A PLUM CURCULIO MANAGEMENT SYSTEM FOR TART CHERRIES USING A DEGREE DAY BASED POST FULL BLOOM CONTROL INTERVAL

By

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ABSTRACT

A PLUM CURCULIO MANAGEMENT SYSTEM FOR TART CHERRIES USING A DEGREE DAY BASED POST FULL BLOOM CONTROL INTERVAL

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Studies conducted in 1991 and 1993 showed that oviposition by plum curculio on tart cherries before 425 ddb50 F after full bloom did not result in larvae in the fruit at harvest. In 1994 a study was conducted to validate and evaluate this threshold in commercial blocks. The results from the harvest sampling data suggests that a 425 ddb50 F after full bloom threshold would prevent infested fruit at harvest except under high plum curculio population pressure. The results have been formulated into a working threshold for use by commercial tart cherry growers of 375 ddb50 F after full bloom to time controls for plum curculio.

Dedicated

To my wife,

Sally J. Laubach

and parents,

Dr. George and Margaret Laubach

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INTRODUCTION

Plum curculio, *Conotrachelus nenuphar* (Herbst), is a primary insect pest of tart cherries in Michigan (Howitt 1993). Damage occurs when adult females oviposit in the cherry and the resulting larvae feeds internally in the fruit. The larvae will usually destroy the fruit by feeding, exit the fruit and pupate in the soil. This damage can reach economic levels in the early season during peak egg laying (petal fall to about 30 days after petal fall) when the number of cherries destroyed by larvae exceeds the costs associated with applying an insecticide or mid to late season (20 days after petal fall to one week pre-harvest) when ovipostion can result in larvae in the cherries at harvest.

Early season damage levels are related to area plum curculio populations. The size of a plum curculio population is a function of the historical use of insecticides, the wild hosts surrounding the orchard and the quality of overwintering habitat that may be present in and around the orchard. In most commercial blocks damage is uncommon or found at low levels, while in abandoned blocks damage can reach 100% (Laubach, unpublished).

Mid to late season injury can result in plum curculio larvae present in the fruit at harvest and is related to when during the season oviposition takes place and when the harvest takes place. The United States Department of Agriculture grade standards for tart cherries published in 1941 (USDA 1941, page 2) and used today, set a zero tolerance for "cherries which are affected by worms". The potential costs for the grower associated with this type of damage is the rejection of the load and possibly their entire crop. This standard has resulted in the tart cherry industry developing conservative control programs for the insects that feed internally in cherry fruit. These insect pests are most commonly plum curculio, *Conotrachelus nenuphar* (Herbst), eastern cherry fruit fly, *Rhagoletis cingulata* (Loew), black cherry fruit fly, *Rhagoletis fausta* (O.S.) and less commonly apple maggot, *Rhagoletis pomonella* (Walsh), cherry fruit worm, *Grapholitha packardi* (Zeller) and mineola moth, *Acrobasis tricolorella* (Grote) (Howitt 1993). Oblique banded leaf roller, *Choristoneura rosaceana* (Harris), which feeds primarily on leaves and externally on cherries has been found at high enough levels in cherry tanks to cause rejection of these tanks (Johnson, unpublished).

Historically an insecticide residue has been maintained from petal fall to harvest in tart cherry orchards to control insects that feed internally in the fruit; requiring up to nine separate insecticide sprays. We theorized that plum curculio oviposition early in the season allows the larvae to produce enough damage so that the cherry abscises before harvest and does not contribute to contamination. Oviposition late in the season often results in insufficient damage to cause abscission and can result in infested fruit at harvest. Defining when during the season damage can result in larval infested fruit at harvest would allow growers to reduce insecticide applications for plum curculio during the early season providing that populations of plum curculio are below economic crop reducing levels.

The objective of these studies was to determine if there is a consistent point in the season when the outcome from plum curculio oviposition changes from pre-harvest drop of tart cherry fruit to larval infested fruit at harvest.

LITERATURE REVIEW

Life History

Plum curculio, *Conotrachelus nenuphar* (Herbst), (Coleoptera: Curculionidae), is a primary insect pest of tart cherries in Michigan (Howitt 1993). Damage occurs when adult females lay eggs in the cherry and the larvae feeds internally in the fruit. The larvae will usually destroy the fruit by feeding, exit the fruit and pupate in the soil. Adults overwinter in orchard borders such as woodlots and fence rows (LaFleur et al. 1987). In the spring they migrate into the orchard when temperatures average 55 F to 65 F for several days. They have been found in orchards pre-bloom, but most will migrate during bloom and after bloom. If alternate hosts such as abandoned fruit trees border the commercial orchard, the threat of continued migration can be as long as 6 weeks after petal fall (Howitt 1993).

The adult plum curculio is a snout beetle, 5 mm long, dark-gray brown, and have three pairs of humps on their back. The jaws of the beetle are on the end of the snout. Eggs are 0.4 mm wide by 0.6 mm long and are pearly white. Larva is whitish and legless and measures about 6 to 9 mm when full grown. The head capsule is brown to light brown. Pupae is found in the upper 1 to 2 inches of soil and measures from 5 to 7 mm (Howitt 1993).

Adults mate after becoming active in the spring and females can lay from 100 to 500 eggs (Howitt 1993). Female plum curculio make a distinct crescent-shaped oviposition mark with their snout on the cherry skin. Eggs are laid under the flap of skin created by the wound. Egg hatch occurs within a few days and larval feeding can be seen beneath the fruit skin within four to seven days. Larvae will continue to feed, eventually destroying the cherry. Peak egg laying occurs 2 to 3 weeks after petal fall and can continue up to 6 weeks after petal fall. The larvae will exit the fruit and pupate in the soil. Adults will begin emerging in mid to late July (Howitt 1993).

Activity

Cook (1890) reports plum curculio does not begin visiting apple trees until petal fall in Central Michigan. After this time during egg laying, when weather is cold, plum curculio are often found beneath the tree under debris. Toward nightfall, activity increases with plum curculio reaching the canopy of the tree by walking up the trunk or flying. Cook observed that plum curculio, when on a limb, will commonly fall to the ground when disturbed. Studies conducted by Chouinard et al. (1992a) showed plum curculio most active from 2000 to 0400 hours with no correlation between temperature or humidity.

Lefleur et al. (1987) found that most plum curculio released in the fall in orchards migrated towards high tree silhouettes at the edge of woodlots. Migration was influenced by leaf litter conditions in the woodlot. Where leaf litter was thin, plum curculio remained at the wood edge or returned to the orchard for hibernation. Most plum curculio hibernated in the leaf litter; less than 1 % entered the soil. Winter survival was higher in forest soil with a thick litter layer than in orchard turf or forest soil with a thin litter layer.

Lafleur and Hill (1987) found that, in spring migration studies of plum curculio after emergence and migration, plum curculio were found on the ground under apple trees until up to petal fall on apples. They felt that future research should look at exploiting this behavior by developing ground-level traps and possible control measures, chemical and biological, that would be directed at them while they are on the ground.

Owens et al. (1982) monitored adult plum curculio activity on apple trees from 0600 hours to 2100 hours from mid May to early July. Observations were only made on warm days with low winds. Adults spent 45% of the time resting, 23% of the time feeding, 19% of the time crawling, 12% of the time in oviposition associated behavior and less than 1% of the time in flight. Dropping behavior was reported frequently occurring after a disturbance caused by an observer. Dropping was also observed from presence of a bird and a loud noise.

Racette et al. (1991) monitored daily activity of adults in field cages containing three to four dwarf apple trees. They found that from full bloom to petal fall plum curculio spent most of the time on the ground beneath the trees. By fruit set, most of their time was spent in the trees. Activity at this time was greatest in late afternoon and at night. Mean daily rate of movement within the cage was positively correlated to mean daily temperature.

Studies by Racette et al. (1990) used actographs to record daily activity of plum curculio in cages. The actograph measured the frequency of plum curculio dropping from the top of the cage. Before apple fruit set, plum curculio were active mostly during the night. During fruit set and June drop, plum curculio were active day and night. During mid-summer plum curculio were active mostly during the night.

Host Finding

Butkewich et al. (1987) found that in laboratory studies wounded plum fruit were visited more often by plum curculio adult females; however, oviposition was done more often in unwounded fruit than wounded fruit. They suggest that wounding of fruit enhances the ability of plum curculio to find fruit.

Chemical Control

Border row sprays have been shown to successfully control plum curculio damage in apple orchards (Chouinard et al. 1992b) . A border spray applied at pink and petal fall successfully controlled plum curculio at economically acceptable levels.

In field tests, Fluke and Dever (1954) found aldrin, dieldrin or heptachlor applied to the ground to significantly reduce plum curculio. Snapp (1960) was able to control plum curculio in peach orchards for fours years with a single ground applied application of aldrin.

Weed (1889) reports that in an efficacy trial comparing London purple with the untreated check the trees treated with London purple had 1.5% fruit damage and the untreated check had 6.17% damage.

Biological Controls

Parasitic wasps from the Braconidae family have been reported to parasitize the larvae of the plum curculio. Cushman (1916) reported that *Thersilochus conotracheli* (Riley) had been reared from plum curculio larvae collected in Connecticut, New York, New Jersey, Pennsylvania, Illinois, Missouri, Kansas and Michigan.

In North Carolina parasitism from *Aliolus rufus* (Riley) on plum curculio larvae feeding in blue berries was 2.9%. *A. rufus* (Riley) and *A. curculionis* (Fitch) were found infesting plum curculio larvae in wild plum at 2.7% and 5.4% respectively (Mampe & Neunzig,1967).

A. curculionis (Fitch) was reported as the most common larval parasite of plum curculio in the Niagara Peninsula, Ontario (Armstrong, 1958). In an unsprayed plum orchard parasitization was 26.6% in 1953 and 7.5% in 1955. Other species reared from plum curculio larvae in that study were *A. rufus* (Riley) and *T. conotracheli* (Riley).

Chouinard et al. (1992b) reports toads, *Bufo americanus americanus* (Holbrook), were found with high level of (^{65}Zn) used to mark adult plum curculio. Cook (1890) identified that the grazing of chickens and livestock in orchards was a successful method of controlling plum curculio. Lefleur et al. (1987) found that in a study using (^{65}Zn) labeled plum curculio, spiders, slugs, earthworms and birds where found contaminated with (^{65}Zn). Lefleur et al. (1987) isolated an unknown pathogenic fungus and bacterium from diseased plum curculio larvae.

Tedders et al (1982) found in laboratory experiments the nematode *Neoaplectana carpocapsae* (Weiser) ineffective in causing mortality to plum curculio larvae. They found the fungi *Metarhizium anisopliae* (Metschnikoff) Sorokin and *Beauveria bassiana* (Balsamo) Vuillemin to cause high levels of mortality to plum curculio larvae and suggest these species should be considered as biological control agents against plum curculio.

Trapping and Monitoring

Cook (1890) described a trap developed by a Mr. Ransom of St. Joseph Michigan that consisted of laying pieces of bark or chips at the base of a fruit tree that were checked daily for plum curculio.

Prokopy (1993) reviewed past and present methods of monitoring plum curculio and concluded that no method presently used accurately predicted plum curculio populations. Prokopy (1993) reported that in previous work he did not find a direct correlation between oviposition on scout apples and subsequent damage to developing apples. Prokopy et al. (1980) reports that visual monitoring for ovipostion scars most be done daily or twice daily to be effective.

Le Blanc et al. (1984) found that using limb jarring gave inaccurate conclusions of plum curculio populations due to variables such as size of jarred limb, size of drop cloth, strength of jarring blows, height of the "jarrer", time of day, temperature and wind velocity. Le Blanc et al. (1984) were able to attract plum curculio to oviposit on "Granny Smith" scout apples that were hung in an abandon apple orchards.

Fruit Abscission

Tart cherry fruit development occurs in three distinct stages. Stage 1, bloom to about 20 to 22 days after bloom, is characterized by rapid cell division and enlargement. Stage 2 lasts for approximately 16 to 20 days and is characterized by a hardening of the pit. Stage 3 lasts for approximately 21 to 23 days and is characterized by rapid cell enlargement (Tukey & Young 1939).

