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Terry D. Schaeffer*
Ventura, CA

Reflections from an Old School Frost Forecaster

I must preface my remarks about the Fruit Frost Service with a look back to the 1890s and early 1900s to see the reasons for its inception. In 1873, the USDA sent two young navel orange trees (from Brazil) to Eliza Tibbets in Riverside, California, and by early in the 20th Century, the citrus industry was exploding, becoming the number two economic power behind petroleum in California. Areas of southern California had near perfect environmental conditions, along with fertile soil, and it was not long that subtropical fruits like citrus and avocados adapted to the climate soon gained in popularity. During 1891, southern California experienced the "Great Disaster", a freeze of major proportions. Orchards were largely unprotected at the time and major damage occurred. Shortly thereafter, in 1893, the Southern California Fruit Exchange was established, becoming the California Citrus Exchange in 1905 and Sunkist in 1907; today's California Avocado Society formed in 1915 as the California Avocado Association. Both of these organizations were evidence that the subtropical fruit industry including avocados had become a major economic force.

In an effort to find protection from hard frosts and freezes, orchard heating experiments began about 1897. The methods were trial

and error. Prior to the development of effective frost protection, growers were not only subject to crop loss, but tree damage and loss as well. Crop failures due to a freeze, could spell disaster for local and regional economies. Active frost protection improved very slowly, and thus protected acreage grew slowly as well. The winter of 1897-98 was quite cold. In 1913 a very severe freeze occurred with heavy crop losses and even tree damage and loss. Record temps were recorded in many California cities, but just how cold was the 1913 freeze?

Unfortunately, there were no reliable or scientific measurements made in the orchards, but in the late 1970s, I had several conversations with Paul Leavens Sr. about the 1913 freeze. As my memory serves me, Paul was a teenager at the time. He told me that there was severe damage to the crop and trees resulting from the freeze. He noted that the tree bark snapped and split making popping noises during the coldest nights. For that to happen, the tree sap would have to freeze solid. Temperatures were probably somewhere in the 10-16 degrees range.

After the 1913 freeze California growers and related businesses demanded help from the Federal government so they could better deal with freeze events. Up to this point there were no real freeze warnings available. The government's response came via the old Weather Bureau when they commissioned an experienced meteorologist named Floyd D. Young to form a small department known as the Fruit Frost Service. Mr. Young, (he was always addressed as "Mr. Young"), set up a semi-autonomous department in 1917, and handpicked his staff. He sought out some of the Weather Bureau's best meteorologists, people that I know about and still admire to this day: Rathbone, Ellison, Lindquist, and Thompson, to name a few. The first Fruit Frost Office opened in the spring of 1917, and was actually not located in southern California, but rather Medford, Oregon. By the winter of 1917/18, associated Fruit Frost Offices were established in Pomona, Corona, Riverside, Redlands and other areas of southern California. These offices were dedicated to serve agriculture, by warning of impending frosts and freezes and to do related research.

A major freeze occurred in 1922 and a minor one in 1924. By this time, Mr. Young and his staff were a seasoned group and did a great job. Initially, they blanketed each frost district with thermometers and thermographs to survey and locate and "banana belt" areas and the cold pockets in each. Key temperature stations were established in the generally colder areas of each district; with 10-15 locations for each of the frost districts. Of course, every grower "needed" to have a key station in his grove. In addition, the service of testing grower thermometers in a subfreezing saltwater ice bath at 28 degrees was begun. During the 1930s and 1940s tens of thousands of thermometers were tested each fall by the frost forecasters. During their summer, these able meteorologists were assigned temporary positions across the western region as Fire Weather Forecasters.

Through the 1920 and 1930s there were no upper air observations, satellites, or radar to rely on. There were only a network of surface weather observation stations located at airports and harbors along with some ship reports. All the weather maps were hand drawn every few hours to identify and categorize weather and frontal systems. Looking ahead two or three days was the most that one could hope for. Frost forecasters paid close attention to ship reports in the Gulf of Alaska, and observations in Alaska and western Canada. With these limited tools I can only imagine how difficult it must have been to make advanced forecasts.

