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Fire Blight Management Experiences in Sacramento Valley and Coastal Mountain Pears of California 1973-2018

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Abstract: A model for predicting fire blight bacterial development based on accumulated heat above 65F was developed in the early 1970's (Van der Zwet, T. et al., 1988. Plant Dis. 72 :464 -472) http://www.apsnet.org/publications/PlantDisease/BackIssues/Documents/1988Articles/PlantDisease72n06_464.pdf). The system predicts times during which increased and decreased treatment frequencies are advisable or permissible based on heat accumulation leading into expected rain events or warm dew situations. Use of this system 1976-1999 generally resulted in improved control of the disease even in years predicted to be among the worst (Zoller, B.G. 2000.Proc.WOPDMC74:103-104. http://entomology.tfrec.wsu.edu/wopdmc/2000PDF/8-TREE%20FRUIT/Tree%20Fruit%2000-1.pdf..Subsequent experience using the system 2000-2018 has generally been supportive of the models predictions, although certain special case seasons such as hail occurring after infections have already occurred earlier, and low winter chilling resulting in extended bloom are thought to remain difficult at times in warm seasons.

The development of fire blight is favored by simultaneous warm, moist conditions following extended warm periods which have allowed build up and distribution of the *Erwinia amylovora* causal bacteria in flowers. The disease can limit the production of sensitive pome fruit cultivars to semi-arid areas of the United States. Unfortunately, the springtime conditions prevailing in California fruit districts may not always be dry and blight free. Ideal conditions for fire blight development occurred in the Central Valley region during 1997, 2000 and 2015, for example. A summary of pear fire blight management for the period 1976-1986 was published earlier (1). This article also included many details regarding monitoring and isolation procedures to detect the bacteria on the trees. Other summaries of California pear blight management through 1999 and 2002 also are available (2,3,4,5). The summary here logs experiences through 2018 and documents currently diminishing blight control in the Sacramento Valley compared with earlier efforts. In order to understand exactly how favorable the conditions must be for disease development, it is important to quantify the three necessary factors as follows:

Critical Factors Determining Disease Numbers

(1) Inoculum Potential. The number of older infections or "holdovers" from previous seasons is the inoculum potential. Research has pointed to the fact that successful blight control programs are predicated on meticulous holdover removal prior to bloom. Later applied chemical treatments, even at high frequency, are not capable of entirely substituting for this step prior to a season favorable for blight (Figures 1 and 2).