Injury of the tart cherry seed during stage one or early to mid stage two will cause the cherry to abscise at the peduncle:pedicel zone. Injury at this time is associated with an increase in ethylene production by the injured fruit. Injury to the mesocarp or endocarp did not induce ethylene production or fruit abscission. Seed injury in late stage 2 and stage 3 will not cause the cherry to abscise (Wittenbach and Bukovac 1974). Injury described in this work was induced by drilling a 0.79 mm diameter hole into the tissue. Injury at this time did not cause an increase in ethylene production by the fruit.

Levine and Hall (1977) reported that plum curculio-induced fruit abscission of immature plums and apples was due to feeding activity by larvae. In a further study (1978) they found that enzymes produced by the larvae cause fruit tissue maceration and may be responsible for premature abscission of fruit while feeding on plum and apples.

Mechanical or Cultural Controls

Weed (1890) reports that the common method of controlling plum curculio in the Ohio fruit growing region lying along the south shore of Lake Erie was to jar trees daily and sometimes twice daily to catch adults on a catching frame. "A sort of inverted umbrella mounted on wheels, it was not uncommon to obtain by jarring a single tree a hundred of them a day" (Weed 1890, p 226). Damage surveys conducted in 1890 in a commercial plum orchard showed 3% fruit injury on trees treated with Paris green and 4% injury on jarred trees. Cook (1890) felt that you could reduce plum curculio damage to fruit crops other than plums by planting plums (the preferred host of plum curculio) near by as a trap crop. This combined with jarring of the trees from 10 to 15 times per season would adequately control plum curculio in cherry, peach and apple orchards.

Conclusion

The literature has covered plum curculio life history, activity, host finding behavior, chemical and biological control and trapping. There are no reports attempting to manage plum curculio on tart cherries looking at applying controls to prevent infested fruit at harvest. It is for this reason that these studies are proposed.

MATERIALS AND METHODS

This study was conducted in a commercial tart cherry orchard in Benzie County, Michigan. The orchard received standard fungicide treatments (Table 1 and Table 2). During the course of the study, insecticides were not used within 18 m of the trees in the study except when insecticides were applied to study trees after infestation periods to prevent re-infestation by plum curculio or other orchard pests.

Adult plum curculio were collected in the Spring of 1991 and 1993 from abandoned apricot, plum, tart cherry and apple trees. Adults were collected using a "beating tray", a cloth device measuring 1 m square and held taut using a hard wood frame. The beating tray was held under a tree branch and the branch was jarred causing plum curculio to drop to the cloth frame. The plum curculio were maintained in 16 oz fruit canning jars with fresh tart cherry shoots for food and moisture, at densities less than 20 plum curculio per jar. Collection began after bloom and continued for approximately 20 days. The plum curculio were used in caging studies as discussed below.

1991

Beginning at the end of shuck split stage of development on tart cherries, eight tart cherry branches were infested with five un-sexed adult plum curculio per cage. The cages were made from mosquito netting and measured about 1/2 meter

Table 1. Maintenance spray schedule for study block in 1991

Date	Common Name	Trade Name and Formulation	Rate Per Acre
5/26/91	Chlorothalonil	Bravo 720	2 pints
5/26/91	Thiophanate-methyl	Topsin-M	0.5 lb.
6/03/91	Fenarimol	Rubigan	3 oz.
6/03/91	Dodine	Dodine 65 WP	0.8 lb.
6/03/91	Sulfur	Liquid Sulfur (6 lb./ gal.)	2 pints
6/08/91	Fenarimol	Rubigan	4 oz.
6/15/91	Fenarimol	Rubigan	3 oz.
6/15/91	Dodine	Dodine 65 WP	0.5 lb.
6/28/91	Dodine	Dodine 65 WP	0.8 lb.
6/28/91	Benomyl	Benalate DF	0.3 lb.
6/28/91	Phosmet	Imidan 50 WP	0.8 lb.
7/08/91	Iprodione	Rovral 50 WP	0.7 lb.
7/22/91	Chlorothalonil	Bravo 720	2 pints
7/22/91	Fenarimol	Rubigan	3 oz.

Table 2. Maintenance spray schedule for study block in 1993

Date	Common Name	Trade Name and Formulation	Rate Per Acre
6/05/93	Myclobutanil	Nova 40	2.4 oz.
6/05/93	Dodine	Dodine 65 WP	0.4 lb.
6/11/93	Myclobutanil	Nova 40	2.9 oz.
6/11/93	Dodine	Dodine 65 WP	0.4 lb.
6/15/93	Myclobutanil	Nova 40	2.9 oz.
6/15/93	Dodine	Dodine 65 WP	0.8 lb.
6/23/93	Myclobutanil	Nova 40	2.4 oz.
6/23/93	Dodine	Dodine 65 WP	0.8 lb.
7/01/93	Phosmet	Imidan 50 WP	0.8 lb.
7/01/93	Dodine	Dodine 65 WP	0.8 lb.
7/10/93	Phosmet	Imidan 50 WP	0.8 lb.
7/10/93	Dodine	Dodine 65 WP	0.8 lb.
7/10/93	Sulfur	Sulfur WP 90%	4 lb.
7/16/93	Iprodione	Rovral 50 WP	0.7 lb.
7/16/93	Sulfur	Sulfur WP 90%	4 lb.
7/31/93	Sulfur	Sulfur WP 90%	4 lb.
7/31/93	Dodine	Dodine 65 WP	0.8 lb.
7/31/93	Carbaryl	Sevin 80S	1.2 lb.

in diameter and 1.3 meters long. Branches were approximately 2/3 to 1 meter long with approximately 50 to 400 cherries per branch. The cages remained on the branches for about 48 hours at which point the cages were removed and the plum curculio adults recaptured. This process was repeated at three day intervals, for a total of 12 infestation periods. Branches were selected randomly in trees and four branches per tree were caged. When the cages were removed from the branches, the number of cherries with oviposition scars were counted. Within 48 hours after the cages were removed, the treatments were sprayed at dilute rate with a backpack sprayer using Imidan 50 WP at 1 lb. per 100 gals.

Cherries were harvested from the infested branches at two periods: 6 July, one week before first normal harvest; and 13 July, first normal harvest. Four branches were randomly selected from each infestation period for each harvest. Cherries with oviposition scars were placed in the following classifications: oviposition scar and no internal feeding; internal feeding with no larvae present; and internal feeding with larvae present. A treatment consisted of branches with the same infestation and harvest date.

Weather data was collected from the nearest NOAA weather station located in Beulah, Michigan (Appendix: Table A1 and A2).

1993

Experiments were conducted as in 1991, except that branches were infested with six to nine unsexed adult plum curculio per cage. Additionally, there were 10 infestation periods rather than 12 as in 1991.

Cherries were harvested from the treatments: 18 July, two weeks before first normal harvest; 25 July, one week before first normal harvest; 31 July, first normal harvest; 7 August, one week after first normal harvest; and 14 August, two weeks after first normal harvest. Three to four branches were randomly selected form each infestation period for each harvest. Cherries with oviposition scars were counted and classified as follows; oviposition scar and no internal feeding; internal feeding with no larvae present; and internal feeding with larvae present. A treatment is considered a series of branches with the same infestation and harvest date.

Weather data was collected on site using an electronic data logger (Automata Inc., Grass Valley California) (Appendix 3-7).

Degree days were calculated by the modified average method, (maximum daily temperature + minimum daily temperature (if minimum daily temperature is less than lower developmental threshold then use lower developmental threshold for minimum daily temperature) /2) - minimum developmental threshold = degree days for that day, (Johnson & Herr 1995).

RESULTS

Environmental Data

This study was conducted in the 1991 and 1993 growing seasons. In 1991 the number of days between full bloom and first normal harvest were 61 calendar days and the accumulated degree days were 1630 ddb42 and 1164 ddb50. (See Appendix: Tables A1 - A7 for detailed seasonal temperature data and degree day accumulation information.) In 1993 the number of days between full bloom and first normal harvest were 78 calendar days and the accumulated degree days were 1600 ddb42 and 1100 ddb50. These data illustrate two very different seasons with respect to temperature accumulations and illustrate the similarities when looking at degree day accumulations between full bloom and first normal harvest.

Infestation Results

In 1991 and 1993 there were 12 and 10 inoculation periods respectively. The results are summarized in table 3 and table 4. In 1991 and 1993, infestations began at the end of shuck split; 229 ddb50 and 231 ddb50 respectively after full bloom. Creating timed ovipostion on tart cherries was successful as attempted with an average of 240 fruit with ovipostions scars produced from infestation periods in 1991 and an average of 529 cherries with ovipostion scars per infestation period in 1993. Peak ovipostion per plum curculio in 1991 was during the infestation period

Table 3. Infestation data for 1991

Infestation date (ending date)	27-May	30-May	2-Jun	4-Jun	7-Jun	10-Jun	13-Jun	16-Jun	19-Jun	21-Jun	23-Jun	25-Jun
# of days PC were caged	2	2	3	2	2	2	2	2	2	2	2	2
ddb50 after full bloom	229	296	353	384	427	486	538	604	665	711	742	776
ddb42 after full bloom	333	424	505	550	615	698	773	864	949	1011	1056	1107
# of stings at infestation	283	537	603	362	371	383	103	105	48	38	38	13
# of PC used to infest	40	40	40	40	40	40	30	30	30	20	30	25
Ave # of stings per PC	7.1	13.4	15.1	9.1	9.3	9.6	3.4	3.5	1.6	1.9	1.3	0.5
Ave # of stings per PC/day	3.5	6.7	5	4.5	4.6	4.8	1.7	1.8	0.8	1	0.6	0.3
ddb50 during infestation	36	43	57	31	29	42	33	41	44	46	31	35
ddb42 during infestation	53	60	81	46	44	58	49	57	60	62	46	51

Table 4. Infestation data for 1993

Infestation date (ending date)	12-Jun	15-Jun	18-Jun	22-Jun	25-Jun	28-Jun	30-Jun	3-Jul	6-Jul	9-Jul
# of days PC were caged	2	2	2	2	2	2	2	2	2	2
ddb50 after full bloom	231	287	315	367	426	474	499	551	634	706
ddb42 after full bloom	372	451	495	579	662	734	771	847	954	1050
# of stings at infestation	307	345	346	526	1009	617	533	459	601	551
# of PC used to infest	64	102	109	117	135	144	126	129	127	121
Ave # of stings per PC	4.8	3.4	3.2	4.5	7.5	4.3	4.2	3.6	4.7	4.6
Ave # of stings per PC/day	2.4	1.7	1.6	2.3	3.7	2.1	2.1	1.8	2.4	2.3
ddb50 during infestation	35	24	23	32	41	25	29	45	52	45
ddb42 during infestation	48	36	39	48	57	40	41	61	68	61

ending on 4 June; 23 days, 551 ddb42 and 384 ddb50 after full bloom and in 1993 on 25 June; 43 days, 662 ddb42 and 426 ddb50 after full bloom.

In 1991 the last inoculation period was on 25 June with a total of 13 ovipostion scars produced from 25 plum curculio. This was 44 calendar days, 1107 ddb42 and 776 ddb50 after full bloom. In 1993 the last inoculation period was on 9 July with a total of 551 oviposition scars from 121 plum curculio. This was 57 calendar days, 1050 ddb42 and 706 ddb50 after full bloom.

Harvest Evaluations

In 1991 and 1993 there were two and five harvest sampling dates respectively. Cherries were examined for plum curculio damage and damaged cherries were classified as follows; larval presence, larval internal feeding damage with no larvae present and oviposition scar with no internal feeding damage. In the harvest samples, cherries that were 13 mm or less in diameter with larvae were noted; however, because these cherries were brownish, hollow and shriveled and would not make it through the processing process, they were not used in determining a pre-harvest interval.

