

CENTRAL VALLEY POSTHARVEST NEWSLETTER

COOPERATIVE EXTENSION

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KIWIFRUIT APPLIED RESEARCH PROGRAM AT THE KEARNEY AGRICULTURAL CENTER

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My extension and applied research activities encompass postharvest studies of the following crops: apricot, nectarine, fresh market peach, plum, kiwifruit, pomegranate, cherry, Asian pear, persimmon, and table grapes. The goal of my program is to develop a better understanding of orchard factors and postharvest factors that control fruit quality and storage, and to develop technology to overcome fruit industry problems.

In an effort to make our information more accessible to our clientele and reduce my extension pressure, I created the KAC Fresh Fruit Postharvest Information web site at <http://www.uckac.edu/uckac/research/>. Our UC postharvest group located at Davis has a lot of good information posted at <http://postharvest.ucdavis.edu/>. My KAC web site includes issues from all 15 years of the Central Valley Postharvest Newsletter and other articles relevant to our California fresh fruit growers, packers, shippers and handlers. All my findings from my postharvest research work at KAC have been published in industry reports, disclosed during workshops, short courses, the Central Valley Postharvest Newsletter (CVPN), research reports, and on the web. The 15 years of newsletter issues and other more technical articles can be downloaded without cost directly from the UCKAC web site at

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<http://www.uckac.edu/uckac/research/> in the "Postharvest" section. This site has been up and available for the last 6 years. We encourage our clientele to visit our web site. Refereed papers (reviewed and approved by international experts in the field) are posted on the UC and UCKAC sites in PDF format and are available from me upon request.

In this article, I summarized the most important kiwifruit publications produced from research supported by the California Kiwifruit Growers that we conduct at the Kearney Agricultural Center. Results of our applied research by Jim Adaskaveg, Scott Johnson, David Slaughter, Themis Michailides and others, have been the basis for the development of a successful Kiwifruit postharvest outreach program at the Kearney Agricultural Center and statewide. More details on these topics can be obtained directly from the web site or by emailing me at carlos@uckac.edu.

KIWIFRUIT APPLIED RESEARCH PUBLICATION SUMMARY

2005. Adaskaveg, J.E., H. Forster, D. Thompson, H. Andris, and J. Hasey.
Development of new reduced risk fungicides for pre- and postharvest management of gray mold of kiwifruit caused by *Botrytis cinerea*.
2004-2005 Annual Report to Kiwi Commission.

Adaskaveg's research has led to the registration of two postharvest fungicides (Elevate and Scholar) and is in the process of getting a preharvest registration of a fungicide (Vanguard) for the industry. Preharvest timings have been evaluated and the concept of having three different chemical classes of fungicides registered should be sustainable in preventing resistance in the target pathogen population. Because these non-systemic (contact) pre- and postharvest treatments are effective, we are also providing information that the primary site for infection is the stem scar as opposed to the sepals. We have also developed new

application methods for the industry – both bin drenching and in-line drenching that has proved to significantly reduce decay. We have also evaluated other novel application methods such as room and in-line fogging of fungicides and we are currently evaluating biofumigation methods to prevent decay.

2004. Adaskaveg, J.E., H. Forster, D. Thompson, H. Andris, and J. Hasey.
Development of new reduced risk fungicides for pre- and postharvest management of gray mold of kiwifruit caused by *Botrytis cinerea*.
2003-2004 Annual Report to Kiwi Commission.

Efficacy of Preharvest Fungicide Treatments – In preharvest fungicide efficacy trials, two applications were made 9 and 2 days PHI using Elevate, Pristine, Vanguard, Scala, or the biocontrol PlantShield. Elevate and Vanguard were the most effective treatments, significantly reducing decay incidence as compared to the control. Pristine had no significant effect, whereas Scala and the biocontrol PlantShield had variable effectiveness. In this trial, incidence of decay of the inoculated control fruit was 16.7% after 10 weeks of storage. When an inducer for fruit senescence was added to the inoculum the incidence increased to 45%. This indicates that gray mold decay is affected by the host physiology and that senescing fruit where defense mechanisms are reduced are more susceptible to decay. This observation may possibly lead to novel treatments for gray mold of kiwifruit using materials that delay senescence such as targeted applications of plant growth regulators. Two non-GLP residue studies were conducted with Elevate to facilitate the Section-18 approval of the fungicide for the fall 2003 crop. For this, fruit were treated in the field either 7 or 1 day before harvest and were then treated postharvest using low-volume sprays, dips, or drenches as described below. Residues for preharvest applications alone ranged from 3.45 (7 day PHI) to 4.6 ppm (1 day PHI), whereas preharvest plus postharvest drench applications gave the highest residues of

