Project No: 5937 (Termination Report)

Title: Influence of Evaporative Cooling on Fruit Development of Fuji Apples

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Reporting Period: 1993-94

Accomplishments:

1. Measured the effects of evaporative cooling (EC) application rates on:
   a) air, fruit core and skin temperatures,
   b) fruit and tree growth,
   c) fruit quality, defects, packout and storability,
   d) leaf gas exchange, photosynthetic capacity and water relations.
2. Measured the effect of fruit bagging on fruit core temperatures.
3. Measured the effects of EC rates and fruit bagging on skin color changes and sunburn.

Results:

Evaporative cooling treatments were established in a 5-acre block of a double row, V-trellis commercial Fuji/M.9 orchard (Pepperbridge Farm) near Walla Walla. EC treatments consisted of different application rates, with all treatments employing cycled control based on fruit core temperatures. In 1993, three EC application rate treatments were established: 1) 30 gal/min/A (GPM/A), 2) 60 GPM/A and 3) 30 GPM/A cycled from fruit core temperatures in the 60 GPM/A plot (30/60 GPM/A). Cycling was controlled from average core temperatures of the same 4 fruits located in the upper canopy of the 30 and 60 GPM/A plots. The 60 and 30/60 GPM/A treatments each comprised <0.25 A. The uncooled control was even smaller, about 50 ft of an outside row. In 1994, the uncooled control was expanded to about an acre, with three EC treatments consisting of equal-sized plots with application rates of 30, 45 and 60 GPM/A. Cycling was controlled from average core temperatures of the 4 hottest fruits out of 20 fruits distributed uniformly within the canopies of each plot. Critical core temperatures for initiation of EC each day were decreased as the season progressed. All EC treatments were applied with overtree Nelson R10 Rotators spaced to maximize application uniformity. EC water was supplied from wells, and in 1994 was amended with 3-5 ppm CH2O Orchard Guard to reduce deposition of salt residues.

When the EC system cycled on a day with maximum air temperature near 92°F, orchard air and fruit core temperatures fluctuated synchronously with amplitudes of 9 and 4-5°F respectively. The core temperatures of uncooled fruits were 5-7°F hotter than those of 60 GPM/A cooled fruits. Core temperatures of bagged fruits exceeded those of unbagged, uncooled fruits by nearly 3°F from 4 p.m. through early night. Air temperatures within the orchard canopy appeared to be unrelated to EC application rate. Core temperatures of the 4 hottest fruits in each plot varied by up to 9°F in the 30 and 45 GPM/A treatments and uncooled control, but by only 4-5°F in the 60 GPM/A treatment. Average core temperature of these 4 hottest fruits was not consistently related to EC application rate, yet the average temperature of these fruits was still 9-14°F hotter in the uncooled control than in the cooled treatments. The diurnal relationship between fruit core and skin temperatures on the east, southeast, southwest and west sides of fruits fully exposed to the sun was evaluated on several days in 1994. On a day when a maximum air temperature of 95°F was reached just before 3 p.m., the maximum core temperature was 104°F at 4 p.m. The highest skin temperatures shifted during the day from the east to the west side of the fruit, with a maximum of 112°F occurring on the west side at almost 5 p.m. While these data can be used to model the air-core-skin temperature relationships of fruits fully exposed to sunlight, measured core temperatures of fruits within the canopy indicate that the variability among the fruit population is large at any particular time.

Measurements of fruit skin color with a Minolta Chromameter during both 1993 and 1994 indicated differences between EC application rates. For most of the cool 1993 season, the skin color of the sunlit exposed side of 30 GPM/A cooled fruits was darker, redder and less yellow than fruits cooled at 60 GPM/A. In the hotter 1994 season, the response of skin color to EC application rate was the opposite, fruits cooled with 45 and 60 GPM/A were less yellow after late July than fruits cooled with 30 GPM/A, and darker from mid-Sept. to early-Oct. In both years, the uncooled fruits were less red, and much lighter and yellower than cooled fruits. While the color differences between cooled and uncooled fruits continued through harvest in 1993, there were only slight differences in color between them by the main harvest in 1994. Also, there were only minor differences in skin background color between cooled and uncooled fruits by the 1994 harvest.

Sunburn could be tracked with the Minolta Chromameter, and consisted of elevated yellow, decreasing red and lightening of the sunlight exposed skin. While these sunburn responses were measured on uncooled fruits from mid-July through early-September in 1994, they were largely absent by harvest when compared with cooled fruits. Verification of this sunburn "recovery" awaits packout analysis in Jan. 1995.

