Management of Dormant Sprays by Chill Accumulation in Bartlett Pear, Final Report 2007

Kitren Glozer[1] and Chuck Ingels[2]

[1] Associate Project Scientist, Plant Sciences Department, U.C. Davis
[2] University of California Cooperative Extension Farm Advisor, Sacramento County

Summary:

A tentative adjustment to minimum chill requirement for 'Bartlett' pear under California Central Valley growing conditions has been established based on shoot forcing experimental data. The broad definition of 850-1500 chill hours is narrowed to 56 chill portions (Dynamic Model; 820 modified chill hours ≤ 45 ºF). Comparison across three years of trials show very real differences in how chill is measured. The perception of 'good' vs 'poor' chilling needs to reflect both observations of bloom and interpretation of patterns of chill and heat accumulation during entry into dormancy, the mid-dormant season, and exit from dormancy, as these phases are highly variable year-to-year in some growing areas of California, frequently creating low-to-moderate chill years.

The trial for 'best timing' of dormant oil application for enhancing bloom and fruiting in European pear was compromised and a major portion of the trial results 'lost' as follows:

On July 16, the cooperator, and the project leader, Kitren Glozer, discussed coordinating data collection with commercial harvest. They agreed that the first commercial harvest would not occur until July 18, so that fruit counts (for final fruit set and cropload) and fruit samples could be obtained from 'data' trees. However, the entire trial site was harvested in a 'first pick' for size early on July 17, prior to researchers arriving to do their sampling. Thus, fruit set counts, crop load per tree, percentage of the crop harvested in the first pick, percentage of the crop that was undersized, and total yields could not be calculated. Treatment effects on fruit quality and cropping are severely limited for this trial year as a result, recommendations for dormant oil applications cannot be updated, and the majority of the benefit that may have been derived from the 2006-7 research year was lost.

Problem and Its Significance:

Chill requirement by a given tree species and variety, and chill accumulation from year-to-year, are important factors for growers in managing their orchard production. In California, as in many other low-chill areas of the world, this is particularly true, with chill accumulation variable in the pattern of accumulation during the dormant season and total chill accumulation variable annually. Patterns of chill accumulation vary geographically, based on location within a continent, altitude, marine influence, and seasonal weather patterns. Microclimates within California are also an important consideration because the state has large topographical changes. Thus, continental United States or Europe has very different growing conditions than California, and the Sacramento Delta pear-growing environment is different than that of the North Coastal valleys.

Methods of chill accumulation for tree crops were developed primarily for continental climates, and while the 'chill hour' method (accumulation of hours < 45 ºF), or the 'Modified chill hour' method (accumulation of hours ≤ 45 ºF) have been used historically in California, those methods do not appear to be best suited to California growing conditions (based on 10 years research in sweet cherry in California). The Dynamic Model, developed for Israel's low chill Mediterranean conditions, appears to better explain tree behavior, taking into account heat cancellation of chilling until sufficient time at sufficiently low temperature has been experienced without interruption.

Our trial results from 2004-5, 2005-6 and 2006-7 growing seasons tested dormant oil application timing by chill accumulation and the response in bloom development, fruit quality and crop components, comparing chill hour and chill portion (Dynamic Model) accumulation to these phenological indices. Our goal is to test growers' anecdotal experiences of effects on bloom and cropping, and to develop a 'best practice' approach to dormant oil application.

Objectives:

Experiment 1: Determination of chilling requirement

The chilling requirement for 'Bartlett' pear is reportedly 850 to 1500 chill hours, depending on source. Better understanding European pear chilling requirements under California conditions may improve grower management of chill accumulation-dependent processes. One method of testing stage of dormancy is by forcing excised shoots; buds will break at varying rates or in varying amounts (e.g. 25, 50, 100% bud break) depending on how much chilling has accumulated. We conducted this experiment using reproductive shoots cut from 'Bartlett' pear trees growing in the UCDavis Pomology orchard on a weekly basis beginning Dec. 1 and determining chill accumulation in chill hours and portions when 50% of flower buds expanded and began to open.

Experiment 2: Use of the Dynamic Model and dormant oil treatments to develop 'best' practice timing application for optimal bloom and cropping results.

