, which peaks about 555 degree-days (accumulated above 53°F threshold) or about 1 to 3 weeks after the peak in the male flight. (For assistance in calculating degree-days, see "Degree-days" on the UC IPM Web site.)

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Organophosphates and carbamates:

Optimal treatment timing varies from year to year because of temperature, but usually occurs in May (first generation) or July (second generation).

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Neonicotinoids:

Apply imidacloprid (Admire) at petal fall in order to avoid bee toxicity. It will take about 6 weeks for full uptake into the tree. The level of control it exerts on California red scale depends on several factors.

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Neonicotinoids:

First there must be adequate root flush, the ground must be preirrigated, the output of the irrigation system must be uniform, the trees need to be healthy and growing vigorously, and the insecticide should not be washed away by excessive irrigation or rain.

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Oils:

Oils can be effective against California red scale if coverage is thorough. They also have the advantage of being relatively less damaging to natural enemy populations than other insecticides.

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Insect Growth Regulators:

Time pyriproxifen and buprofezin sprays for after crawlers have completely emerged and become white caps because these insect growth regulators will kill the scale when it tries to molt to the next stage.

Degree day models for California red scale

http://www.ipm.ucdavis.edu/PMG/A/I-HO-AAUR-AD.028.html

Insect Growth Regulators:

Optimal timing for insect growth regulators is the second generation of scale (June-July) in order to protect vedalia beetle during the time it is controlling cottony cushion scale (Feb.-May).

California red scale recommendations from California

Kern: 1072 DD
S. Tulare: 931 DD
N. Tulare: 1000 DD
Fresno: 936 DD
Madera: 784 DD
Second flight of males occurs: 1100 DD
Second crawler activity occurs: 1750 DD

The first emergence of California red scale crawlers in the Lindcove area was seen the week of May 17, but significant activity began the week of the 24th at about 470 DD after the first males were caught on sticky cards; a bit earlier than the expected 550 DD.

California red scale recommendations from California

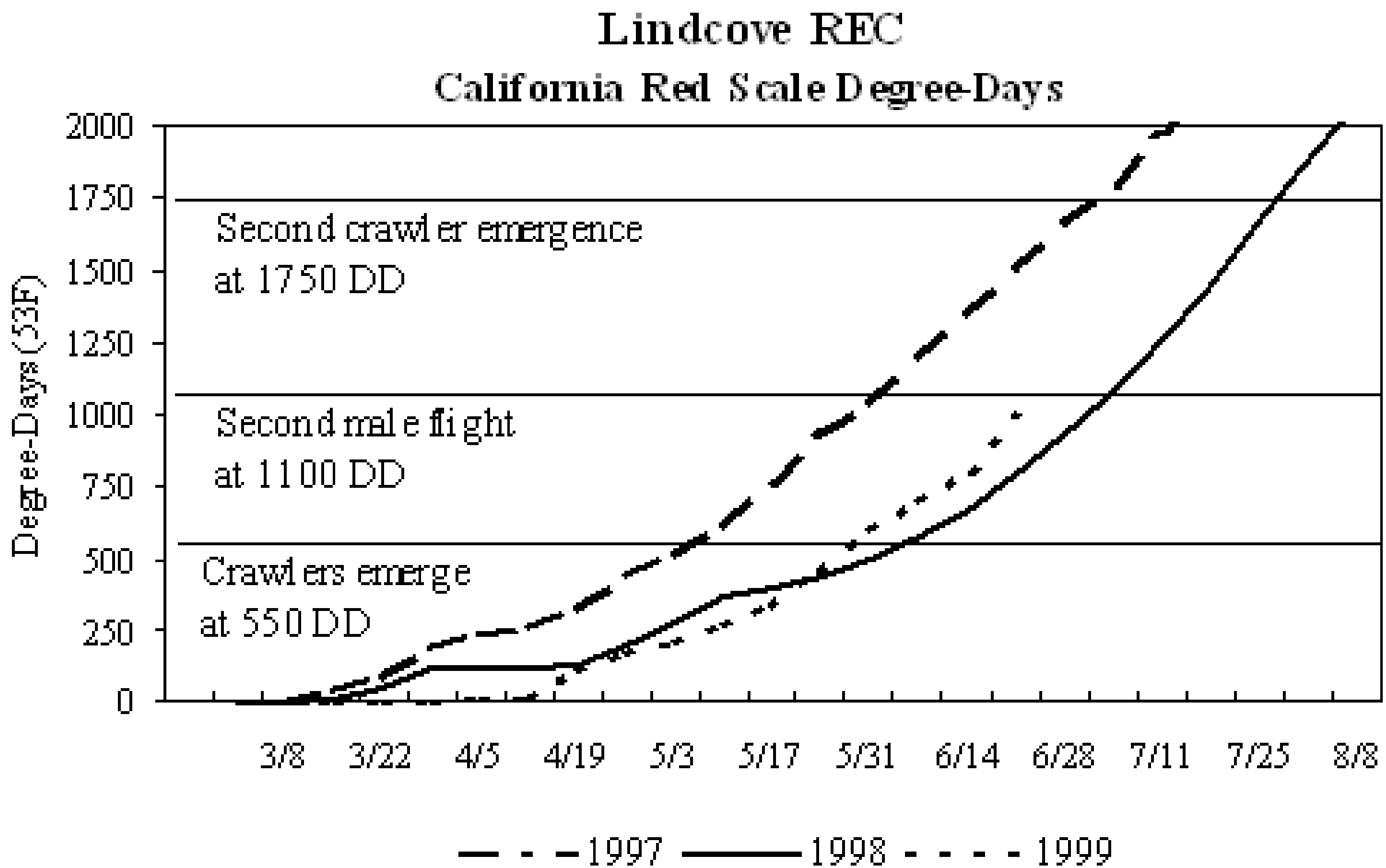
Red scale crawlers also began emerging the same week in Kern county. Because of the cool springs, crawler activity started at a later date in 1998 and 1999 compared to 1997 (Fig. 1 & 2).