1991 Harvest

There were two harvests In 1991. The first harvest was 6 July, 1 week before first normal harvest and the second harvest was 13 July, first normal harvest. In the first harvest of 1991, three larval infested cherries with larvae were found in the 7 June infestation sample. These larvae were all in cherries less than 9 mm in diameter, brown, hollow and shriveled. The first infestation period to have larval infested cherries greater than 13 mm in diameter was in the 13 June infestation sample; therefore, the 10 June infestation period would be considered the last infestation period allowing a crop free of larvae-infested cherries 1 week before first normal harvest (Table 5).

In the second harvest of 1991, two cherries with one larvae each were found in the 7 June infestation sample. These cherries were less than 13 mm in diameter, brownish, hollow and shriveled. The first infestation period to have larval infested cherries greater than 13 mm in size was 10 June; therefore, the infestation period of 7 June would be considered the last infestation period allowing a crop free of larvae-infested cherries at first normal harvest (Table 6).

1993 Harvest

There were five harvests in 1993. In the first harvest of 1993 , 2 weeks before first normal harvest, the first infestation period to have larval infested cherries was 25 June; therefore, the 22 June infestation period would be considered the last infestation period allowing a crop free of larvae-infested cherries (Table 7). In the second harvest of 1993, 1 week before first normal harvest, the first infestation period to have larval infested cherries was 28 June; therefore, the 25 June infestation period would be considered the last infestation period allowing a crop free of larvae-infested cherries (Table 8). In the third harvest of 1993, first normal harvest, the first infestation period to have larval infested cherries was 30 June; therefore, the 28 June infestation period would be considered the last infestation period allowing a crop free of larvae-infested cherries (Table 9). In the fourth harvest of 1993, 1 week after first normal harvest, the first infestation period to have larval infested cherries was 30 June; therefore, the 28 June infestation

Table 5. Data for harvest date 7-06-91, one week before first normal harvest

Infestation date (ending date)	27-May	30-May	2-Jun	4-Jun	7-Jun	10-Jun	13-Jun	16-Jun	19-Jun	21-Jun	23-Jun	25-Jun
# of cherries with oviposition scars at infestation	187	254	262	158	187	196	41	70	25	16	23	8
# cherries with larvae at harvest	0	0	0	0	3*	0	1	11	9	11	11	2
# of cherries with internal feeding, no larvae	0	3	27	45	87	63	22	19	4	9	19	15
# of cherries with oviposition scar, no internal feeding	26	56	67	48	35	33	10	29	4	5	0	0
# of days after full bloom infested	15	18	21	23	26	29	32	35	38	40	42	44
ddb42 after full bloom infested	333	424	505	551	615	698	773	864	949	1011	1056	1107
ddb50 after full bloom infested	229	296	353	384	427	486	538	604	665	711	742	776

* the 3 larvae were in cherries less than 9 mm in diameter

Table 6. Data for harvest date 7-13-91, first normal harvest

Infestation date (ending date)	27-May	30-May	2-Jun	4-Jun	7-Jun	10-Jun	13-Jun	16-Jun	19-Jun	21-Jun	23-Jun	25-Jun
# of cherries with oviposition scars at infestation	96	283	341	204	184	187	62	35	23	22	15	5
# cherries with larvae at harvest	0	0	0	0	2*	6	4	2	3	2	3	1
# of cherries with internal feeding, no larvae	0	4	45	67	61	67	10	3	18	3	8	3
# of cherries with oviposition scar no internal feeding	16	96	77	61	49	10	9	12	0	0	0	0
# of days after full bloom infested	15	18	21	23	26	29	32	35	38	40	42	44
ddb42 after full bloom infested	333	424	505	551	615	698	773	864	949	1011	1056	1107
ddb50 after full bloom infested	229	296	353	384	427	486	538	604	665	711	742	776

* the 2 larvae were in a badly decomposed cherry less than 13 mm in diameter

Table 7. Data for harvest date 7-18-93, two weeks before first normal harvest

Infestation date (ending date)	12-Jun	15-Jun	18-Jun	22-Jun	25-Jun	28-Jun	30-Jun	3-Jul	6-Jul	9-Jul
# of cherries with oviposition scars at infestation	49	61	46	128	242	116	96	129	198	121
# cherries with larvae at harvest	0	0	0	0	1	7	8	27	6	2
# of cherries with internal feeding no larvae	0	0	6	11	48	37	24	41	77	32
# of cherries with oviposition scar no internal feeding	7	15	20	46	77	60	43	59	115	87
# of days after full bloom infested	30	33	36	40	43	46	48	51	54	57
ddb42 after full bloom infested	372	451	495	579	662	734	771	847	954	1050
ddb50 after full bloom infested	231	287	315	367	426	474	499	551	634	706

Table 8. Data for harvest date 7-25-93, one week before first normal harvest

Infestation date (ending date)	12-Jun	15-Jun	18-Jun	22-Jun	25-Jun	28-Jun	30-Jun	3-Jul	6-Jul	9-Jul
# of cherries with oviposition scars at infestation	82	138	70	129	172	148	101	89	134	95
# cherries with larvae at harvest	0	0	0	0	0	3	7	10	4	6
# of cherries with internal feeding, no larvae	0	0	2	10	19	18	26	45	51	17
# of cherries with oviposition scar, no internal feeding	18	25	32	43	67	52	48	68	108	89
# of days after full bloom infested	30	33	36	40	43	46	48	51	54	57
ddb42 after full bloom infested	372	451	495	579	662	734	771	847	954	1050
ddb50 after full bloom infested	231	287	315	367	426	474	499	551	634	706

Table 9. Data for harvest date 7-31-93, first normal harvest

Infestation date (ending date)	12-Jun	15-Jun	18-Jun	22-Jun	25-Jun	28-Jun	30-Jun	3-Jul	6-Jul	9-Jul
# of cherries with oviposition scars at infestation	70	65	91	111	201	125	134	77	168	125
# cherries with larvae at harvest	0	0	0	0	0	0	1	3	0	2
# of cherries with internal feeding, no larvae	0	0	12	9	31	9	18	25	79	21
# of cherries with oviposition scar, no internal feeding	16	31	41	37	95	38	39	40	126	93
# of days after full bloom infested	30	33	36	40	43	46	48	51	54	57
ddb42 after full bloom infested	372	451	495	579	662	734	771	847	954	1050
ddb50 after full bloom infested	231	287	315	367	426	474	499	551	634	706

Table 10. Data for harvest date 8-07-93, one week after first normal harvest

Infestation date (ending date)	12-Jun	15-Jun	18-Jun	22-Jun	25-Jun	28-Jun	30-Jun	3-Jul	6-Jul	9-Jul
# of cherries with oviposition scars at infestation	90	63	57	69	261	130	105	133	83	117
# cherries with larvae at harvest	0	0	0	0	0	0	1	0	1	0
# of cherries with internal feeding, no larvae	0	0	4	10	38	6	17	81	39	19
# of cherries with oviposition scar, no internal feeding	18	23	23	22	116	27	25	86	66	102
# of days after full bloom infested	30	33	36	40	43	46	48	51	54	57
ddb42 after full bloom infested	372	451	495	579	662	734	771	847	954	1050
ddb50 after full bloom infested	231	287	315	367	426	474	499	551	634	706

period would be considered the last infestation period allowing a crop free of larvae-infested cherries (Table 10). In the fifth harvest of 1993, 2 weeks after first normal harvest, the first infestation period to have larval infested cherries was 3 July; therefore, the 30 June infestation period would be considered the last infestation period allowing a crop free of larvae-infested cherries (Table 11).

Table 11. Data for harvest date 8-14-93, two weeks after first normal harvest

Infestation date (ending date)	12-Jun	15-Jun	18-Jun	22-Jun	25-Jun	28-Jun	30-Jun	3-Jul	6-Jul	9-Jul
# of cherries with oviposition scars at inestation	16	18	82	89	133	98	97	81	86	96
# cherries with larvae at harvest	0	0	0	0	0	0	0	2	0	0
# of cherries with internal feeding, no larvae	0	0	3	7	7	8	13	25	22	9
# of cherries with oviposition scar, no internal feeding	4	3	30	22	20	23	39	46	48	71
# of days after full bloom infested	30	33	36	40	43	46	48	51	54	57
ddb42 after full bloom infested	372	451	495	579	662	734	771	847	954	1050
ddb50 after full bloom infested	231	287	315	367	426	474	499	551	634	706

DISCUSSIONS

The objective of this study was to determine if there is a consistent point in the season when the outcome from plum curculio oviposition changes from pre-harvest drop of fruit to larval infested fruit at harvest. This point in the season can be measured differently to determine the most consistent method during seasons of high variability. Data measuring: 1) calendar days; 2) degree days base 42 F; and 3) degree days base 50 F after full bloom were evaluated for their predictive ability. Using calendar days to predict a post-full bloom control interval would be extremely inaccurate with the 23 and 43 calendar day periods after full bloom I measured for 1991 and 1993 respectively. Using ddb42 would be less accurate than ddb50 as evidenced in the data for 1991 and 1993 (Table 12). Data collected on calendar days, degree days base 42 F and degree days base 50 F before harvest, were not reliable for predicting a control interval due to the unreliability of predicting harvest 30 days in advance. This data may be of use in the future if methods of forecasting tree growth and weather improve.

We achieved our objective by demonstrating that cherries did not contain plum curculio larvae at first normal harvest when they were infested before 427 ddb50 and 475 ddb50 after full bloom in 1991 and 1993 respectively. A low percentage of cherries infested later than this time in the season did contain larvae at harvest (Table 6 and 9). The penalty to a grower for having larval infested fruit at

Table 12. Summary for 1991 and 1993: Second infestation period before first infestation period with infested fruit at harvest

Harvest date	7/6/91	7/13/91	7/18/93	7/25/93	7/31/93	8/7/93	8/14/93
Infestation date (ending date)	6/7/91	6/4/91	6/18/93	6/22/93	6/25/93	6/25/93	6/28/93
# of cherries with oviposition scars at infestation	187	204	46	129	201	261	98
# cherries with larvae at harvest	3*	0	0	0	0	0	0
# of cherries with internal feeding, no larvae	87	67	6	10	31	38	8
# of cherries with oviposition scar, no internal feeding	35	61	20	43	95	116	23
# of days after full bloom infested	26	23	36	40	43	43	46
ddb42 after full bloom infested	615	551	495	579	662	662	734
ddb50 after full bloom infested	427	384	315	367	426	426	474

* the 3 larvae were in cherries less than 9 mm in diameter

harvest can be the rejection of a load and possibly the entire crop. For this reason, we opted to develop a threshold that would have a high degree of safety. We examined the harvest dates of first normal harvest for 1991 and 1993 and used the second to the last infestation date before the first infestation date that had larval infested fruit. For 1991, this data was 4 June, 23 calendar days, 551 ddb42 and 384 ddb50 after full bloom. For 1993, 25 June, 43 calendar days, 662 ddb42 and 426 ddb50 after full bloom (Table 12). For a recommendation using this data we would use the 1991 data because it is more conservative and round it off to 375 ddb50 after full bloom. This threshold has a safety factor of an added 50 ddb50 built into it.

In 1993 we examined the hypothesis that if harvest was delayed, the post-full bloom control interval would also be delayed. This would allow growers with long harvests (15 to 21 days are not unusual) to delay control sprays in orchards that are harvested later than first normal harvest.

Delaying harvest would allow a small shift in the post-full bloom interval to later in the season (Table 12). In 1993, 2 harvest sample dates were added; 1 week after first normal harvest and 2 weeks after first normal harvest. Using the same method as above in building in a safety factor, a grower could delay applying a control spray approximately 50 ddb50 F for each week harvest was delayed. This data should not be used in formal recommendations due to the fact it was only collected for one season and that it has not been validated using larger sample sizes such as whole orchards. However, It could provide a strategy for blocks that have plum curculio infested fruit at harvest. In these blocks, harvest could be delayed for one or two weeks and the infested fruit would likely abscise. It also provides the basis for future research in determining the validation of this concept by conducting a second season of caging studies and a follow up whole orchard validation study.