Based on trial results from 2004-5 and 2006-7, we determined that 4% Dormant Plus® emulsifiable oil (UAP; upper label concentration) was an appropriate treatment for 'rest-breaking' for pear, with results dependent on application timing and the pattern of annual chill accumulation, compared to other rest-breaking products tested in the second of the prior trial years. CAN17 exacerbated freeze damage to flower buds incurred in the 2005-6 dormant season, and EvenBreak® (a modified CAN product) + Break-thru® (nonionic surfactant) did not show a benefit, although these products have been reformulated and purportedly have better activity (personal communication, Western Farm Service). Defoliation with urea and chelated copper, a treatment that improved pear bloom and cropping in the 2004-5 trial, has been applied in the new trial and results will be reported subsequent to the 2008 growing season. We continue to compare the Modified chill hour model and the Dynamic Model to temperature data accumulated at the trial site for 'best fit' to observed tree behavior and dormant oil application timings. The responses to treatments have been evaluated as flowering behavior, fruit quality, rat-tail bloom, cropping and yield.

Experiment 1: Bud forcing for chill requirement

Plans and Procedures:

Shoots with several inflorescence buds were cut on a weekly basis beginning Dec 1 from mature 'Bartlett' trees in the UCDavis Pomology orchard. Ten shoots per date were collected, stems recut under water and kept in 'forcing' conditions on a day/night regimen of ~70 ºF/ 55 ºF, constant light until 50% of inflorescence buds expanded and began to open. Chill accumulation for modified chill hours and chill portions for each collection date was calculated from Yolo County, Davis CIMIS station #6.

Results and Discussion:

Approximate chill requirement for 'Bartlett' pear under California growing conditions for the Central Valley was determined to be 56 chill portions, 820 modified chill hours (number of hours ≤ 45 ºF). These results were obtained from shoots cut Jan 18. While this chill requirement approaches that currently accepted in the literature (850-1500 chill hours), it should be kept in mind that the chill hour models do not take into account heat cancellation of chilling, as does the Dynamic Model, which was based on observed bloom phenology in relation to a temperature gradient that does take into account heat cancellation of a purported chemical intermediate generated during chilling. In fact, timing of bud expansion and bloom tend to depend more on heat accumulation than chill accumulation, although relative date of bud expansion and full bloom (including duration of bloom) also depend greatly on whether chilling was 'adequate'. Comparisons of chill accumulation will be made in discussing the results from Experiment 2 below.

Experiment 2: Use of the Dynamic Model and dormant oil treatments to maximize bloom and fruiting behavior

Site location, temperature data and plant material:

Chill accumulation was calculated from hourly temperature data from two WatchDog Model 110-Temp 8K (Spectrum Technologies, Inc.) data loggers placed in our treatment site (Yolo County). The experimental site consisted of a solid block, approximately 60 rows wide of >Bartlett== trees planted in approximately 1920 (rootstock unknown) on an 11' x 22' spacing (180 trees per acre) and flood-irrigated. Rows included 30 to 33 trees each oriented on an east-west axis.

Treaments:

4% Dormant Plus® emulsifiable oil was tested for rest-breaking responses. Treatment applications were timed by the Dynamic model (Table 1) and chill portion accumulation. All dormant oil treatments were applied with a commercial airblast sprayer at a volume of 400 gallons per acre to 10 contiguous tree rows and 4 single-tree replicates per treatment were selected for recording treatment effects within those rows from the interior of each block of 10 rows, with trees standardized for size, vigor and canopy spread. A single untreated row was reserved, between the first and second oil applications, for an untreated control, with an attempt made to restrict spraying into that row by turning off nozzles on one side of sprayer when directed toward the 'control' row. No additional rows were left untreated as the grower had concerns about pest management.

Table 1. Treatment timings for Dormant Oil Plus in dormant season 2006-2007.