In addition, crawlers have continued to emerge for a longer time (more than 6 weeks).

California red scale recommendations from California

Even though the crawlers are continuing to emerge, the second male flight is about to begin (Fig. 1). We expect the second flight to begin some time during the week of June 28 in most citrus growing regions.

Figure 1 shows that Lindcove is running a little warmer than last year on this date, but is still much cooler than the warm spring of 1997. If we accumulate 30 degree-days per day, which translates to a daily high temperature of 96° and a low of 70° , we should see the second emergence of crawlers at 1750 DD sometime during the last week of July.


Lindcove REC
California Red Scale Degree-Days
Degree-Days (53F)
2000
1750
1500
1250
1000
750
500
250
0
Second crawler emergence at 1750 DD
Second male flight at 1100 DD
Crawlers emerge at 550 DD
3/8
3/22
4/5
4/19
5/3
5/17
5/31
6/14
6/28
7/11
7/25
8/8
1997
1998
1999

California red scale recommendations from California

The reason that you need to be aware of crawler activity is because pesticide applications are more effective if they are timed properly.

Organophosphate (Lorsban and Supracide) and carbamate (Sevin) insecticides work best if applied when the crawlers have just settled.

Therefore, the best timing for these pesticides is just after peak crawler activity has occurred, usually 1-2 weeks after the crawlers begin to emerge.