CONCLUSIONS

The goal of this research project was to define when during the season the outcome of plum curculio oviposition on tart cherries changes from fruit abscission before harvest to larval infested fruit at harvest. We demonstrated in two seasons with very different daily temperature characteristics that there was definable point in the season when this outcome changed. In this study the populations of infested cherries were low when compared to a potential infestation found in commercial orchards with high plum curculio pressure. It is for this reason that it would be important to validate the threshold developed in this study in commercial tart cherry orchards.

CHAPTER 2: Commercial Orchard Validation Study

INTRODUCTION

In the 1991 and 1993 caging studies we identified a consistent point in the season when the outcome from plum curculio oviposition of tart cherries changed from pre-harvest abscission to larval infested fruit at harvest. The experiments were done using small populations of infested fruit, an average of 371 infested fruit per treatment. These experiments provided information to begin formulating a threshold that could be recommended to tart cherry growers to control plum curculio. To validate this threshold we designed a study that would use whole orchards as study units. The objective of this study was to evaluate a post-bloom control threshold for plum curculio control in commercial tart cherry orchards.

MATERIALS AND METHODS

During the pre-bloom portion of the season 14 orchards in Northwest MI were identified for inclusion in this study. All had a history of plum curculio damage in previous seasons and growers agreed to follow timing suggestions of insecticides for controlling plum curculio. Seven of the 14 orchards were randomly selected to have controls applied for plum curculio at 300 ddb50 after full bloom and 7 of the 14 orchards were randomly selected to have controls applied for plum curculio at 425 ddb50 after full bloom.

These orchards were scouted weekly during the season and weather data for these sites were collected (Appendix: Tables A8-A10). In addition to weekly scouting for plum curculio, two damage surveys were conducted. The first survey was conducted after the plum curculio threshold control sprays were applied and the second survey was conducted at harvest from tanks of cherries on the growers cooling pad.

The first survey was conducted by doing a 1 min./tree visual survey for plum curculio ovipostion scars. Twenty-four trees per orchard were surveyed. All surveys were conducted by the same observer. In each orchard, on each of four borders, three border trees were surveyed; four rows in from the surveyed border trees, three additional trees were surveyed.

The second survey was conducted at harvest. Results from the first survey were used to identify the border in each block with the highest levels of oviposition scars and cherries from these borders were sampled. Two sampling methods were used. The first sampling method was to visually survey cherries in cherry tanks for plum curculio ovipostion related injury for 2 minutes. Four tanks per orchard were surveyed using this technique. The second sampling method was designed to be identical to the method used by USDA raw product inspectors located at cherry processing facilities during the cherry harvest. This method sampled 1000 grams of cherries randomly selected from cherry tanks and each cherry examined for damage. Cherries with oviposition scars were dissected and placed in the following classifications: oviposition scar and no internal feeding; internal feeding with no larvae present; and internal feeding with larvae present.

RESULTS

The 1994 pest pressures in Northwest MI cherry orchards were characterized by high populations of green fruit worm larvae during the period of 1 to 3 weeks after bloom. Most orchards exceeded the action threshold for this pest. Due to this reason, 6 of the 14 orchards in the study received insecticide applications that disqualified them for use in this study. These controls were applied late enough so it was not possible to replace them with other orchards in the region. One orchard of the 14 was not harvested due to quality problems unrelated to plum curculio and a harvest damage survey was not possible.

As thresholds were approached in the study orchards, growers were advised to apply control sprays. Table 13 summarizes the assigned thresholds and the actual timing of control sprays.

Mid-Season Damage Sample

The primary objective of the first survey was to identify relative damage levels in the orchards. Table 14 summarizes this data. This data reinforces the observations that plum curculio populations and related damage vary widely between orchard and within orchards.

Table 13. Study Orchards

Orchard Name	Assigned Threshold: Control Applied After Full Bloom	Actual Timing of Control: After Full Bloom
Diagonal Tarts	300 ddb50	327 ddb50
Six Rows	300 ddb50	327 ddb50
Reshaped Tarts	300 ddb50	327 ddb50
East Tarts	425 ddb50	466 ddb50
Mare Tarts	425 ddb50	437 ddb50
House Tarts	425 ddb50	426 ddb50
Blackberry Tarts	425 ddb50	426 ddb50

Table 14. Mid-season damage sample: number of oviposition scars

Border Area	Diagonal Tarts	Six Rows Tarts	Reshaped Tarts	East Tarts	Mare Tarts	House Tarts	Blackberry Tarts
North/ 6 trees	5	0	6	0	21	20	0
East/ 6 trees	0	2	11	0	109	11	0
South/ 6 trees	2	0	6	0	33	4	0
West/ 6 trees	1	0	0	0	24	5	0
Total stings/ 24 trees	8	2	23	0	187	40	0

Harvest Damage Sample.

The primary question this sample was answering was if insecticide control sprays for plum curculio were delayed to 300 ddb50 or 425 ddb50 after full bloom, would fruit be free of larvae in a commercial orchard at harvest as it was in studies conducted in 1991 and 1993 using smaller study units. In the harvest damage samples no cherries with larvae were found, see Table 15. In the Mare tart orchard three cherries with larvae were found floating in tanks as they were harvested. These cherries are generally skimmed off the tanks before they reach the cooling pad. However, this finding indicates that when the density of ovipostion stings are extremely high the 425 ddb50 threshold can fail.

Table 15. Harvest damage sample: number of cherries with plum curculio damage

Orchard/ Threshold	Survey 1. # of stings, 1 min. visual survey, 24 trees/block	Harvest sample: sting, no internal feeding, no larvae		Harvest sample: sting, internal feeding, no larvae		Harvest sample: sting, internal feeding, larvae in cherry	
		1000 g	2 min.	1000 g	2 min.	1000 g	2 min.
Diagonal Tarts/300	8	0	0	0	0	0	0
Six Rows/300	2	0	0	0	0	0	0
Reshaped Tarts/300	23	1	0	0	0	0	0
East Tarts/425	0	0	0	0	0	0	0
Mare Tarts/425	187	2	7	1	8	0*	0*
House Tarts/425	40	0	0	3	3	0	0
Blackberry Tarts/425	0	0	0	0	0	0	0

* Although no cherries with larvae were found in the sampling, 3 cherries infested with larvae were found floating in tanks on the harvesting equipment.

DISCUSSIONS

The 1991 and 1993 caging studies showed that oviposition by plum curculio on tart cherries before 425 ddb50 after full bloom did not result in larvae in the fruit at harvest. The purpose of the 1994 study was to validate and evaluate this threshold in commercial blocks. The results from the harvest sampling data suggests that the 425 ddb50 threshold would be safe to use under most orchard conditions. Although no larval infested fruit were found in the harvest sampling, infested fruit were observed in the cherry tanks on the harvest equipment in the Mare Tart orchard, (three cherries with larvae floating in tanks while observing four tanks of cherries being harvested). This indicates that in orchards with high plum curculio pressure this threshold would not be appropriate given the quality requirements of processed tart cherries, (zero tolerance of larvae in fruit at harvest). From the 1994 data, it appears that at lower, more typical plum curculio pressures the 425 ddb50 threshold is very reliable. In orchards with high plum curculio pressure this threshold may fail and for that reason as will as the costs associated with that failure we are suggesting that the grower community in Michigan use a threshold of 375 ddb50 after full bloom in combination with a scouting program.

In 1979 when I became active as a grower of tart cherries in Northwest Michigan it was common for extension personnel to recommend spraying for plum curculio on tart cherries at petal fall and using a calendar spray program thereafter. This illustrates the fear and extreme penalties that larval infested fruit at harvest can cause, but it also indicates the lack of knowledge in the relationship between larval and fruit development and the lack of confidence in scouting programs for plum curculio. Figure 1 and Figure 2 illustrate the savings in reduced pesticide use and costs that theoretically could be attained by using the threshold developed by this research compared to using a calendar approach. If this saving could be experienced by the Michigan tart cherry industry in 1994 there would have been a cost savings of approximately $600,000 and a reduction in use of 43,312 lbs of pesticide active ingredients.

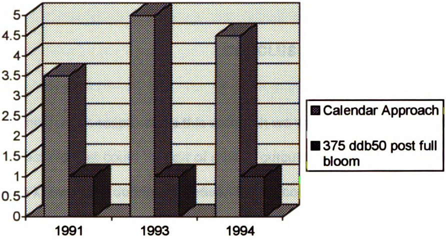

Figure 1. Theoretical pesticide use measured in alternate middle insecticide applications comparing plum curculio control strategies.

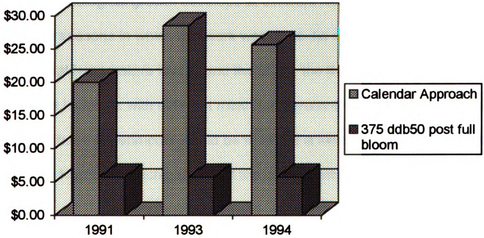

Figure 2. Material cost per acre not including application costs, based on using Guthion 50 WP at 1.5 lb. per acre.

CONCLUSIONS

When we conceptualized this research we were looking for a degree day based threshold that could be part of a plum curculio management program. We needed to know when during the season the outcome from plum curculio oviposition changed from pre-harvest drop of the cherry to infested fruit at harvest. This knowledge would allow growers to accept low levels of plum curculio damage before the threshold is reached and apply a control spray when the threshold is reached.

A possible weakness to the threshold we established is the fact that this work was done in one region of Michigan. The sites used were located in Northwest Michigan where mean seasonal temperatures are cooler than in Southwest Michigan. Tart cherry phenological growth develops at different rates than plum curculio. However, the seasons in which this work was done did represent extremes in possible mean seasonal temperature levels, and therefore, the threshold developed should be appropriate at locations with different mean temperature levels. An improvement in he design of these experiments would be to locate a treatment site in Southwest Michigan and Northwest Michigan to test the effectiveness of the threshold at both locations.

The threshold will be used in a management program that will include a scouting program and an environmental monitoring program. Further research is necessary to develop sampling techniques and economic damage thresholds for plum curculio on tart cherries. These are challenging areas for research because the biology and behavior of plum curculio are poorly understood. Damage thresholds, a component of the scouting program, are difficult to establish on tart cherries because the price of cherries are usually not established until after the season is over and will fluctuate between $.05 and $.50 per pound from year to year.

Despite the lack of scientifically derived scouting protocols and economic thresholds there should be widespread use by growers and consultants of the information gained from this research. Best-guess scouting protocols and action thresholds can be established by extension specialists and consultants for managing plum curculio.

The grade standard that does not allow for any tolerance of larvae in the fruit at harvest is the driving force for the pest management program we currently use in cherries. Despite this regulation we have been able to greatly reduce insecticide use for the direct feeding insect pests such as plum curculio and cherry fruit fly. This is a result largely of developing pest management programs using best-guess methods for establishing scouting protocols and action thresholds. These techniques used in formal IPM programs by growers or consultants have allowed for significant reductions in pesticide use. With the potential penalties of having infested fruit a harvest at any levels, further reductions in insecticide use will only come when the zero tolerance regulation is modified to allow a small percentage of infested fruit at harvest.

