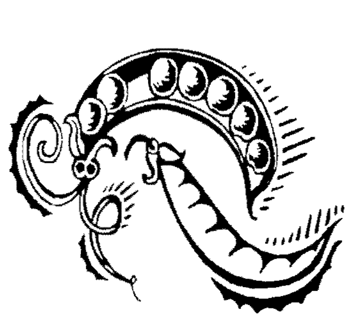
CHAPTER 9



POSTHARVEST INTEGRATED PEST MANAGEMENT

Many of the practices described so far in Part I are valuable because they help reduce pest problems during postharvest handling, storage and marketing. The first line of defense against insects and disease is good management during production. Monitoring to determine actual pest levels and a combination of appropriate genetic, biological, cultural, physical and chemical controls is usually enough to prevent serious pest damage. The second defence is careful harvesting and preparation for market in the field, since most diseases can't gain a good start without easy entry through cuts, bruises or injuries. Next, sorting out damaged, over-ripe or decaying produce will limit contamination of the remaining, healthy produce. Finally, even when the greatest care is taken, sometimes produce must be treated to control insects or decay-causing organisms.

Postharvest IPM Tools

Genetic: pest resistance
Biological: yeasts, antagonistic bacteria
Cultural: sanitation, decrease mechanical damage
Physical: sorting, heat treatment, temperature and RH management
Chemical: chlorinated wash water, pesticides

This chapter will review some of the postharvest technologies related to pest control and outline the practices recommended for postharvest Integrated Pest Management (IPM). Also provided is information that will help you to identify pest problems and implement specific postharvest IPM methods and treatments.

GENERAL DOs AND DON'Ts FOR POSTHARVEST IPM

Consider the entire system (production, harvest, postharvest and marketing) when developing pest management strategies.

PRE-HARVEST
Begin with cultivars offering some natural resistance to the pests you expect to have to deal with in your region.

Plant only good quality, clean seed or stock.

Use appropriate cultural practices during production to assist the produce to avoid and/or resist pest attack (proper planting density, fertilization, irrigation, pH modification, weeding, pruning, thinning, ventilation/air movement through the canopy).

Monitor fields/orchards to determine actual pest levels before implementing pest controls.

Use a combination of appropriate pest control methods (biological control, chemical pesticides, protectants, sanitation practices).

Keep fields and orchards free of debris and discarded produce. Eradicate diseased produce.

HARVEST
Avoid damage during harvest by handling produce gently.

Harvest at the proper maturity for produce to have the maximum resistance against pests.

Use sharp, clean tools for harvest and trimming processes.

Do's and Don'ts continued:

CURING
Cure root, tuber and bulb crops to heal harvest wounds and increase resistance to pests.

PACKINGHOUSE
Sort to remove any damaged, decayed, over-mature or under-ripe produce.

Wash or clean produce to remove soil and debris and to reduce the amount of innoculum on surfaces.

Trim senescent leaves from vegetables and remove dried flower parts from fruits.

Use appropriate postharvest treatments to manage pest problems (chemicals, heat, hot water, pesticides).

PACKING
Avoid over-use of liners that constrict air flow in the package and contribute to condensation (free moisture) and poor cooling efficiency.

Use ventilated plastic bags as liners for produce highly susceptible to water loss.

STORAGE
Avoid ethylene damage to sensitive commodities by using ethylene scrubbers and avoiding mixed lots of produce in storage.

Keep produce at its lowest safe temperature for maximum pest management.

Avoid chilling injury by keeping sensitive commodities at appropriate moderate temperatures.

Keep leafy vegetables, carrots, and cool season vegetables at very high relative humidity (98-100%) to reduce incidence of decay.

Store certain fruits at slightly lower RH than commonly recommended in order to reduce decay.

Store onions and garlic at low humidity to reduce decay (60-70% RH).

Most diseases cannot gain a good start without your help:

- wounds, cuts, bruises
- chilling injury
- free moisture on produce surface
- advanced stages of ripening or senescence

Common Postharvest Diseases

FUNGAL DISEASES

A variety of fungal diseases cause the greatest market and storage losses:

