USE OF THE DYNAMIC MODEL TO TIME SPRAYS OF REST BREAKING AGENTS IN CALIFORNIA PRUNE PRODUCTION, 2008

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PROBLEM AND ITS SIGNIFICANCE

Consistent cropping is essential for economically sustainable prune production. Virtually all commercial prune production in California is limited to a single variety ('Improved French'), and the full bloom "window" throughout the state can be limited to a single week. Consequently, the entire California prune industry is at risk of serious crop damage from even a short spike of extreme weather (cold or hot) at bloom.

Bloom temperatures above 80^{o}F severely limited prune fruit set in the southern Sacramento Valley in two out of the last three years (2005, and 2007) and in the entire state in 2004. Low production in those years has negatively impacted the entire industry, and raised doubts about the future of commercial prune production in this state.

California prune growers need a strategy to implement in existing orchards to reduce production risk from extreme weather at bloom. High rates of horticultural oil (4-5 gallons/acre) in the dormant spray has long been used to advance or tighten prune bloom, with a general window of late December through the middle of January targeted to advance bloom. This timing window was identified over time, with no published information available to explain field experience and potentially maximize effect.

Research based practices from other orchard crops in California and other fruit growing regions could help California prune growers maximize benefit from sprays intended to manipulate bloom timing. California sweet cherry growers routinely apply dormant sprays to "break" dormancy, advance bloom and harvest timing for logistics and marketing purposes (Glozer, unpublished data). Dormant applications of horticultural oil, fertilizer, or plant growth regulator are timed after a certain amount of chilling has accumulated. Chilling accumulation is measured using the 'Dynamic Model' (Fishman, et al., 1987)). This model was developed to track chilling accumulation in regions with warmer winters (Mediterranean climates) and has been extensively tested in Israel and South Africa (Erez, et al, 1990; Erez, et al., 1998.)

Advancing prune bloom may affect harvest date, which is closely related to the Growing Degree Days in the first 30 calendar days following 50% bloom (DeJong, et al., 2006). Extending prune harvest should allow growers and dryers to more effectively manage existing equipment and labor resources and, perhaps, reduce harvest/drying costs.

OBJECTIVES

1. Test a range of rest-breaking chemicals, including CAN17, Potassium nitrate, horticultural oil, and a range of surfactants to advance bloom timings in 'French' prune, improve fruit set, and advance harvest date (fruit maturity).

2. Test the Dynamic Model for assessing when to spray rest breaking agents, timing applications of rest-breaking chemicals to a sequence of accumulated chill portions.

3. Develop predictive model(s) to help growers plan application of rest breaking materials.

PROCEDURES

The 2007-2008 study was conducted in a mature prune orchard in Yuba County. The orchard is spaced 17' x 19' and planted in an north-south orientation. Oil was eliminated from commercial dormant sprays in the study block by arrangement with the grower. Chill hours (CH; Weinberger, 1956) and chill portions (CP; using the Dynamic Model; Fishman et al., 1987; Erez et al., 1998, 1990) were calculated from temperature data recorded by a datalogger in the study orchard. Fifteen treatments were established between fall, 2007 and the end of January, 2008 (Table 1). Several sources of N fertilizer were tested in combination with 2% Activator 90 non-ionic surfactant (NIS) to determine if low N/acre treatments were more cost effective than the CAN17+NIS tested in previous years (Table 2). All treatments were applied with a Stihl mistblower to individual trees using a spray volume calculated to be equivalent to 100 gallons per acre. A completely randomized block design with four single tree replicates per treatment was used.

In early March, 2008, three branches, 0.5-1.0 inch in diameter and of similar orientation, from each replicate tree were chosen from each of three locations in the canopy prior to flower bud break. One branch was selected on the western, southern, and north sides of the canopy at approximately 6' above the orchard floor. Buds (an average of 68 buds/branch) were counted prior to flowering. Bloom progression over time, starting at first flower open and ending with the last open flower was measured by counting open flowers at 2-3 day intervals from March 4 to March 21. Fruit set was determined in July, after small fruit drop. Fruit maturity (firmness and soluble solids) for fruit from control trees and those treated with oil on January 18 were evaluated for several weeks prior to commercial harvest.