APPENDIX

APPENDIX

Table A1. Temperature data for harvest 1, 1991

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H1: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H1	FB: # of ddb42 F Before H1	FB: # of ddb50 F Before H1
5/12/91	81	57	27	19	FB*				55	1456	1038
5/13/91	84	56	28	20		1	28	20	54	1429	1019
5/14/91	82	50	24	16		2	52	36	53	1401	999
5/15/91	86	48	25	18	PF**	3	77	54	52	1377	983
5/16/91	81	55	26	18		4	103	72	51	1352	965
5/17/91	54	48	9	2		5	112	74	50	1326	947
5/18/91	62	44	11	6		6	123	80	49	1317	945
5/19/91	70	35	14	10		7	137	90	48	1306	939
5/20/91	74	34	16	12		8	153	102	47	1292	929
5/21/91	76	44	18	13		9	171	115	46	1276	917
5/22/91	79	56	26	18		10	197	133	45	1258	904
5/23/91	81	62	30	22		11	226	154	44	1233	886
5/24/91	78	64	29	21		12	255	175	43	1203	865
5/25/91	78	57	26	18		13	281	193	42	1174	844
5/26/91	79	59	27	19		14	308	212	41	1149	826
5/27/91	77	58	26	18		15	333	229	40	1122	807
5/28/91	87	60	32	24		16	365	253	39	1096	790
5/29/91	84	60	30	22		17	395	275	38	1065	766
5/30/91	80	63	30	22		18	424	296	37	1035	744
5/31/91	75	59	25	17		19	449	313	36	1005	723
6/1/91	83	59	29	21		20	478	334	35	980	706
6/2/91	75	63	27	19		21	505	353	34	951	685
6/3/91	79	59	27	19		22	532	372	33	924	666
6/4/91	74	47	19	12		23	551	384	32	897	647
6/5/91	77	48	21	14		24	571	398	31	879	635
6/6/91	80	48	22	15		25	593	413	30	858	621
6/7/91	79	49	22	15		26	615	427	29	836	606
6/8/91	81	53	25	17		27	640	444	28	814	592
6/9/91	85	53	27	19		28	667	463	27	789	575

Table A1. (cont'd)

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H1: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H1	FB: # of ddb42 F Before H1	FB: # of ddb50 F Before H1
6/10/91	79	67	31	23		29	698	486	26	762	556
6/11/91	82	55	27	19		30	725	505	25	731	533
6/12/91	72	58	23	15		31	748	520	24	705	514
6/13/91	86	49	26	18		32	773	538	23	682	499
6/14/91	87	65	34	26		33	807	564	22	656	481
6/15/91	77	63	28	20		34	835	584	21	622	455
6/16/91	79	62	29	21		35	864	604	20	594	435
6/17/91	82	53	26	18		36	889	622	19	566	415
6/18/91	85	56	29	21		37	918	642	18	540	397
6/19/91	87	59	31	23		38	949	665	17	512	377
6/20/91	87	59	31	23		39	980	688	16	481	354
6/21/91	83	63	31	23		40	1011	711	15	450	331
6/22/91	74	54	22	14		41	1033	725	14	419	308
6/23/91	83	48	24	17		42	1056	742	13	397	294
6/24/91	78	55	25	17		43	1081	758	12	373	277
6/25/91	85	51	26	18		44	1107	776	11	349	261
6/26/91	93	61	35	27		45	1142	803	10	323	243
6/27/91	93	75	42	34		46	1184	837	9	288	216
6/28/91	84	75	38	30		47	1221	867	8	246	182
6/29/91	93	67	38	30		48	1259	897	7	208	152
6/30/91	77	63	28	20		49	1287	917	6	170	122
7/1/91	78	58	26	18		50	1313	935	5	142	102
7/2/91	83	63	31	23		51	1344	958	4	116	84
7/3/91	80	61	29	21		52	1373	978	3	85	61
7/4/91	79	62	29	21		53	1401	999	2	57	41
7/5/91	79	61	28	20		54	1429	1019	1	28	20
7/6/91	88	65	35	27	H1***	55	1464	1045			

* FB is full bloom

Table A1. (cont'd)

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H1: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H1	FB: # of ddb42 F Before H1	FB: # of ddb50 F Before H1

** PF is petal fall
***H1 is harvest 1

Table A2. Temperature data for Harvest 2, 1991

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H2: # of Days After FB	Cumulative ddb42 F	Cumulative ddb50 F	FB: # of Days Before H2	FB: # of ddb42 F Before H2	FB: # of ddb50 F Before H2
5/12/91	81	57	27	19	FB*				62	1657	1183
5/13/91	84	56	28	20		1	28	20	61	1630	1164
5/14/91	82	50	24	16		2	52	36	60	1602	1144
5/15/91	86	48	25	18	PF**	3	77	54	59	1578	1128
5/16/91	81	55	26	18		4	103	72	58	1553	1110
5/17/91	54	48	9	2		5	112	74	57	1527	1092
5/18/91	62	44	11	6		6	123	80	56	1518	1090
5/19/91	70	35	14	10		7	137	90	55	1507	1084
5/20/91	74	34	16	12		8	153	102	54	1493	1074
5/21/91	76	44	18	13		9	171	115	53	1477	1062
5/22/91	79	56	26	18		10	197	133	52	1459	1049
5/23/91	81	62	30	22		11	226	154	51	1434	1031
5/24/91	78	64	29	21		12	255	175	50	1404	1010
5/25/91	78	57	26	18		13	281	193	49	1375	989
5/26/91	79	59	27	19		14	308	212	48	1350	971
5/27/91	77	58	26	18		15	333	229	47	1323	952
5/28/91	87	60	32	24		16	365	253	46	1297	935
5/29/91	84	60	30	22		17	395	275	45	1266	911
5/30/91	80	63	30	22		18	424	296	44	1236	889
5/31/91	75	59	25	17		19	449	313	43	1206	868
6/1/91	83	59	29	21		20	478	334	42	1181	851
6/2/91	75	63	27	19		21	505	353	41	1152	830
6/3/91	79	59	27	19		22	532	372	40	1125	811
6/4/91	74	47	19	12		23	551	384	39	1098	792
6/5/91	77	48	21	14		24	571	398	38	1080	780
6/6/91	80	48	22	15		25	593	413	37	1059	766
6/7/91	79	49	22	15		26	615	427	36	1037	751
6/8/91	81	53	25	17		27	640	444	35	1015	737
6/9/91	85	53	27	19		28	667	463	34	990	720
6/10/91	79	67	31	23		29	698	486	33	963	701
6/11/91	82	55	27	19		30	725	505	32	932	678
6/12/91	72	58	23	15		31	748	520	31	906	659
6/13/91	86	49	26	18		32	773	538	30	883	644
6/14/91	87	65	34	26		33	807	564	29	857	626
6/15/91	77	63	28	20		34	835	584	28	823	600

Table A2. (cont'd).

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H2: # of Days After FB	Cumulative ddb42 F	Cumulative ddb50 F	FB: # of Days Before H2	FB: # of ddb42 F Before H2	FB: # of ddb50 F Before H2
6/16/91	79	62	29	21		35	864	604	27	795	580
6/17/91	82	53	26	18		36	889	622	26	767	560
6/18/91	85	56	29	21		37	918	642	25	741	542
6/19/91	87	59	31	23		38	949	665	24	713	522
6/20/91	87	59	31	23		39	980	688	23	682	499
6/21/91	83	63	31	23		40	1011	711	22	651	476
6/22/91	74	54	22	14		41	1033	725	21	620	453
6/23/91	83	48	24	17		42	1056	742	20	598	439
6/24/91	78	55	25	17		43	1081	758	19	574	422
6/25/91	85	51	26	18		44	1107	776	18	550	406
6/26/91	93	61	35	27		45	1142	803	17	524	388
6/27/91	93	75	42	34		46	1184	837	16	489	361
6/28/91	84	75	38	30		47	1221	867	15	447	327
6/29/91	93	67	38	30		48	1259	897	14	409	297
6/30/91	77	63	28	20		49	1287	917	13	371	267
7/1/91	78	58	26	18		50	1313	935	12	343	247
7/2/91	83	63	31	23		51	1344	958	11	317	229
7/3/91	80	61	29	21		52	1373	978	10	286	206
7/4/91	79	62	29	21		53	1401	999	9	258	186
7/5/91	79	61	28	20		54	1429	1019	8	229	165
7/6/91	88	65	35	27		55	1464	1045	7	201	145
7/7/91	88	63	34	26		56	1497	1071	6	167	119
7/8/91	80	61	29	21		57	1526	1091	5	133	93
7/9/91	77	54	24	16		58	1549	1107	4	105	73
7/10/91	83	58	29	21		59	1578	1127	3	81	57
7/11/91	84	57	29	21		60	1606	1148	2	53	37
7/12/91	69	63	24	16		61	1630	1164	1	24	16
7/13/91	77	59	26	18	H2***	62	1656	1182			

* FB is full bloom
** PF is petal fall
***H2 is harvest 2

Table A3. Temperature data for Harvest 1, 1993

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H1: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H1	FB: # of ddb42 F Before H1	FB: # of ddb50 F Before H1
5/13/93	59	30	9	5	FB*				66	1276	865
5/14/93	66	42	12	8		1	9	5	65	1267	861
5/15/93	63	33	11	7		2	21	13	64	1255	853
5/16/93	58	27	8	4		3	31	19	63	1245	846
5/17/93	55	30	7	3		4	39	23	62	1237	842
5/18/93	48	30	3	0		5	46	26	61	1230	840
5/19/93	58	25	8	4		6	49	26	60	1227	840
5/20/93	63	27	11	7		7	57	30	59	1219	836
5/21/93	64	32	11	7		8	67	36	58	1208	829
5/22/93	74	32	16	12		9	78	43	57	1197	822
5/23/93	60	53	15	7		10	94	55	56	1181	810
5/24/93	63	42	11	7	PF**	11	109	62	55	1167	804
5/25/93	66	40	12	8		12	119	68	54	1156	797
5/26/93	61	39	10	6		13	131	76	53	1145	789
5/27/93	62	40	10	6		14	141	81	52	1135	784
5/28/93	65	34	12	8		15	151	87	51	1125	778
5/29/93	64	29	11	7		16	162	95	50	1114	770
5/30/93	55	42	7	3		17	173	102	49	1103	763
5/31/93	49	30	4	0		18	180	105	48	1096	760
6/1/93	63	28	10	6		19	183	105	47	1092	760
6/2/93	67	39	13	9		20	194	111	46	1082	754
6/3/93	65	38	12	8		21	206	120	45	1069	746
6/4/93	65	29	12	8		22	218	127	44	1058	738
6/5/93	65	40	12	8		23	229	135	43	1046	730
6/6/93	77	29	18	14		24	241	142	42	1035	723
6/7/93	68	54	19	11		25	259	156	41	1017	709
6/8/93	79	60	28	20		26	278	167	40	998	698
6/9/93	72	57	23	15		27	305	187	39	970	678
6/10/93	77	50	22	14		28	328	201	38	948	664
6/11/93	83	45	22	16		29	350	215	37	926	650
6/12/93	84	52	26	18		30	372	231	36	904	634
6/13/93	89	53	29	21		31	398	250	35	878	615
6/14/93	78	55	25	17		32	427	270	34	849	595
6/15/93	64	39	11	7		33	451	287	33	824	578
6/16/93	69	36	13	9		34	462	294	32	813	571

Table A3. (cont'd).