	Chill portions accumulation
Untreated control	
22 December	38
29 December	43
6 January	49
19 January	57
26 January	62

Data recorded:

The project goals could not be met in their entirety as significant data was 'lost'. On July 16, the cooperator, and the project leader, Kitren Glozer, discussed coordinating data collection with commercial harvest. They agreed that the first commercial harvest would not occur until July 18, so that fruit counts (for final fruit set and cropload) and fruit samples could be obtained from 'data' trees. However, the entire trial site was harvested in a 'first pick' for size early on July 17, prior to researchers arriving to do their sampling. Thus, fruit set counts, crop load per tree, percentage of the crop harvested in the first pick, percentage of the crop that was undersized, and total yields could not be calculated. Treatment effects on fruit quality and cropping are severely limited for this trial year as a result, recommendations for dormant oil applications cannot be updated, and the majority of the benefit that may have been derived from the 2006-7 research year was lost.

Flowering data: primary bloom, Type I, II and V rat-tail bloom incidence

Data was recorded from each treated tree, with inflorescences and flowers counted on 4 large limbs per tree, approximately in 4 quadrants, selected prior to inflorescence opening. Date of first open flower (DFF) was recorded and bloom progression recorded as percentage of flowers within inflorescences open from March 14 to March 22, counting approximately every 2 days. Full bloom date (FBD) was designated when 80% of flowers were open; bloom duration was 'date of first flower' to 'date of full bloom' (BD). Numbers of Types I, II and V rat tail blooms were counted beginning from bloom onset and ending April 22. Dead inflorescence buds were counted at the end of bloom. Incidence of dead buds and rat-tail blooms was recorded differentiating by diameter of shoot, at base of observed shoot. Shoots were categorized into two classes based on whether they were below the mean diameter of 35 mm, or equal or greater than the mean diameter, to test for correlation with shoot age or vigor, with diameter as a rough measure. Diameter of shoot was also intended to be used as a measure of cropping efficiency for final fruit set.

Final fruit set could not be determined as number of fruit set on each 'data' limb was compromised during the first commercial harvest.

Harvest data:

The only data obtained from the first harvest timing (commercial harvest 'first' pick for sized fruit only) was number of bins per 4 row-blocks. These blocks combined rows from different dormant oil treatment timings, thus, only those 4 row-blocks that were limited to a single treatment timing could be considered. The untreated control row was combined with other rows, thus, not yield data could be obtained. Bins each contained approximately 1100 lb of fruit and numbers of bins was obtained from the cooperator for the first commercial harvest only; neither the project leader nor the cooperating farm advisor have been able to obtain matching data from the grower, thus, total yields or percentage of the crop harvested in either harvest can't be estimated.

Second harvest data that was obtained included: mean fruit weight (randomly selected from all exposures of 'data' trees), percentage of undersized fruit, and fruit quality for #1 fruit (equatorial diameter ≥ 2 5/8"; weight per fruit, %soluble solids from a blended sample of 10 fruit, diameter and firmness). Firmness was measured by UC pressure tester on a single cheek after removal of peel. Soluble solids were measured by Atago digital refractometer.

Statistical analyses:

Analyses of variance were performed with Proc GLM in SAS (SAS Institute Inc., Cary, NC) and mean separations tested by Duncan=s Multiple Range Test, $P = 0.05$. Correlations between shoot diameter or shoot 'type' and DFF, FBD, BD, incidence of inflorescence bud death and rat-tail bloom production were tested with Proc CORR, $P = 0.05$. All data were normal and did not require transformation (Adler and Roessler, 1964).

Results and Discussion:

Chill accumulation began September 16 at the trial site, so that 4 chill portions had accumulated by November 1, the traditional starting date of chill accumulation. In all trial years (Years 1-3), chill accumulation for CH and CP began prior to the traditional calendar date of November 1, thus total chill accumulation should be calculated based on the models used for either CH or CP with starting date determined by the models. Total chill hour accumulation and chill portion accumulation with comparisons made among the three years of trial results are shown in Table 2 and Figures 1 and 2. Full bloom dates for Years 1-3 are found in Table 2 and other bloom phenology (date of first flower and bloom duration) are summarized in the text for Years 1 and 2, and in Table 3 for Year 3 (2006-7).

