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Editor

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NEW POSTHARVEST RESEARCH CENTER AT KEARNEY

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UC Public Information Representative

The first phase of the F. Gordon Mitchell Postharvest Center was dedicated on Feb. 8 at the Kearney Agricultural Center.

The new 6,150-square-foot building was donated to the University by Dinuba farmer/packer LeRoy Giannini. He suggested naming the new building after Mitchell.

Research in the new facility, which begins immediately, allows UC scientists to use state-of-the-art technology to find the best ways of handling produce after it is harvested.

"Without Gordon's technical support and LeRoy's generosity, this building may never have become a reality," said Regional Director Bill Hambleton. "Gordon's legacy of excellence in postharvest work will continue not only at Kearney, but throughout the state."

Construction of the second phase of the postharvest building will begin this summer with $1.3 million provided by the higher education construction bond, which was approved by California voters in June 1992.

The new building has seven walk-in controlled temperature boxes, a preparation laboratory, an evaluation laboratory, an instrumentation lab and a clean lab.

Phase II will include a processing laboratory, seven more controlled temperature boxes, eight temperature control chambers and an engineering wing.

"The facility pulls together in one location everything necessary for postharvest evaluation of a product," said Gordon Mitchell, UC Davis extension horticulturist emeritus.

The majority of postharvest research had been conducted at UC Davis and UC Riverside. The new laboratory at the Kearney Agricultural Center will bring research to the Central Valley, where most of California's fresh fruit is produced.

"Over the years, I saw the limitations we had working with rapidly maturing products from a great distance," Mitchell said. "We need to be in the Valley on a day-to-day basis."

Kearney postharvest physiologist Carlos Crisosto, UC Riverside subtropical horticultural Mary Lu Arpaia, and other researchers based at Kearney, UC Davis, UC Riverside and UC Berkeley will conduct research in the new laboratory.

"This facility will draw scientists into the Valley," Mitchell said.

SHOULD WE USE PLASTIC BINS?

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Introduction

Plastic bins for apples and pears have been used in Europe for over 20 years. A major fruit-growing area, the Bolzano region in northern Italy began using plastic bins in 1970. Changing from wooden bins to plastic has continued, and the industry in the Bolzano region seems determined to make a complete change to plastic bins.

Until last year, plastic bins were not available in the United States. This has changed. Plastic bins were shown at the 1992 Washington Tree Fruit Postharvest Conference in Yakima. During a presentation at the Postharvest conference, Alan F. Hauff (1992) explored the use of collapsible plastic bins that could be used not only for storage but also for shipping of fruit to local markets. In his study, Hauff did extensive marketing research and a comparison of standard wood bins to plastic bins. He interviewed researchers, manufacturers and other industry representatives to arrive at strengths and weaknesses of different types of bin designs and different materials used.

Hauff concluded the major advantages of rigid wood bins are low cost, superior strength, and having been the industry standard since 1957. Wood bin kits are produced and assembled locally which minimizes transportation cost from manufacturer to users. Wood bins also have disadvantages. They are subject to weathering, resulting in rough surfaces that can harbor various disease-causing organisms. They absorb moisture and chemicals. Wooden bins with solid plywood construction allow minimum ventilation. They cannot be recycled, and old ones must be discarded.

Plastic bins have several advantages. They have smooth surfaces that do not absorb moisture or chemicals. They are easy to clean and sanitize, do not harbor disease organisms, and are resistant to weathering. They have an interlock system that provides easier and safer stacking. Plastic can be recycled and has a longer life.

However, plastic bins have a substantially higher initial cost than wooden bins. They are slippery when wet, thus requiring more careful handing.

Western Fruit Grower, June 1992, featured an article on the use of plastic bins by Fowler Packing Co., Fowler, California. This past season they were handling soft fruit in plastic fruit bins manufactured by Macro Plastics, Fairfield, CA. Comments by users indicated that there was less bruising and less surface scuffing and they liked the smooth bin surfaces which are easier to clean than wooden bins.

As the use of postharvest chemicals is reduced or eliminated, it will become more difficult to combat postharvest diseases. Sanitation will become more important and plastic bins will make sanitation easier.

History of plastic bins

Plastic bins have been used by growers in the major tree fruit-growing area located in the Bolzano district, Italy, since 1970. Ten years later, about 25 percent of the total number of bins used were plastic. In the 1980s, the change to plastic bins continued as most old wooden bins were replaced with plastic. Most of these bins were produced by a local manufacturing plant, Palbox, Inc., which started production in 1972. Initially, bins were produced with fiberglass-reinforced foam plastic. These bins had low impact resistance and bin breakage was moderate. They have a recycling program that reuses all old and broken bins. Damaged bins can be exchanged for new ones for the first five years. After five years, three damaged bins can be exchanged for one new bin.

Outside dimensions of the bins used in Italy are 1120 mm x 1120 mm x 770 mm (44 in x 44 in x 30.4 in). These dimensions have not changed since introduction of the plastic bin. Improvements in design and manufacturing techniques have increased the inside volume from about 600 to 700 liters which increased the bin capacity from 300 kg to 330 kg of apples (660 lbs to 730 lbs). The new bins are made of a solid polyethylene plastic, which is stronger than the foam plastic. The walls are thinner and inside dimensions larger, but the weight is still only 33 kg (73 lbs). These bins are stronger and more resistant to impact. Breakage has decreased dramatically.

In Switzerland, a plastic manufacturing firm, George Utz, AG, began producing plastic bins in 1980. Switzerland has a standard that requires the bin dimensions to be 1000 mm x 1200 mm x 765 mm high (39.3 in x 47.2 in x 30.1 in). The plastic bins produced by Utz have an inside volume of 650 liters which holds 315 kg of apples (695 lbs). They are made of high-density polyethylene plastic, are heavy duty and weigh 42 kilograms (92 lbs). To reduce cost and weight, Utz is now manufacturing a model with thinner walls. The largest plastic bin manufacturer is Capp-Plast located in Capalle, near Florence, Italy. The Capp-Plast bins are used mostly in Italian tree fruit production areas other than the Bolzano region.

I recently toured the major tree fruit region in Europe where plastic bins are commonly used. I talked with researchers and warehouse managers about their experiences with changing to plastic bins and the use of plastic bins in general. The goals of this tour were to:

1. Visit plastic bin manufacturers and become familiar with their products.

2. Visit commercial storages that are using only wooden bins, only plastic bins and those using both kinds to discover advantages and disadvantages of both, reasons for changing from wood to plastic, or reasons to stay with wooden bins.

3. Obtain information from researchers and extension personnel about the use of plastic bins.

I visited three manufacturers: Utz AG, Bremgarten, Switzerland; Palbox, Egna (Bolzano), Italy; and Capp-Plast, Capalle (Florence) Italy.