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H1: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H1	FB: # of ddb42 F Before H1	FB: # of ddb50 F Before H1
6/17/93	70	54	20	12		35	475	303	31	800	562
6/18/93	68	54	19	11		36	495	315	30	780	550
6/19/93	61	56	17	9		37	514	326	29	761	539
6/20/93	72	59	24	16		38	531	335	28	745	530
6/21/93	77	55	24	16		39	555	351	27	721	515
6/22/93	81	50	24	16		40	579	367	26	697	499
6/23/93	86	55	29	21		41	602	382	25	674	483
6/24/93	90	56	31	23		42	631	403	24	645	462
6/25/93	76	59	26	18		43	662	426	23	614	439
6/26/93	80	56	26	18		44	687	443	22	588	422
6/27/93	75	50	21	13		45	713	461	21	562	404
6/28/93	73	50	20	12		46	734	474	20	542	391
6/29/93	77	42	18	14		47	754	486	19	522	379
6/30/93	78	52	23	15		48	771	499	18	504	366
7/1/93	85	52	27	19		49	794	514	17	481	351
7/2/93	76	60	26	18		50	821	533	16	455	332
7/3/93	92	62	35	27		51	847	551	15	429	314
7/4/93	94	65	37	29		52	881	577	14	394	288
7/5/93	90	64	35	27		53	919	607	13	357	258
7/6/93	85	64	33	25		54	954	634	12	322	231
7/7/93	89	62	33	25		55	986	658	11	289	207
7/8/93	81	64	30	22		56	1020	684	10	256	181
7/9/93	81	65	31	23		57	1050	706	9	226	159
7/10/93	85	56	29	21		58	1081	729	8	195	136
7/11/93	78	58	26	18		59	1109	749	7	166	116
7/12/93	77	50	22	14		60	1135	767	6	140	98
7/13/93	80	48	22	15		61	1157	781	5	119	84
7/14/93	80	50	23	15		62	1179	796	4	97	69
7/15/93	79	45	20	15		63	1202	811	3	74	54
7/16/93	85	47	24	17		64	1222	825	2	54	40
7/17/93	86	58	30	22		65	1245	843	1	30	22
7/18/93	68	62	23	15	H1***	66	1276	865			

* FB is full bloom
** PF is petal fall
***H1 is harvest 1

Table A4. Temperature data for Harvest 2, 1993

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H2: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H2	FB: # of ddb42 F Before H2	FB: # of ddb50 F Before H2
5/13/93	59	30	9	5	FB*				73	1447	986
5/14/93	66	42	12	8		1	9	5	72	1438	982
5/15/93	63	33	11	7		2	21	13	71	1426	974
5/16/93	58	27	8	4		3	31	19	70	1416	967
5/17/93	55	30	7	3		4	39	23	69	1408	963
5/18/93	48	30	3	0		5	46	26	68	1401	961
5/19/93	58	25	8	4		6	49	26	67	1398	961
5/20/93	63	27	11	7		7	57	30	66	1390	957
5/21/93	64	32	11	7		8	67	36	65	1380	950
5/22/93	74	32	16	12		9	78	43	64	1369	943
5/23/93	60	53	15	7		10	94	55	63	1353	931
5/24/93	63	42	11	7	PF**	11	109	62	62	1338	925
5/25/93	66	40	12	8		12	119	68	61	1328	918
5/26/93	61	39	10	6		13	131	76	60	1316	910
5/27/93	62	40	10	6		14	141	81	59	1306	905
5/28/93	65	34	12	8		15	151	87	58	1296	899
5/29/93	64	29	11	7		16	162	95	57	1285	891
5/30/93	55	42	7	3		17	173	102	56	1274	884
5/31/93	49	30	4	0		18	180	105	55	1267	882
6/1/93	63	28	10	6		19	183	105	54	1263	882
6/2/93	67	39	13	9		20	194	111	53	1253	875
6/3/93	65	38	12	8		21	206	120	52	1240	867
6/4/93	65	29	12	8		22	218	127	51	1229	859
6/5/93	65	40	12	8		23	229	135	50	1217	852
6/6/93	77	29	18	14		24	241	142	49	1206	844
6/7/93	68	54	19	11		25	259	156	48	1188	830
6/8/93	79	60	28	20		26	278	167	47	1169	819
6/9/93	72	57	23	15		27	305	187	46	1141	800
6/10/93	77	50	22	14		28	328	201	45	1119	785
6/11/93	83	45	22	16		29	350	215	44	1097	771
6/12/93	84	52	26	18		30	372	231	43	1075	755
6/13/93	89	53	29	21		31	398	250	42	1049	736
6/14/93	78	55	25	17		32	427	270	41	1020	716
6/15/93	64	39	11	7		33	451	287	40	995	699
6/16/93	69	36	13	9		34	462	294	39	985	692

Table A4. (cont'd).

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H2: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H2	FB: # of ddb42 F Before H2	FB: # of ddb50 F Before H2
6/17/93	70	54	20	12		35	475	303	38	971	683
6/18/93	68	54	19	11		36	495	315	37	951	671
6/19/93	61	56	17	9		37	514	326	36	933	660
6/20/93	72	59	24	16		38	531	335	35	916	651
6/21/93	77	55	24	16		39	555	351	34	892	636
6/22/93	81	50	24	16		40	579	367	33	868	620
6/23/93	86	55	29	21		41	602	382	32	845	604
6/24/93	90	56	31	23		42	631	403	31	816	584
6/25/93	76	59	26	18		43	662	426	30	785	561
6/26/93	80	56	26	18		44	687	443	29	759	543
6/27/93	75	50	21	13		45	713	461	28	733	525
6/28/93	73	50	20	12		46	734	474	27	713	512
6/29/93	77	42	18	14		47	754	486	26	693	501
6/30/93	78	52	23	15		48	771	499	25	675	487
7/1/93	85	52	27	19		49	794	514	24	652	472
7/2/93	76	60	26	18		50	821	533	23	626	453
7/3/93	92	62	35	27		51	847	551	22	600	436
7/4/93	94	65	37	29		52	881	577	21	565	409
7/5/93	90	64	35	27		53	919	607	20	528	380
7/6/93	85	64	33	25		54	954	634	19	493	353
7/7/93	89	62	33	25		55	986	658	18	460	328
7/8/93	81	64	30	22		56	1020	684	17	427	303
7/9/93	81	65	31	23		57	1050	706	16	397	280
7/10/93	85	56	29	21		58	1081	729	15	366	258
7/11/93	78	58	26	18		59	1109	749	14	338	237
7/12/93	77	50	22	14		60	1135	767	13	312	219
7/13/93	80	48	22	15		61	1157	781	12	290	206
7/14/93	80	50	23	15		62	1179	796	11	268	190
7/15/93	79	45	20	15		63	1202	811	10	245	175
7/16/93	85	47	24	17		64	1222	825	9	225	161
7/17/93	86	58	30	22		65	1245	843	8	201	143
7/18/93	68	62	23	15		66	1276	865	7	171	121
7/19/93	82	63	30	22		67	1299	880	6	148	106
7/20/93	80	54	25	17		68	1329	902	5	118	84
7/21/93	79	46	21	15		69	1354	919	4	93	67

Table A4. (cont'd).

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H2: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H2	FB: # of ddb42 F Before H2	FB: # of ddb50 F Before H2
7/22/93	80	44	20	15		70	1374	934	3	72	52
7/23/93	84	48	24	17		71	1394	949	2	52	37
7/24/93	80	60	28	20		72	1419	966	1	28	20
7/25/93	87	64	33	25	H2***	73	1447	986			

* FB is full bloom
** PF is petal fall
***H2 is harvest 2

Table A5. Temperature data for Harvest 3, 1993

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H3: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H3	FB: # of ddb42 F Before H3	FB: # of ddb50 F Before H3
5/13/93	59	30	9	5	FB*				79	1625	1116
5/14/93	66	42	12	8		1	9	5	78	1616	1112
5/15/93	63	33	11	7		2	21	13	77	1604	1104
5/16/93	58	27	8	4		3	31	19	76	1594	1097
5/17/93	55	30	7	3		4	39	23	75	1586	1093
5/18/93	48	30	3	0		5	46	26	74	1579	1091
5/19/93	58	25	8	4		6	49	26	73	1576	1091
5/20/93	63	27	11	7		7	57	30	72	1568	1087
5/21/93	64	32	11	7		8	67	36	71	1558	1080
5/22/93	74	32	16	12		9	78	43	70	1547	1073
5/23/93	60	53	15	7		10	94	55	69	1531	1061
5/24/93	63	42	11	7	PF**	11	109	62	68	1516	1055
5/25/93	66	40	12	8		12	119	68	67	1506	1048
5/26/93	61	39	10	6		13	131	76	66	1494	1040
5/27/93	62	40	10	6		14	141	81	65	1484	1035
5/28/93	65	34	12	8		15	151	87	64	1474	1029
5/29/93	64	29	11	7		16	162	95	63	1463	1021
5/30/93	55	42	7	3		17	173	102	62	1452	1014
5/31/93	49	30	4	0		18	180	105	61	1445	1012
6/1/93	63	28	10	6		19	183	105	60	1441	1012
6/2/93	67	39	13	9		20	194	111	59	1431	1005
6/3/93	65	38	12	8		21	206	120	58	1418	997
6/4/93	65	29	12	8		22	218	127	57	1407	989
6/5/93	65	40	12	8		23	229	135	56	1395	982
6/6/93	77	29	18	14		24	241	142	55	1384	974
6/7/93	68	54	19	11		25	259	156	54	1366	960
6/8/93	79	60	28	20		26	278	167	53	1347	949
6/9/93	72	57	23	15		27	305	187	52	1319	930
6/10/93	77	50	22	14		28	328	201	51	1297	915
6/11/93	83	45	22	16		29	350	215	50	1275	901
6/12/93	84	52	26	18		30	372	231	49	1253	885
6/13/93	89	53	29	21		31	398	250	48	1227	866
6/14/93	78	55	25	17		32	427	270	47	1198	846
6/15/93	64	39	11	7		33	451	287	46	1173	829
6/16/93	69	36	13	9		34	462	294	45	1163	822

Table A5. (cont'd).

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H3: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H3	FB: # of ddb42 F Before H3	FB: # of ddb50 F Before H3
6/17/93	70	54	20	12		35	475	303	44	1149	813
6/18/93	68	54	19	11		36	495	315	43	1129	801
6/19/93	61	56	17	9		37	514	326	42	1111	790
6/20/93	72	59	24	16		38	531	335	41	1094	781
6/21/93	77	55	24	16		39	555	351	40	1070	766
6/22/93	81	50	24	16		40	579	367	39	1046	750
6/23/93	86	55	29	21		41	602	382	38	1023	734
6/24/93	90	56	31	23		42	631	403	37	994	714
6/25/93	76	59	26	18		43	662	426	36	963	691
6/26/93	80	56	26	18		44	687	443	35	937	673
6/27/93	75	50	21	13		45	713	461	34	911	655
6/28/93	73	50	20	12		46	734	474	33	891	642
6/29/93	77	42	18	14		47	754	486	32	871	631
6/30/93	78	52	23	15		48	771	499	31	853	617
7/1/93	85	52	27	19		49	794	514	30	830	602
7/2/93	76	60	26	18		50	821	533	29	804	583
7/3/93	92	62	35	27		51	847	551	28	778	566
7/4/93	94	65	37	29		52	881	577	27	743	539
7/5/93	90	64	35	27		53	919	607	26	706	510
7/6/93	85	64	33	25		54	954	634	25	671	483
7/7/93	89	62	33	25		55	986	658	24	638	458
7/8/93	81	64	30	22		56	1020	684	23	605	433
7/9/93	81	65	31	23		57	1050	706	22	575	410
7/10/93	85	56	29	21		58	1081	729	21	544	388
7/11/93	78	58	26	18		59	1109	749	20	516	367
7/12/93	77	50	22	14		60	1135	767	19	490	349
7/13/93	80	48	22	15		61	1157	781	18	468	336
7/14/93	80	50	23	15		62	1179	796	17	446	320
7/15/93	79	45	20	15		63	1202	811	16	423	305
7/16/93	85	47	24	17		64	1222	825	15	403	291
7/17/93	86	58	30	22		65	1245	843	14	379	273
7/18/93	68	62	23	15		66	1276	865	13	349	251
7/19/93	81.8	62.7	30.3	22.3		67	1299	880	12	326	236
7/20/93	79.8	54.2	25	17		68	1329	902	11	296	214
7/21/93	79.3	46.1	20.7	14.7		69	1354	919	10	271	197

Table A5. (cont'd).