Disease organism	Scientific name	Affects these crops
Alternaria black rot	*Alternaria citri*	citrus
Alternaria rot	*Alternaria alternata*	tomatoes, peppers
	Alternaria sp.	stone fruits
Black rot	*Physalospora obtusa*	apples, pears, quinces
	Endocondiophora frimbriata	sweet potatoes
Blue mold	*Penicillium expansum*	apples, pears, quinces
	Penicillium italicum	citrus
	Penicillium sp.	grapes, berries, stone fruits
Bitter rot	*Glomerella cingulata*	apples, pears, quince
Brown rot	*Monolinia fructicola*	stone fruits
Buckeye rot	*Phytophthera* sp.	tomatoes, peppers
Bull's eye rot	*Pezicula malicorticus*	apples, pears, quince
Cladosporium rot	*Cladosporium hebarum*	grapes, small fruits
Crate rot	*Rhizoctonia carotae*	carrots
Fusarium tuber rot	*Fusarium* spp.	potatoes
Fusarium wilts	*Fusarium* spp.	potatoes
Fusarium rot	*Fusarium* spp.	leafy vegetables, root crops, onions, melons, beans

Fungal diseases continued:

Disease organism	Scientific name	Affects these crops
Gray mold	*Botrytis cinerea*	grapes, berries, stone fruits, tomatoes, peppers, leafy vegetables, root crops, onions, melons, beans
Green mold	*Penicillium digitatum*	citrus
Late blight	*Phytophthora infestans*	potatoes, tomatoes, peppers
Rhizopus rot	*Rhizopus* sp.	leafy vegetables, root crops, onions, melons, beans, sweetpotatoes
	Rhizopus stolonifer	tomatoes, peppers, grapes, berries, stone fruits
Sour rot	*Geotrichum candidum*	citrus, stone fruits, tomatoes, peppers
Stem end rot	*Phomopsis citri* *Diplodia natalinsis*	citrus citrus
Watery soft rot	*Sclerotinia sclerotiorum*	leafy vegetables, root crops, onions, melons, beans
White rot	*Botryospheria ribis*	apples, pears, quince

Bacterial Diseases

In general, bacteria cause few losses in tree fruits or small fruits. Potatoes are highly susceptible to bacterial disease when injured during harvest or handling. The following bacterial diseases are most common and cause the greatest market and storage losses:

Disease organism	Scientific name	Affects these crops
Bacterial soft rot	*Erwinia* sp.	Leafy vegetables, root crops, beans, onions, peppers, melons, cucumbers, tomatoes
	Erwinia carotovora	potatoes
Brown rot	*Pseudomonas solanacearum*	potatoes
Ring rot	*Cornybacterium sepedonicum*	potatoes
Slimy soft rot	*Clostridium* spp.	potatoes

Viral and Nematode Diseases

These tend to be uncommon and of minor importance, with the following exceptions:

Disease organism	Scientific/common name	Affects these crops
Net necrosis	potato leaf roll virus	potatoes
Root knot nematode	*Meloidogyne* spp.	potatoes, carrots, root crops

Source: Moline 1984

PRE-HARVEST AND HARVEST PRACTICES

Genetic Factors and Planting

Begin by planting cultivars offering some natural resistance to the pests you expect to have to deal with in your region. Plant only good quality, clean seed or stock. Paying more for certified seed or planting materials will pay off in reduced costs for pest management and lower losses due to disease.

Genetic resistance to pest problems differs by variety:

	Problem	Low or no resistance	Good to high resistance
Potatoes	'Gangrene'	'Blanka' 'Gracia' 'Vanessa'	'Golden Wonder'
Berries	*Botrytis cinerea*	soft varieties	firm fruited varieties
Onions	neck rot	sweet varieties	pungent varieties

Field and Orchard Management

As discussed in Chapter 2, keeping the field and orchard clean will prevent the buildup of pests and disease organisms, and minimize the opportunities for the produce to be attacked. Keep fields and orchards free of debris and discarded produce. Eradicate diseased produce by burning or removing waste. Using appropriate cultural practices during production will assist the produce to avoid and/or resist pest attack. Proper planting density will reduce susceptibility to pests, avoiding over-fertilization and over-irrigation will keep plants healthy. You may need to prune to ensure proper ventilation and adequate air movement through the canopy. Thinning not only improves fruit size and quality, but protects trees from damage caused by over-weight branches.

Monitoring pest levels during production can save you a lot a expense by limiting your treatments to those that are actually necessary for pest control. Sampling kiwifruit sepals 4 months after fruit set for *Botrytis cinerea* (gray mold) can predict incidence in storage. If less than 6% of fruits are determined to be infected, no pre-harvest fungicides are required (Michailides and Morgan, 1996).

