Using the Dynamic Model for Calculating Chill Accumulation in Bartlett Pear: Management of Dormant Sprays

Kitren Glozer[1], Chuck Ingels[2] and Steve Southwick[3]

[1] Plant Sciences Department, U.C. Davis
[2] Farm Advisor, Sacramento County
[3] *formerly of the Pomology Dept, U.C. Davis*

Summary: 2004-2005 Dormant Season

· 2% Volck oil applied between 20 Dec at 41 chill portions (505 chill hours) and 18 Jan (63 chill portions, 972 chill hours) advanced inflorescence and flower bud opening. No phytotoxicity was observed in any treatment.

· Fruit size (diameter and weight) of #1 fruit (fruit ≥ 2 3/8") was increased by all but the last dormant oil treatment, compared to the control.

· The percentage of undersized fruit (fruit < 2 3/8") was reduced by 63-85% by all oil treatments with the exception of the last. The control trees had 45% undersized fruit and the best oil treatment for improved fruit size had less than 7% undersized fruit.

· Number of fruit per tree was not statistically different among treatments, with the exception of a single treatment, although there was a trend toward reduction in fruit number due to oil treatments.

· Improvements in fruit size and number of #1 fruit did not statistically reduce overall yield

· Very few Type I rat tail blooms were observed (side blooms occurring during and shortly after primary bloom) and no treatment differences were found. The percentage of the Type I rat-tail bloom as a portion of the normal bloom was 1-3% among treatments.

· Chill accumulation started well before Nov 1 and timing of treatments, therefore, should use total chill accumulation from the start of the Dynamic Model

2% Volck Supreme oil advanced opening of both inflorescences and individual flower buds of 'Bartlett' pear when applied in late December and mid-January. Trees with oil applied 20 Dec had 12% of inflorescences open on March 9 compared to 2% in the control, and 9% of flower buds within open inflorescences were open compared to 0.4%, respectively. Five days later 63% of infloresecences were open in the Dec. 20 treatment, compared to 37% in the control (~41% of flowers open vs 15%, respectively). Treatment on 18 Jan showed similar advance. Full bloom dates, however, varied only slightly.

Total number of fruit per tree, fruit size (diameter and weight of #1 fruit), total estimated yield and percentage of undersized fruit (#2, 2 3/8") were evaluated for treatment effects. Fruit diameter was least in control fruit and those of the last dormant oil treatment (14 Feb, 82 chill portions). All other dormant oil treatments increased fruit size. Total number of fruit per tree was equal among all treatments except the oil applied on 18 January (#fruit reduced by 18% compared to the control). Weight of #1 fruit was highest in the 18 Jan and 20 Dec treatments, lowest in the last oil treatment and the untreated control. Total estimated yield (in kg) was equal among treatments, however, the %undersized was highest in the last oil treatment and the control (48 and 45%, respectively) and ranged from 7-17% in all other dormant oil treatments.

Problem and Its Significance:

Pear growers in the Sacramento River Delta, and to some extent, other pear-growing areas in California, use dormant oils for pest control and dormant bud growth stimulation. It is generally believed that well-timed applications can advance flowering, improve uniformity of flowering and fruit ripening overall, as well as time of fruit ripening. "Delayed foliation" or irregular bud break caused by inadequate winter chilling results in lower yields in the long term, poor tree architecture, less uniform fruit size and makes other orchard management practices (such as pest control) more difficult. Traditionally, dormant oils have been applied in early to mid-January based on experience and calendar date. However, bud development and full bloom dates may differ from year to year with variable weather cycles and chill accumulation experienced by the plant. With our trials in sweet cherries testing dormant oils and other rest-breaking chemicals, we found that the traditional calendar date model led to year-to-year variation in response that did not support bloom phenology well. In order to better time applications and control variation in flowering response, we investigated various models based on chill accumulation. Based on nearly 10 years experience with chill accumulation mathematical models and rest-breaking agents in sweet cherry, we determined that the Utah chill unit model (Richardson et al., 1974; Erez and Lavee, 1971) and the chilling hours modified 45 F model (Powell and Harker, 1995) were not as accurate as required to calculate chilling accumulation for sweet cherry in California. While chill hours were reasonably useful in predicting time of spray, year-to-year variation in chill hour accumulation and time of most effective response remained problematic. In 2002-2003 we compared our historic data from 1994 onward to a new model developed in the late 1980s and early 1990s called the Dynamic Model (see Erez references). We found that using chill portions to identify effective spray timing of rest-breaking sprays significantly reduced variation in response compared to the same accumulated chilling when calculated as chill hours.