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H3: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H3	FB: # of ddb42 F Before H3	FB: # of ddb50 F Before H3
7/22/93	80.3	43.6	20	15.2		70	1374	934	9	250	182
7/23/93	84.3	48.2	24.3	17.2		71	1394	949	8	230	167
7/24/93	80.3	59.7	28	20		72	1419	966	7	206	150
7/25/93	86.8	63.7	33.3	25.3		73	1447	986	6	178	130
7/26/93	81.3	67.2	32.3	24.3		74	1480	1011	5	145	105
7/27/93	84.3	63.7	32	24		75	1512	1036	4	113	81
7/28/93	82.8	67.2	33	25		76	1544	1060	3	81	57
7/29/93	72.3	57.7	23	15		77	1577	1085	2	48	32
7/30/93	80.3	52.7	24.5	16.5		78	1600	1100	1	25	17
7/31/93	84.3	49.2	24.8	17.2	H3***	79	1625	1116			

* FB is full bloom
** PF is petal fall
***H3 is harvest 3

Table A6. Temperature data for Harvest 4, 1993

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H4: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H4	FB: # of ddb42 F Before H4	FB: # of ddb50 F Before H4
5/13/93	59	30	9	5	FB*				86	1780	1219
5/14/93	66	42	12	8		1	9	5	85	1772	1214
5/15/93	63	33	11	7		2	21	13	84	1760	1206
5/16/93	58	27	8	4		3	31	19	83	1749	1200
5/17/93	55	30	7	3		4	39	23	82	1741	1196
5/18/93	48	30	3	0		5	46	26	81	1735	1193
5/19/93	58	25	8	4		6	49	26	80	1732	1193
5/20/93	63	27	11	7		7	57	30	79	1724	1189
5/21/93	64	32	11	7		8	67	36	78	1713	1183
5/22/93	74	32	16	12		9	78	43	77	1702	1176
5/23/93	60	53	15	7		10	94	55	76	1686	1164
5/24/93	63	42	11	7	PF**	11	109	62	75	1672	1157
5/25/93	66	40	12	8		12	119	68	74	1661	1151
5/26/93	61	39	10	6		13	131	76	73	1649	1143
5/27/93	62	40	10	6		14	141	81	72	1640	1137
5/28/93	65	34	12	8		15	151	87	71	1630	1131
5/29/93	64	29	11	7		16	162	95	70	1618	1124
5/30/93	55	42	7	3		17	173	102	69	1607	1117
5/31/93	49	30	4	0		18	180	105	68	1601	1114
6/1/93	63	28	10	6		19	183	105	67	1597	1114
6/2/93	67	39	13	9		20	194	111	66	1587	1108
6/3/93	65	38	12	8		21	206	120	65	1574	1099
6/4/93	65	29	12	8		22	218	127	64	1562	1092
6/5/93	65	40	12	8		23	229	135	63	1551	1084
6/6/93	77	29	18	14		24	241	142	62	1539	1077
6/7/93	68	54	19	11		25	259	156	61	1522	1063
6/8/93	79	60	28	20		26	278	167	60	1503	1052
6/9/93	72	57	23	15		27	305	187	59	1475	1032
6/10/93	77	50	22	14		28	328	201	58	1452	1018
6/11/93	83	45	22	16		29	350	215	57	1431	1004
6/12/93	84	52	26	18		30	372	231	56	1409	987
6/13/93	89	53	29	21		31	398	250	55	1383	969
6/14/93	78	55	25	17		32	427	270	54	1354	948
6/15/93	64	39	11	7		33	451	287	53	1329	932
6/16/93	69	36	13	9		34	462	294	52	1318	925

Table A6. (cont'd).

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H4: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H4	FB: # of ddb42 F Before H4	FB: # of ddb50 F Before H4
6/17/93	70	54	20	12		35	475	303	51	1305	915
6/18/93	68	54	19	11		36	495	315	50	1285	903
6/19/93	61	56	17	9		37	514	326	49	1266	893
6/20/93	72	59	24	16		38	531	335	48	1250	884
6/21/93	77	55	24	16		39	555	351	47	1226	868
6/22/93	81	50	24	16		40	579	367	46	1202	852
6/23/93	86	55	29	21		41	602	382	45	1178	837
6/24/93	90	56	31	23		42	631	403	44	1150	816
6/25/93	76	59	26	18		43	662	426	43	1119	793
6/26/93	80	56	26	18		44	687	443	42	1093	775
6/27/93	75	50	21	13		45	713	461	41	1067	757
6/28/93	73	50	20	12		46	734	474	40	1046	745
6/29/93	77	42	18	14		47	754	486	39	1027	733
6/30/93	78	52	23	15		48	771	499	38	1009	720
7/1/93	85	52	27	19		49	794	514	37	986	705
7/2/93	76	60	26	18		50	821	533	36	960	686
7/3/93	92	62	35	27		51	847	551	35	934	668
7/4/93	94	65	37	29		52	881	577	34	899	642
7/5/93	90	64	35	27		53	919	607	33	862	612
7/6/93	85	64	33	25		54	954	634	32	827	585
7/7/93	89	62	33	25		55	986	658	31	794	560
7/8/93	81	64	30	22		56	1020	684	30	761	535
7/9/93	81	65	31	23		57	1050	706	29	730	513
7/10/93	85	56	29	21		58	1081	729	28	700	490
7/11/93	78	58	26	18		59	1109	749	27	671	470
7/12/93	77	50	22	14		60	1135	767	26	645	452
7/13/93	80	48	22	15		61	1157	781	25	624	438
7/14/93	80	50	23	15		62	1179	796	24	601	423
7/15/93	79	45	20	15		63	1202	811	23	579	408
7/16/93	85	47	24	17		64	1222	825	22	559	393
7/17/93	86	58	30	22		65	1245	843	21	535	376
7/18/93	68	62	23	15		66	1276	865	20	505	354
7/19/93	82	63	30	22		67	1299	880	19	482	339
7/20/93	80	54	25	17		68	1329	902	18	452	317
7/21/93	79	46	21	15		69	1354	919	17	427	300

Table A6. (cont'd).

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H4: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H4	FB: # of ddb42 F Before H4	FB: # of ddb50 F Before H4
7/22/93	80	44	20	15		70	1374	934	16	406	285
7/23/93	84	48	24	17		71	1394	949	15	386	270
7/24/93	80	60	28	20		72	1419	966	14	362	253
7/25/93	87	64	33	25		73	1447	986	13	334	233
7/26/93	81	67	32	24		74	1480	1011	12	300	207
7/27/93	84	64	32	24		75	1512	1036	11	268	183
7/28/93	83	67	33	25		76	1544	1060	10	236	159
7/29/93	72	58	23	15		77	1577	1085	9	203	134
7/30/93	80	53	25	17		78	1600	1100	8	180	119
7/31/93	84	49	25	17		79	1625	1116	7	156	103
8/1/93	82	65	32	24		80	1649	1133	6	131	86
8/2/93	77	54	24	16		81	1681	1157	5	99	62
8/3/93	75	52	21	13		82	1705	1173	4	75	46
8/4/93	72	49	19	11		83	1726	1186	3	54	33
8/5/93	77	46	19	13		84	1745	1197	2	36	22
8/6/93	62	55	16	8		85	1764	1210	1	16	8
8/7/93	80	49	23	15	H4***	86	1780	1219			

* FB is full bloom
** PF is petal fall
***H4 is harvest 4

Table A7. Temperature data for Harvest 5, 1993

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H5: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H5	FB: # of ddb42 F Before H5	FB: # of ddb50 F Before H5
5/13/93	59	30	9	5	FB*				93	1972	1356
5/14/93	66	42	12	8		1	9	5	92	1964	1351
5/15/93	63	33	11	7		2	21	13	91	1952	1343
5/16/93	58	27	8	4		3	31	19	90	1941	1337
5/17/93	55	30	7	3		4	39	23	89	1933	1333
5/18/93	48	30	3	0		5	46	26	88	1927	1330
5/19/93	58	25	8	4		6	49	26	87	1924	1330
5/20/93	63	27	11	7		7	57	30	86	1916	1326
5/21/93	64	32	11	7		8	67	36	85	1905	1320
5/22/93	74	32	16	12		9	78	43	84	1894	1313
5/23/93	60	53	15	7		10	94	55	83	1878	1301
5/24/93	63	42	11	7	PF**	11	109	62	82	1864	1294
5/25/93	66	40	12	8		12	119	68	81	1853	1288
5/26/93	61	39	10	6		13	131	76	80	1841	1280
5/27/93	62	40	10	6		14	141	81	79	1832	1274
5/28/93	65	34	12	8		15	151	87	78	1822	1268
5/29/93	64	29	11	7		16	162	95	77	1810	1261
5/30/93	55	42	7	3		17	173	102	76	1799	1254
5/31/93	49	30	4	0		18	180	105	75	1793	1251
6/1/93	63	28	10	6		19	183	105	74	1789	1251
6/2/93	67	39	13	9		20	194	111	73	1779	1245
6/3/93	65	38	12	8		21	206	120	72	1766	1236
6/4/93	65	29	12	8		22	218	127	71	1754	1229
6/5/93	65	40	12	8		23	229	135	70	1743	1221
6/6/93	77	29	18	14		24	241	142	69	1731	1213
6/7/93	68	54	19	11		25	259	156	68	1714	1200
6/8/93	79	60	28	20		26	278	167	67	1695	1189
6/9/93	72	57	23	15		27	305	187	66	1667	1169
6/10/93	77	50	22	14		28	328	201	65	1644	1154
6/11/93	83	45	22	16		29	350	215	64	1623	1141
6/12/93	84	52	26	18		30	372	231	63	1601	1124
6/13/93	89	53	29	21		31	398	250	62	1575	1106
6/14/93	78	55	25	17		32	427	270	61	1546	1085
6/15/93	64	39	11	7		33	451	287	60	1521	1068
6/16/93	69	36	13	9		34	462	294	59	1510	1062

Table A7. (cont'd).

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H5: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H5	FB: # of ddb42 F Before H5	FB: # of ddb50 F Before H5
6/17/93	70	54	20	12		35	475	303	58	1497	1052
6/18/93	68	54	19	11		36	495	315	57	1477	1040
6/19/93	61	56	17	9		37	514	326	56	1458	1030
6/20/93	72	59	24	16		38	531	335	55	1442	1021
6/21/93	77	55	24	16		39	555	351	54	1418	1005
6/22/93	81	50	24	16		40	579	367	53	1394	989
6/23/93	86	55	29	21		41	602	382	52	1370	973
6/24/93	90	56	31	23		42	631	403	51	1342	953
6/25/93	76	59	26	18		43	662	426	50	1311	930
6/26/93	80	56	26	18		44	687	443	49	1285	912
6/27/93	75	50	21	13		45	713	461	48	1259	894
6/28/93	73	50	20	12		46	734	474	47	1238	881
6/29/93	77	42	18	14		47	754	486	46	1219	870
6/30/93	78	52	23	15		48	771	499	45	1201	856
7/1/93	85	52	27	19		49	794	514	44	1178	841
7/2/93	76	60	26	18		50	821	533	43	1152	823
7/3/93	92	62	35	27		51	847	551	42	1126	805
7/4/93	94	65	37	29		52	881	577	41	1091	778
7/5/93	90	64	35	27		53	919	607	40	1054	749
7/6/93	85	64	33	25		54	954	634	39	1019	722
7/7/93	89	62	33	25		55	986	658	38	986	697
7/8/93	81	64	30	22		56	1020	684	37	953	672
7/9/93	81	65	31	23		57	1050	706	36	922	650
7/10/93	85	56	29	21		58	1081	729	35	892	627
7/11/93	78	58	26	18		59	1109	749	34	863	606
7/12/93	77	50	22	14		60	1135	767	33	837	588
7/13/93	80	48	22	15		61	1157	781	32	816	575
7/14/93	80	50	23	15		62	1179	796	31	793	560
7/15/93	79	45	20	15		63	1202	811	30	771	545
7/16/93	85	47	24	17		64	1222	825	29	751	530
7/17/93	86	58	30	22		65	1245	843	28	727	513
7/18/93	68	62	23	15		66	1276	865	27	697	491
7/19/93	82	63	30	22		67	1299	880	26	674	476
7/20/93	80	54	25	17		68	1329	902	25	644	453
7/21/93	79	46	21	15		69	1354	919	24	619	436

Table A7. (cont'd).