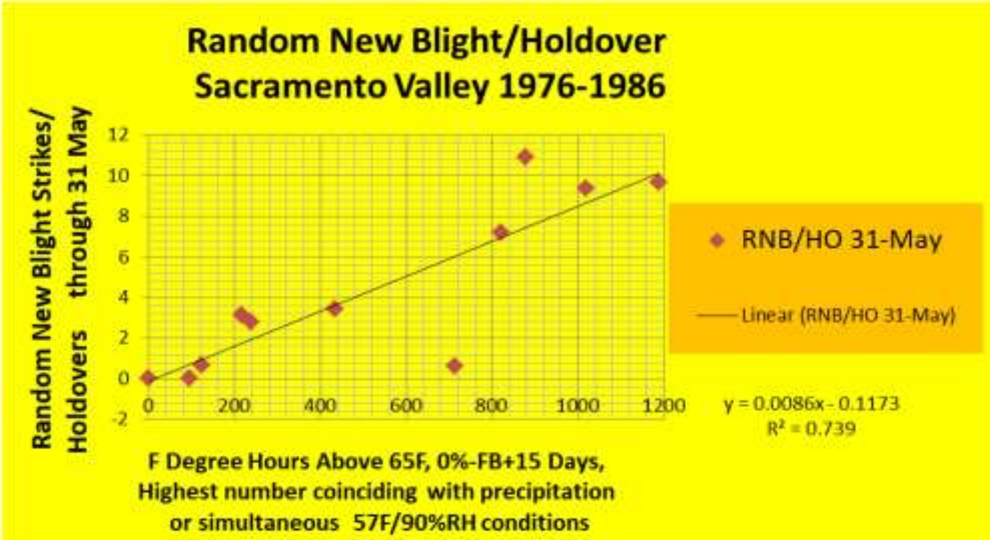

Figure 1

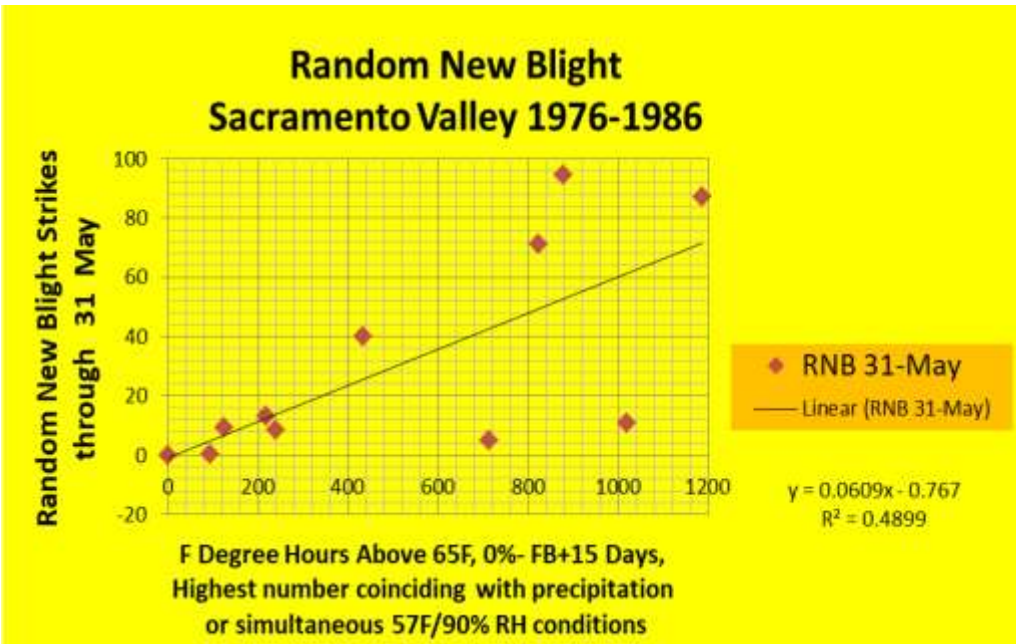

Figure 2

Figures 1 and 2. The relationship between Holdover (HO) inoculum potential and warm, moist conditions favorable for new infections can be seen in comparing these two figures describing Random New Infections (RNB) counted through 31 May 1976- 1986 in the mid-Sacramento Valley. When the RNB number is divided by HO number as in Figure 1, the data points are a better fit with one another than just using the RNB number as in Figure 2, and the linear R^2 value is much higher and more significant. It should be noted that these are random infections at least 2 trees distant from holdovers.

(2) Blossom Numbers. Blossom numbers are at a season maximum during the period early bloom through 15 days past full bloom, which makes this the most critical period in avoiding the potentially most devastating situations. Additional secondary bloom continues well past this time in late April and May. Because of warmer temperatures later in the season, these blossoms are very blight susceptible and require continuing protection. Observations suggest that infections occurring as a result of favorable weather through 15 days past full bloom increase the inoculum potential to impact the number of new infections that occur later in the season.

Seasons of low winter chilling can also result in a longer primary bloom period with increased early season secondary bloom, as well.

(3) Weather Favorability. Extended warm periods favor bacterial build up on the stigmas of blossoms. Rainfall or the simultaneous occurrence of warm humid conditions, often at night, supply a moisture film allowing movement of the bacteria to the actual infection courts, the nectaries of the floral cup of the flowers. Moisture also allows movement of bacteria from existing earlier infections into all sorts of wounds, such as from hail or frost, as well.

