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Tree Recovery After the December 1990 Freeze

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On December 20, 1990, California was hit by a record freeze. After nearly two weeks of temperatures dropping to critical levels in many districts, this episode went down in history as perhaps the worst freeze on record. As we near the end of this century, 1913, 1922, 1937, 1949, and 1990 will be remembered as major freeze years. While the damage caused by the 1990 freeze was devastating to some growers, we have learned many lessons from events leading up to the freeze and in the subsequent recovery of orchards. This is a record summarizing some of these lessons.

The Nature of the Freeze

From a meteorological standpoint, the freeze of 1990 was arctic in nature. Very cold air swept boldly southward through the San Joaquin Valley, and then turned southeastward at the extreme southern end of the valley. While the bulk of this cold air moved eastward across the Coachella and Imperial valleys, some frigid air spilled down coastal valleys in the Santa Paula district and, to a lesser extent, the Santa Maria district. Redlands and western Riverside were impacted as the cold air mass swung eastward, while only the fringes of this arctic air invaded Orange and San Diego Counties.

There was no temperature inversion during the coldest nights; the further up you went above the surface, the colder the air became. This made conventional frost protection techniques ineffective in most areas. Further, the prolonged California drought enhanced the damage caused by the freeze. In spite of sophisticated irrigation systems, most groves had not received adequate winter rainfall for many years and lacked natural deep wetting and leaching. This decreased tree tolerance of low temperatures.

A detailed record of the low temperatures reached and their duration, by district, would be excessive for this report, but some of these records deserve mention. The temperatures and other data recorded were provided by Ron Hamilton, the Meteorologist in Charge of the Fruit Frost Office at the National Weather Service, Riverside. In Tulare County minimum temperatures were at or below 27 F for 14 consecutive nights, and eight nights were below 20 F. The lowest temperature ever recorded in Tulare County occurred east of Lindsay: 11.5 F. Avocados, primarily 'Zutanos', were severely damaged or killed depending on local situation and orchard conditions.

In the Santa Maria district, the freeze was a lot less severe. The coldest two nights had temperatures below 25 F for a duration of 12 hours. Shoot tips of most 'Hass' avocado groves were damaged, setting back the crop by 50-100%. In the Santa Paula district, damage was severe in localized regions, while other locations had very little visible damage. Minimum temperatures at monitoring stations ranged from 15 to 42 F on the coldest three nights.

The Riverside/Corona area had 10 nights of temperatures below 27 F in at least part of the district. The lowest temperature reached was 18 F, but generally lows were around 25 F on the nights during the freeze. Critical temperatures ranged in duration from 4 to 12 hours on these nights. Damage to 'Hass' was severe in some locations but slight in other areas.

In the Redlands district, critical temperatures were observed for a total of from 4 to 10 nights and ranged from 17 F on the coldest night to 25 F. 'Hass' and 'Gwen' avocado trees were defoliated in most areas and fruit were lost. As mentioned before, Orange County, southwestern Riverside County (Temecula area), and San Diego County sustained moderate to minimal damage, depending on location of groves.

Ron Hamilton had warned in January 1991 that continued drought over the Far West region would likely result in conditions favoring consecutive freezes, as historically reflected in the 1948/1949 and 1949/1950 freezes. At the time of writing (March, 1992), the industry is undoubtedly relieved to be through the frost season of 1991/1992, having had a very mild and wet winter. Heavy rains in March of 1991 and then a series of storms in January through March of 1992 have returned California to a more normal weather pattern.

Management Prior to the Freeze

Of all the management practices employed in grove care, irrigation prior to the freeze had the largest impact on the damage sustained. It was obvious, right after the freeze, which blocks in individual groves had received irrigation a few days prior to cold temperatures and which blocks were scheduled to be irrigated some days later. The relationship became even clearer as recovery progressed after the freeze. Recovery time was shorter in blocks irrigated a few days before the onset of cold weather.

Irrigated blocks sustained significantly less damage, although the prolonged drought conditions and a lack of deep soil water reserve probably aggravated damage on even the adequately irrigated blocks. Heat storage during the day and re-radiation at night occurs most in moist soils. The heat storage capacity is directly related to the moisture content. In addition to this, water stressed trees are physiologically less able to endure freezing temperatures than those not stressed.