Objectives: 2004-2005 Dormant season, bloom and harvest

8. Spray dormant oil (2% Volck) beginning approximately December 15 at 2 week intervals, continuing until February 14, or as judged appropriate by current grower practices. 2% Volck oil was used by approximately half of the European pear growers in the Sacramento Delta, thus was chosen for this trial season.
9. Apply the Dynamic Model to temperature data recorded in or near a commercial Bartlett pear orchard in the Sacramento River Delta for calculation of chill portions in winter 2004-2005 and evaluate the calculated results with respect to bud break and flowering behavior in Bartlett pear.
10. Compare the Dynamic Model, Chill hours and calendar date with respect to response.
11. Evaluate fruit set and harvest fruit quality as a function of treatment.

Plans and Procedures: 2004-2005:

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 (Joe Green Ranch on Lambert Road, Courtland) and compared to the California Irrigation Management Information System (CIMIS) Stations Lodi West and Twitchell Island for calculations of chill hours (CH) and Dynamic Model chill portions (CP). The experimental site was near Courtland and consisted of mature 'Bartlett' trees. Treatments included an unsprayed control and periodic applications of 2% Volck Supreme oil (applied at intervals of 41, 52, 63, 73 and 82 CP on 20 Dec, 4 and 18 Jan, 1 and 14 Feb, respectively). Actual chill portion accumulation when measured by onset of the Dynamic Model began 20 Oct on site, thus, the previously-stated chill portion accumulations are from that date. All treatments were applied with a commercial airblast sprayer at a volume of 100 gallons per acre to 6 single-tree replicates per

treatment within a single row and treated trees within a treatment 'block' were separated from the next treatment by 2 guard trees. Data was recorded from each treated tree, with inflorescences and flowers counted on 2 large limbs per tree, on opposite sides of the tree, selected prior to inflorescence opening. Date of first open flower was recorded and bloom progression recorded as percentage of inflorescences and flowers within inflorescences open on 9, 12, 14, 16, 18, 21 and 25 March. Numbers of Type I rat tail blooms (side blooms appearing during and immediately after the primary bloom) were counted on these dates and calculated as a percentage of the entire bloom (primary + Type I rat-tails).

Fruit were counted on the west half of each tree for estimation of crop load and yield was calculated from this number and the weight of 20 fruit selected at random from the counted half of the tree. This 20-fruit sample was used to determine percentage of undersized fruit (#2, less than 2 3/8" in diameter), and weight and diameter of a 10-fruit subsample was used to determine fruit size and weight of #1 fruit.

Statistical analyses and chill model calculations:

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, $P = 0.05$. For all percentage data arcsine transformation was made in order to meet ANOVA assumption of normality, although actual means were shown (Adler and Roessler, 1964). Chilling accumulation was calculated from hourly data and the Dynamic Model was used to calculate chill portions (Fishman et al., 1987; Erez et al., 1998, 1990).

Results and Discussion:

Chill accumulation began on 20 October at the trial site, so that 7 chill portions and 107 chill hours had accumulated by November 1, the traditional starting date of chill accumulation (Table 1). The chill accumulated at Twitchell Island, a CIMIS station often used by local pear growers for chill data, was less than that at our site; Lodi West CIMIS station showed even less chill. Chill hours calculated from the data were more variable from site to site than chill portions. We recommend using a starting date set by the actual temperature data, applied to the Dynamic Model to calculate chill portions accumulated.

Inflorescences opened earlier with 2% Volck oil applied on 20 Dec at 41 chill portions (505 chill hours) and 18 Jan (63 chill portions, 972 chill hours), such that 12% of inflorescences were open on 9 March in the first oil treatment and 2% in the control, and on 14 March 63% in the 20 Dec treatment, 60% in the 18 Jan treatment, but only 37% in the control (Table 2). By 18 March all treatments were statistically equal in %inflorescences open. When flowers open were counted within inflorescences, it was found that 9% of flowers were open in the earliest oil treatment on 9 March, compared to 0.4% in the control (Table 3). Three days later, the control had 5% flowers open and the 20 Dec treatment had 27% open flowers, the 18 Jan treatment had 15% open flowers. These two treatments tended to advance bloom most, although by 21 March, all treatments had equivalent percentages of flowers open. Dates for first flower open (Table 4) show that the 20 Dec treatment had the first flower open on 6 March, the 18 Jan treatment 1.5 days later, and the control on 8 March. Full bloom date was different only for the 18 Jan treatment and days from first flower to full bloom, while ranging from 12 days (18 Jan treatment) to 16 days (4 Jan treatment), there were no statistically significant differences. Thus, the oil treatment at 56 chill portions (972 chill hours) both advanced and compressed bloom, while the earliest oil treatment advanced the beginning part of bloom the most. The number of Type I rat-tail flowers was quite low across all treatments, and not changed significantly by treatment (Table 4).