Application of Degree Hours to Describe the Disease in California

In California, two models are routinely employed in fire blight forecasting, particularly in the pear industry. The first is a mean temperature model, which is a simple rule-of-thumb predicting that fire blight bacteria are first present in blossoms, once mean temperatures of near 60° F are reached for the first time in bloom (6,7). The second model, the Zoller degree hour system, is a clinical prediction system which is an outgrowth of work describing growth of the pathogen *in vitro* and of heat summation concepts developed earlier to describe blight epiphytotics in New York and Illinois (8,9,10,11). It is based on blossom monitoring studies in California pear orchards as well as disease incidence observations (Figures 3-4) (1,3,12,13). Some aspects of this model have been incorporated into the Maryblyt model, which has found use in California apples (14,15,16). A related degree hour model has been developed in Washington State and is widely used in pears and apples (17)

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Figures 3 and 4. Percent of samples colonized with *E. amylovora* vs. degree hours above 65°F since the last three-day period with no temperature above 65° F. The rate of colonization of pear flowers becomes greater with increases in the accumulated degree hours prior to sampling. The reaching of 500 F degree hours in the Sacramento Valley (600 degree hours in Lake County) is used as a trigger to increase treatment frequency if it occurs during major bloom periods with rain or warm night conditions predicted.

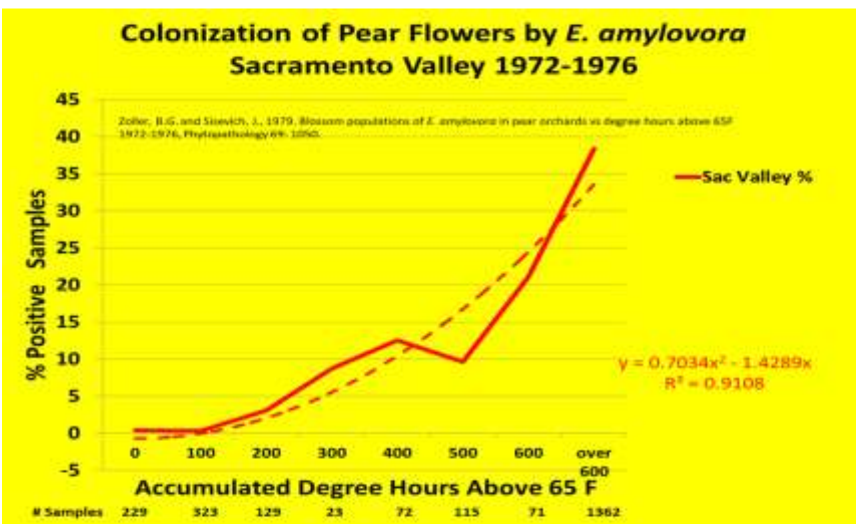

Figure 3

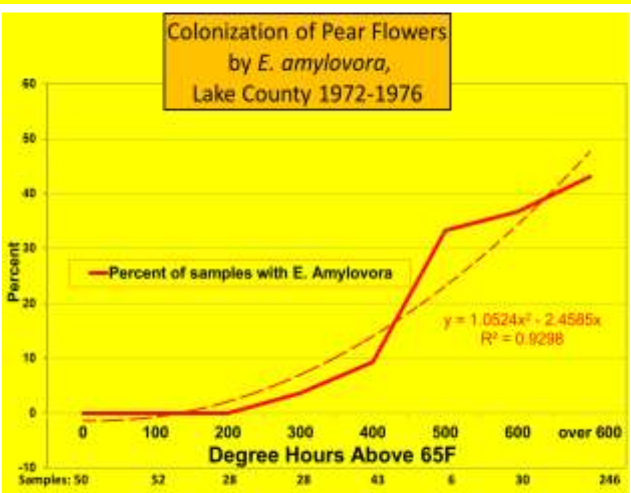

Figure 4

Use of the Zoller degree hour system is presented below as a 45 year (1973-2018) summary of commercial management of fire blight for the Sacramento Valley and North Coast pear districts of California. The accumulation of 150 degree hours (250 degree hours in the North Coast) above 65° F usually occurs on the same day in a district that the mean temperature threshold is crossed. Although both models predict the first appearance of the fire blight bacteria in blossom samples, the degree hour model allows treatment ahead of this time if necessary in very sensitive situations. These cases might include, for example, when overwintering cankers are too numerous, use of the model with the fire blight sensitive Starkrimson cultivar, or after a winter of particularly low chilling when cankers may be suspected to be more active leading into the season. The degree hour model also resets in those seasons which may trigger early season concern from warm temperatures during bloom, but which may subsequently revert to extended periods of cold temperatures less conducive to blight bacteria population development. The real value of the system, however, comes in those difficult times predicted to require increased treatment frequency to match increased bacterial multiplication and spread in orchards. This necessity to alter treatment response is dictated by the lengthy California primary and secondary bloom season of 2-3 months in pears.