Flower samples (100 flowers/tree) were taken to assess impacts of rest breaking sprays on flower nutrient levels. Harvested flowers were dried at 55^{o}C and processed and analysed for %nitrogen and calcium concentrations on a dry weight basis at the UC ANR Analytical Lab at UC Davis.

Dates on which each treatment achieved 50% bloom were estimated using the logit transformation after averaging flower opening data from the three branches per tree. These data were then used in an ANOV to determine if bloom dates were significantly different for each treatment. Flower analysis data were evaluated using analysis of variance and the General Linear Model (Statgraphics XV) followed by mean separation using Bonferroni to determine any treatment effect on flower nutrient levels.

RESULTS AND DISCUSSION

Bloom date was significantly advanced or delayed, depending on treatment material and/or timings (Table 3).

- Zinc sulfate 36% (20 lb/acre), alone, delayed bloom by an average of 2 days over untreated control.
- Tank mixing urea (20 lb/acre) with zinc sulfate (20 pounds/acre) advanced bloom by one day compared to untreated control.
- Horticultural oil (4 gallons IAP 440 oil/acre) at 30, 38, 50, or 60 CP advanced bloom by 3-6 days over untreated controls. Early treatment (30 CP) advanced bloom 3 days over untreated controls. Oil at later treatments (38 or 50 CP) advanced bloom by 5 days, significantly more than oil at 30 CP or untreated controls. Bloom date on trees treated with oil treatment at 60 CP was not significantly different from bloom dates following 30, 38, or 50 CP spray timings.

- CAN-17+NIS at the same timings as oil advanced bloom by 5 days over untreated controls, regardless of treatment timing.
- Horticultural oil (4 gallons IAP 440 oil/acre) + 1% Stiletto 28-0-0 advanced bloom by 5 days compared to untreated controls.
- Stiletto 28-0-0 plus 2% NIS OR potassium nitrate + 2% NIS advanced bloom by 5 days over untreated control when treated at 30 or 38 CP.

Fruit set was significantly increased or decreased by location of the flowers on the tree and treatments (Table 3).

- Zinc sulfate or zinc sulfate + urea applications at 2 CP did not significantly affect fruit set, although there was a trend to reduced set with zinc sulfate, alone. The addition of urea to the zinc sulfate appeared to reverse this trend.
- Oil sprays significantly increased fruit set over untreated controls. There was no affect of treatment timing on fruit set. Adding 1% 28-0-0 at 38 CP timing did not significantly affect fruit set compared to oil alone at that timing.
- CAN-17+NIS sprays did increase fruit set, but not for all application timings. The 30 CP application did not significantly increase fruit set, while the 38, 50, and 60 CP timings did significantly increase fruit set.
- 1% 28-0-0 + 2% NIS increased fruit set compared to untreated controls. The increase in fruit set was only statistically significant at the 50 CP timing.
- Potassium nitrate + NIS at 50 CP appeared to increase fruit set compared to set from untreated controls, but this increase was not statistically significant.
- Branch orientation significantly affected fruit set ($p=0.0143$). Flowers on the south side of the trees set more fruit than flowers on the north side of the tree. Percent fruit set from flowers on the west side of the tree was not significantly different from those on the north or south portions of the tree (Table 4).
- Differences in fruit set between treatments appear to be related to warm temperatures following the beginning of bloom. The lower set of later blooming treatments may be due to the warm weather of March 23-25 (Figure 1). Research by Vito Polito and lab at UC Davis indicates a reduction in pollen germination and pollen tube growth at temperatures above 75^{o}F.

Flower sample analysis showed no significant differences in N or Ca concentration on a dry weight basis (Table 5). Trees treated with CAN17 + NIS at 60 CP (Jan 30) had generally higher nutrient levels than other treatments.