Comparing methods of calculating chill show that in 2004-5 (Year 1), onset of chill hour (CH) accumulation began Oct. 20, chill portion (CP) accumulation, however, began a month earlier. This year was the lowest in three for chill hour accumulation, but the highest for chill portion accumulation, when calculating from September 1 until April 30. Full bloom was at a typical timing for the Sacramento Delta production region—March 18 at 1207 CH and 96 CP, however, bloom duration (BD) was 10 days for untreated trees, and very similar for all but the last Volck oil timing, applied Feb 18 at 82 CP. In Year 2 (2005-6), CH accumulation began September 18, CP accumulation began October 27 and total CH was the highest for the three years (1777), CP total was intermediate (109). Bloom duration (first flower open to 80% of flowers open) was 11 days in the warmest end of the treated row and 6 days in the coldest end of the row, with both untreated. In Year 3 (2006-7), onset for CH was September 16, for CP onset was October 6. Year 3 had the lowest total CP accumulation (95) and intermediate CH accumulation (1677). DFF was March 18 for all treatments; there was not timing effect of dormant oil application on onset of bloom. FBD differed by a single day for only one treatment, averaging 3 to 4 days (Table 3), so no treatment effect can be concluded for Year 3. We can say that BD was least in Year 3, more or less the same for Year 1 and the 'poorly chilled' trees in Year 2, confounded by temperature gradient and bud death due to a late freeze when buds were highly susceptible following an early warming trend.

Inflorescence bud death was very high in Year 2 due to unseasonably warm days and nights followed by a freeze prior to bloom (Figure 3), during the second week of February. Inflorescence bud death for Year 3 was negligible and not different among treatments (Table 3). Rat-tail bloom production, although marginally different among some treatments when measured across time (data not shown), these differences were not sufficiently different as total production to conclude treatment effects. No correlations were found between shoot diameter/shoot type (above or below the mean diameter) and any measure of bloom development or bud death.

Effects on bloom can generally be interpreted by an overall comparison of 'high' chill year vs 'bad' chill year, or 'moderate' chill year, in California fruit production. Year 2 was generally considered a 'low' chill year, although freezing conditions were an overwhelming concern compared to total chill accumulation. However, one can compare 'high' vs 'low' chill years in California based on chill hours, chill portions or bloom phenology (early bloom, tight bloom, good fruit set). When we compare Years 1 through 3 by CH vs CP, we see that these measures lead to very different conclusions. Year 1 had the highest CP and the lowest CH, yet was considered a 'low-to-moderate' chill year with a straggly bloom. Year 2 was a lower chill year with respect to warm orchards, moderate in others; bloom was very late and pre-bloom temperatures were moderately cool. Year 3 was considered a 'moderate-to-high' chill year with tight bloom.

Patterns of chill accumulation under California conditions should consider onset of chill and early chilling which determine entry into dormancy, which part of the dormant season receives 'good' chilling, with the greatest differences being the earliest and the latest portions, and total chill accumulation. Method of determining chill accumulation should take into account periods of heat accumulation that cancel chill accumulation (such as in the early and middle of the dormant season) and heat accumulation that advances and tightens bloom, which is aided by 'adequate' chill accumulation.

Cropping and fruit quality

All data are from fruit harvested after the first commercial harvest (Table 4), with the exception of number of bins harvested per row as a partial determination based on treatment; no data exists for the untreated control for comparison. Data do not show any trends based on timing of dormant oil application, and no meaningful conclusion can be drawn with respect to yield. When fruit remaining on the ‘data’ trees were compared, the random sample showed no difference in fruit size of unsorted fruit, no statistically significant differences among treatments in %undersized, although the last treatment showed a considerably higher percentage than all other treatments. The untreated and other oil timings tended to be similar, with the exception of the oil applied at 43 chill portions (December 29), with respect to percentage of undersized fruit. Quality attributes for #1 fruit (%soluble solids, diameter and firmness) did not show significant differences in general, although a trend toward improved soluble solids was found with later oil treatments (Jan 6-26 at chill portions 49-62). Firmness was not clearly increased or decreased in these timings, and no clear trend was apparent among treatments.

Results from fruit and crop data in Year 3 cannot be compared to that of Years 1 and 2 due to the loss of the first harvest. Misleading conclusions could result, and that could be non-productive for advancing an understanding of managing dormant oil applications by chill accumulation.

Table 2. Response of 'Bartlett' pear to chill accumulation in 3 trial years; chill hours = number of hours ≤45 F° (CH), chill portions (Dynamic Model; CP). Total accumulation from September 1 to April 30.