Avocado trees stressed by *Phytophthora cinnamomi, P. citricola,* nitrogen deficiency, or any other management factor which reduced leaf canopies were damaged more than non-stressed trees. Pruning, thinning or stumping also effectively reduced canopies, and trees subject to any of these practices before the freeze sustained serious damage. Weed management is critical in avocado groves prone to freezing. Several 'Zutano'

groves in the Porterville area went into the freeze with weeds in the row middles. The trees in these groves were very severely damaged or killed, very likely as a result of colder temperatures resulting from weed-interrupted day heat storage and night re-radiation from the grove floor.

Protection During the Freeze

The December 1990 freeze was for many areas the first major freeze since 1949, some 41 years before. During the period between these major freezes, orchard heaters declined in use because of economic and environmental problems. Growers have been faced with having few choices for frost protection, and most must rely on good tree health going into the freeze as their most useful tool. Ron Hamilton of the National Weather Service estimated that groves would have needed four heaters per tree for complete protection in 1990. With no inversion layer, most of the heat from heaters was lost to the sky; only the radiant heat from the glowing stacks was available for tree protection. Oil costs, labor costs and availability, and pollution laws made the use of orchard heaters impossible in almost all situations.

Some growers erroneously used helicopters during the freeze and as a result aggravated tree damage considerably. Helicopters are useful when warm air near the inversion layer can be moved back down into the grove. In 1990 there was essentially no inversion layer and helicopters forced colder air into the groves they intended to protect.

Some avocado groves have flood or furrow irrigation, and where this existed, irrigation water was used to effectively add heat to the grove. Most groves have micro-irrigation systems, and used correctly, these were effective in providing some protection for the grove. However, power interruptions led to freezing in the emitters and laterals, essentially crippling this method of protection unless growers had backup generators. By the third consecutive night of freezing temperatures, irrigation systems were strained and orchard floors saturated, making this tool impractical.

Wind machines are generally not used in California avocado groves. Interestingly, wind machines in citrus groves were ineffective when run normally, because of the lack of an inversion layer. However, machines run at slow speeds were able to provide some protection by mixing heat moving up out of groves and re-directing downward and horizontally.

Action Taken After the Freeze

During the first few weeks following the freeze, growers were faced with assessing the extent of the damage to their avocado trees, and preparing for a period of recovery and the re-establishment of production. Farmers received advice from University of California Farm Advisors, Specialists and other faculty as well as from other grower organizations. We have attempted to summarize the bulk of the advice given, and action taken.

It was very difficult to assess the extent of freeze damage to individual fruit trees until new growth started in spring and early summer. The trees determined their own injury limits and resumed growth from living tissues. For this reason, farmers were advised to delay pruning for 6 to 12 months to determine the degree of damage to the trees and to establish the limit of recoverable wood. Previous reports from past freezes indicated that dieback may be worse if trees are pruned shortly after a freeze.

All regrowth from above the graft union, which is true varietal wood, was encouraged. Rootstock shoots which are of little use were removed. In some cases where the scion was killed, but the rootstock produced strong shoots, new scion material was grafted to the shoots in early summer. However, in most cases trees in this condition were removed and replaced with new nursery stock.

In most situations, farmers were advised to whitewash defoliated trees with a lime based or latex based paint. This was done as soon as the frozen leaves began to fall, and growers were advised to pay particular attention to the hot south and west sides of the trees. This minimized damage to the sensitive bark and cambium of avocado trees. Damaged and cracked bark invited occasional infections of wood rotting bacteria and fungi like *Dothiorella.* Although these infections appeared alarming, growers were advised not to apply dressings or other painted-on sealants to cracked bark, because this could have worsened bacterial or fungal infections. In most cases these pathogens were weak and disappeared soon after recovered trees began to regrow.

The irrigation requirements of freeze damaged trees were reduced in proportion to the amount of canopy lost. Growers were advised to irrigate trees according to their evapotranspiration requirements taking the degree of canopy loss into account. Growers needed to be very careful at this stage because a waterlogged rootzone would further have stressed the trees, as well as inviting *Phytophthora* infection.