Fire blight infection periods are certain wetting events supplying a moisture film, such as rainfall or the simultaneous occurrence of 57° F temperatures (or greater) with at least 90% relative humidity. These latter events can be read using hygrothermographs, and are likely related to the development of warm moisture films at night or early morning in the absence of rain. The role of moisture in movement of the pathogen from blossom stigmas to nectary infection courts has been described (18, 19).

During 1976 to 1986, extensive monitoring of individual infections occurring in 'Bartlett' pear orchards in the middle Sacramento district around Yuba City was performed. This assessment showed a high correlation of the ratio of new infections to older, holdover infections, with the number of heat units accumulated prior to those wetting events described above during the period early bloom through full bloom plus 15 days (1). The record of seasonal accumulated degree hours above 65° F prior to infection periods during 1973-2002 in the mid- Sacramento Valley area around Yuba City is shown (Figure 5). The record of new infections counted per block (divided by holdovers present) through May 31 is included so that the correlation with accumulated prior heat for the 1976-1986 period is apparent. Later experiences 1987-2002 can also be compared with the blight potential as predicted by degree hours. As can be seen, control experiences greatly improved since the 1976-1986 period in spite of many years with blight favorable heat unit accumulation (2,3,4,5).

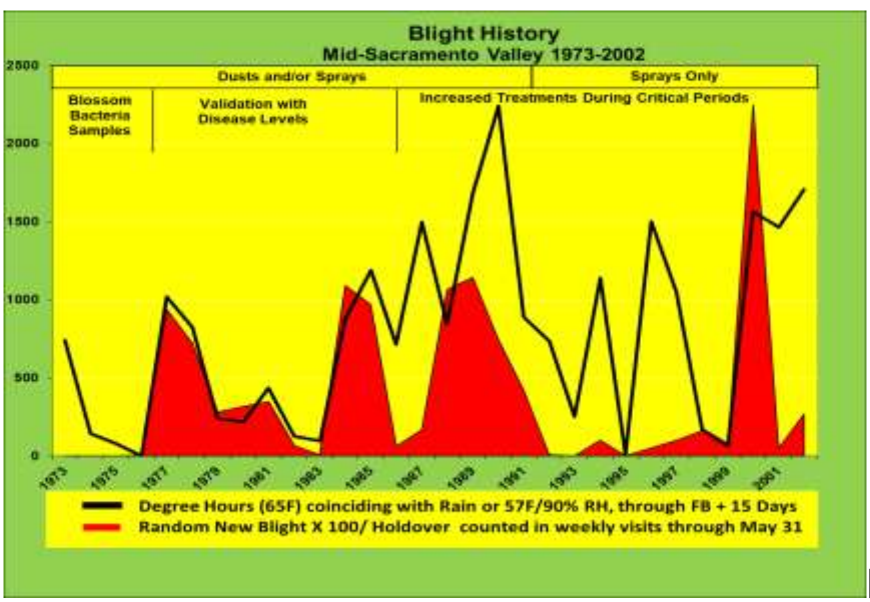

Figure 5

Figure 5. During the 1976-1986 period when infections were counted, the correlation between the accumulated degree hours preceding infection periods and the ratio of new infections to holdover infections was high; $Y=-0.15+0.00087X$; $r=0.86$; $P=0.001$. Increased treatment frequency in 500 F degree hour seasons 1986-2002 usually resulted in lower disease incidence, even in favorable seasons. Treatments applied are described in the caption under Figure 6.