Dormant season (full bloom date)	Chill hours				Chill portions			
	Onset	Full bloom	Total	At most effective dormant oil timing for optimal crop	Onset	Full bloom	Total	At most effective dormant oil timing for optimal crop
2004-5 (3/18)	10/20	1207	1277 (lowest)	505-972 (Dec 20-Jan 18)[x]	9/20	96	112 (highest)	34-56
2005-6 (4/25)	9/18	1777	1777 (highest)	787-1051 (Jan 9-25)	10/27	109	109	43-54
2006-7 (3/21)	9/16	1568	1677		10/6	87	95 (lowest)	

[x] Range of effective timing of dormant oil application, based on bloom development, number of Type I rat-tail flowers, fruit size and yield components. In 2005-6 the results were complicated by a temperature gradient down the row with both application date of dormant oil and amount of chill accumulated increasing down the row.

Table 3. Effects of Dormant Oil Plus application timing on bloom behaviour in 'Bartlett' pears, 2007. Rat-tail bloom shown as a cumulative total over bloom period, ending 22 April.						
Treatment	Date of		First flower to full bloom (days)	%Dead inflorescence buds	#Type I+II rat-tail blooms per shoot	#Type V rat+tail blooms per shoot
	First flower	Full bloom				
Untreated control	18 March	21 March	3.6 ab[y]	3.0 a	1.4 a	0.2 b
Dormant Oil Plus[x] application timing (chill portions calculated by the Dynamic Model)						
22 Dec (38)	18 March	22 March	4.5 a	8.3 a	1.0 a	0.9 b
29 Dec (43)		22 March	3.8 ab	5.1 a	0.5 a	0.8 ab
6 Jan (49)		21 March	3.3 b	8.1 a	1.1 a	1.9 ab
19 Jan (57)		22 March	2.9 b	5.6 a	0.4 a	2.2 a
26 Jan (62)		22 March	3.1 b	3.9 a	0.9 a	2.1 a

[x] Applied at 400 gallons per acre.

[y] Mean separation by DMRT, $P = 0.05$.

Table 4. Effects of application timing of Dormant Oil Plus on fruit quality and crop components in 'Bartlett' pear, 2007, fruit remaining on trees after first commercial harvest. Data obtained July 23.

Treatment	#Bins per row at first harvest [y]	Wt per fruit, randomly sampled (oz)	%Undersized	Quality measures for #1 fruit (diameter ≤2 5/8")		
				%Soluble solids	Diameter (mm)	Firmness (lb)
Untreated control	no data	6.4 a [x]	32.5 a	9.8 a	72 a	15.1 c
Dormant Oil Plus application timing (chill portions)						
22 Dec (38)	1.2 (2)	7.0 a	28.7 a	9.5 a	73 a	15.0 c
29 Dec (43)	1.8 (2)	6.8 a	20.0 a	9.4 a	73 a	16.3 a
6 Jan (49)	1.5 (1)	6.4 a	31.2 a	10.3 a	74 a	16.0 ab
19 Jan (57)	1.6 (2)	6.4 a	31.2 a	10.5 a	73 a	15.6 b
26 Jan (62)	2.0 (1)	5.7 a	46.2 a	10.4 a	72 a	14.7 c

[x] Mean separation by DMRT, $P = 0.05$.
[y] Data obtained in 4-row composites, with number of composites dependent on orchard layout, not treatment design, and harvest methodology. Number of 4-row composites indicated in parentheses ().

Figure.1. Chill accumulation in 'chill hours' (number of hours ≤ 45ºF) and full bloom dates for 'Bartlett' pear rest-breaking project, 2004 to 2007.