I visited two small storages in Switzerland and the Swiss Federal Research Station in Wadenswil. In Italy, I visited several storages in the Bolzano area, also the Laimburg Research Station and the extension office in Terlan (Bolzano).

Considerations and Issues Regarding the Use of Plastic Bins

All storage personnel visited in the Bolzano area were positive about the use of plastic bins. All said that they were committed to changing completely from wood to plastic bins. As their old wooden bins needed to be replaced or when storage capacity was increased, they purchased plastic bins. One cooperative with a total storage capacity of 75,000 bins of apples, of which 90% are Golden Delicious, used only plastic bins. The management is convinced that with plastic bins they have better sanitation, better storage environment, better air circulation and less scald. This warehouse emphasized small, high-quality specialty packs of mountain-grown apples. Another warehouse built new storage rooms with 11 m (36.6 ft) high ceilings to stack plastic bins 13 high. They indicated that this is possible only with plastic bins that interlock and can be stacked more accurately.

Two small storages in Switzerland, each with 4,000-5,000 bin capacity, are using some plastic bins. One storage uses lower height plastic bins for pears. The other warehouse would switch to plastic bins if the price difference were smaller. A larger storage in the southern section of Switzerland used only plastic bins because plastic bins are lighter and they can haul more fruit per truckload, thereby reducing transportation costs.

Higher purchase price for plastic bins was a concern for most bin users. The highest prices were found in Switzerland where the heavy duty bin cost was 250 Swiss Francs (US $200). This bin weighs 96 pounds. A lighter version weighs 77 pounds and costs 150 SFr. (US $120). These bins also have 10 percent less capacity than the ones used in Italy. Wood bins cost 100 SFr. (US $80). In Italy the plastic bins cost 70,000 Lire (US ($67), and wood bins are available for 40,000 Lire (US $38). Due to an improved design, the capacity of the new Italian plastic bins is only slightly less than that of wood bins.

Why Are They Switching to Plastic Bins?

1. Plastic bins are 30-40 lbs. lighter than wood bins. Less bin weight reduces tare weight, thus increasing the amount of fruit that can be transported on a truck. Lighter bins are also easier to handle or move by the pickers, for example, when moving bins into the shade before filling.

2. Plastic bins all weigh the same. In the production areas visited, the growers are usually paid for the grade and weight of the fruit brought to the warehouse. By knowing the tare weight of the bins, it was easy to determine the actual weight of the fruit delivered to the warehouse. In the US, growers are paid for the grade and amount of fruit packed, therefore, this would not be important in this country. However, some of the warehouses do weight the bins before going into storage and again upon removal at the end of the storage season. Having bins that do not absorb moisture in storage would offer the opportunity to determine the exact weight loss of the fruit in storage.

3. The new solid polyethylene bin has excellent strength and will maintain its strength over its useful life. Better stability and interlocking allow the plastic bins to be stacked up to 13 bins high.

4. Better sanitation is possible because plastic bins have smooth surfaces that do not harbor disease-carrying organisms. They do not weather, crack, splinter, warp or become rough with age. They resist

ultraviolet light. They can be cleaned more easily and the smooth surfaces cause less bruising or scuffing of the fruit.

5. Plastic bins do not absorb water or chemicals. Rapid absorption of moisture by dry wooden bins during the early storage season (Waelti et al., 1989) reduces the relative humidity of the storage air which causes more weight loss of the stored fruit.

6. Plastic bins have slots in the floor and sides of bins amounting to 7-11% of the total surface area. Plywood bins have only about 1.5% open area, which greatly limits the amount of air flow through the bins. Cooling air can circulate through plastic bins and around the fruit, greatly increasing the cooling rate. Tests conducted by Patchen et al. (1962) indicate that bins with 8-10% open area cool fruit twice as fast as plywood bins with limited ventilation. Similar findings were obtained by Bartsch et al. (1984) and Waelti et al. (1992). Increased air flow through the bins results in more even cooling and reduces temperature gradients and temperature differences between various locations in a room. With better ventilated bins, the rows could be stacked close together and still have sufficient cooling air flow through the stacks. Thus, in most rooms, one more row could be added, significantly increasing the room capacity.

7. Plastic bins are either in good condition or not usable. Therefore, bins that are weak and may damage fruit or cause problems with stacking cannot be used.

Disadvantages of Plastic Bins

1. They hold less fruit per bin because side walls and floor are thicker due to reinforcing ribbing. This was a significant disadvantage with the older designs when foam plastic was used. The newer bins made with solid polyethylene have thinner walls and hold almost as much fruit as wood bins of the same outside dimensions.

2. Plastic bins are slippery, especially when wet, thus may slide on the forks when going around corners. It takes time for forklift drivers to get used to plastic bins. The forks must be set out as far as possible so that the bins cannot slide sideways.

3. Plastic bins are more expensive to buy, but they have a longer life. Plastic bins can be recycled. By trading in three old bins, it is possible to receive one new bin. When considering a longer life and a salvage value of 33.3%, the actual longterm cost of plastic bins is not much different from wooden bins.

Summary

It took the South Tyrolians in the Bolzano area 12 years to replace 25% of the wood bins with plastic bins. Initial acceptance of plastic bins was slow. Today, 22 years later, they still have not completely switched. However, as a whole, the industry clearly is convinced that the benefits derived from plastic bins are worth the extra initial costs.

As plastic bins become available in the United States, they will be used first by more progressive warehouses and their merits, advantages and disadvantages evaluated. Issues such as sanitation, quality and environmental concerns will be major driving forces. Change will be slow. For example, the State of Washington holds about 3,400 million pounds of apples in cold storage (Wash. Agric. Statistics, 1988). To store this crop requires 4.5 million bins. To replace only 1% of these bins per year would require a yearly production and distribution of 45,000 bins.

References

1. Hauff, Alan F. 1992. Studies on apple bins. Proceedings, 8th Annual Washington Tree Fruit Postharvest Conference, March 11-12, 1992. Yakima, WA. Washington State Horticultural Association, P. O. Box 136, Wenatchee, WA 98807.

2. Patchen, Glenn O. and G. F. Sainsbury. 1962. Cooling apples in pallet boxes. Marketing Research Report No. 532. Agricultural Marketing Service, U.S. Department of Agriculture, U.S. Government Printing Office.

3. Bartsch, J. A. and G. D. Blanpied. 1984. Cooling rates of apples in tight and spaced stacking patterns. Staff Report No. 84-3, Agricultural Engineering Department, Cornell University, Ithaca, NY.