Action Thresholds Suggested by Degree Hours in California

As a result of these experiences in the mid-Sacramento Valley in the 1980's, focus was begun on seasons of at least 500 F degree hour accumulations as ones which require shortened treatment intervals if these heat units occur during major bloom periods with high night temperatures. This has worked well enough that it was usually possible in the next 25 years to achieve good blight control even in seasons predicted to be among our worst. The final step allowing success in difficult years had been the total abandonment of dust formulations as treatments since 1991. Blight years had not been completely eliminated, but control success had become more frequent, even in years predicted by heat units in the past to have been potentially difficult. 1997 was such a season in which over 1000 degree hours accumulated in all Sacramento-San Joaquin Valley areas prior to infection periods during the most critical early bloom through full bloom plus 15 days time frame. In spite of this, orchardists utilizing the degree hour system achieved excellent blight control while much of the Central Valley pear and apple industries suffered blight so severe it even reached the local newspapers. A similar occurrence of over 1000 degree hours accumulated prior to warm, humid infection periods developed again in 2000 to devastate large areas of the Sacramento pear district, when winds and poor economic conditions hampered treatments. Unfortunately this occurred in some orchards in spite of the lessons of the previous 20 years!

Action thresholds expressed in accumulated degree hours [one degree hour = time spent 1 hour one degree above 65° F] for use of this system are listed in the UCIPM-DPR California Pestcast System and in the table, below (3,4,5).

(http://www.ipm.ucdavis.edu/DISEASE/DATABASE/fireblight.html)

Sacramento Valley Degree Hour System Action Thresholds

http://www.ipm.ucdavis.edu/MODELS/FBEA/aboutfireblight.html

Degree-Hours	Weather	Action
0	Not relevant	None
1-150	Rain predicted within 24 hours	Spray in the 24 hr. period prior to rain
150-500	Predicted rain or warm, humid weather where the Temperature is at least 57F and Humidity is at least 90%	Repeat treatment every 3-4 days with treatment in the 24 hours prior to predicted conducive weather
Over 500	Predicted rain or warm, humid weather where the Temperature is at least 57F and Humidity is at least 90%	Treat every other day during major bloom

Treatments are half treatments applied every other row. Higher thresholds (+ 100 added to each threshold) are used in the North Coastal Mountain districts as long as dormant season chilling has been typically greater than in the Sacramento Valley districts.

The thresholds for Sacramento Valley pear orchards are listed in the table. Higher thresholds are used in the colder, less blight prone northern California coastal mountain districts as long as winter chilling has been typically greater than Sacramento Valley areas. Freezing temperatures during primary bloom and later can also often delay pathogen establishment in these districts. Treatments refer to half treatments applied every other row. See the discussion below of current control materials used.

The key to successful use of the degree hour system is to carefully monitor the accumulation of heat [degree hours above 65° F since the last 3-day period of no temperatures above 65° F] each day. This allows identification of the frequency of treatments needed based on blossoms present. High accumulations (over 500 in the Sacramento Valley and over 600 in the North Coast) during the maximum blossom period of early bloom through 15 days past full bloom do not occur every year, but are to be especially feared when they do.

Watch the nightly weather forecasts to predict the continuing heat accumulation and to note approaching fronts, which can bring precipitation. However, sometimes no precipitation results, but infections can occur anyway, as the night temperature of moisture films (dew) increases with the first arrival of these sometimes-rainless changes in atmospheric moisture content. There is no control of this, only a too late reaction to these conditions as they pass. The best practice has been to increase treatment frequency according to the heat unit thresholds without waiting to see predictions of moisture. This is the only way to be protected ahead of a dangerous situation, which may occur and leave no chance to apply treatment in a timely fashion.

Current Control

Control treatments are currently oxytetracycline in fresh market orchards needing cosmetically clean fruit finish. In processing orchards and currently in organic orchards, copper materials are also used. Resistance to streptomycin is present in all pear districts (20,21,22,23,24,25). Consequently, this material must be used sparingly. Unfortunately resistance to oxytetracycline has now also been identified in the Sacramento Delta district, at least. The new antibiotic, kasugamycin, has just been registered in California in 2018, but for somewhat minimal use (26).