The Santa Paula Frost District was established in 1922, by Eckley S. Ellison, who through his exploits became a legend. The Santa Paula District was comprised of southern Santa Barbara and Ventura counties, and the San Fernando Valley. Ellison and his successor, H.D. Lindquist, surveyed about 250 locations over a period of 15 years or so. Some of the coldest locations they found were the key stations at West Bardsdale, Santa Rosa Valley, and Chatsworth. These two men, along with Mr. J.C. Thompson, who succeeded Lindquist in 1939, all turned out to be superb meteorologists. Each would distinguish themselves a number of times during their careers, particularly during and after the 1937 freezes.

Beginning December 31, 1936 until February 1, 1937 moderate to heavy frosts occurred somewhere within the California citrus

growing region on all but two nights. Growers were undoubtedly tired, stressed, worn out, and their resources depleted during this prolonged cold spell. On January 4th 1937, Mr. Young and his able cohorts warned of an impending freeze and exhorted growers and packing associations to stock up on smudge oil. This warning was amplified on the 6th, stating that this freeze would be comparable to 1922. The arctic air began to arrive in the Sacramento Valley on the night of the 6th, and in the San Joaquin Valley the following night. Firing began as early at 5:00 p.m. up north and prior to 7:00 p.m. down south. The damaging cold was delayed a night for southern California because of rain squalls the night of the 7th.

Temperatures ranged in the upper teens to the low and mid 20s for long durations. There was 100% loss in unprotected orchards in the San Joaquin valley, but in heavily protected orchards damage was much less. Stocks of solid fuel, such as the charcoal and coke used in some heaters were completely depleted. More than 600 vehicles waited in line up to 48 hours for solid fuel, sometimes in vain, as only the small daily output was available later in the freeze. Growers began to turn to wood, coal, old tires and other scrap rubber, peach and olive pits, and even straw and hay as a last resort. Heating oil held out better than the solid fuel, but on the night of the 10th, orchard heaters had to be simultaneously filled and lighted! Some growers, who had protected their crop up to this point, lost it on this night because they were unable to secure oil to refill.

Damage assessments were not completed before the second freeze was upon them. Exhausted growers had scarcely recovered as on the morning of the 18th, Mr. Young and his "boys" identified another major freeze on the horizon. Storage tanks had not been topped off, as there was a general feeling amongst growers that two major freezes in one winter was not possible. Grower associations were in the midst of negotiating the lowest prices possible before refilling their storage tanks. With this latest freeze warning in hand, all the stops were pulled. Back in those days, a 2-day warning was about all that could be hoped for with the forecasting tools available. The railroads began to run special oil

trains, and all motor transports capable of carrying oil were put into service. On the night of January 19th, the second round of cold air began to arrive, but fortunately for some there was intermittent cloud cover during the night and temperatures rocketed up and down throughout the night, which caused considerable consternation. Temperatures during the remainder of the freeze event fell into the mid-teens to low 20s, in many areas, again for long durations. Heavy firing began in many areas by 7:00 p.m on the 19th, but by the nights of the 24th through the 26th, the firing had slacked off depending upon the location.

In comparison to the1937 freezes to those in 1913 and 1922, even though scientific measurements were not available for 1913, the data does suggest that the 1937 freezes were colder than in 1922, and colder or about the same as the 1913 freeze. What makes the 1937 freezes most memorable is the length, breadth, and the extremely long durations at critical. The accumulated durations at 27 degrees Fahrenheit or below: San Joaquin Valley generally experienced 100-135 hours, with a max of 186 hours. Southern California racked up 40-80 hours, with a max of 188 hours. Desert valleys experienced 65-105 hours, with a max of 129 hours. Santa Barbara & Ventura counties only accumulated 10-40 hours, with a max of 68 hours. The coastal strip came out of the freeze very well. In general, for Santa Barbara and Ventura counties durations were much less than the rest of California because significant down valley breezes in the east to west valleys that helped to mitigate damage. Typically, Ventura and Santa Barbara counties will fare better than the remainder of the state during a major freeze.