As harvest approached, fruit from oil treated trees were less firm than untreated trees. However, there was no difference in firmness within a week of harvest. These results are consistent with previous studies. Data not presented. Comparison of fruit pressures is difficult, as differences in crop set may have affected maturity.

Deciduous fruit trees require 1) adequate chilling and then 2) adequate heat units so that economically sustainable bloom occurs.

A review of current and previous work with RBA in prunes shows a strong relationship between the chilling accumulated at the time of treatment and the heat accumulated between treatment timing and bloom (Figure 2). Similar relationships have been reported for apple, cherry, and peach using lab and field data. The more chilling, the less heat required for bloom.

In years with cool January temperatures, it appears that there can be no difference in bloom dates across a five week (30 CP) window of RBA application timings. This is may be caused by limited heat accumulation between spray dates (Figure 3) and natural reduction in heat accumulation requirements when more chilling is allowed to accumulate before the RBA is applied (Figure 2).

RBA spray timing prediction tool: A simple model to help prune growers synchronize RBA applications with Chill Portions has been developed. It is based on the following points:

- In the Sacramento Valley, chilling accumulation using the Dynamic Model follows an S-curve shape (Figure 4).
- During December and January, the coldest months of the year in the Sacramento Valley, the chilling accumulation using the Dynamic Model is virtually linear (Figure 4).
- The maximum possible chilling accumulation using the Dynamic Model is 0.83 CP/calendar day.

To calculate the earliest possible date for spraying oil at 40 CP a grower or their consultant should follow these steps:

1. Determine CP accumulation as of December 1 (visit www.fruitsandnuts.ucdavis.edu and click on “Weather services”. Then click on “Cumulative Chilling Portions” and select the weather station site closest to the orchard to be sprayed.
2. Subtract the Dec 1 CP accumulation from the chill portion accumulation when you want to spray.
3. Divide this number by 0.83, and that number = spray target date (as the number of days past Dec 1)

For example, a grower wants to spray oil at 40 CP to advance bloom. If he/she has 15 CP accumulated by Dec 1, then they should divide the difference between the target CP (40) by the December 1 CP accumulation (15) by 0.83. That is, (40-15)/0.83 = 30. This means that the earliest date that 40 CP will accumulate at his/her location is 30 days past December 1 or December 30. Once December 30 approaches, the grower should recheck with the UC Davis Fruits and Nuts Center to monitor current chilling to best match spray date to chilling. This model only provides growers with a ballpark estimate of THE EARLIEST TIME OF APPLICATION based on a certain target chilling date. This model provides growers with a planning tool for RBA sprays.

Table 1. Treatment materials, rates, and application timings measured as the number of chill portions at application during the 2007 – 2008 season. Yuba County.

-Chilling accumulated at spray timing-

Treatment	Rate/acre in 100 gallons of water	**2 CP**	**30 CP**	**38 CP**	**50 CP**	**60 CP**
Zinc sulphate	20 pounds 36% ZnSO4	X				
Zinc sulphate + urea	20 pounds 36% ZnSO4 + 20 lb urea	X				
4% oil*	4 gallons IAP 440 oil		X	X	X	X
CAN-17 + NIS**	25 gallons CAN-17 + 2 gallons Activator 90		X	X	X	X
4% oil + 1% Stiletto 28-0-0***	4 gallons IAP 440 oil + 1 gallon Siletto		X			
1% Stilleto28-0-0*** + NIS	1 gallon Stiletto + 2 gallons Activator 90			X	X	
KNO_3 + NIS	40 pounds KNO_3+2 gallons Activator 90				X	

*IAP 440 horticultural oil
**Non-ionic surfactant
** Stiletto foliar N triazone fertilizer 28-0-0 (Wilbur-Ellis Co.)

Table 2. Pounds of nitrogen/acre and relative costs/acre applied in rest breaking treatments in 2008. Costs are based on current prices in the Yuba City farm input market in December, 2008.