The fear of loss of antibiotics for control of the disease has spawned an on-going search for biological control agents the last 25 years. This effort in California has been funded by the California pear industry and carried out by University of California plant pathologists (27,28). A parallel effort is being carried out in the Northwest (29,30,31,32,33). The results to date are promising and a commercial product, Blight Ban A506™ has had some use for many years. This material has been suppressive of infection numbers, but needs antibiotic augmentation for success in most commercial situations. This is unfortunate, since the most utilized antibiotic, oxytetracycline, as well as certain pear scab fungicides and coppers may not be tank mixed nor be applied within 2 days of the biological control agent without reducing its colonization of pear blossoms (31). Use of alternative materials such as Blight Ban A506 in combination with antibiotics shows the complexity and integration necessary to manage fire blight if total reliance on antibiotics is to be avoided. Another new biological product is Bloomtime Biological with similar complexities of integration. The yeast product Blossom Protect has performed well in fire blight control studies but can contribute significantly to fruit russet in moist conditions. Fungicides such as sulfur are also inhibitory to the yeast that is the basis of this product (32).

Unfortunately, recent disease control experiences in the Sacramento Valley support the fear and discovery cited above that increasing resistance to the most widely used control product, oxytetracycline, may be contributing to reduction in control. Increasing numbers of infections in the mid Sacramento Valley district have been experienced in 3 of the last 5 years in spite of model specified increased treatment frequency in the critical period through full bloom plus 15 days (Figure 6)

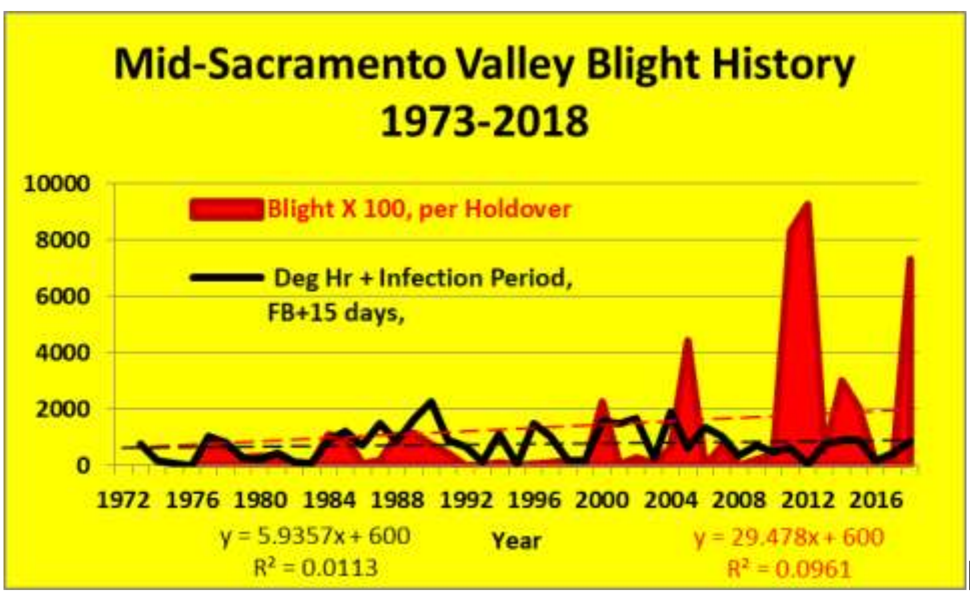

Figure 6

Figure 6. Continuation of the data of Figure 5 with the same increased treatment frequency in blight favorable bloom period years, to include 2003-2018 experiences. Disease levels have been much higher in the recent 2011, 2014, 2015 and 2018 favorable seasons. (Disease levels were also high in an unfavorable season 2012 as a result of some inadvertent treatment omissions at 16-21 days after full bloom when the season subsequently became favorable.

Every other row (EOR) half treatments of wettable coppers at 0.4-0.5 lb metallic copper equivalents (MCE) or copper dusts at 0.45 lb MCE/acre were applied in the 1970's. Oxytetracycline use began in the late 1970's and has continued to the present in the mid Sacramento Valley district at 200 ppm oxytetracycline (0.5 lb of 17-18% material) applied EOR 50 gal/acre. In the North Coastal mountain districts half these 200 ppm oxytetracycline amounts (0.25 lb) are used EOR 25 gal/acre, and mixed with 60 ppm streptomycin (1.2 oz of 17% material EOR 25 gal/acre). From 2013 to 2018 in the mid-Sacramento Valley orchards, streptomycin at 60 ppm (2.4 oz of 17% material EOR 50 gal/acre has been added to the oxytetracycline treatments, as well.
In one of 10 mid Sacramento Valley blocks in 2018 kasugamycin (32 oz of 2% material) was used once EOR 50 gal/acre.