Past freezes lasted 4 days in 1913, 4 days in 1922, and 11 days in 1937. Some other interesting aspects of the 1937 freezes: on a few nights the winds aloft were out of the north at 75 mph at 12,000 feet, and Mount Wilson recorded a low temperature of 7 F. Orchards in the foothills and in other banana belt regions, some which had not been below 32 for a good number of years, took a big hit. “Banana Belts” are generally hill sides and where there is good drainage of the cold air. During advection freezes the Banana Belts can be as cold or even colder depending upon down valley air movement in the main valleys. As to

the distribution of the all important Weather Forecasts during this time, an elaborate telephone tree had been devised in 1922, which promptly broke down as all local and long distance lines were tied up. The principle of the phone tree being that growers were to call their neighbors with the forecast, but when some left for their orchards to light pots, their neighbors were left to fend on their own! In 1930, CBS began to broadcast the frost warnings across California to the sponsorship ley and company Fruit gum). Grow- their local operator on the forecasts. was asked to limit periods. In spite volume was 190% the freeze. Movies,

for 76 key stations twice daily, thanks of William Wrig- (that's right Juicy ers could also call and she would pass The general public calls during freeze of that appeal, call of normal during socials, parties, and even church activities were halted during the issuance of the frost warnings. Usually there was a lull in telephone activity just prior to and during the frost warning, followed by a glut of calls as growers lined up their crews and ordered additional fuel or supplies. Quoting Floyd D. Young, "The extreme nervous tension under which growers and their families were laboring was reflected in their voices. In many cases, women burst into tears after obtaining the forecast by telephone".

1937 Freeze damage resulted in a crop loss of 30-40% or 35,000 carloads and another 10,000 carloads were downgraded in quality. Compare this to 60% in 1913, and 50% in 1922, and it was obvious that growers had learned effective frost protection, and heaters had been improved and placement techniques had been refined. It did and still does pay to frost protect. Tree loss was much less than one might have anticipated.

Lindquist noted after the epic freezes of 1937, when 45,000 rail car of citrus were lost or damaged in spite of effective and heroic efforts, that "The thousands of ranchers, including some professional men, such as doctors and lawyers, their farm hands, not to mention dogs, cats, chickens, cattle, and other critters were a tired and begrimed looking lot by the end of the prolonged cold weather".

Lindquist and Thompson each wrote papers highlighting aids

and techniques for forecasting in southern California. Each fall over the past 37 years, I have reread these insightful notes from these great men. Lindquist went on to distinguish himself once again as a fire weather forecaster, writing a number of papers on the subject, which I would reread each of 20 summers that I worked as a fire weather forecaster. Thompson went to become a Professor of Meteorology at San Jose State University, retiring in Santa Barbara. Ellison went on to set up the Fruit Frost Service for the state of Florida at Lakeland. During WWII, he was assigned top secret duty in the chemical corps researching smoke production to hide air bases from enemy raids and other research. After the war he became the Meteorologist in Charge at the Forecast Office in Portland, Oregon, where he spent the remainder of his career. These men were pioneers and giants within the field of meteorology; men for whom I have a great deal of respect.

During WWII great strides were made in weather forecasting and observations. By 1940, the Weather Bureau operated 35 radiosonde

stations (weather balloons), allowing for the routine measurement of atmospheric pressure, temperature, humidity, wind direction and speed. In 1942, the Weather Bureau received 25 surplus radars from the military, launching the network of weather surveillance radars.

The Weather Bureau, in cooperation with local telephone companies, made weather forecasts more accessible to the public in a handful of large U.S. cities in 1940 with recorded forecasts the public could access by phone.