12.2 to 12.4 ppm. These data will be used to specifically support the registration label for either preharvest or postharvest applications of Elevate. An IR-4 request was made for preharvest treatments including bloom treatments for Vanguard and Elevate on kiwifruit. The Vanguard (cyprodinil) request received an "A" priority; whereas the Elevate request was considered amendable under the current label as described above. Vanguard will only be evaluated as a preharvest application and IR-4 personnel at Kearney Ag Center will do residue studies this fall (2004).

Efficacy of Postharvest Fungicide Treatments – In postharvest trials, treatments with Elevate, Scholar, or the biocontrol PlantShield were applied as in-line drenches, dips, or low-volume spray applications (CDA-controlled droplet application) on an experimental packing line at the Kearney Agricultural Center. Drench treatments with Elevate and Scholar were very effective in reducing decay on fruit that were inoculated before or after treatment. Room fogging studies were conducted with Penbotec and Scholar. Scholar was less effective in these applications than in the drench treatments. For Penbotec this comparison was not done. Commercial packinghouse studies were conducted in Butte, Tulare, and Kings counties. Natural incidence of decay and decay of inoculated fruit were evaluated in these commercial studies. The results indicated that Elevate significantly reduced the incidence of gray mold of commercially treated and stored fruit. A staining problem did develop on commercial fruit that were stored wet after harvest in commercial cold storage facilities. The problem occurred on Elevate treated and non-treated fruit. Samples were taken from commercial facilities. The staining was caused by *Cladosporium herbarum*, a fungus that grows superficially on fruit without causing decay on non-injured fruit, and other sooty mold fungi. Elevate is not effective against this organism. Stained fruit did not get off-graded when the fruit were washed and brushed after storage.

2003. Adaskaveg, J.E., H. Forster, D. Thompson, H. Andris, and J. Hasey. Development of new reduced risk fungicides for pre- and postharvest management of gray mold of kiwifruit caused by *Botrytis cinerea*. 2002-2003 Annual Report to Kiwi Commission.

Preharvest treatments for postharvest decay management

Incidence of decay of inoculated and non-inoculated fruit after cold temperature storage. Preharvest treatments were applied 7 and 1 days PHI in a field site in Fresno Co. After harvest, treated fruit were either inoculated with conidia of *B. cinerea* at the freshly broken stem end or left non-inoculated for evaluation of natural incidence of decay. Fruit were then stored at 1-2°C. Incidence of gray mold decay was measured after 12 and 18 weeks of storage for inoculated fruit and after 19 weeks for natural incidence for non-inoculated fruit. In the inoculation studies, decay incidence among the treatments was similar for the two evaluation dates. Vanguard and Elevate treatments significantly reduced decay incidence to less than 3% as compared to the control treatment where decay incidence was greater than 8% after 18 weeks. Ronilan and Scala (pyrimethanil) were intermediate in their performance, whereas BAS516 was not significantly different from the control treatment. In non-inoculation studies, natural incidence of decay in the control treatment was 0.4% and all of the fungicide treatments significantly reduced decay to 0%.

Postharvest treatments for postharvest decay management studies

Evaluation of selected application methods for management of gray mold. Harvested fruit were inoculated at the freshly broken stem-end with conidia of *B. cinerea* and incubated at 20°C for 14-18 hr. After 20-21 weeks of storage, gray mold decay was completely inhibited by dip treatments with Elevate, PenBoTech (pyrimethanil), BAS516, or Scholar, whereas in the control decay ranged from 0.75 to 0.8%.