The same treatment that both advanced and compressed bloom (18 Jan) also most increased fruit diameter and weight (of #1 fruit), most decreased the percentage of undersized (#2) fruit,

and while number of fruit overall was decreased, the estimated total yield was not (Table 5). The 18 Jan oil treatment increased the diameter of #1 fruit by 11%, increased the weight of those fruit by 25%, and decreased the percentage of undersized fruit from 45% of the total fruit sampled in the control to less than 7%. The number of fruit overall estimated from a half-tree count was significantly reduced by this treatment, however, the yield was not. Thus, the benefits of timing a dormant oil treatment appropriately, may be realized as an overall improvement in fruit size, quality and yield of premium fruit without a reduction in total tonnage. The equivalent effect is that of hand or chemical thinning, without the labor cost.

The use of chill portions and the Dynamic Model to time applications of dormant oil appears to have benefit on fruit quality. Although chill was not limiting in 2004-5, there may be benefit even in years when chill accumulation is adequate. Bloom was advanced by some oil treatments, although bloom still occurred over a period of several days, thus, damage from frost does not appear to be a major concern at this time. Repetition of these, and more rest-breaking treatments, are underway in the current dormant season to test these results.

We wish to acknowledge the support of the California Pear Advisory Board and the cooperation of the Joe Green Ranch.

Table 1. Chill portions (CP)[z] and chill hours (CH)[y] for the experimental site and two nearby CIMIS stations, prior to, and beginning November 1, 2004. Chill portion accumulation began Oct. 20 and chill hour accumulation began Oct. 11, 2004 at the experimental site.

Application date	Experimental site: from Nov. 1 /including chill prior to Nov. 1		Twitchell Island		Lodi West (near intersection of Hwys 5 and 12)	
	CP	CH	CP	CH	CP	CH
20 Dec	34/41	398/505	31	378	31	327
4 Jan	45/52	683/763	42	574	42	470
18 Jan	56/63	918/972	53	806	53	640
1 Feb	66/73	1127/1173	63	871	63	770
14 Feb	75/82	1219/1271	72	980	71	874

[y]1 hour # 45EF.
[z] Fishman et al., 1987.

Table 2. Treatment effect on inflorescence opening by 2% Volck Supreme oil applied to >Bartlett= pear 2004-2005; Courtland, Sacramento County, California. Chill portions (CP)[z] and chill hours (CH)[y] are based on temperatures recorded hourly on site in trial orchard. Chill portion accumulation began Oct. 20 and chill hour accumulation began Oct. 11, 2004 at the experimental site.

Treatment	Applied	Chill accumulation		%Inflorescences open						
				Successive dates in March, 2005						
		CP	CH	9	12	14	16	18	21	25
Control				1.9b[x]	10.9c	37.3b	72.5ab	85.2a	95.0a	99.1a
Oil	20 Dec	41	505	12.0a	48.2a	63.3a	84.1a	87.8a	89.9a	95.9a
	4 Jan	52	763	0.5b	24.0bc	51.6ab	79.9ab	84.1a	84.1a	99.1a
	18 Jan	63	972	1.9b	33.4ab	60.0a	86.7a	91.7a	91.7a	100.0a
	1 Feb	73	1173	0.0b	21.5bc	45.3ab	74.2ab	79.4a	80.9a	98.7a
	14 Feb	82	1271	0.0b	13.0c	31.7b	59.4b	80.4a	90.9a	100.0a

[x] Mean separation within columns by Tukey=s, $P = 0.05$. Percentages transformed by arcsine; actual means are shown.
[y] 1 hour # 45EF.
[z] Fishman et al., 1987.