Date	Maximum Temperature	Minimum Temperature	Degree Days Base 42 F	Degree Days Base 50 F	Phenology	H5: # of Days After FB	Cummulative ddb42 F	Cummulative ddb50 F	FB: # of Days Before H5	FB: # of ddb42 F Before H5	FB: # of ddb50 F Before H5
7/22/93	80	44	20	15		70	1374	934	23	598	422
7/23/93	84	48	24	17		71	1394	949	22	578	407
7/24/93	80	60	28	20		72	1419	966	21	554	389
7/25/93	87	64	33	25		73	1447	986	20	526	369
7/26/93	81	67	32	24		74	1480	1011	19	492	344
7/27/93	84	64	32	24		75	1512	1036	18	460	320
7/28/93	83	67	33	25		76	1544	1060	17	428	296
7/29/93	72	58	23	15		77	1577	1085	16	395	271
7/30/93	80	53	25	17		78	1600	1100	15	372	256
7/31/93	84	49	25	17		79	1625	1116	14	348	239
8/1/93	82	65	32	24		80	1649	1133	13	323	222
8/2/93	77	54	24	16		81	1681	1157	12	291	199
8/3/93	75	52	21	13		82	1705	1173	11	267	183
8/4/93	72	49	19	11		83	1726	1186	10	246	170
8/5/93	77	46	19	13		84	1745	1197	9	228	159
8/6/93	62	55	16	8		85	1764	1210	8	208	145
8/7/93	80	49	23	15		86	1780	1219	7	192	137
8/8/93	80	49	23	15		87	1803	1234	6	169	122
8/9/93	80	53	25	17		88	1826	1249	5	147	107
8/10/93	83	61	30	22		89	1850	1266	4	122	90
8/11/93	90	59	33	25		90	1880	1288	3	92	68
8/12/93	90	54	30	22		91	1913	1312	2	59	43
8/13/93	88	55	30	22		92	1943	1334	1	30	22
8/14/93	85	60	30	22	H5***	93	1972	1356			

* FB is full bloom
** PF is petal fall
***H5 is harvest 5

Table A8. Temperature data for Bardenhagen farm

DATE	Maximum Temperature	Minimum Temperature	Degree Day Base 50 F	Cumulative Degree Day Base 50 F	
5/25/94	65	44	8		Full Bloom
5/26/94	53	34	2	2	
5/27/94	60	27	5	7	
5/28/94	73	43	12	18	
5/29/94	75	51	13	31	
5/30/94	83	60	22	53	80% Petal Fall
5/31/94	75	52	13	66	
6/1/94	57	38	3	69	
6/2/94	64	33	7	76	
6/3/94	71	30	10	87	
6/4/94	75	35	13	99	
6/5/94	81	45	16	115	
6/6/94	71	49	11	126	
6/7/94	65	45	7	133	
6/8/94	66	35	8	141	
6/9/94	72	33	11	152	
6/10/94	79	37	15	166	
6/11/94	77	44	14	180	
6/12/94	77	51	14	194	
6/13/94	64	48	7	201	
6/14/94	81	45	15	216	
6/15/94	92	72	32	248	
6/16/94	90	68	29	277	
6/17/94	93	61	27	304	
6/18/94	85	57	21	325	
6/19/94	78	53	16	341	
6/20/94	82	61	22	363	
6/21/94	79	51	15	378	
6/22/94	81	49	16	393	
6/23/94	70	51	10	404	
6/24/94	62	55	8	412	
6/25/94	71	50	10	422	

Table A8. (cont'd).

DATE	Maximum Temperature	Minimum Temperature	Degree Day Base 50 F	Cumulative Degree Day Base 50 F
6/26/94	81	47	16	438
6/27/94	82	47	16	454
6/28/94	86	56	21	475
6/29/94	60	52	6	481
6/30/94	68	49	9	490
7/1/94	79	52	16	506
7/2/94	69	45	10	516
7/3/94	80	43	15	531
7/4/94	78	58	18	549
7/5/94	78	59	18	568
7/6/94	83	61	22	590
7/7/94	81	63	22	612
7/8/94	80	65	23	634
7/9/94	72	51	11	646
7/10/94	71	45	11	656
7/11/94	77	42	13	670
7/12/94	79	56	18	687
7/13/94	69	47	9	697
7/14/94	64	53	9	706
7/15/94	74	53	13	719
7/16/94	77	53	15	734
7/17/94	68	55	11	745
7/18/94	77	52	14	759
7/19/94	79	61	20	780
7/20/94	76	65	21	800
7/21/94	83	62	22	823
7/22/94	72	60	16	838
7/23/94	79	59	19	857
7/24/94	75	56	15	873
7/25/94	74	53	14	886
7/26/94	69	48	9	896
7/27/94	68	48	9	905

Table A8. (cont'd).

DATE	Maximum Temperature	Minimum Temperature	Degree Day Base 50 F	Cumulative Degree Day Base 50 F
7/28/94	73	45	11	916
7/29/94	76	51	13	929
7/30/94	81	57	19	949
7/31/94	81	62	22	970
8/1/94	72	58	15	985
8/2/94	75	51	13	998
8/3/94	78	50	14	1012
8/4/94	65	52	8	1021
8/5/94	67	44	9	1029
8/6/94	69	41	9	1039
8/7/94	74	47	12	1051
8/8/94	63	49	6	1057
8/9/94	63	47	7	1064
8/10/94	69	41	10	1073
8/11/94	70	49	10	1083
8/12/94	72	47	11	1095
8/13/94	74	51	13	1107
8/14/94	62	52	7	1114
8/15/94	69	51	10	1124

Table A9. Temperature data for Sun Blossom farm

DATE	Maximum Temperature	Minimum Temperature	Degree Day Base 50 F	Cumulative Degree Day Base 50 F	
5/23/94	78	42	14		Full Bloom
5/24/94	78	44	14	14	
5/25/94	67	47	9	23	
5/26/94	51	38	1	23	
5/27/94	63	27	6	30	
5/28/94	78	45	14	44	Petal Fall
5/29/94	75	50	13	56	
5/30/94	85	60	23	79	
5/31/94	77	51	14	93	
6/1/94	55	39	3	96	
6/2/94	63	36	7	102	
6/3/94	71	32	11	113	
6/4/94	81	38	15	128	
6/5/94	80	42	15	143	
6/6/94	73	50	11	155	
6/7/94	64	49	7	162	
6/8/94	63	35	7	168	
6/9/94	73	33	12	180	
6/10/94	79	39	15	194	
6/11/94	81	43	16	210	
6/12/94	81	53	17	227	
6/13/94	81	47	16	243	
6/14/94	83	48	16	259	
6/15/94	96	74	35	294	
6/16/94	95	72	34	328	
6/17/94	96	60	28	356	
6/18/94	106	60	33	389	
6/19/94	82	57	20	408	
6/20/94	88	56	22	430	
6/21/94	84	51	18	448	

Table A9. (cont'd).

DATE	Maximum Temperature	Minimum Temperature	Degree Day Base 50 F	Cumulative Degree Day Base 50 F
6/22/94	85	50	17	465
6/23/94	73	54	13	479
6/24/94	63	56	9	488
6/25/94	72	52	12	500
6/26/94	82	48	16	517
6/27/94	84	52	18	534
6/28/94	86	58	22	556
6/29/94	64	55	10	566
6/30/94	74	49	12	578
7/1/94	84	51	18	596
7/2/94	70	48	10	606
7/3/94	82	44	16	622
7/4/94	80	60	20	642
7/5/94	87	64	25	667
7/6/94	89	64	27	694
7/7/94	87	64	25	719
7/8/94	86	67	27	746
7/9/94	76	53	14	760
7/10/94	76	47	13	773
7/11/94	80	42	15	788
7/12/94	84	59	21	810
7/13/94	71	46	10	820
7/14/94	69	55	12	832
7/15/94	77	55	16	848
7/16/94	76	56	16	864
7/17/94	73	56	14	879
7/18/94	82	53	17	896
7/19/94	87	62	25	921
7/20/94	73	69	21	942
7/21/94	87	64	25	967

Table A9. (cont'd).

DATE	Maximum Temperature	Minimum Temperature	Degree Day Base 50 F	Cumulative Degree Day Base 50 F
7/22/94	76	62	19	986
7/23/94	84	60	22	1008
7/24/94	79	56	18	1026
7/25/94	78	53	15	1042
7/26/94	71	50	11	1052
7/27/94	70	48	10	1062
7/28/94	74	47	12	1075
7/29/94	80	56	18	1093
7/30/94	83	57	20	1113
7/31/94	83	62	22	1135
8/1/94	71	58	14	1149
8/2/94	82	51	16	1166
8/3/94	67	53	10	1176
8/4/94	67	53	10	1186
8/5/94	71	46	11	1197
8/6/94	78	43	14	1211
8/7/94	76	47	13	1224
8/8/94	66	51	8	1232
8/9/94	64	48	8	1240
8/10/94	75	44	7	1247
8/11/94	74	44	12	1260
8/12/94	75	56	12	1272
8/13/94	80	49	15	1287
8/14/94	80	63	15	1302
8/15/94	75	47	12	1315

Table A10. Temperature data for Laubach farm

DATE	Maximum Temperature	Minimum Temperature	Degree Day Base 50 F	Cumulative Degree Day Base 50 F	
5/23/94	84	43	17		Full Bloom
5/24/94	77	49	14	14	
5/25/94	73	47	12	25	
5/26/94	53	41	2	27	
5/27/94	64	27	7	34	
5/28/94	78	44	14	48	80% Petal Fall
5/29/94	75	58	17	64	
5/30/94	85	60	23	87	
5/31/94	81	62	22	108	
6/1/94	61	40	6	114	
6/2/94	65	34	8	121	
6/3/94	74	33	12	133	
6/4/94	81	40	16	149	
6/5/94	86	46	18	167	
6/6/94	73	47	12	178	
6/7/94	70	47	10	188	
6/8/94	71	37	11	199	
6/9/94	72	34	11	210	
6/10/94	82	42	16	226	
6/11/94	82	46	16	242	
6/12/94	81	52	17	258	
6/13/94	66	58	12	270	
6/14/94	80	48	15	285	
6/15/94	95	75	35	320	
6/16/94	96	72	34	354	
6/17/94	97	65	31	385	
6/18/94	94	62	28	413	
6/19/94	89	55	22	435	
6/20/94	82	61	22	457	
6/21/94	87	59	23	480	
6/22/94	88	52	20	500	
6/23/94	75	58	17	516	
6/24/94	63	58	11	527	

Table A10. (cont'd).

DATE	Maximum Temperature	Minimum Temperature	Degree Day Base 50 F	Cumulative Degree Day Base 50 F
6/25/94	80	55	18	544
6/26/94	90	52	21	565
6/27/94	83	51	17	582
6/28/94	86	60	23	605
6/29/94	61	55	8	613
6/30/94	72	50	11	624
7/1/94	84	56	20	644
7/2/94	78	50	14	658
7/3/94	91	46	21	679
7/4/94	84	60	22	701
7/5/94	88	62	25	726
7/6/94	80	65	23	748
7/7/94	87	64	26	774
7/8/94	83	67	25	799
7/9/94	77	60	19	817
7/10/94	75	48	13	830
7/11/94	78	45	14	844
7/12/94	85	64	25	868
7/13/94	79	46	15	883
7/14/94	69	53	11	894
7/15/94	80	59	20	913
7/16/94	85	57	21	934
7/17/94	71	60	16	950
7/18/94	83	55	19	969
7/19/94	87	63	25	994
7/20/94	83	69	26	1020
7/21/94	83	61	22	1042
7/22/94	72	60	16	1058
7/23/94	80	59	20	1077
7/24/94	75	56	16	1093
7/25/94	75	53	14	1107
7/26/94	74	52	13	1120
7/27/94	70	48	10	1130

Table A10. (cont'd).

DATE	Maximum Temperature	Minimum Temperature	Degree Day Base 50 F	Cumulative Degree Day Base 50 F
7/28/94	74	47	12	1142
7/29/94	80	56	18	1160
7/30/94	83	57	20	1180
7/31/94	83	62	22	1202
8/1/94	71	58	14	1217
8/2/94	82	51	16	1233
8/3/94	67	53	10	1243
8/4/94	67	53	10	1254
8/5/94	71	46	11	1264
8/6/94	78	43	14	1278
8/7/94	76	47	13	1291
8/8/94	66	51	8	1299
8/9/94	64	48	7	1306
8/10/94	75	44	12	1319
8/11/94	74	44	12	1331
8/12/94	75	56	15	1346
8/13/94	80	49	15	1361
8/14/94	80	63	22	1383
8/15/94	75	47	12	1395

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