4. Washington Agricultural Statistics, 1987 - 88. 1988. Washington Agricultural Statistics Service, 417 West 4th Avenue, Olympia, WA 98501.

5. Waelti, Henry, R. P. Cavalieri and K. R. Zaugg. 1989. Reduced evaporator fan operation; effect on storage environment. Paper No. 89-1636 presented at the 1989 International Winter Meeting, American Society of Agricultural Engineers, New Orleans, LA (Dec. 12-15, 1989).

6. Waelti, Henry, M. Johnson and R. P. Cavalieri. 1992. Energy conservation, cooling rate and storage environment in fan-cycled rooms. Paper No. PNW 92-113, presented at the Pacific Northwest Section, American Society-Canadian Society of Agricultural Engineers 47th Annual Meeting, Bozeman, MT (Sept. 16-18, 1992).

TIPS TO REDUCE BRUISING DURING APPLE HARVESTING

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During 1972-1984, inspections conducted by Cappelini on 6% of the apples delivered to the New York market (Table 1) from 23 states and eight countries indicated the following: Bruising damage was the most important non-disease disorder, with 75% of the shipments affected and approximately 21% of the loads in these shipments sustaining 11 to more than 50% damage. The most damaging physiological disorders were scald, bitter pit, and internal breakdown accounting for almost 75% of the physiological disorders. The other non-disease disorders of note were freeze damage, scars, cuts/punctures, misshapen fruit, and shriveling.

Table 1. Frequency of physiological disorders, physical disorders and diseases reported in USDA inspections of 4,453 apple shipments.

Disease, physical and physiological disorders	Shipments affected (%)
Unidentified decays	15.1
Blue mold rot	7.6
Scald	4.6
Bitter pit	3.5
Internal breakdown	1.9
External discoloration	1.6
Gray mold rot	1.1

Bitter rot	0.2
Water core	0.2
Scab	0.2
Bull's eye rot	0.2
Internal browning	0.1
Alternaria rot	0.1
Cork spot	0.1
Black rot	0.1
<u>Disorder</u>	
Bruise damage	75.1
Freeze damage	4.3
Scarring	3.8
Cuts/punctures	3.3
Misshapen fruit	2.0
Insect damage	0.7
Hail damage	0.7
Shriveling	0.4
Overripe fruit	0.2
Russeting	0.2
Sunburn	0.1
Chemical damage	0.1

Source: Cappelini, R. 1987.

What do we know about bruising?

Any mechanical injury (bruise, cut, puncture, etc.) can increase the rate of respiration and ethylene production which consequently, speeds up fruit ripening, softening, water loss, and general deterioration.

Surface damage can also result in inoculation by fruit rot organisms and a free point for disease entry. Injuries can result from any impact of the fruit, and the incidence and severity of bruises increases with the increased height that the fruit is dropped.

<u>Impact bruising.</u> This injury is caused either by dropping the fruit onto a surface or by dropping an object onto the fruit. Impact bruising can be caused by dropping fruit into a picking bucket, by dumping into the field bin, by various drops in the packing operation, or even during the filling of containers on the packing line. Prior to unitized handling, serious impact bruising often resulted from rehandling of individual packages of fruit. Impact bruising frequently occurs in apples and is important because of its effect on fruit appearance. An impact bruise may or may not be visible on the surface of the fruit, and normally will not cause a surface indentation. However, this type of bruise often causes brown flesh discoloration extending well below the surface.

<u>Compression bruising.</u> This is caused by pressing the fruit into some object such as another fruit, the container lid, a stack of containers, the picking bag, etc. This type of bruise usually appears as an indentation on the surface and brown discoloration of the flesh underneath.

<u>Roller bruising.</u> Also called belt burn or vibration bruise, roller bruising is a surface injury. The bruise results from vibration or abrasion of the fruit surface against some other surface such as another fruit, the package, the packing belt, etc. After packing, it often occurs as a result of fruit movement within the package during transit. This can be reduced or prevented if the fruit is immobilized within the shipping container. The roller bruise is a brown discoloration on the fruit surface which normally does not extend into the flesh. Very soft fruits may sometimes develop tissue disruption beneath the surface.

All types of bruises result from rough or improper handling, poorly designed equipment, improper packaging, or inadequate supervision during handling of the fruit. Minimizing these bruises involves an understanding of their causes, and a careful evaluation of the entire packing system. Once the sources of injury are identified, steps can be taken to modify equipment or develop procedures to reduce their incidence and severity.

Where is bruising damage occurring?

Studies done in Michigan on 'MacIntosh' apples demonstrated that an average apple can accumulate a total of 13.5 bruises/fruit before being displayed at the retail store (Sargent et al., 1989). About 35% of the total bruising injury occurred during harvesting (apple placement into bins) and hauling. At the packing line 63% of the total bruising occurred while only 4% resulted during maritime transport (Table 2). This study also pointed out the large variability in bruising incidence among orchards used and suggested that bruising reduction can be achieved by good supervision during the harvesting operation.

Harvesting operation. Within orchards a significant increase in bruise-free fruit was achieved when either deluxe cushioned picking buckets were used (compared to the standard steel bucket or picking bag) or by the addition of cushioning to the bin bottom (Table 3). High incidence of bruising was observed when pickers were wearing gloves. Recently, Schulte et al. (1991) demonstrated that pickers were the most important factor in determining the amount of bruising accumulated within the orchard (Table 4).

Table 2. Bruising incidence during apple harvesting and postharvest operation.

Operation	No. of bruises/fruit
Picking/Dumping	2.6
Hauling	2.2
Packing Line	5.5
Packing	3.0
Transport	0.5
	13.8

Source: Sargent et al., 1987.

Hauling. The type of equipment used during harvesting and hauling operations affect bruising incidence (Table 5). Studies done by Burton et al. (1989) demonstrated that apples gently placed in the bins, handled by a standard fork-lift (long tines) and transported by a tri-axle, 5th wheel trailer pulled by a pick-up induced 1.46 bruises/fruit (B/F). If a stake-truck replaced the trailer, they ended up with 1.88 B/F. The worst combination was a bin hauled in the rear of a bin carrier in the orchard and transported by truck (2.32 B/F). When bins with foam plastic liners were used in the above combinations, the number of B/F was reduced by almost 40%.

Table 3. Comparison of picking buckets, using percent bruised fruit and average number of bruises/fruit as criteria.