Both the Army and Navy established weather centers in the 1940s, and the Weather Bureau began training and sharing atmospheric data with the military. Many experienced forecasters were called to

military duty to support the war effort in Europe and other parts of the world. Weather forecasting played an important role in key battles that influenced the outcome of World War II, including the Battle of Midway in June 1942 and the decision to invade Normandy in June 1944. The Allies had the advantage of knowing weather conditions in the Western Hemisphere and over the Atlantic Ocean, which aided their success in battle. Later in the decade, other advancements were explored and developed, like the use of computers for weather forecasting and the use of fax for transmitting weather maps. The 1940s also saw the first weather forecasts specifically to support battling forest fires.

William Rodgers was the forecaster for the Santa Paula District during the 1949 freeze when several inches of snow fell as low as sea level. Wind machines were becoming more common during this period, supplementing the heaters. Floyd D., "Mr." Young retired in 1956, and I believe grateful Sunkist growers gave him a new Packard as a reward for a job superbly done over the years.

Joe Mihelic was forecaster in charge during the two night freeze in December 1968, which was followed by a 100 year flood in January 1969, when more than 2000 acres of orchards were lost as the Santa Clara River broke its banks, and hillsides were deluged. The Santa Paula Frost Office recorded 34.55" for the season, with more than 17" falling over an 8 day period around the 3rd week of January. Seasonal rainfall

at Casitas Dam was more than 46" and in Matilija Canyon 89" was recorded.

Here is the list of forecasters that have served and run the Santa Paula Frost District and their respective years of service:

1922-1935	Eckely S. Ellison
1935-1939	H. D. Lindquist
1939-1944	J. C. Thompson
1944-1956	William Rodgers
1956-1976	Joe Mihelic
1976-present	Terry D. Schaeffer

In my first years in the Santa Paula district I teamed up with experienced Cooperative Extension Farm Advisors Bob Burns and Bud Lee. They helped me understand what the important weather issues for growers were at the time, and made the important introductions to my constituents. It was Bob Burns who went out in the field with me at night during the two freezes in winter of 1978-79.

That winter of 1978-1979 had hard freezes that occurred in the first week of December and again in the last week of January. This was notable as the earliest and latest freezes in the Santa Paula District. Dew points that December were recorded as low as 13 degrees below zero, yet in January they were as much as 30 degrees higher.

In the 1980's micro irrigation came into being which help make avocado plantings on the steeper hillsides practical. During hard frosts and some freezes the hillside plantings are warmer than the canyons and lower valley location. During that period we also experienced a number of mild winters thanks to the effects of El Nino, which was a phenomenon forecasters had begun to identify. Local growers helped me add a data line in the small office, where I was able to receive satellite pictures

2-4 times an hour. The Santa Paula District was the first small or mid size National Weather Service Office to receive real time satellite pictures.

January 1987's freeze was three nights in duration, characterized with a "reverse drift", which allowed damaging cold air to penetrate the "banana belt" areas. Reverse drift as I call it has the air moving up valley which in turn stopped the cold air drainage out of the side canyons. This reverse drift inhibited the natural cold air drainage, hence colder "banana belt" temperatures.

December 1987's "Christmas Freeze" occurred in another drought year. This was a more typical freeze with most of the damage occurring inland away from the coast. As the decade of the 1980's had passed, and orchard heaters were beginning to be phased out in favor of wind machines, helicopters, and sprinkler protection.

The December 1990 freeze lasted three nights. There was enough down valley air movement that the main E-W valleys sustained minimal damage. The more sheltered areas like the side canyons, the Ojai Valley, and the south coast of Santa Barbara sustained major damage, similar to the 1937 freezes. By this time, only a few ranches in the coldest wind protected areas deployed orchards heaters. Notably, this winter saw a continuation of the 1987-1988 drought; but fortunately this long drought was broken with the "March Miracle" when nearly 17 inches fell at the Santa Paula Frost Office during a 28 day period starting in February 27th.