The nutrition requirement of damaged groves was adjusted downward until the new canopy was well into a period of regrowth. In avocados, it was suggested that growers withhold nitrogen fertilization until midsummer (or longer), and reduce the amount of nitrogen when applications were eventually made. Generally, the natural soil fertility was adequate to meet the trees' nutritional requirements during the initial part of canopy recovery. However, in many groves farmers were advised to apply zinc sprays to the expanding young foliage.

In avocado groves where the fruit was not completely lost, growers were asked to meet with packhouse representatives and prioritize fruit harvesting depending on the urgency. This was determined according to the degree of fruit stem browning; completely brown stemmed fruit were harvested first, followed by partially browned stemmed fruit.

Recovery and Outlook for Damaged Groves

A few weeks after the freeze, most 'Zutano' growers in the Central Valley were asking themselves, and others in the industry, if the severe damage to their groves had ended their participation in the business of growing avocados. The temperatures recorded in many groves had been all time lows, and according to the literature and past experience

of the industry, the chance of trees surviving this freeze was poor. Several indicated that they would cut out their trees, replanting with citrus or other fruit crops. We spent time with these growers in their groves, and although the external appearance of most groves was dismal, there were almost always signs of living tissue in the main branches and trunks of the trees.

Now one of the more difficult tasks at hand was to convince growers to hold off with chain saws until the trees had been given a chance to begin regrowth from any surviving tissues. Most growers were anxious to begin pruning, feeling that they had to do something to improve the devastated appearance of their orchards. A few growers did go in a few weeks after the freeze and cut their trees back to 4-6 feet in height. Some got rid of the eyesore—completely, and cleared for a new crop. Most took the more common advice, but less popular action, of waiting until any regrowth appeared before pruning dead wood out.

The following months took even the most optimistic in the industry by surprise. Regrowth of 'Zutanos' was vigorous and arose from relatively high in the trees in most groves. Relatively few trees were frozen down to the rootstock. In some cases regrowth was from isolated pockets of living tissue high up in trees, and in cases where this pocket was isolated from other living tissues, the regrowth soon collapsed. However, the most common occurrence was for the trees to produce many vigorous shoots very rapidly and spaced all over the main framework of the trees.

There were reports that the trees dehorned or stumped early on after the freeze had more vigorous regrowth, and this may have been so in some locations. The problem with severely pruned trees however, was the overproduction of many closely spaced shoots which needed continuous thinning and heading back to reform the tree. In trees with most of the framework branches left intact, this job was easier because the overall tree shape was preserved. However, even in initially unpruned trees, excessive shoot production was a problem, and some pruning was done to thin out crowded shoots. There were no scientifically laid out trials in the Central Valley to determine the best method of post-freeze pruning of 'Zutanos', and this will likely be a grower debate for many years to come—especially in the event of another freeze this generation.

The same argument for 'Hass' in the Santa Paula district is far more clear, largely because the local Farm Advisor, Ben Faber, was able to establish pruning and stumping trials soon after the freeze. Although the results from this trial are not complete yet, it was obvious that the trees allowed to determine their own limits of damage before any pruning was done have shown better performance in regrowth than trees stumped or dehorned before shoots appeared.

Overall, the recovery of groves in the worst hit regions of our industry has been remarkable. Most industry spokespersons and growers predict a moderate crop for 1992—from fruit set on flowers produced barely a year after the freeze—, and see a return to almost normality by 1993.

Fig. 1 *March 1991—Freeze damaged 'Zutanos' near Porterville in the Central Valley. Trees were completely defoliated. (Photo by Paul Erickson).*

Fig. 2 *June 1991—Early regrowth on freeze damaged 'Zutanos'. Note the relatively high position of recovering wood. (Photo by Paul Erickson)*

Fig. 3. *July 1991—Mechanical pruning of freeze damaged 'Zutanos' some 6 months after the freeze. The trees had determined their damage limits; most wood above regrowth was removed with orchard machinery. (Photo by Paul Erickson)*

Fig. 4. *December 1991—Recovered 'Zutanos' showing vigorous regrowth after mechanical pruning. (Photo by Paul Erickson)*