	% Bruised Fruit			
Picking bucket[Z]	Picker A	Picker B	Picker C	Average
Standard	89.3	85.0 ab[Y]	71.5 a	81.9 a
Deluxe	85.5	80.6 b	55.6 b	73.9 c
Deluxe, Extended Flap	81.1	78.9 b	64.4 ab	74.8 bc
Padded, Soft Sided Bag	79.9	88.9 a	71.6 a	80.1 ab

		No. of Bruises/Fruit		
Standard	2.38	1.91 bc	1.25	1.85
Deluxe	2.07	2.20 bc	1.02	1.77
Deluxe, Extended Flap	2.11	1.68 c	1.28	1.69
Padded, Soft Sided Bag	1.79	2.41 a	1.43	1.88

[Z] Picking buckets: **Standard** - 1/2 Bu. capacity standard steel bucket with canvas bottom release flap (Wells & Wade Co., Wenatchee, WA); **Deluxe** -1/2 Bu. capacity, standard steel bucket with padded interior and padded leather covered rim, canvas bottom release flap (Wells & Wade Co., Wenatchee, WA); **Modified Deluxe** - Deluxe bucket with 560 mm (22.0 in) wide, 300 mm (11.8 in) long, 6.4 mm (0.25 in) thick padded [microfoam encased canvas sleeve] extension of the underside of the canvas bottom release flap, and additional padding extending up to bottom of the steel bucket; **Padded Soft Sided Bag** - Fruitsaver bag (R. J. Co., Wenatchee, WA).
[Y] Within column mean separation by Duncan's multiple range test, P = 0.05.
Source: Schulte et al., 1991.

Table 4. Picker affects averaged over all picking aide treatments.

Picker	Bruised fruit %	Bruises per fruit no.	Average apple grade[Z] no.
A	83.94 a[Y]	2.09 a	2.00 a
B	83.33 a	2.05 a	1.96 a
C	65.75 b	1.25 b	1.48 b
Average	77.67	1.80	1.81

[Z] 1.0 = U.S. Extra Fancy; 2.0 = U.S. Fancy; 3.0 = U.S. No. 1; 4.0 = U.S. Utility; 5.0 = Reject.
[Y] Within column mean separation by Duncan's multiple range test, P = 0.01.
Source: Brown et al., 1991.

Table 5. Apple damage incurred when bins were transported by different orchard handling equipment over a 2 km course.

	Bin carrier				Forklifts					
	Front		Rear		Long Tines		Short Tines		X-action[Z]	
Damage measure	Pad[Y]	No pad	Pad	No pad	Pad	No pad	Pad	No pad	Pad	No pad
	- Damage (%) -									

Undamaged fruit	87.9	87.9	77.3	47.0	83.1	66.7	72.7	77.3	73.4	66.7
Bruised	10.6	12.1	21.2	50.0	15.4	31.8	25.0	22.7	25.0	30.3
Cuts	1.5	1.5	0.0	1.5	0.0	0.0	0.0	1.5	0.0	0.0
Punctures	0.0	0.0	1.5	1.5	1.5	1.5	4.6	0.0	1.6	7.6
	Averages									
Bruises/fruit	0.12	0.14	0.30	0.82	0.19	0.38	0.27	0.27	0.30	0.36
Bruise area/fruit[X] (mm/dia.)	9.7	14.8	31.6	87.7	14.8	34.2	21.9	25.2	23.9	31.0

[Z] Cross-action air-shock rear tractor.
[Y] Microfoam 12.2 mm on floor and 6.1 mm on sides.
[X] Bruise area/fruit: 6.4 mm dia. = 32.7 mm^2, 12.8 mm dia. = 128.4 mm^2, 19.0 mm dia. = 283.5 mm^2, 22.0 mm dia. = 380.1 mm^2, 31.8 mm dia. = 794.2 mm^2.
Source: Burton et al., 1989.

Based on this information, some guidelines can be recommended:

1) Pickers should cut fingernails closely to prevent fingernail punctures.

2) The picking buckets should have rigid sides to prevent bruising when the picker leans against it. Use of the deluxe cushioned picking bucket instead of picking bag or standard steel bucket is recommended.

3) Apples should be gently placed in the picking bucket instead of being dropped from the rim of the bucket or higher.

4) A full picking bucket should be gently lowered to and released at the bottom of the field bin, allowing the fruit to roll instead of dropping onto the bin bottom.

5) Adding liners and/or cushioning in the bin bottoms will help reduce bruising.

6) To reduce bruising incidence within the orchard due to handling, adequate harvest labor training and continuous supervision are essential, even when cushioned picking buckets and bins are used.

7) Considerably less bruising occurs during fruit hauling on trucks equipped with air suspension rather than spring suspensions.

EXPORT OF CALIFORNIA GRAPES

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For several years quality problems continue to occur with California grapes more than with other California horticultural crops. In 1992, California exported 8676 metric tons of grapes to the EEC. These problems include residues (mostly dust) on grapes, black widow spiders in packages of grapes and condition problems.

The condition problems are bruising, crushing, shatter, senescent and excessively dry looking stems, and decay of grapes. The bruising and crushing (split berries) of grapes is caused by packing too many grapes within a given sized box and the shocks and vibrations during transit. We have observed five kilo (11 lb) boxes packed with six or seven kilos (13-15 lb) of grapes and 11 kilo (23 lb) boxes packed with 12-13 kilos (24-27 lb) of grapes. Most grapes grown in Europe and those imported from Southern hemisphere countries are not packed as tightly as U.S. grapes. Consideration should be given to developing a new grape package, particularly for export.

Observations indicate that grapes shipped across the U.S. by rail to the East Coast for export to Europe seem to have more bruising and shatter than grapes shipped through the Panama Canal to Europe. California grapes also arrived with dried-out brown stems. This problem may be related to transit temperatures somewhat higher than recommended. Even though the thermostat setting may be correctly set at 0-1EC (32 to 34EF), poor air circulation in the van containers result in actual grape temperatures being 3 to 4EC (38 to 40EF) during transit.

For the export of grapes, the following specifications should be followed:

1. Season. The harvest of table grapes begins in southern California and Arizona in mid May and ends in central California in early November. Early cultivars such as `Thompson Seedless', `Perlette' and `Flame Seedless' are best shipped immediately after harvest and precooling. Late season cultivars such as 'Ruby Seedless', 'Emperor', 'Ribier', 'Red Globe' and 'Calmeria' may be shipped after short duration (∃ 3 weeks) storage.

2. Quality. Table grapes for export to Europe, Japan and some other countries must meet the requirements of the U.S. Fancy grade. For export, the grapes must be free of dust, spiders, decay and serious damage. When selecting grapes particularly for the European market, select lots that are free of dust and other residues as European health inspectors may reject importation of grapes having any type of residue. Grapes for export should be dry when packed, mature with high soluble solids content, well-colored as characteristic of the cultivar with green and turgid stems. Quality of grapes is judged by stem freshness by most receivers. For Europe, grape bunches must weigh about 200 (1/2 lb) grams each for Category No. 1. Grapes harvested after rain should not be exported as they may be susceptible to decay. Early season cultivars should be shipped as soon as possible after harvest since their shelf life is only 4 to 6 weeks. Late season cultivars may be shipped from storage, but storage conditions must be optimal [0EC (32EF) and 90-95 percent relative humidity].