Treatment	Pounds N/acre	$/acre
25% CAN-17 + 2% NIS	53.50	100.71
40 lbs potassium nitrate + 2% NIS	5.20	76.80
1% 28-0-0 + 2% NIS	3.00	52.00
4 gallons of oil/acre	0.00	29.00

Table 3: The effect of rest breaking treatments applied following certain accumulation of chilling portions on subsequent bloom dates and %final set in French prune. Yuba County, 2008. Data points in a column showing the same letter are not statistically different (95% certainty).

Treatment	Application Date	CP at application	Date of 50% full bloom, 2008	% Fruit Set
Zinc sulphate	10/26/2007	4	March 21 a	10 a
Untreated Control	----	-----	March 19 b	13 ab
Zinc sulphate + urea	10/26/2007	4	March 18 b	21 bcde
4% oil	12/22/2007	30	March 16 c	28 de
4% oil	1/30/2008	60	March 15 cd	29 e
25% CAN-17 + 2% NIS*	12/22/2007	30	March 14 cd	17 abc
4% oil	1/2/2008	38	March 14 d	27 de
25% CAN-17 + 2% NIS*	1/2/2008	38	March 14 d	23 bcde
4% oil + 1% 28-0-0**	1/2/2008	38	March 14 d	25 cd
1% 28-0-0 + 2% NIS*	1/2/2008	38	March 14 cd	18 abcd
25% CAN-17 + 2% NIS*	1/18/2008	50	March 14 d	24 cde
1% 28-0-0 + 2% NIS*	1/18/2008	50	March 14 d	21 bcde
40 lbs potassium nitrate + 2% NIS*	1/18/2008	50	March 14 d	19 abcde
25% CAN-17 + 2% NIS*	1/30/2008	60	March 14 d	24 cde
4% oil	1/18/2008	50	March 13 d	28 de

*NIS = non-ionic surfactant. (Activator 90)
** Stiletto 28-0-0 foliar N fertilizer

Table 4. Percent final fruit set (July 9, 2008) for flowers on different sides of study trees across all treatments. n=60. Set values are not significantly different at the 5% level, based on Bonforoni mean separation, if followed by the same letter.

Location on the tree	Percent Fruit Set

South	24 a
West	22 ab
North	20 b

Table 5. Nutrient concentrations (% dw) in prune flowers sampled on March 14, 2008. Data followed by the same letter are not signficiantly different at the 5% level.

Treatment	Flower nitrogen	Flower calcium	Flower potassium
KNO_3 + NIS @ 50 CP	2.87 a	0.29 a	1.78 ab
CAN-17 + NIS @ 38 CP	2.92 a	0.30 a	1.73 b
1% 28-0-0 + NIS @ 50 CP	2.96 a	0.30 a	1.80 ab
4% oil @ 50 CP	2.97 a	0.32 a	1.81 ab
CAN-17 + NIS @ 50 CP	2.98 a	0.29 a	1.77 ab
CAN-17 + NIS @ 30 CP	3.01 a	0.31a	1.76 ab
CAN-17 + NIS @ 60 CP	3.10 a	0.32 a	1.87 a

Figure 1. Average temperature per hour VS. % Fruit Set for Shoots with 50% open flowers on certain dates. Yuba County. 2008