Several additional application methods were evaluated on an experimental packingline using Scholar. With low disease incidence in the control, none of these methods including CDA applications at different volumes and T-jet and wig-wag applications reduced the incidence of decay as compared to the control. In additional evaluations using the wig-wag application method at different rates of Scholar, decay was only significantly reduced from the control using the highest (150 gal/200 K fruit) application volume. For comparison, the Scholar dip application again reduced the decay to zero levels. A wig-wag application with PenBoTech at 100 gal/200K fruit was similarly effective as a wig-wag application with Scholar at 150 gal/200K fruit.

Evaluation of fogging methods for management of gray mold. Fogging was evaluated as in-line and as fumigation room treatments. The in-line fogging with Scholar at a slower retention time (10 sec) was more effective than the faster retention time (7.5 sec). Decay was significantly reduced from the control using Scholar or Xedathane (pyrimethanil) with the slower retention times. In the fumigation room treatments, Scholar significantly reduced decay in the upper bulk boxes or in single layers, whereas the formulation of Xedathane that was specifically designed for fogging was highly effective in upper and lower bulk boxes, as well as in single layers. Residue levels ranged between 0.9 and 1.9 ppm for Scholar and 8.6 and 10.2 ppm for Xedathane.

2001. Crisosto, Carlos H., and Gayle M. Crisosto. Understanding consumer acceptance of early harvested ‘Hayward’ kiwifruit. *Postharvest Biology and Technology* 22: 205–213.

During two seasons, “in-store” consumer acceptance tests were performed to determine the relationship between ripe soluble solids concentrations (RSSC) and/or ripe titratable acidity (RTA) on ‘Hayward’ kiwifruit consumer acceptance. For this, 252 consumers

were presented kiwifruit slice samples with RSSC of 11.0%, 12.0%, 13.0%, and 14.0% with a RTA ranging from 0.8-1.2%. Kiwifruit with RSSC that ranged from 11.6% to >13.5% were always liked by consumers but with different degrees of liking. A 12.5% RSSC is proposed as a minimum quality index for early-marketed kiwifruit. RTA played a significant role in consumer acceptance only on kiwifruit that had RSSC <11.6% with RTA \geq 1.17% (“sour”). Our kiwifruit quality survey indicated that some vineyards had kiwifruit with RSSC higher than 12.5% before they met the recommended minimum maturity standard of 6.5% RSSC. Kiwifruit picked with SSC <6.2% developed flesh breakdown. This work demonstrated that some California vineyards could produce high taste quality (12.5% RSSC) kiwifruit before they reach 6.5% SSC measured when the kiwifruit are hanging on the vines.

2000. Crisosto, C.H. Optimum procedures for ripening kiwifruit. *Central Valley Postharvest Newsletter* 9(2):8-10.

2000. Crisosto, C.H. Preconditioning guidelines for kiwifruit shippers. *Central Valley Postharvest Newsletter* 9(3):7-10.

2000. Crisosto, C.H. and F.G. Mitchell. Postharvest handling systems: small fruits. III. Kiwifruit, In: A.A. Kader (ed), *Postharvest Technology of Horticultural Crops, Third Edition, DANR Publication #3311.*

1999. Crisosto, C.H. Kiwifruit postharvest handling strategies: new developments. *Central Valley Postharvest Newsletter* 8(3):6-7.

To maximize kiwifruit returns, five main new approaches are being used: reduction of production costs, delayed cooling (“curing”), supplying tasty fruit to consumers (“ready to eat”), extending supply availability (early harvest) and quality segregation. The use of

bin storage under air or controlled atmosphere (CA or MAP) before packaging is a successful approach to reduce packaging and other costs, although kiwifruit water loss and softening should be carefully monitored during storage. Controlled environmental conditions during delayed cooling are essential for a successful “curing” treatment to reduce Botrytis. Ripening protocols for shippers, buyers, warehouse managers, store managers and consumers have been developed for marketing conditions in different countries (California and New Zealand). As it has been proved that delivery of kiwifruit “ready to eat” increases fruit sales; a pre-ripening treatment is becoming a requirement for early season sales in California. The pressure for early harvested fruit, as a way to extend the marketing period and increase returns, is challenging the current minimum maturity standards. Detailed sensory evaluation work on developing a “minimum quality index” based on consumer acceptability is being investigated for California kiwifruit. The potential commercial use of quality segregation according to the fruit total solids (TS) in the packingline by using non-destructive optical technology (NIR) and fruit individual labeling are also putting pressure on to develop a “minimum quality index”.