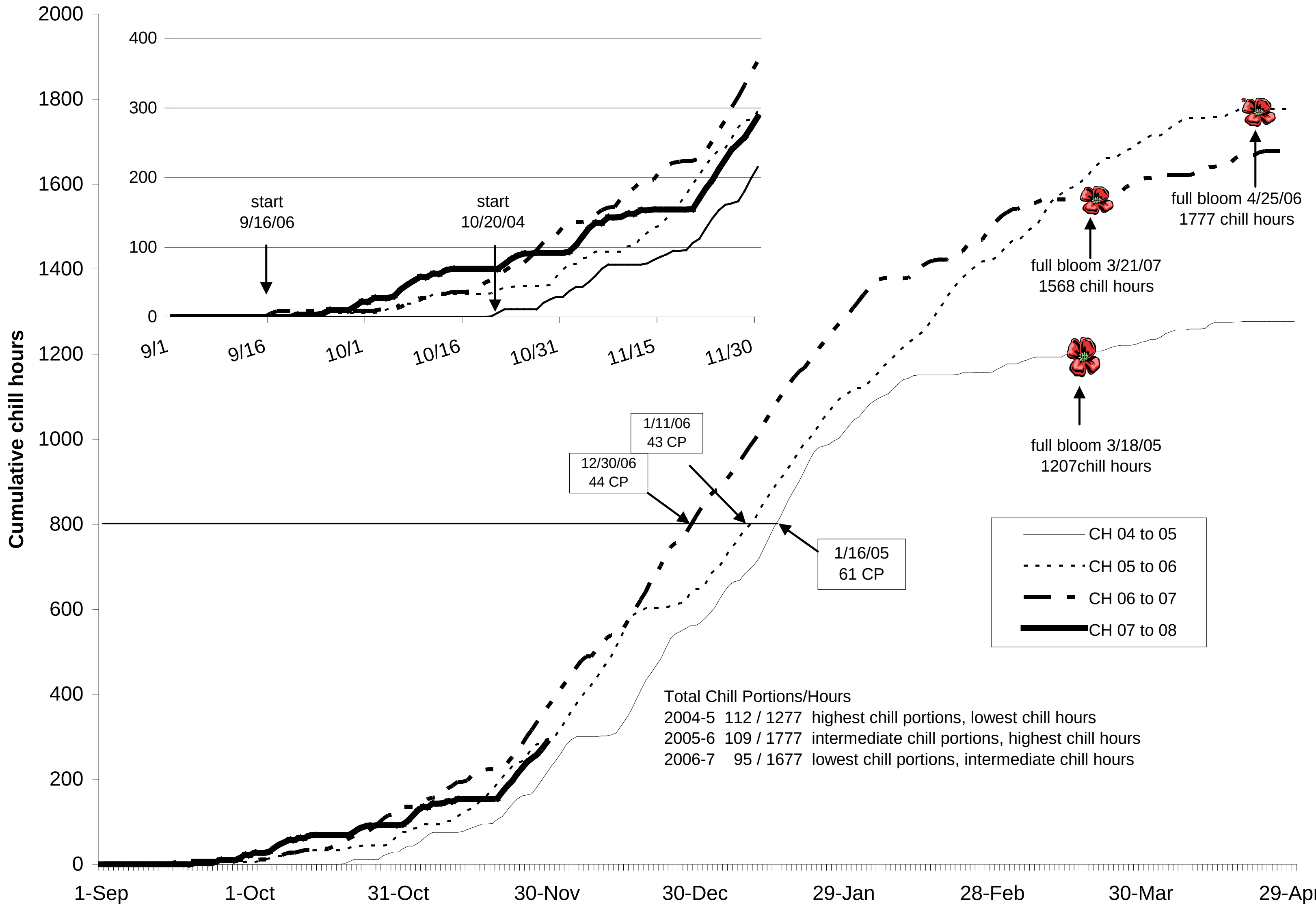


Figure 2. Chill accumulation in ‘chill portions’ and full bloom dates for ‘Bartlett’ pear rest-breaking project, 2004 to 2007.