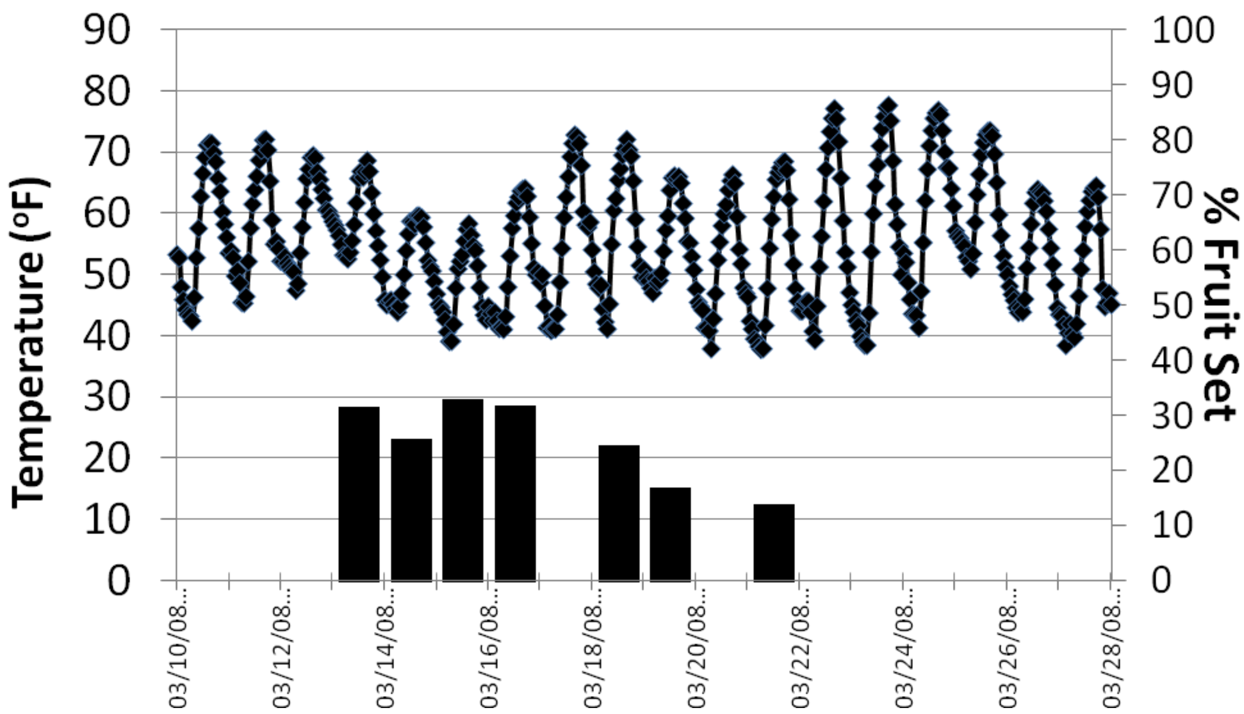

Figure 2. The relationship between chill portions accumulated by the time of rest breaking agent (RBA) application and heat (degree days, base 4°C) accumulated between RBA spray and bloom for bloom.