MATURITY AT HARVEST AND PEST MANAGEMENT

Harvesting at the proper maturity will ensure that produce has the maximum level of natural protection against pests and diseases. As discussed in Chapter 3, this moment will differ for various commodities. Under-mature and over-ripe produce is often more susceptible to diseases and insect damage than produce at prime maturity. As produce ripens, the flesh and skin softens and offers less protection against pests. And when produce bruises more easily pests are allowed easy entry.

TEMPERATURE AND RH MANAGEMENT

The importance of proper cooling cannot be over-emphasized. Chapter 6 provides many examples of how reducing temperature also reduces disease problems.

Handle and store at proper RH: While high humidity in the storage environment is important for maintenance of high quality produce, free water on the surface of commodites can enhance germination and penetration by pathogens. When cold commodities are removed from storage and left at higher ambient temperatures, moisture from the surrounding warm air condenses on the colder product's surfaces. A temporary increase in ventilation rate (using a fan) or increasing exposure of the commodity to drier air can help to evaporate the condensed moisture and to reduce the chances of infection.

Remember: Serious disease problems can result from over-cooling chilling sensitive commodities.

Decay in fruits can be increased if free water is available from condensation and drips onto the produce. These fruits and vegetables will decay less when held at a lower RH than the typical recommendation of 95-99% (Spotts, 1984):

apples	88% RH
grapes	60%
pears	90-95%
persimmon	75-83%
squash (winter)	40%
strawberry	85-90%
sweetpotatoes	79%

Remember, also, that increased rooting and decay will occur in onions and garlic when these crops are handled or stored in a high humidity environment.

POSTHARVEST TREATMENTS

Heat and Cold

Certain fungi and bacteria in their germination phase are susceptible to cold, and infections can be reduced by treating produce with a few days of storage at the coldest temperature the commodity can withstand without incurring damage. *Rhizopus stolonifer* and *Aspergillus niger* (black mold) can be killed when germinating by 2 or more days at 0 °C (32 °F). On the other hand, brief hot water dips or forced-air heating can also be effective, especially for reducing the microbial load for crops such as plums, peaches, papaya, cantaloupe and stone fruits, sweetpotatoes and tomatoes. See Chapter 4 for specific recommendation for heat treatments in the packinghouse.

Cold treatments can control some insect pests, and are currently used for the control of fruit flies. Treatment requires 10 days at 0 °C (32 °F) or below, or 14 days at 1.7 °C (35 °F) or below, so treatment is only suited to commodities capable of withstanding long-term low-temperature storage such as apples, pears, grapes, kiwifruit and persimmons. For produce packed before cold storage treatment, package vents should be screened to prevent the spread of insects during handling.

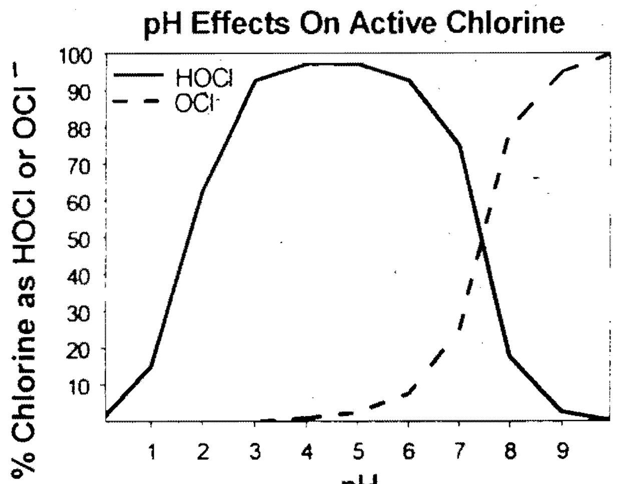
Control of storage insects in nuts and dried fruits and vegetables can be achieved by freezing, cold storage (less than 5 °C or 41 °F), heat treatments, or the exclusion of oxygen (0.5% or lower) using nitrogen. Packaging in insect-proof containers is needed to prevent subsequent insect infestation.

Hot water dips or heated air can also be used for direct control of postharvest insects. In mangoes, an effective treatment is 46.4 °C for 65 to 90 minutes, depending on size. Fruit should not be handled immediately after heat treatment. Whenever heat is used with fresh produce, clean, cool water showers or forced cold air should be provided to help return the fruits to their optimum temperature as soon as possible after completion of the treatment. Refer to the current USDA *APHIS Plant Protection Quarantine Treatment Manual* for the latest information and details on heat treatments.