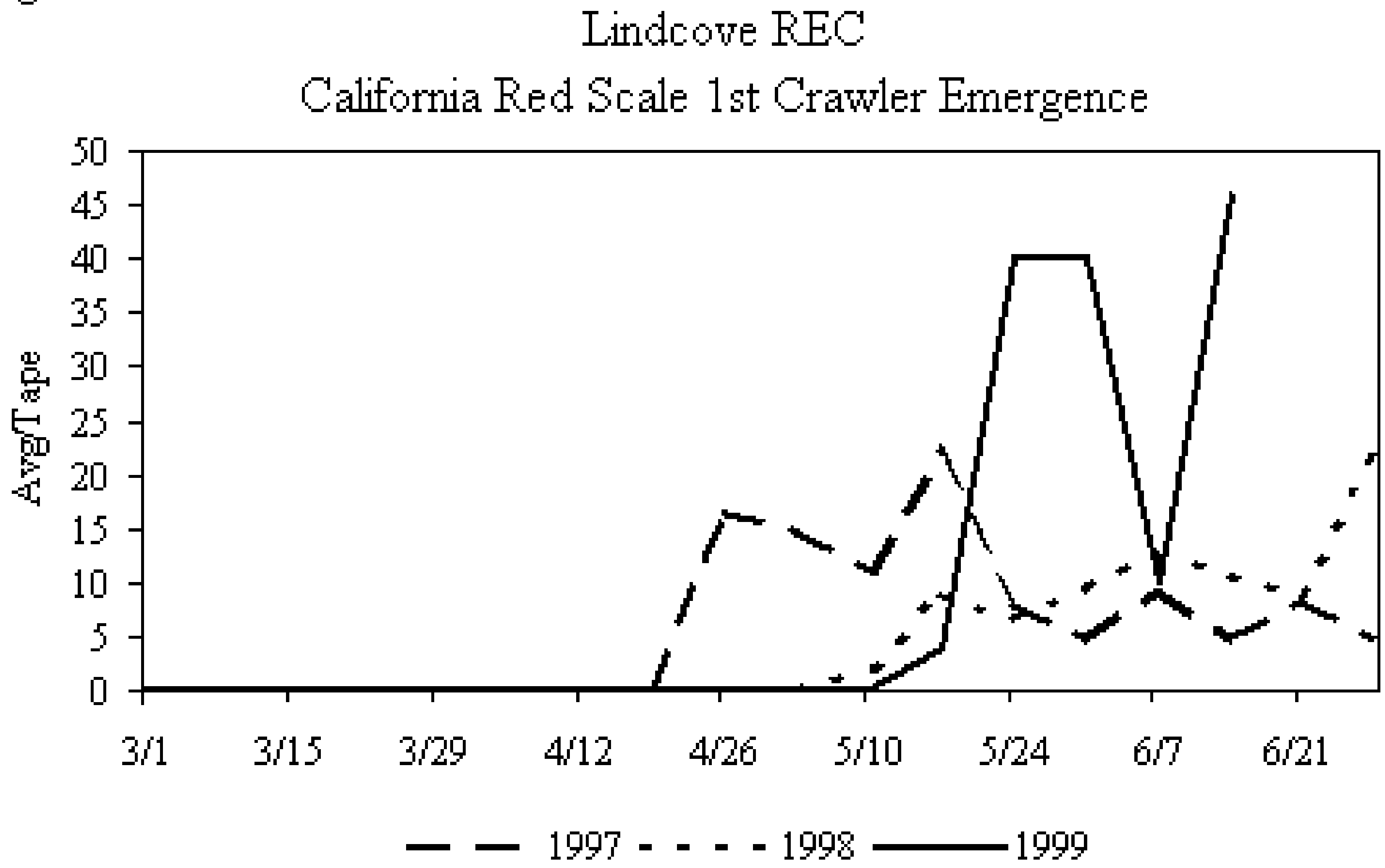
California red scale recommendations from California

Crawler emergence can be monitored using double-sticky tape wrapped around branches and changed weekly to catch crawlers as they move along the branch.

Notice in Figure 2 that crawler emergence begins and peaks at different times from year to year.

In warm years (1997), the bulk of the crawlers emerged over a 3-4 week period and the peak period is fairly obvious.

Fig 2



Lindcove REC
California Red Scale 1st Crawler Emergence
Avg/Tape
50
45
40
35
30
25
20
15
10
5
0
3/1
3/15
3/29
4/12
4/26
5/10
5/24
6/7
6/21
1997
1998
1999

California red scale recommendations from California

In a cool year, you simply have to wait a few weeks longer and hope that the insecticide residues will kill the scale crawlers as they continue to emerge. The organophosphates and carbamates will also kill most of the scales if they are sprayed at other times of the year.

However, the pesticides do a better job when applied while most of the population is a young stage. The only really poor time to spray insecticides for red scale control is while the males are flying. This is because most of the population consists of recently mated females and that is the hardest stage to kill with insecticides.

California red scale recommendations from California

The insect growth regulators Esteem (Knack) and Applaud kill the scale as it molts and so are best applied when the crawlers settle down as white caps.

Oil smothers the insect and so the best application timing for this pesticide is also when the scale have settled as whitecaps.

For these insecticides you want to wait longer before you spray than you would for the organophosphates and carbamates.

California red scale recommendations from California

In cool years (1998 & 1999), emergence lasts much longer and it is not certain when is the best time to spray. There are several methods to determine the best time to spray in a warm year;

1) detect when the crawlers first emerge using sticky tape and then wait for 1-2weeks for them to finish emerging before you spray or,

2) calculate degree days and wait until about 650 degree days after the males began to fly before you spray.

In summary:

1. Degree day (DD) models give an idea when an insect emerges; best time to use pesticides.
2. Unless degree day models are regional, the DD range can be too large.
2. Need good scouting from multiple sources.
3. Phenological models easier, less infrastructure needed.
4. Use tape to monitor for crawlers to confirm DD estimates.