3. Pretransit treatment. Recommended preharvest, harvest and packing procedures should be thoroughly followed with extra care for grapes destined for export. Grapes should be thoroughly precooled immediately after harvest using forced-air cooling before storage and/or shipment. Grapes are also fumigated with sulfur dioxide (SO_2) immediately after packing to help control decay and to maintain the light-green stem color. Grapes destined for export are best precooled and fumigated in a single operation promptly after harvest. Pressure or forced-air cooling speeds cooling and enhances gas penetration into packages. A label for SO_2 fumigation was finalized by the EPA in 1992 and approved by Cal EPA in 1993. It states requirements for safety, maximal dosages, number of fumigations, labeling and other aspects of SO_2 use. Regulations allow up to 10,000 ppm (1.8 lb. per 1000 cu. ft.) SO_2 for the first

fumigation. All subsequent fumigations cannot exceed 5000 ppm. SO_2 generating pads are often used in export packages. If export of these packages is delayed and they are repeatedly fumigated, injury and excessive residues can result. If SO_2 fumigation is done in van containers, it should be done 20-30 minutes with doors closed and the refrigeration unit operating for thorough circulation. After fumigation, the doors can be opened with the refrigeration unit operating and ventilated for 15 minutes before shipment to reduce the chances of SO_2 injury to the berries. Plant health inspectors in Europe check for sulfur dioxide injury and have refused entry for such injury and/or sulfur residue.

4. Packaging. Most European receivers prefer a 5 kilo (11 lb) fiberboard box for grapes. The grapes should be carefully place-packed in the box without overpacking the bunches. Fiberboard boxes must be strong enough to withstand the long transit times to export markets. Some receivers prefer the polystyrene foam box for grapes, but some disposable problems may arise in the future with this box. Polystyrene boxes offer the advantages of minimizing quality deterioration by not absorbing moisture from the grapes and absorbing some of the vibration during transit. Boxes should be palletized on a 120 by 100 cm approved wooden pallet and adequately secured to the pallet with strapping or netting.

5. Pretransit Vehicle Check. Check the transport vehicle before loading to be sure it is clean, check doors for proper closure and that floor drains are clean and operable. The transport vehicle should be precooled to desired transit temperature. Keep loading time to a minimum.

6. Transit Environment. The optimum transit temperature for table grapes is 0EC (32EF) and the desired relative humidity is 90 to 95 percent. The air exchange or venting system should be set at 15-18 CFM for fresh air.

7. Loading Pattern and Bracing. Most van containers used for export of grapes are equipped with state-of-art refrigeration systems with bottom-air delivery. Since most export shipments of grapes are palletized, the pallets should be loaded against each sidewall of the van container leaving a void channel down the center of the van container or two pallets stacked alternately against each sidewall (Fig. 1). For maximum air circulation, the void floor space should be covered with fiberboard and the ends or entry of the last two pallets should be covered with fiberboard. If four-way entry pallets are used, the openings for the forklift entry must also be covered on the side facing the void space. If the floor at the rear of the van container is not covered with a metal plate, then any floor space at the rear of the van container not covered with pallets should also be covered with fiberboard. It is also recommended that the load be braced with either an air bag or wood bracing to maintain pallet stack placement.

8. Vehicle Routing. For early season grape cultivars, route the shipment by the fastest combination of overland and ocean routes to keep transit time to a minimum. Late season cultivars may be routed by the fastest ocean routes which for European shipments may be through the Panama Canal instead of overland to the East Coast of the U.S.

9. Care of Product upon Arrival. The quality and shelf life of table grapes are highly dependent upon storage temperature at 0EC (32EF) and relative humidity at 90 to 95 percent. Upon arrival, grapes should be kept under refrigeration and moved to

retail outlets as quickly as possible under refrigeration.

EXPORT OF CALIFORNIA PLUMS

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In the past several years many quality and condition problems have been reported with California plums. In 1992, the U.S., mostly from California, exported 5740 metric tons of plums to the EEC. Many receivers state that they would import more plums if consistent quality can be assured. The principal problems with California plums were internal browning and decay.

This past year six shipments of 'Roysum' plums were destroyed because of internal browning. In addition to the costs of plums and transport, there is the cost for the removal and the destruction of the plums. Fourteen other van container shipments of plums had varying degrees of decay and internal browning with 50 percent losses. Most problems with plums are related to maintenance and setting of the proper transit temperature and the length of time from harvest to destination. Temperature control at 0EC (32EF) is of utmost importance in the control of internal browning of plums. Most plum cultivars are susceptible to internal browning at temperatures of 2EC (36EF) and above. Temperature setting at 4EC (40EF) is particularly detrimental depending upon exposure time. The temperature setting of most van containers was 0-1EC (32-34EF), but due to loading technique and inadequate air circulation within the van container, actual plum temperatures during transit averaged about 4EC (40EF). In the case with the `Roysum' plums, which were harvested in early October and stored until shipment in late October, the time from harvest to arrival in Europe was six to eight weeks. The maximum recommended storage/transit time (shelf life) for `Roysum' plums is only four weeks.

For the export of plums the following specifications should be used:

1. <u>Season.</u> The harvest of plums begins in California and moves to Oregon, Washington and Idaho. The harvesting season starts in early May and continues through early October. There are over 140 varieties of fresh plums available in the U.S. but they are not all adapted to long term storage/transit. Some varieties have a longer shelf life and store and ship better than others. Plums are susceptible to internal browning or breakdown with some varieties more susceptible than others. For export, select only varieties which have a long shelf life of 3 or more weeks and are less susceptible to internal breakdown.

2. <u>Quality.</u> Export only freshly harvested plums with high quality, well-colored and a high soluble solids content. They should be U.S. Fancy or U.S. No. 1 grade.

3. <u>Pretransit Treatment.</u> Recommended harvest and packing procedures should be thoroughly followed with extra care for plums that are to be exported. Plums should be precooled immediately after packing. The time between harvesting and precooling should be kept to a maximum of a few hours. Precool plums by hydro-cooling and /or forced-air cooling to 0EC (32EF) as soon as possible and maintain this temperature prior to shipment.

4. <u>Packaging.</u> Plums for export should be place-packed or tray packed one or two layers in fiberboard boxes. European receivers prefer boxes with 5 to 6 kilos (11 to 13 lb) net weight. Fiberboard boxes must be strong enough to withstand the

rigors of export. Boxes should be palletized on a 120 by 100 cm approved wooden pallet and adequately secured to the pallet with strapping or netting.