SANITATION

Washing produce with chlorinated water can prevent decay caused by bacteria, mold and yeasts on the surface of produce. Calcium hypochlorite (powder) and sodium hypochlorite (liquid) are inexpensive and widely available. The effectiveness of the treatment will be decreased if organic matter is allowed to build up in the wash water. The effectiveness of chlorine increases as pH is reduced from pH 11 to pH 8, but at lower pH chlorine becomes unstable.

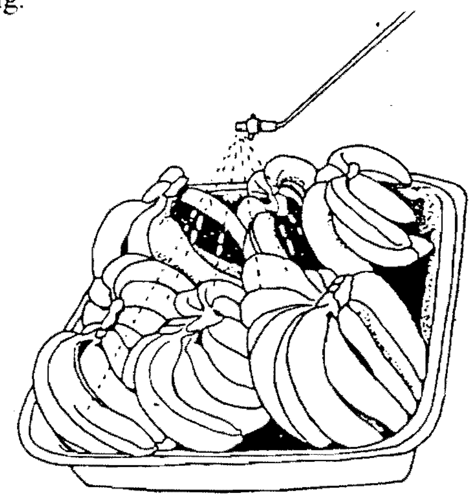
Fruits and vegetables can be washed with hypochlorite solution (25 ppm available chlorine for two minutes) then rinsed to control bacterial decay. Alternatively, these commodities can be dipped in hypochlorite solution (50 to 70ppm available chlorine) then rinsed with tap water for control of bacteria, yeasts and molds. Follow local regulations on disposal of chlorinated waste water.



PESTICIDES

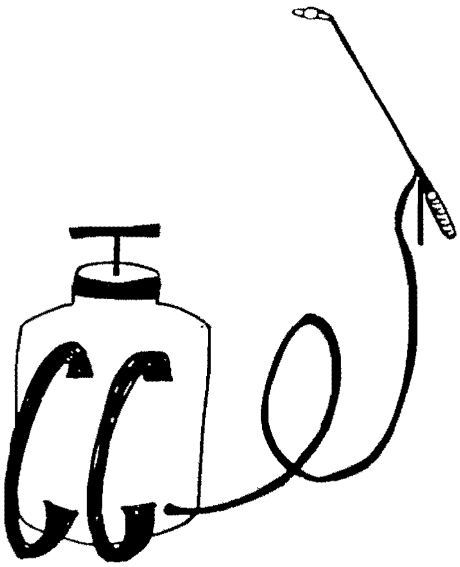
A wide variety of chemicals are available for postharvest pest management. They are used in various ways-- as dips, sprays, dusts or applied on a pad of absorbent paper. Always follow label instructions and be aware that recommendations for use may differ by state and commodity. When using chemical pest controls, you need to consider cost, availbility, regulations for proper use, and residue tolerances. Recently many chemical controls have been banned due to concerns over residues and the possible consequences for human health. Others, such as benomyl are no longer registered for postharvest applications. Whenever possible it is a good idea to try to reduce your reliance on chemical controls.

When using chemicals in solution in the field on packinghouse, make sure you get good coverage by applying to the run-off stage. Always use potable water for spraying— recent *Cyclospora* outbreaks in raspberries in Guatamala were traced to contaminated water used to apply pesticides. The low cost, simple equipment illustrated here can ensure postharvest chemicals are applied as intended. The tray has perforations on the base to allow the solution to drain and the produce to dry before further handling.



Some plant materials are useful as natural pesticides. The pesticidal properties of the seeds of the neem tree (as an oil or aqueous extract) are becoming more widely known and used throughout the world. Native to India, neem (*Azadirachta indica*) acts as a powerful pesticide on food crops but appears to be completely non-toxic to humans, mammals and beneficial insects (NRC, 1992). Any "natural pesticide" must be shown to be safe for humans before its approval by regulatory authorities.

Bioneem (developed by Ringer Corp. Minneapolis, MN, US) currently has EPA registration in all US states except AZ, CA and NY, but only for use on ornamentals. The EPA has also approved a neem-based biological pesticide developed by Tata Oil Mills Ltd. (TOMCo) for use on a wide range of food crops, fruits and grains during production. We expect to hear more about this bio-pesticide in the next few years, and eventually to be able to use it safely in postharvest horticulture applications.



CONTROLLED / MODIFIED ATMOSPHERE TREATMENTS

For commodities that tolerate high CO_2 levels, 15 to 20% CO_2-enriched air can be used as a fungistat to control decay-causing pathogens, such as *Botrytis cinerea* on strawberry, blueberry, blackberry, fresh fig and table grapes during transport. See Chapter 5 for a description of the method for modified atmosphere packaging within a pallet cover.