The 1990's saw the proliferation of affordable personal computers as well as the employ of super computers back at the National Meteorological Center in Washington D.C. to assist in forecasting, communication, and recordkeeping.

The December 1998 freeze lasted four nights with moderate cold mostly mid to upper 20's but long durations in the colder locations. Intermittent down valley winds mitigated the cold in some areas.

Our most recent event occurred in January 2007, with the freeze lasting 2-3 nights depending upon location, with one exceptionally cold night. The more sheltered areas endured additional nights of mid and upper 20s. The Freeze of January 2007 will be a memorable event, much more severe than the hard frost of 1998, and generally less severe than the December 1990 freeze. I say generally, because the east-west valleys in our area came through the 1990 freeze pretty well. On the other hand, our more protected areas like Santa Barbara County, Ventura County

side canyons and the Ojai Valley were hit much harder, with longer durations at critical temperatures in 1990 than in 2007. Similar to the 1990 freeze, the hardest hit areas in California were the production areas like the Salinas Valley, and the San Joaquin and the desert Valleys.

Musings

I feel that since the winter of 1978-79, our regional climate has changed. The winters are milder overall and our seasonal rainfall has increased by 10%, and by as much as 15% in some areas. The freezes in January 1987, December 1987, and December 1990 were relatively short in duration, lasting for the most part, three nights. Depending upon your location, the 2007 freeze lasted two to three nights, with Ojai receiving seven nights of long durations at critical temperatures.

To tackle the increasingly complex business of farming, the weather tools we have made available to growers have morphed. Today, Agricultural Weather and Frost Warnings include: daily weather information and specific forecasts for 14 key temperature stations, a characterization of the nights temperature ceiling, timing of protection, freezing level. Our tools allow us to predict how long will freeze last and what to expect weather-wise after the freeze.

Summer inversion forecasts for soil fumigation have been added to assist berry growers in the district.

Orchard drying time predictions based on dew forecasts help picking crews minimize standby time on wet mornings.

Going back to the 1937 freezes growers have always had trouble obtaining fuel during significant freezes lasting more than three or four long nights. It is frequently due to insufficient storage and the logistic once everyone is clamoring for more fuel at the same time. If my memory serves me correctly the Limoneira Ranch in Santa Paula at one time had a storage capacity of more than 100,000 gallons of fuel. Today, using lessons learned from the past, many of today's wind machines which utilize propane systems, have larger tanks than in the past, and many growers have added centralized storage to match the expected durations.

Just how often do significant freezes occur? Looking back over the past 100 years, they can occur back to back as in January 1937, or two years in a row as in 1987. Generally speaking they occur every 7-8 years, and last 3-5 nights. Again generally speaking, the east to west valleys will likely experience a night or two of down valley breezes that

mitigate the overall durations at critical temperatures. Our more sheltered areas like the side canyons, Ojai Valley, and Santa Barbara County may experience a cold lasting an additional week. On occasion, wind machines have in a very localized sense exacerbated frost damage, such as on the lee side of wind breaks and if the wind machines happened to inhibit the normal cold drainage by causing a "damming and pooling" of the cold air.

Understanding the past events, and recognizing that cold temperatures are just part of the Southern California landscape may help growers make better long range decisions, but being the old school forecaster that I am, I'd like to close with some basic information on how to test the important instrument that drives decisions in dealing with the cold weather that inevitably will arrive. That is on testing and deploying your own orchard thermometers, and interpreting the forecasts that are available to you.

Testing Orchard Thermometers

The process is fairly simple. One of the original reasons the old Weather Bureau began to test thermometers back in 1917, was that there were tens of thousands of thermometers in southern California alone. In the "old days" in Ventura County alone we tested 8,000+, but today that number has now dwindled to the hundred. Formal testing by the Fruit Forecast Office's successor, the National Weather Service, is no longer offered, but here are the simple steps that you can take to test your own thermometers.