5. Pretransit Vehicle Check. Check the transport vehicle before loading to be sure it is clean, check doors for proper closure and that floor drains are clean and operable. The transport vehicle should be precooled to desired transit temperature before loading. Keep loading time to a minimum.

6. Transit Environment. The recommended transit temperature is -0.5 to 0EC (31-32EF) and relative humidity 90 to 95 percent. The air exchange or venting system of the van container should be set to allow 40-50 CFM. Some cultivars of plums may benefit from modified or controlled atmosphere during transit.

7. Loading Pattern and Bracing. Most containers used for export of plums are equipped with state-of-art refrigeration systems with bottom-air delivery. Since most export shipments of plums are palletized, the pallets should be loaded against each sidewall of the van container leaving a void channel down the center of the van container or two pallets may be stacked alternately against each sidewall (Figure 1). For maximum air circulation, the void floor space should be covered with fiberboard and the ends or entry of the last two pallets should be covered with fiberboard. If four-way entry pallets are used, the openings for the forklift entry must also be covered on the side facing the void space. If the floor at the rear of the van container is not covered with a metal plate, then any floor space at the rear of the van container not covered with pallets should also be covered with fiberboard. It is also recommended that the load be braced with either an air bag or wood bracing to maintain pallet stack placement.

8. Vehicle Routing. Route the shipment by the fastest overland and ocean routes possible to keep transit time to a minimum. For shipment to Europe, overland shipments to Gulf or East Coast ports should be by truck or unit train to keep total transit time from packing to arrival in Europe to three weeks or less.

9. Care of Product upon Arrival. On arrival at destination, plums should be marketed rapidly since most of their market life has been exhausted. Plums should be ripened at retail or by the consumer at 18EC (65EF). Plums should not be stored after arrival in export markets for more than a few days at about 1EC (34EF).

POTENTIAL POSTHARVEST LIFE AND RIPENING PERIOD ON STONE FRUIT

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One of the most frequent complaints by consumers and wholesalers is the presence of flesh browning, flesh mealiness, black pit cavity, flesh translucency, red pigment accumulation (bleeding), and loss of flavor on apricot, peaches, nectarines, and plum. These symptoms are consequence of internal breakdown also called chilling injury, dry fruit, mealiness, or woolliness. These symptoms normally appear after placing fruit at room temperature while some ripening is occurring, following cold storage. For this reason, this problem is usually experienced by the consumers, and not by the grower and/or packers. This disorder is the main limitation on the shipping of some plums and late California peaches and nectarines. The symptom intensity and time of appearance during the postharvest life varied according to cultivars, cultural practices and postharvest handling.

Among stone fruits the greatest symptom development occurs at temperatures between about 36°F and 46°F (2.2° and 7.8°C). While symptoms will still develop at 32°F (0°C) or below, they develop more slowly and normally become less severe than at higher temperatures. Stone fruit cultivars vary greatly in susceptibility to internal breakdown injury (Table 1). Some of them show no apparent susceptibility when grown under California climatic conditions. Among peaches and nectarines; early season cultivars are least susceptible, late-season cultivars most susceptible. Among plums, there is no seasonal pattern of susceptibility. Even under the best storage and handling conditions, stone fruit have a limited postharvest life. An evaluation of the potential postharvest life of stone fruit stored is presented under market life in Table 1. This market life means the maximum number of weeks for each of the cultivars tested under a continuously exposure to 32°F and 90% RH. As these conditions never occurred during the storage, transportation and handling at the retail end the potential postharvest life of stone fruit cultivars never is reached, normally it is shorter than these given on Table 1.

The best way to eliminate this problem would be to produce cultivars resistance to this problem. Different conditioning treatments to extent postharvest life of our actual stone fruit cultivars are starting being studied for our California conditions at the F. Gordon Mitchell Laboratory at the KAC.

In the meantime, temperature management is the only tool commercially available to delay the onset of internal breakdown. Storage below 0°C (32°F) but above the freezing point is beneficial to delay chilling injury symptoms and extent market life. Use of controlled atmosphere (CA) conditions has been shown some beneficial effect on extent postharvest life on Angelino and Friar but not in Casselman grown in California (Table 2).

The rate of fruit softening, number of days to be ready to be eaten, varies among different peach, nectarine and plum cultivars (Table 1). Although, physiological maturity stage and conditions during ripening can modify the general guideline information presented in Table 1. Application of ethylene will only assure more uniform ripening without shortening the ripening period. Except for the "very slow" ripening plum cultivars such as: Angeleno, Black Beaut, Casselman, Kelsey, Late Santa Rosa, Nubiana, Queen Ann, Red Rosa, and Roysum in which ethylene application induces and accelerates the ripening period.

On the other hand, ethylene removal during postharvest handling will not shorten the ripening period for nectarine, peach and some plum cultivars. The benefit of extending postharvest life of "very slow" plum cultivars by using ethylene removal devices has not been tested under commercial conditions.

Table 1. Postharvest performance rating of different stone fruit cultivars grown in California.

	Postharvest performance		
Variety	Ripening[Z] period (No. days)	Internal breakdown susceptibility[Y] @ 41°F	Market life wks @ 32°F
NECTARINE			
Armking	<3	L	6
Armqueen	<3	L	6
August Red	8	M	3
Aurelio Grand	<3	H	6
Autumn Grand	5-9	H	2-3
Early Sungrand	<3	L	6
Fairlane	4-5	H	3
Fantasia	4-5	M	4-6
Firebrite	4-5	L	3-6
Flamekist	4-6	M	3

Flaming Red	6	M	3
Flavortop	4-5	L	4-5
Gold King	6-9	H	3-5
Granderli	4-5	L	6
Independence	4-5	L	5-6
July Red	5	L	6
June Glo	4	L	>6
Late Le Grand	6-9	L	3
Le Grand	4-5	L	4-6
May Diamond	4	L	6
May Glo	3	L	4
May Fair	4-5	L	6
May Grand	3-5	L	6
Moon Grand	4-5	L	6
Niagra Grand	-[X]	L	4
Red Diamond	4-9	M	2-4
Red Free	4-5	L	6
Red Grand	4-5	M	3-5
Red June	4-5	M	3-6
Regal Grand	6-9	H	2-4
Royal Giant	4-5	M	2-4
September Grand	<3	M	3-4
September Red	3-8	M	3
Sparkling Red	4	M	5
Spring Grand	4-5	L	6
Springred	3-5	L	6
Summer Diamond	3	-	-
Summer Grand	4-9	L	5
Summer Red	8	M	5
Sun Grand	<3	L	4