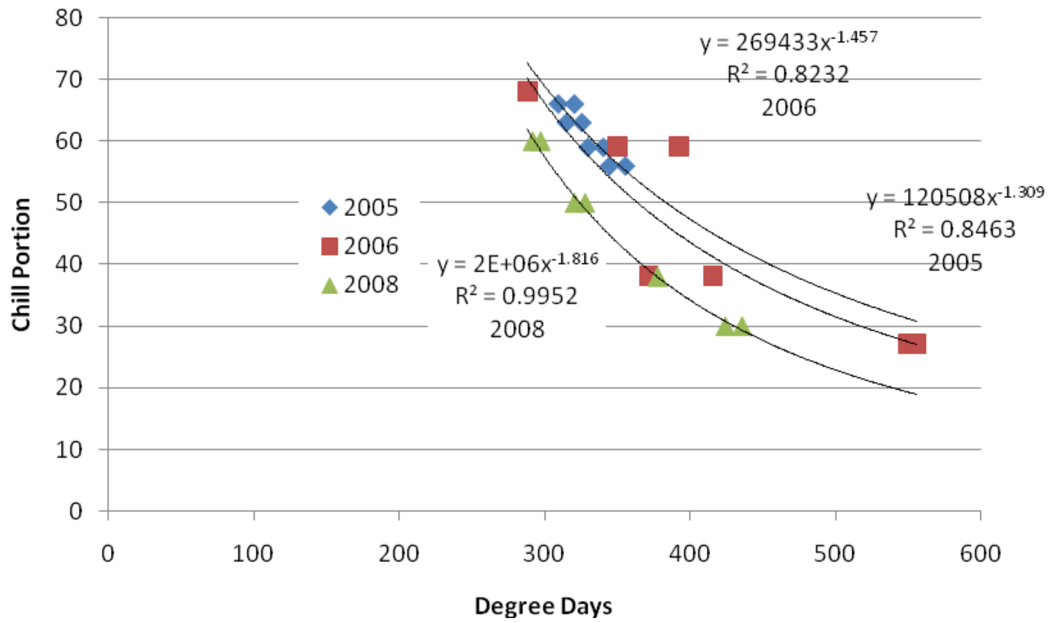

Figure 3. Heat unit accumulation (Degree days with 4°C base) in 2004-2008. Full bloom dates for three years are provided. Limited return bloom in 2007 affected determination of full bloom date.

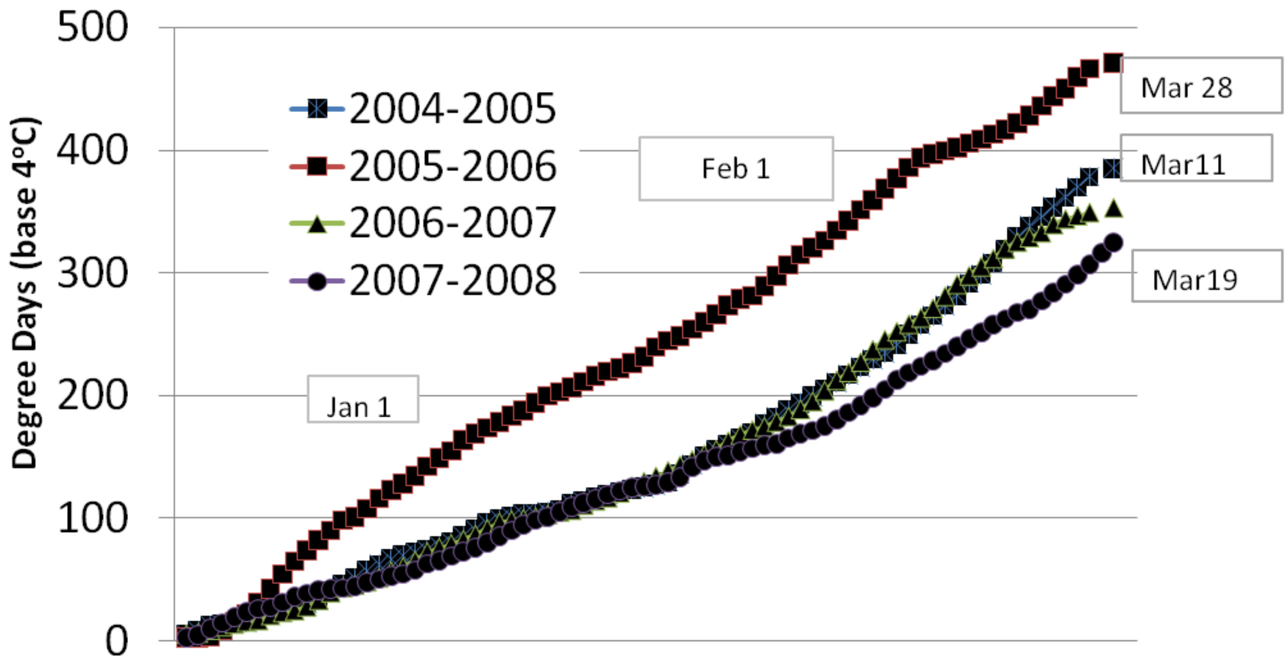

Figure 4. Hourly temperatures (^{o}F) and chilling accumulation using the Dynamic Model through the 2007-2008 winter. Yuba County.