Table 3. Treatment effect on individual flower (primary bloom) opening by 2% Volck Supreme oil applied to >Bartlett= pear 2004-2005; Courtland, Sacramento County, California. Chill portions (CP)[z] and chill hours (CH)[y] are based on temperatures recorded hourly on site in trial orchard. Chill portion accumulation began Oct. 20 and chill hour accumulation began Oct. 11, 2004 at the experimental site.

Treatment	Applied	Chill accumulation		%Flowers open						
				Successive dates in March, 2005						
		CP	CH	9	12	14	16	18	21	25
Control				0.4 b[x]	5.0 c	15.3 c	53.2 ab	76.8 ab	94.2 a	97.9 a
Oil	20 Dec	41	505	9.0 a	27.4 a	40.5 a	67.0 a	81.8 a	89.6 a	93.6 a
	4 Jan	52	763	0.3 b	8.3 bc	26.2 bc	57.7 ab	79.6 a	93.5 a	97.0 a
	18 Jan	63	972	0.4 b	15.1 b	34.3 ab	62.8 ab	84.6 a	94.6 a	97.4 a
	1 Feb	73	1173	0.0 b	8.6 bc	22.6 bc	49.4 ab	77.0 ab	92.9 a	98.1 a
	14 Feb	82	1271	0.0 b	4.0 c	13.6 c	43.3 b	66.0 b	88.7 a	93.0 a

[x] Mean separation within columns by Tukey=s, $P = 0.05$. Percentages transformed by arcsine; actual means are shown.
[y] 1 hour # 45EF.
[z] Fishman et al., 1987.

Table 4. Treatment effect on bloom dates by 2% Volck oil applied to >Bartlett= pear 2004-2005; Courtland, Sacramento County, California. Chill portions (CP)[z] and chill hours (CH)[y] are based on temperatures recorded hourly on site in trial orchard. Chill portion accumulation began Oct. 20 and chill hour accumulation began Oct. 11, 2004 at the experimental site.

Treatment	Applied	Chill accumulation		Bloom dates (first flower open, full bloom, days from first flower to full bloom) in March, 2005			%Type I rat-tail flowers (percentage of primary bloom + rat-tail bloom during or immediately after primary bloom)
		CP	CH	First flower (FF)	Full bloom (FB)	FB-FF	
Control				8.0 c [x]	21.3 ab	13.3 a	1.5 a
Oil	20 Dec	41	505	6.2 f	21.6 ab	15.4 a	2.7 a
	4 Jan	52	763	8.2 b	24.4 a	16.2 a	0.9 a
	18 Jan	63	972	7.5 e	19.8 b	12.2 a	1.4 a
	1 Feb	73	1173	7.8 d	22.8 ab	14.9 a	1.1 a
	14 Feb	82	1271	8.3 a	21.5 ab	13.2 a	3.2 a

[x] Mean separation within columns by Tukey=s, $P = 0.05$. Percentages transformed by arcsine; actual means are shown.

[y] 1 hour # 45EF.

[z] Fishman et al., 1987.

Table 5. Treatment effect on fruit size, crop load and yield components by 2% Volck oil applied to >Bartlett= pear 2004-2005; Courtland, Sacramento County, California. Chill portions (CP)[z] and chill hours (CH)[y] are based on temperatures recorded hourly on site in trial orchard. Chill portion accumulation began Oct. 20 and chill hour accumulation began Oct. 11, 2004 at the experimental site. Crop load based on #fruit counted on half of tree canopy.

Treatment	Applied	Chill accumulation		Size of #1 fruit[x]		%Undersized fruit	Crop load (#fruit/tree)	Estimated total yield (lb)
		CP	CH	Diameter (mm)	Weight (oz)			
Control				63.5 c[w]	3.3 c	45.0 a	500.7 a	91.5 a
Oil	20 Dec	41	505	66.6 b	4.0 ab	16.7 b	488.0 a	108.3 a
	4 Jan	52	763	66.2 b	3.8 b	10.0 b	434.3 ab	101.0 a
	18 Jan	63	972	71.0 a	4.4 a	6.7 b	360.0 c	92.7 a
	1 Feb	73	1173	67.6 b	3.9 b	15.8 b	419.3 ab	95.5 a
	14 Feb	82	1271	64.0 c	3.3 c	47.5 c	493.0 a	90.2 a

[w] Mean separation within columns by Tukey=s, $P = 0.05$. Percentages transformed by arcsine; actual means are shown.
[x] #1 fruit diameter ∃ 2 3/8".
[y] 1 hour # 45EF.
[z] Fishman et al., 1987.