Low O_2 and/or high CO_2 have been used to kill certain insects in commodities that can tolerate these conditions. The effectiveness of insecticidal atmospheres depends upon the temperature, relative humidity, duration of exposure and life stage of the insect. The following are some examples from Mitcham et al (1997):

Insecticidal atmospheres (0.5% or lower O_2 and/or 40% or higher CO_2) have been shown to be an effective substitute for methyl bromide fumigation to disinfest dried fruits, nuts and vegetables.

The first and third instars of the greenheaded leafroller (*Planotortrix excessana*) and the first and fifth instars of the brownheaded leafroller (*Ctenopseustis obliquana*) and the light brwon apple moth (*Epiphyas postvittana*) are completely killed in 2 months when apples are stored at 0.5 °C in 3% O_2 and 3% CO_2.

The eggs of the apple rust mite (*Aculus schlechtendali*) and the European red mite (*Panonychus ulmi*) are killed in 5.3 months when apples are stored at 2.8 °C in an atmosphere of 1% O_2 and 1% CO_2.

Codling moth larvae (*Cydia pomonella*) are killed in 3 months when apples are stored at 0 °C, 1.5-2% O_2 and less than 1% CO_2.

In kiwifruit, the adult two-spotted spider mite (*Tetranychus urticae*) is killed by 40°C, 0.4% O_2 and 20% CO_2 in only 7 hours.

When persimmons are stored at 20 °C, 0.5% O_2 and 5% CO_2, the third instar of leafrollers (*Planotortrix excessana*) is killed in 4 days and the larvae and adult mealy bug (*Pseudococcus longispinus*) is killed in 7 days.

Sweetpotato weevil (*Cylas formicarius elegantulus*) has been controlled at ambient temperature in stored tropical sweetpotatoes by treatment with low oxygen and high carbon dioxide atmosheres. At 25 °C (76 °F), storage in 2 to 4% O_2 and 40 to 60% CO_2 results in 100% mortality of adult weevils in 2 to 7 days.

Codling moth (*Cydia pomonella*) in stone fruits can be controlled at 25 °C (76 °F) by using atmospheres of 0.5% oxygen and 10% carbon dioxide for 2 to 3 days (adult or egg) or 6 to 12 days (pupa). Normal color and firmness changes during ripening are not affected by treatment.

COSTS AND BENEFITS OF POSTHARVEST IPM PRACTICES

Costs:
materials
labor
power

Benefits:
reduced decay rates or insect losses
longer shelf life
improved quality

Example 1:
Harvest 1000 lbs of green beans, sort, cool and pack beans for marketing in California within one week. Postharvest IPM in this case involves a quick hot water dip to reduce disease problems during storage and marketing.

	Minimal pest controls	Postharvest IPM
labor for harvest (5 hours at $7.50/hr)	$35	$35
labor for sorting/grading	$12	$12
hot water treatment (0.5 minutes at 52 °C)		$10
ice bath		$10
postharvest losses	20%	5 %
amount available to market	800 lbs	950 lbs
market value	$0.50/lb	$0.79/lb
	$400	$750
costs: labor	($47)	($47)
pest control	0	($20)
Potential net sales	$353	$683

Example 2:

Harvest 400 kg of french green beans, sort, cool and pack beans for marketing in India within one week. Postharvest IPM in this case involves a quick hot water dip followed by an ice bath to reduce disease problems during storage and marketing.

	Minimal pest controls	Postharvest IPM
labor for harvest (6 hours @ Rs 80/day)	Rs 50	Rs 50
labor for sorting/grading		Rs 30
hot water treatment (0.5 minutes at 52 °C)		Rs 200
ice bath		Rs 200
postharvest losses	20%	5 %
amount available to market	320 kg	380 kg
market value	Rs 10/kg	Rs 20/kg
	Rs 3200	Rs 7600
costs: labor	(Rs 50)	(Rs 80
pest control	0	(Rs 400)
Potential net sales	Rs 3150	Rs 7120

SOURCES OF PEST MANAGEMENT EQUIPMENT AND SUPPLIES

automatic chlorine dispenser	Orchard Equipment and Supply Co.
fungicides	Brogdex Co.
sprayers, knap-sack, backpack	A.M. Leonard Orchard Equipment and Supply Co. Northern
sulfur dioxide pads	Zellerbach

For addresses and phone/FAX numbers of suppliers, please refer to Appendix D.

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