1999. Crisosto, C.H. and A.A. Kader. Kiwifruit postharvest quality maintenance guidelines. *Central Valley Postharvest Newsletter* 8(3):1-6.

1999. Crisosto, C.H., K.R. Day, T. Michailides, J. P. Zoffoli, and N. Lallu. Developing a safe and successful curing treatment for California kiwifruit. *Central Valley Postharvest Newsletter* 8(3):7.

Different environmental parameters affecting kiwifruit “curing” performance were studied during three seasons. Our work indicated that environmental conditions such as absence of ethylene, relative humidity, fruit temperature,

length of curing period and air velocity during delayed cooling were important for the control of Botrytis gray mold of kiwifruit grown in California. The 48-hour delayed cooling treatment at 59°F (15°C) combined with high relative humidity (95%) and medium air velocity (2 m/sec) under ethylene free (less than 10 ppb) conditions was the most effective in inhibiting Botrytis gray mold development on stem-end inoculated kiwifruit. After 4 months in cold storage, fruit quality attributes such as fruit firmness, soluble solids concentration, and fruit shriveling were not significantly different between treatments. Cumulative water loss was significantly related to the length of the cooling delay period. The differences in percent water loss among the treatments were still present without any obvious fruit shriveling after four months cold storage. This work confirmed information from New Zealand on the importance of environmental conditions that are necessary to develop decay resistance to Botrytis gray mold during the delayed cooling period.

1999. Crisosto, C.H., D. Garner, G.M. Crisosto, and R. Kaprielian. Kiwifruit preconditioning protocol. *Central Valley Postharvest Newsletter* 8(3):11.

Kiwifruit (*Actinidia deliciosa* var. Hayward) flesh softening, the conversion of starch to sugars, and soluble solids content accumulation in response to temperature and exogenous ethylene applications have been studied for the last three seasons. The result of this research is a ripening protocol which deals with preconditioning kiwifruit prior to shipment (packers/shippers) by using ethylene and temperature combination treatments. The preconditioning treatment triggers the ripening process which continues during storage/transit. This protocol allows the California kiwifruit industry to deliver “ready to eat” kiwifruit early in the California season (September-December).

1999. Crisosto, Carlos H., David Garner, and Katia Saez. Kiwifruit size influences softening rate during storage. *California Agriculture*, July-August 53: 29-31.

Large (~101 grams), medium (~93 grams) and small (~81 grams) 'Hayward' kiwifruits were stored in either ethylene-free air or in a controlled atmosphere (CA) of 5% carbon dioxide (CO₂) and 2% oxygen (O₂) at 32°F for 16 weeks. Under both storage conditions, large fruit had a slower rate of softening than smaller fruit. Air-stored kiwifruit softened approximately 2.6 times faster than CA-stored fruit. Under air conditions, large, medium and small kiwifruit reached 5.0 lbf (the minimum pounds firmness required for packaging with minimal bruising) by 12, 10 and 8 weeks, respectively, while those stored under CA conditions softened to 5.0 lbf by 49, 30 and 20 weeks. Understanding the relationship between fruit size and the rate of softening under air and CA conditions will help cold storage managers safely monitor kiwifruit softening during bin storage.

1999. Ritenour, Mark A., Carlos H. Crisosto, David T. Garner, Guiwen W. Cheng, and Juan Pablo Zoffoli. Temperature, length of cold storage and maturity influence the ripening rate of ethylene-preconditioned kiwifruit. *Postharvest Biology and Technology* 15: 107-115.

The effect of temperature, length of cold storage and maturity on the ripening of ethylene-preconditioned (100 μl^{-1} for 12 or 24 h) kiwifruit was investigated. Low (0°C) temperatures at any point prior to, during or after ethylene preconditioning significantly delayed softening and soluble solids concentration (SSC) accumulation compared to higher temperatures (i.e. 20°C). Freshly-harvested kiwifruit responded to ethylene-preconditioning (100 μl^{-1} at 0°C for 24 h) by softening faster than control fruit even if harvested 5 weeks after commercial maturity.