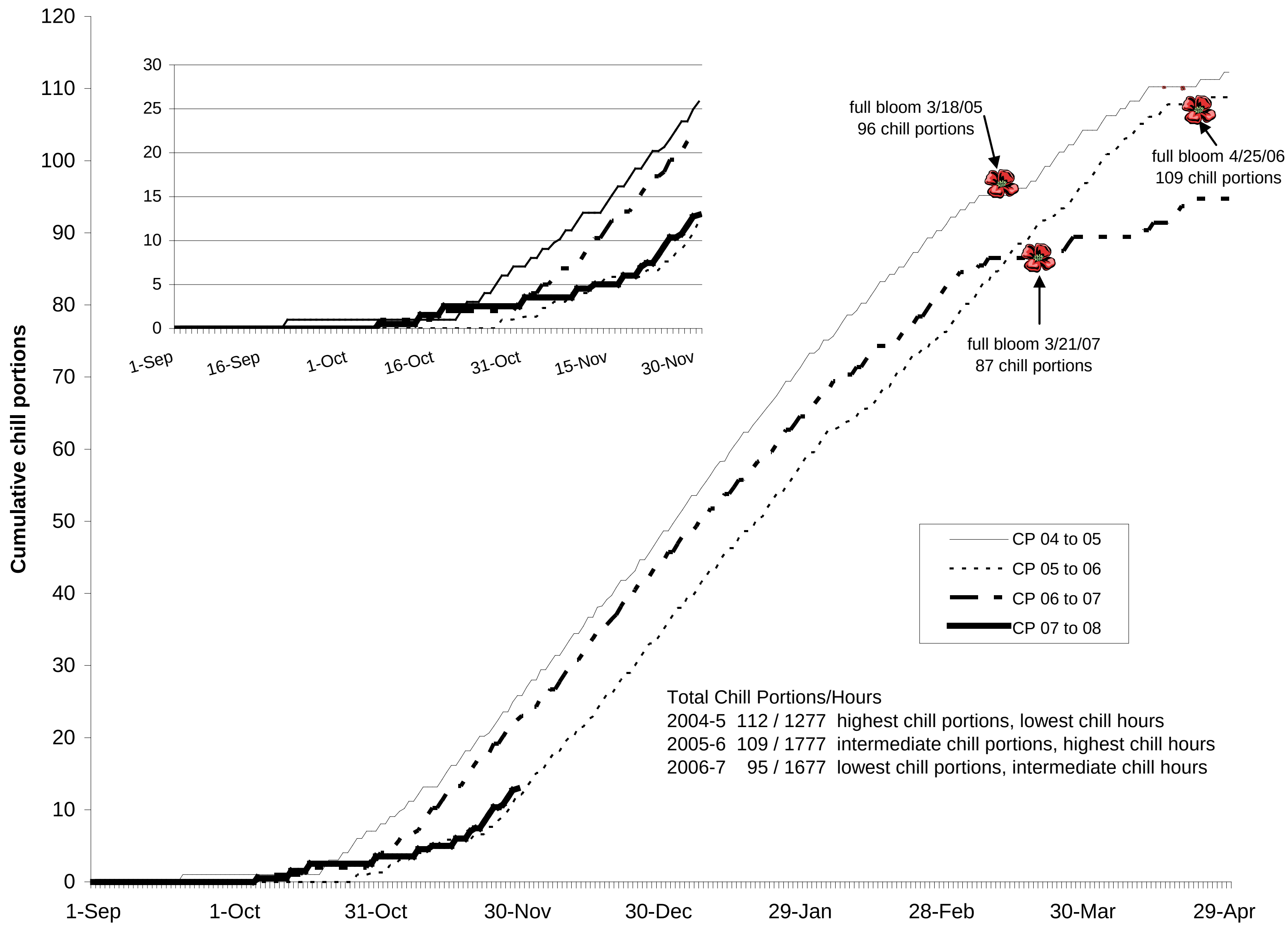
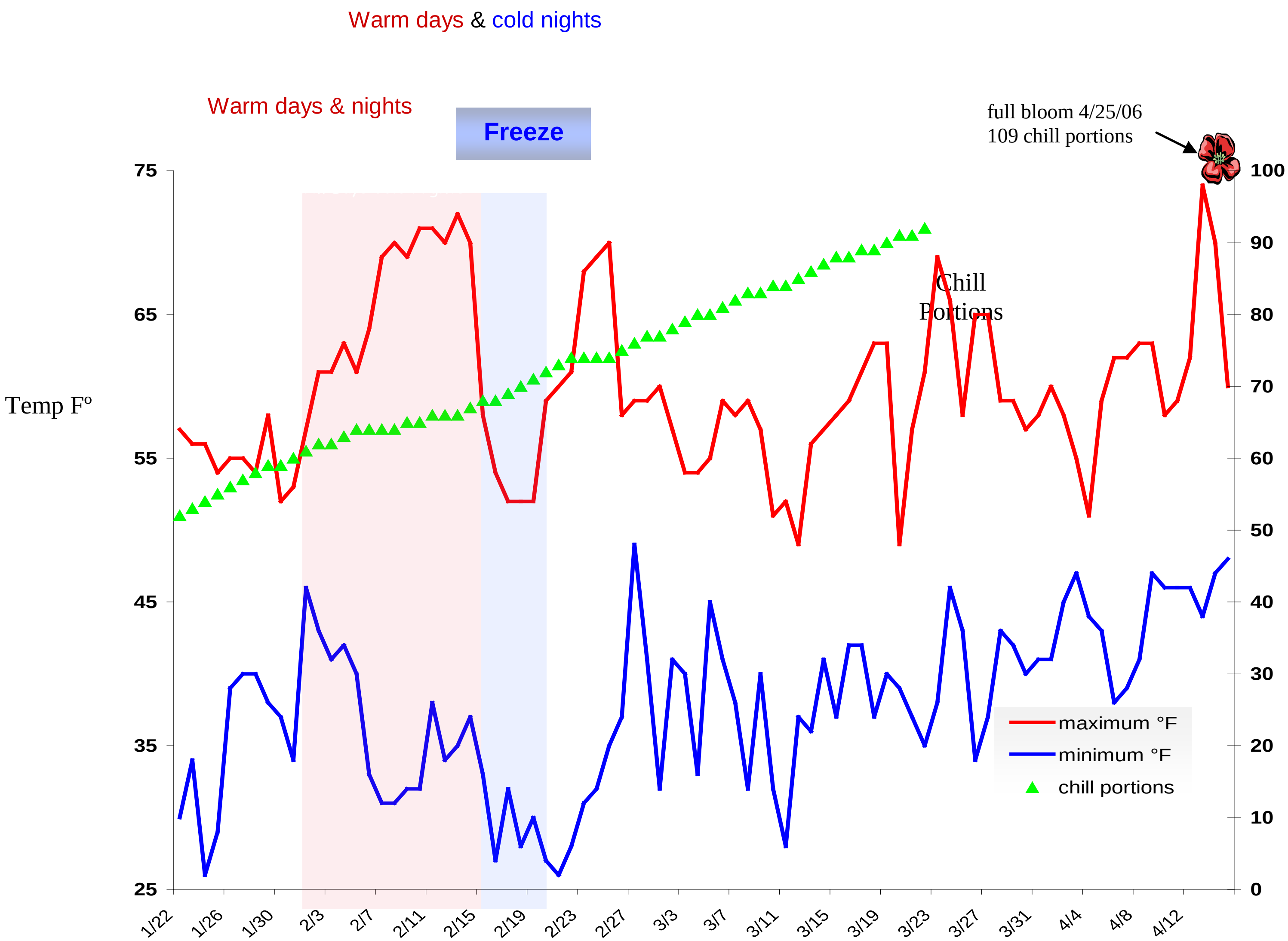