A. Make sure there is no separation in the red alcohol.
B. If there is a separation, these can sometimes be fixed by placing the thermometer in hot water of 130 degrees or so allowing the alcohol to rejoin in the reservoir at the top of the thermometer. Be careful that it is not too hot or you thermometer could crack.
C. Once any separation is fixed (it may not be), place thermometer into an ice bath, which is simply a bucket half full of ice. Add just enough water to cover the bottom 4 inches of the thermometers.
D. Allow thermometers to sit in ice bath 15 minutes, allowing them to reach equilibrium at 32 degrees.

E. Stir the ice slurry a time or two and then read your thermometer.

F. It should read 32 degrees. If it reads 33 you "subtract 1". If it reads 31 "add 1".

A fairly simple operation all things considered.

Thermometer Placement

Orchard thermometers should be located throughout the orchard with another "control" thermometer outside away from frost protection at eye level and protected from direct sunlight. Electronic and vehicle thermometers, along with data loggers, should be compared and tested for accuracy at the beginning of frost season.

Key Temperature Stations

Key Temperature Stations are the 14 stations that I currently forecast for. It is advisable to listen to all the temperature forecast paying particular attention to the key stations that are representative of your orchards colder areas. An example being, say your orchard is between Santa Paula and Fillmore. Over the years you have noted that your orchard is usually warmer than the Bardsdale key by 2-3 degrees and maybe a degree or so colder than the Sespe key. The forecast is: Bardsdale 24, Sespe 29 and Santa Paula 28. Then you would expect your orchard to come in at 27-28 degrees. Incidentally, 2 of these 3 stations have been in the same area since 1922.

Dew Point

Dew point and its significance to frost: the dew point is simply the temperature at which condensation (white frost or dew) forms. With a 40 degree dew point, we expect to see temperatures falling at a gradual pace, slowing further once condensation occurs. With a dew point of 10 degrees we'd see temperatures drop like a rock after sunset, just like occurred in December 1978. With variations in local dew points, temperatures can vary widely from area to area and likely fluctuate considerably during the night. With this low dew point example, it would be considered a black frost night (no white frost). A black frost may be more dangerous as temperatures can fall as much as 10 degrees in an hour once the warming east winds die off. The lowest dew point that I have measured was minus 13 degrees in Santa Paula.

Wet soil verses dry soil

With wet/moist soil, temperatures across the district will tend to be grouped closer than when the soil is dry. With dry soil one can expected large variations in temperatures from area to area. Passive frost protection is keeping the top 12 inches of soil in your orchards moist. Ground cover may well exacerbate frost damage if the soil cannot warm during the daylight hours.

Temperature Ceilings

Temperature ceilings are important as well. A low temperature ceiling means that protection with wind machines and helicopters will work well. On the other hand high temperature ceilings will be more problematic. It is always better to stay ahead of the frost curve starting protection at the proper time. Once temperatures drop below critical it is more difficult to bring them back to where you would like to see them.

Listen to your weatherman

It is important to keep up to date with the forecasts as a hard frost or freezes can usually be identified a week or more in advance. A light frost is a bit trickier.

Being the sentimental type who enjoys the interaction with my clients, I must say that I miss the 1970s and 1980 monthly Citrus – Avocado meetings and BBQ's in Santa Paula. A lot of good information was learned and shared in those meetings. In 1984 we, along with the help of the Farm Bureau put on a 4-5 hours frost protection workshop dealing with relevance of orchard heats, wind machines, helicopters, sprinkles for frost protection as well as the danger of evaporative cooling with low dew points. I thank you for the opportunity to continue to serve your industry, and the opportunity to provide this retrospective look over my career.

**The author is the 2011 recipient of the Oliver Atkins Award, and served as the lead forecaster in the Agricultural Weather Service's Santa Paula office from 1976 until its closure in 1996. He continues to serve the Santa Paula district's growers as proprietor of "Weather by Schaeffer"*