PEACH

Angelus	4-5	H	2
Autumn Gem	6-9	H	1
Belmont	5	H	1
Calred	4-5	H	2
Carnival	4-5	H	2
Cassie	2	H	2
Coronet	<3	L	4
Early Coronet	4-5	H	3
Early Fairtime	<3	H	2
Early O'Henry	4-5	H	4
Elegant Lady	4	H	4
Fairtime	<3	H	2
Fay Elberta	4-5	H	3-6
Fayette	4-5	H	2
Firered	6-9	H	2
Flamecrest	5-9	L	3
Flavorcrest	4-5	H	4
Fortyniner	<3	M	4
June Lady	4-5	H	3-4
Kings Lady	3	H	2
Lacey	6	M	6
Maycrest	4-5	H	3-6
Merricle	4-5	M	3
Merrill Gemfree	4-6	L	6
O'Henry	4-5	M	4
Pacifica	4-5	H	2
Pageant	4-5	H	2
Parade	4-5	H	3
Redcal	4-5	H	2
Redtop	3-4	L	4
Regina	4-5	L	3
Royal Gold	<3	H	4+
Royal May	-	L	6
Ryansun	4	M	3
Sparkle	4	M	3
Springcrest	3-5	H	3-4
Springold	<3	H	3
Spring Lady	5	L	5
Summer Lady	6	H	5
Summerset	6-9	H	3
Suncrest	<3	M	2
Windsor	6-9	H	2

PLUM

Ambra	4-5	H	2
Angeleno	>10	-	-
Black Amber	4	-	-
Black Beaut	>10	L	3
Black Diamond	>10	-	-
Casselman	>10	M	5-6
Catalina	5	L	6
Durado	6-9	H	1
El Dorado	6-9	M	3-5
French Prune	8	L	>8
Friar	4-5	M	3-4
Frontier	<3	H	4+
Grand Rosa	4-8	H	3
July Santa Rosa	4-5	H	3
Kelsey	>10	H	2
Laroda	4-5	L	4
Late Santa Rosa	>10	L	3
Moyer	>10	L	5
Nubiana	>10	H	2
President	6-9	L	3
Queen Ann	>10	M	4
Queen Rosa	4-5	M	4+
Red Beaut	6-9	H	1-2
Red Rosa	>10	H	4
Rosemary	10	L	4
Roysum	>10	M	4
Royal Diamond	8	M	6
Santa Rosa	6-9	L	3-5
Simka	6-9	M	3
Spring Beaut	>10	L	2
Wickson	4-5	L	4

[Z] Days to reach 2 pounds or less. Based on an initial flesh firmness of 12 lbf (5.4 kgf) for nectarines or peaches, and 7 lbf (3.2 kgf) for plums.

[Y] Rankings are summarized from detailed test results. Ripening period and market life can vary accordig to initial maturity, orchard influence and conditions during the ripening and storage period. For convenience a common designation of low (L), medium (M), and high (H) is used for internal breakdown symptoms. Same cultivars can display different internal breakdown susceptibility when they are growing under different environmental conditions.

x Data unavailable.

Table 2. Estimating postharvest life of three plum cultivars as influenced by storage conditions.

	Postharvest Life (months)			
	Air		Ca	
Cultivar	-1.1°C	0.6°C	-1.1°C	0.6°C
Angelino	4	2	1-2	5
Casselman	2-3	1	1	2-3
Friar	1	<1	2	2

z "Postharvest Life" is the length of time for which fruit could be stored with at least 75% of the fruit remaining marketable.

LIGHTING FOR FRUIT AND VEGETABLE SORTING

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Suggested Lighting Guidelines for Produce sorting:

1. Use General Electric SP-30 (or equivalent) illumination at the sorting area on all fresh produce packing lines.

2. Adjust fluorescent fixture height and type, and select lamp power levels (standard, high, or very high output), so that light-colored produce receives 2000 or 2500 1x of illumination and dark-colored produce receives 4000 to 5000 1x of illumination.

3. Use a dark background color (black, gray, dark brown) on the conveyor surface carrying the produce, so that reflected light energy from the carrier is not greater than that from the produce.

4. Select similar dark colors for equipment parts and worker clothing in the immediate sorting area so that bright areas can not interfere with the established vision conditions for the workers.

5. Screen, block or direct all task light sources to that they can not glare in the workers eyes.

6. Minimize the influence of natural, stray, and general area lighting in the sorting area.

THE IMPORTANCE OF PICKING APPLES AT THE OPTIMUM MATURITY

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According to their respiration and ethylene production patterns, apples are classified as climacteric fruit. These fruit produce large amounts of CO_2 (respiration) and ethylene at the time of ripening. As apples ripen, they develop sweetness and aroma and become more soft; they also become more susceptible to diseases and bruising. In general, to extend postharvest life, apples are commercially picked when they are mature but not ripe. They then must undergo a climacteric phase (ripen) prior to consumption. Thus, many apples undergo climacteric ripening during storage or marketing. Harvest maturity effects fruit quality, the rate of fruit deterioration (senescence) and susceptibility to storage disorders. If the fruit are picked under-mature, they will fail to ripen or will ripen abnormally and the quality will be poor. High water loss, low sugar content, high acidity, low volatile production, and high starch content are characteristics of immature fruit which contribute to inadequate flavor development. Immature apples are also more susceptible to storage scald and bitter bit problems. Over-mature fruit can result in a short storage life. These fruit often have reduced firmness in comparison to mature fruit and are more susceptible to mechanical injury and disease infection. Over-mature fruit may develop poor eating quality and off-flavors. Furthermore, these fruit are more susceptible to water core and internal breakdown (physiological disorders) and are poor candidates for controlled atmosphere storage.

For these reasons, determination of the apples' optimum harvest maturity is the key factor for insuring maximum storage life and quality while minimizing postharvest losses. However, determination of optimum maturity in apples has been a challenge to many postharvest physiologists. Although the literature relating to predicting maturity in apples is voluminous, a satisfactory method has not been found for all of the major apple varieties. A maturity standard that works in one growing region may not be appropriate for another region. The use of climatic data to predict the date of harvest by a modification of the "days from full bloom" or even the improved method based on days from the "T" stage has provided only vague predictions. In an attempt to provide a more satisfactory prediction of the maturation date, researchers have studied a number of changes which occur during fruit development: respiration rate, ethylene production rate, sugar content (soluble solids), starch content and firmness changes. Unfortunately, some of these changes occur too late to be useful as a predictor of optimum maturity (respiration, ethylene, firmness) and others are too variable year to year and orchard to orchard (soluble solids). An improvement of the old starch pattern, the starch-iodine index, has proved to be a satisfactory indicator of 'Granny Smith' apple maturity in California, the Pacific Northwest, and New Zealand.