In contrast, kiwifruit harvested at commercial maturity and stored at 0°C softened faster than the control only if preconditioned with ethylene during the first 2 weeks of storage. Kiwifruit had high respiration rates 1 day after being transferred from 0 to 20°C, but respiration dropped to near base-line levels by day 2. Fruit stored at 0°C always respired faster upon transfer to 20°C than did freshly-harvested fruit and preconditioning with ethylene increased the initial rate of respiration of freshly-harvested fruit but had less of an effect on stored fruit. Ethylene preconditioning did not significantly hasten the climacteric rise in respiration or ethylene production of either freshly-harvested or stored kiwifruit. The climacteric rise of individual kiwifruit began only after fruit softened to ≤ 7 N.

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1999. Wiley, P., C.H. Crisosto, and F.G. Mitchell. Adapting perforated box liners to the California kiwifruit industry. *Acta Horticulturae* 498:299-306.

The performance of California kiwifruit packed using solid liners, perforated liners, and micro-perforated liners on the rate of initial cooling time, water loss, and quality attributes after shipping was evaluated under controlled laboratory and commercial conditions. Controlled cooling tests using a portable cooling tunnel indicated an important cooling time reduction (reaching 7/8 cooling time) without affecting quality when perforated liners were used instead of solid ones. The use of these vented box liners will result in direct energy savings to packinghouses proportional to the reduction in cooling times. Also, shorter cooling times will allow scheduling operations for the off-peak utility periods. Fruit quality attributes such as fruit firmness, soluble solids, and titratable acidity were not affected by any of the box liner treatments. Kiwifruit weight loss depended on the box liner vented area (V.A.) and storage temperature. After 18 weeks at 0°C kiwifruit packed in the solid (0%

V.A.), perforated (0.6% V.A.) and micro-perforated (1.2% V.A.) box liners had water losses of 0.7, 2.4 and 5.2%, respectively. Fruit shrivel was only observed on fruit packaged in the micro-perforated liners when water loss exceeded 4.0% in relation to the harvest fresh weight. In one of the two seasons, pitting incidence was measured on fruit from the micro-perforated box liner treatment.

1998. David C. Slaughter and Carlos H. Crisosto. Nondestructive internal quality assessment of kiwifruit using near-infrared spectroscopy. *Seminars in Food Analysis* 3: 131-140.

A nondestructive optical method for determining the internal quality of intact kiwifruit was investigated. The method, based upon near-infrared spectrophotometric techniques, was found to be capable of predicting the fructose content ($r = 0.96$, $SEC = 1.96\%$), glucose content ($r = 0.97$, $SEC = 1.68\%$), soluble solids content ($r = 0.99$, $SEC = 0.78^\circ\text{Brix}$), and dry weight ($r = 0.97$, $SEC = 0.61\%$) of kiwifruit.

1997. Hasey, J.K., R.S. Johnson, R.D. Meyer, and K. Klonsky. An organic versus a conventional farming system in kiwifruit. *Proc. Third Int'l. Symp. on Kiwifruit*, Eds. E. Sfakiotakis and J. Porlingis. *Acta Hort.* 444 Vol. I, pp. 223-228.

To determine the feasibility of growing kiwifruit organically, a kiwifruit vineyard converted to an organic farm was compared to a conventionally farmed vineyard from 1990 through 1992. January or March applications of composted chicken manure (organic system) or NH_4NO_3 plus $\text{CaNH}_4(\text{NO}_3)_3$ through micro sprinklers during the growing season (conventional system) were applied to give nearly equal rates of 168 kg N ha^{-1} . Soil analysis showed a trend toward a higher pH and organic matter over time for the organic system.