Figure 3. Temperature pattern during 2006 dormant period (daily minimum and maximum air temperatures).



We wish to acknowledge the support of the California Pear Advisory Board.

Selected references:

Allan, P. (1999) Measuring winter chilling in areas with mild winters. Decid. Fruit Grow. 49: 1-6.

Dennis, F. G. (2003) Problems in standardizing methods for evaluating the chilling requirements for the breaking of dormancy in buds of woody plants. HortScience 38(3):347-350.

Erez, A., And Couvillon G.A. (1987) Characterization of the influence of moderate temperatures on rest completion in peach. J. Amer. Soc. Hort. Sci. 112:677-680

Erez, A., Couvillon G.A., And Hendershott, C.H. (1979) Quantitative chilling enhancement and negation in peach buds by high temperatures in a daily cycle. J. Amer. Soc. Hort. Sci.104: 536- 540.

Erez, A., And Fishman S. (1997) The Dynamic Model for chilling evaluation in peach buds. 4th Peach Symposium. Acta Hort. 465: 507-510.

Erez, A., Fishman S., Gat Z., And Couvillon G.A. (1998) Evaluation of winter climate for breaking bud rest using the dynamic model. Acta Hort. 232: 76-89.

Fishman, S., Erez, A., And Couvillon G.A., (1987). The temperature dependence of dormancy breaking in plants: Two-step model involving a co-operation transition. J. Theor. Bio. 124: 437-483.