For the last 7 years or so, delayed dormant copper treatments (at higher treatment levels than used during the bloom season (have been applied to Bartlett pears with oils just prior to green tip in the mid SacramentoValley district and partially in the North Coastal mountain district to blocks with higher blight experienced the previous year, especially in blight sensitive varieties like Bosc and Starkrimson. Research has shown that in 3 of 4 seasons of trial that the treatment delayed the epiphytic population development in blossoms, later (34).

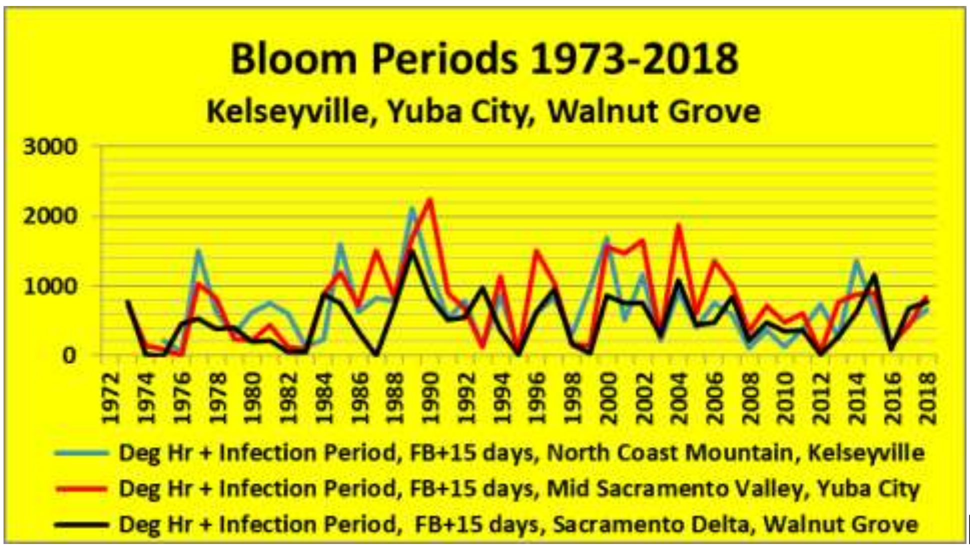

Figure 7

Figure 7. The maximum degree hours 1973-2018 coinciding with rain or warm dew (simultaneous 57^{o}F and 90% RH) infection periods during the critical bloom period through 15 days past full bloom is graphed for comparison of three pear districts, North Coastal Mountain (Kelseyville), Mid-Sacramento Valley (Yuba City) and Sacramento Delta (Walnut Grove).
The Mid-Sacramento Valley district has enjoyed the most favorable fire blight conditions over the years. Lower in the Sacramento Valley near Walnut Grove, closer to the gap in the coastal range that is the outlet to San Francisco Bay, more winter-chilling fog and cooler sea breezes create a typically earlier and crisper bloom situation with lower temperatures that have resulted in historically less fire blight. In spite of this, 2015 and 2018 resulted in predictably the worst blight in the state in this district. Part of the problem likely was that these conditions had not surfaced as severely for 11 years previously, and some may have become accustomed to an easier blight environment. Resistance to both streptomycin and oxytetracycline are known in the district (26). New copper materials were also used that are far lower in MCE than those used successfully in the 1970's, and may have received their first real test.

In the North Coastal Mountain district around Kelseyville, the bloom + infection period conditions are also generally much lower than the Mid-Sacramento Valley, especially when it is considered that treatment thresholds are 100 degree hours less than in the valley districts. Typically excellent winter chilling results in narrow bloom periods that progress with less heating. It is probably also helpful that blight cankers may need more time to become active in the spring under these conditions (35).

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