Fuji

We have little objective information about harvest maturity of California grown 'Fuji' apples. However, we do know that this variety requires several pickings. During maturation, red skin color turns from muddy brown to clear bright red. However, red color development is not a good indicator of maturity. Many 'Fuji's are selected for harvest based on ground color. The change from green to yellow to golden indicates advancing maturity. By the time the fruit reach a golden yellow ground color, many apples will have severe watercore. Soluble solids content has not been a useful guide to maturity since seasonal differences due to cultural practices, climatic conditions and cropping levels cause large variations in soluble solids content. Preliminary testing in Washington indicates that respiration and ethylene production rates may also be poor indicators of maturity. Some growers are harvesting at the first sign of watercore in the most mature fruit on the tree. This delay in harvest for the purpose of obtaining additional red color may affect fruit quality and storability. Testing will be underway this season to answer this question and begin to determine the optimum harvest date for California-grown 'Fuji' apples to ensure optimum storage life and fruit quality.

Gala

We also have very little information about 'Gala' apples grown in California. However, it appears that 'Gala' should be picked on the basis of ground color and multiple picks are required to obtain fruit of good size, color, and eating quality, and with uniform maturity. Washington growers seem to be harvesting fruit of excellent eating quality when the ground color is changing from green to yellow. Delaying harvest time to improve fruit size or color can result in the development of cracks in the stem bowl. Red skin color, firmness, soluble solids content and acidity do not relate well to maturity. A study is also underway this season with 'Gala' apples which should provide objective information about optimum harvest maturity of California-grown 'Gala's.

Granny Smith

In California, there is a minimum harvest maturity standard in place for 'Granny Smith' apples which requires that the average score for about 30 apples be 2.5 or greater at harvest. This corresponds to 15% of the cortex white after starch-iodine staining and normally occurs about 170 days from full bloom. Three years of extensive testing determined that this level of starch was well correlated with good storage life, a minimum of postharvest disorders such as scald, bitter pit and watercore, and optimum eating quality after four months of storage in air. The California standard is remarkably similar to that developed in New Zealand for 'Granny Smith' but is quite different from the Washington State maturity standard which is also based on the starch-iodine index but tests the shipping maturity instead of the harvest maturity.

SIGNIFICANCE OF MUCOR DECAY ON APPLES

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Historical perspective. Mucor decay on apples is caused by *Mucor piriformis*, the postharvest pathogen noted primarily for decaying pears kept in cold storage in the Pacific Northwest. *Mucor* spp. were of relatively minor importance as postharvest pathogens until recently when *M. piriformis* caused a number of serious losses. *Mucor piriformis*, initially described by A. Fischer in 1892, was first reported as a cause of fruit decay in 1895. Subsequent reports cover approximately a century of Mucor rot, mainly of pome fruit but also some stone fruit. In 1975 a Mucor rot outbreak on pome fruit occurred in the mid-Columbia area of Oregon and Washington. In 1977 Mucor rot caused significant losses of stone fruit in California when an unusual amount of decay developed during cold-temperature (42^{o}F) transit of fresh-market peaches from California to markets in the eastern United States and of nectarines shipped from Chile to California. *M. piriformis* also caused serious fruit losses in cold storage during 1988-1989 in Asian pears, Fuji apples, and plums, all grown in California. Mucor rot of apples remains an annual problem in Washington State.

In 1988 Fuji apples packed in gift boxes showed unusual, water-soaked decay and the causal pathogen of this decay was identified as *M. piriformis*. Decay was initiated in the core area of apples or around the calyx area. Because drench solutions containing fungicides are ineffective against *M. piriformis*, propagules from the solutions sucked into the cavity cause decay that starts from inside the apples. We were able to reproduce this type of decay after placing the apples in a solution containing spores of *M. piriformis* and applying vacuum force.

In December 1992 a major lot of Granny Smith apples from a packinghouse in California's Central Valley had an outbreak of two major decays: in samples we examined at the Postharvest Facility at Kearney Agricultural Center, we found 68% of the decaying fruit had Botrytis gray mold caused by *Botrytis cinerea* and 32% Mucor rot, the latter caused by *M. piriformis. M. piriformis* belongs in the same family as *Rhizopus* and

Gilbertella, two other pathogens that cause significant postharvest losses. Although storing fruit below 42^{o}F will prevent the development of Rhizopus and Gilbertella rots (common on peaches and nectarines but not on apples), Mucor rot will still develop since spores of *M. piriformis* can germinate and grow even at 31^{o}F. Within two to three months of storage of apples at 31^{o}F, the fungus can grow and sporulate, causing very distinct brown, water-soaked lesions. Sporulation of the fungus can be seen as tufts of white, straight, hair-like mycelia bearing a gray spherical sporangium that contains thousands of spores. Because the fungus produces strong pectinolytic enzymes, liquid from decaying fruit can drip on healthy fruit and cause secondary infections in storage bins. Liquid from fruit dripping directly from a decaying fruit contained near 50,600 spores per milliliter, and liquid dripping from a wooden box where decayed fruit was held had 48,200 spores/ml of *M. piriformis*. Such decay was noticed in samples brought to our laboratory from the packinghouse in the Central Valley. We located the orchard where the fruit originated and found that the soil of that orchard contained 108 propagules of *Mucor* species including *M. piriformis* per gram of soil, suggesting that contamination of the fruit occurred through the soil.

Seventy isolates of *M. pririformis* were isolated from Granny Smith apples and five random isolates were tested for pathogenicity on healthy Granny Smith apples. All tested isolates were highly pathogenic, causing lesions of 63.5 mm in diameter after 7 to 8 days incubation at room temperature.

How to avoid Mucor rot (extrapolation from what we know about preventing Mucor rot of pears).

1. **Do not harvest apples when it rains and avoid picking up fruit fallen to the ground unless fruit is for making juice.**

2. **Because *M. piriformis* requires wounds for infection, avoid wounding and bruising fruit.**

3. **Fruit dropped on the orchard floor should be removed from the orchard because it decays from *M. piriformis*, increasing the fungal spore inoculum in the soil.**

4. **Avoid contamination of harvest bins with soil; in Oregon, it was shown that pear fruit can be contaminated by soil attached to the bottoms of harvest bins.**

<u>For more general information on Mucor on stone and pome fruit you may read</u>:

Michailides, T.J., and Spotts, R.A. 1990. Postharvest diseases of pome and stone fruits caused by Mucor piriformis *in the Pacific Northwest and California. <u>Plant Disease 74:537-543</u>*.