Selected references:

Adler, H.L., and Roessler, E.B. (1964) Introduction to Probability and Statistics. (3rd Ed.) W.H. Freeman and Co. p. 261.

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

Allan, P., Linsley-Noakes G. C., Matthee G. W., And Rufus G. (1995) Winter chill models in a mild subtropical area and effects of constant 6°C chilling on peach bud break. Acta Hort. 409:9-17.

Arora, R.., L.J. Rowland, and K. Tanino. 2003. Induction and release of bud dormancy in woody perennials: A science comes of age. HortScience 38(5): 911-921.

Battey, N.H. 2000. Aspects of seasonality. Journal of Experimental Botany. 51(352):1769-1780.

Couvillon G.A., And Erez A. (1985) Effect of level and duration of high temperatures on rest in the peach. J. Amer. Soc. Hort. Sci. 110:579-581

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. 2000. Bud Dormancy; phenomenon, problems and solutions in the tropics and subtropics. In: Fruit Crops, (A. Erez, ed.) Klewer Academic Publishers, Netherlands. P. 17-48.

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., Couvillon G.A., And Hendershott C.H. (1979) The effect of cycle length on chilling negation by high temperatures in dormant peach leaf buds. J. Amer. Soc. Hort. Sci. 104:573-576.

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., Linsley-Noakes., and Allan, P. (1990) The Dynamic Model for rest completion in peach buds. Acta Hort. 276: 165-173.

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.

Erez, A. And Lavee, S. (1971). The effect of climatic conditions on dormancy development of peach buds: I. Temperature. J. Amer. Soc. Hort. Sci . 96:711-4.

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.

Jacobs, J.N., G. Jacobs and N.C. Cook. 2002. Chilling period influences the progression of bud dormancy more than does chilling temperature in apple and pear shoots. J. Hort. Sci. Biotech. 77(3):333-339.

Kobayashi, K.D. and L.H. Fuchigami. 1983. Modeling bud development during the quiescent phase in red-osier dogwood (*Cornus sericea* L.). Agric. Met. 28:75-84.

Kobayashi, K.D., L.H. Fuchigami and M.J. English. 1982. Modeling temperature requirements for rest development in *Cornus sericea*. J. Amer. Soc. Hort. Sci. 107:914-918.

Lang, G.A., J.D. Early, G.C. Martin, and R.L. Darnell. 1987. Endo-, Para-, and Ecodormancy: physiological terminilogy and classification for dormancy research. HortScience 22(3):371-377.

Linsley-Noakes, G. C., Allan, P., And Matthee G. W. (1994) Modification of rest completion models for improved accuracy in South African stone fruit. J. S. Afr. Soc. Hort. Sci. 4: 13-15.

Richardson, E. A., Seeley, S. D., And Walker, D. R. (1974) A model for estimating the completion of rest for ‘Redhaven and ‘Elberta’ peach trees. HortScience 9: 331-332.

Richardson, E. A., Anderson, J. L., and Campbell, R. H. (1986) The omnidata biophenometer (Ta45-P): a chill unit and growing degree hour accumulator. Acta Hort. 184: 95-90.

Seeley, SD.1996. Modelling climatic regulation of bud dormancy. In: Lang GA, ed. Plant dormancy. Wallingford: CAB International.

Snir, I., and Erez, A. (1988) Bloom advancement in sweet cherry by hydrogen cyanamide. Fru. Var. J. 42:120-121.

Southwick, S.M., K. Glozer and J.Grant. 2003, 2004. CCAB reports.

Thomas B. and V. Prue. 1997. Photoperiodism in plants, 2nd edn. London: Academic Press.

Valentini, N., G. Me, R. Ferrero and F. Spanna. 2001. Use of bioclimatic indexes to characterize phenological phases of apple varieties in Northern Italy. Int J Biometeorol (2001) 45:191–195.

Wareing, P. F. (1969). Germination and dormancy. In 'Physiology of Plant Growth and Development'. (Ed. M. B. Wilkins.) pp. 607-44. (McGraw-Hill: London.)

Weis, K.G., S.M. Southwick, and M.E. Rupert. 1996. Abnormal anther and pollen development in sweet cherry cultivars resulting from lack of winter chilling. ASHS 93rd Annual Meeting (Abstract 700).