In 1992, there was a trend for the organic system to have higher $\text{NH}_4\text{-N}$ and lower $\text{NO}_3\text{-N}$ concentration in the soil. Leaf nitrogen levels from the organic system were consistently lower than those from the conventional system but were not deficient. Leaf concentrations of sodium and chloride increased over the three-year period in the organic system but not to phytotoxic levels. Leaf zinc levels were adequate and increased over time in both systems. Organically grown fruit was as firm as or firmer than conventionally grown fruit at harvest and four months after harvest. No differences were seen in percent soluble solids content. Damage from lantania scale and omnivorous leaf roller was small in both systems except scale damage in the organic system in 1992. An economic analysis of the cultural practices showed that the organic system cost almost \$720 per ha more than the conventional system. The grower reported fewer repack losses for organically grown fruit in 1992. We conclude that growing kiwifruit organically is feasible if an economic premium is received.

1997. Johnson, R.S., F.G. Mitchell, C.H. Crisosto, W.H. Olson, and G. Costa. Nitrogen influences kiwifruit storage life. *Proc. Third Int'l. Symp. on Kiwifruit*, Eds. E. Sfakiotakis and J. Porlingis. *Acta Hort.* 444 Vol. I, pp. 285-289.

Fruit from certain vineyards maintain firmness during storage better than other vineyards. These differences tend to remain consistent from year to year. A survey of numerous vineyards within the central valleys of California indicates vineyard nutrition can largely account for these differences. In particular, after 3 years of evaluation, nitrogen has consistently shown a strong correlation, where high nitrogen levels were associated with more rapid fruit softening in storage. Potassium and calcium were also correlated with fruit storageability but less consistently than nitrogen. In 1993, a nitrogen

rate experiment was initiated in a 2.5 acre kiwifruit vineyard that had a history of rapid fruit softening during storage. Rates of 0, 150, 300 and 450 kg N/ha were applied to 4 vine plots and replicated 4 times. The objective of this trial was to see whether fruit storage life could be altered by fertilization alone. In both 1993 and 1994, leaf N level indicated a

separation of the 4 treatments although the unfertilized treatment was still vigorous with a leaf N level above 2.5%. Yields and fruit sizes were not affected by the treatments. After 2 to 4 months storage, fruit firmness correlated negatively with N levels, supporting the conclusions from the earlier survey.

OTHER KIWIFRUIT RELATED WEB SITES

<http://www.kiwifruit.org/> – California Kiwifruit Commission

<http://www.crfg.org/pubs/ff/kiwifruit.html> – California Rare Fruit Growers

http://www.hort.purdue.edu/newcrop/morton/kiwifruit_ars.html – Purdue University

<http://www.zesprikiwi.com/> – Zespri

<http://www.kiwifruitcountry.co.nz/> – Kiwi360

<http://www.sfc.ucdavis.edu/pubs/brochures/kiwi.html> – UCCE Family Farm Series

<http://postharvest.ucdavis.edu/Produce/ProduceFacts/Fruit/kiwi.shtml> – UC Davis Postharvest

Technology Research and Information Center

<http://fruitsandnuts.ucdavis.edu/crops/kiwi.shtml> – UC Davis Fruit & Nut Research and Information Center

<http://www.hortresearch.co.nz/index/page/396> – Hort Research

FUTURE DATES

2005 Variety Display and Research Update Seminars at the Kearney Agricultural Center.

Mark your calendars for these dates:

- Friday, July 1
- Friday, August 12.

8:00 – 9:00 a.m.: Variety display by stone fruit nurseries, breeders and the USDA.

9:00 – 10:00 a.m.: Research Update Topics (For example: Nutrient deficiencies, Dwarfing & semi-dwarfing rootstocks, Keeping trees short, IPM updates, Irrigation management and water stress).

For more information contact: Scott Johnson (559) 646-6547 or sjohnson@uckac.edu; Kevin Day (559) 685-3309, Ext. 211 or krdav@ucdavis.edu; Harry Andris (559) 456-7557 or hlandris@ucdavis.edu; Brent Holtz (559) 675-7879, Ext. 209 or baholtz@ucdavis.edu; or Bob Beede (559) 582-3211, Ext. 2737 or bbeede@ucdavis.edu.

Other upcoming events posted on the Postharvest Calendar at the ANR website can be found at:

<http://ucce.ucdavis.edu/calendar/calmain.cfm?calowner=5423&group=w5423&keyword=&ranger=3650&calcat=0&specific=&waste=yes>

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