Artificial field and environmental chamber experiments were conducted in 1994 to examine the short-term relationships between light, temperature and sunburn. Preliminary analysis of a diurnal experiment with detached fruits suspended from the top trellis wire on a hot day in late July indicated that skin color progressively lightened and yellowed on the east, southeast, southwest and east sides of the fruit. Green color, however, decreased mostly on the southeast side of the fruit, but not at all on the west side. These results suggest that pigment changes may vary on the fruit as different portions of the skin surface are exposed to sunlight during the day. Preliminary experiments were conducted in a plant growth chamber modified by installing higher output metal halide lamps and UV-A lamps. Approximately 24-hr exposure of fruits to skin temperatures up to 115°F and light intensities 25% of full sunlight, resulted in increased yellow color of exposed skin. A chamber capable of higher light intensities that simulate solar radiation is required to test the effects of orchard management practices (e.g. EC) on sunburn.

In 1994, Japanese apple bags were removed at intervals from mid-Aug. through mid-Oct. and skin color was measured from removal through harvest. The only significant change in color of the sunlight exposed side, between removal of the outer and inner bags, was increased yellow. Regardless of bag removal date, the color of exposed skin rapidly darkened, became redder and less yellow after the inner bag was removed. At the earlier removal dates, skin color plateaued rapidly, then changed only gradually until harvest. Removal of the inner bag at 27 and 10 days before harvest resulted in nearly identical skin color at harvest. Background skin color at harvest was lighter as bag removal was delayed. At all bag removal dates, there was a significant increase in yellowing of both exposed and background skin color during the last three days before harvest. Skin color changes near harvest may be more sensitive in bagged than unbagged fruits.

There were no differences in fruit growth between EC treatments; however, the rate of increase in diameter and final size of uncooled fruits were less than EC fruits in both years. Differences in soil water did not explain these differences. EC improved leaf water status and increased gas exchange. Lower leaf temperatures from EC would be expected to improve photosynthetic rate, however, EC did not consistently improve the rate of sunlit leaves. There were minor structural changes in specific chlorophyll antennae pigments which may confer improved efficiency of light harvesting by leaves.

Fruit quality was not appreciably different between cooled and uncooled fruits. Titratable acidity was slightly higher at the higher EC rates in both years. While this could indicate delayed maturity, other measures of maturity (e.g. soluble solids, firmness, watercore, ethylene evolution, background and flesh colors) did not support this conclusion. Packout analysis of 1993 fruit stored in regular atmosphere storage until mid-Dec., indicated few differences between cooling treatments, except fruits cooled at 60 GPM/A appeared to have a higher percentage in WA Extra Fancy and Fancy grades. WA Extra Fancy grade peaked on 56's for all cooled treatments in 1993, however, fruits cooled at 60 GPM/A had a higher combined percentage of 56's plus 64's than the other EC treatments. The uncooled plot in 1993 was too small for packout analysis. Commercial harvests from 1994 cooled and uncooled treatments were stored in CA storage; packout and cull analyses will be run in Jan. 1995

Commercial packout of the 1993 treatments indicated that the percent culls was 13-14% for the 30 and 60 GPM/A treatments, and 17% for the 30/60 GPM/A treatment. Cull samples from 1993 cooled and uncooled treatments were analyzed for defects. Sunburn was slight on both cooled and uncooled fruits, but a higher percentage of russeting occurred on cooled fruits. A majority of culls showed lenticel breakdown, with >25% of the culls having 5 or more spots. Incidence of staining was 30-40% regardless of treatment. Based on a preliminary examination of a small sample of 1994 fruit stored for one month in regular atmosphere, a significant percentage of stain was present on cooled, uncooled and bagged fruits.

Publications:

1) Andrews, P. K. 1991. Water management in tree fruit production, p. 64-72. Proceedings 87th Annual Meeting Washington State Horticultural Association.
2) Andrews, P. K. 1993. Tree water relations: How does evaporative cooling fit in?, p. 87-92. Proceedings 89th Annual Meeting Washington State Horticultural Association.
3) Oral presentation to Nelson Irrigation Corp. dealers in Dec. 1993 and Jan. 1994.
4) Andrews, P. K. 1994. Physiology of water-related stress in fruit trees, p. 23-36. *In* Tree fruit irrigation (K. M. Williams and T. W. Ley, eds.). Proceedings of the Washington State University Irrigation Management Shortcourse. Good Fruit Grower, Yakima, WA.

R. G. Evans' publications are cited in the progress report for his EC project.