2. HORTICULTURAL CROPS

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ABSTRACT

Post-harvest handling has a decisive effect on the extent of post-harvest losses, the final quality, and the market value of horticultural crops. Modern technologies applied in grading, packaging, precooling, storage, and transportation, which minimize losses, preserve quality, and enhance value-added of horticultural crops, have been used successfully in developed countries. However, some modifications, particularly of the equipment and facilities used, may be necessary in order to make them practical in small-scale farming systems. Taiwan's experience in modernizing post-harvest handling technologies may have a reference value for many Asian countries.

INTRODUCTION

Horticultural crops not only provide human beings with nutritional and healthy foods, but also generate a considerable cash income for growers in many countries. However, horticultural crops typically have a high moisture content, tender texture, and high perishability. If not handled properly, a high-value nutritious product can deteriorate and rot in a matter of days or even hours. Therefore, a series of sophisticated technologies have been developed and applied in post-harvest handling of horticultural crops in the last few decades. Unfortunately, many Asian countries have not been able to use this advanced equipment, owing to cost or adaptability problems. Post-harvest losses, therefore, remain high.

This paper includes a general discussion of the nature of post-harvest losses, a brief review of modern technologies, Taiwan’s experiences of both failure and success, and suggestions for strategies to improve post-harvest handling in less industrialized countries. Although horticultural crops include fruits, vegetables, flowers, and ornamental crops, this paper deals primarily with fruits and vegetables.

The quality of fresh fruits and vegetables has a decisive effect on their value. This is particularly true when consumers have a high income and the market provides a wide choice of produce. It is not uncommon in Taipei markets for high-quality fruit to have a price two to three times higher than mediocre produce of the same kind.

While it is cultural practices which determine the quality of produce at harvest, proper handling ensures that the quality is preserved until the produce reaches the consumer. Quality assurance is a prerequisite for high-value fresh fruits and vegetables. In recent years, a variety of fruit and vegetables are being lightly processed for the convenience of consumers while still maintaining their fresh nature. Examples are pre-cut and pre-packaged fruits, salads, and vegetable mixes for cooking.

CAUSES AND MAGNITUDE OF POST-HARVEST LOSSES

Post-harvest losses have many different forms. The most obvious loss is a quantitative loss, such as reduced weight and partial or total waste of a product due to

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decay or senescence. A less discernible loss is a qualitative one, such as deterioration in texture, flavor or nutritional value. Other forms include loss of viability of propagules and reduction in monetary value due to reduced prices.

Post-harvest losses can occur in the field, in packing areas, in storage, during transportation, and in wholesale or retail markets. Severe losses occur because of poor facilities, lack of know-how, poor management, market dysfunction, or simply the carelessness of farmers or workers. Post-harvest losses may also occur at consumers' homes, in the kitchen or on dining tables. However, losses after produce has left the retail market are generally difficult to control by agricultural means and, will not be covered in this Bulletin.

The causes of post-harvest losses can be divided into four categories.

Mechanical Injury

Owing to their tender texture and high moisture content, fresh fruits and vegetables are very susceptible to mechanical injury. Poor handling, unsuitable containers, improper packaging and transportation can easily cause bruising, cutting, breaking, impact wounding, and other forms of injury.

Physiological Deterioration

Fruit and vegetable cells are still alive after harvest, and continue their physiological activity. Physiological disorders may occur due to mineral deficiency, low or high temperature injury, or undesirable atmospheric conditions, such as high humidity. Physiological deterioration can also occur spontaneously by enzymatic action leading to overripeness and senescence, a simple aging phenomenon.

Parasitic Diseases

High post-harvest losses are caused by the invasion of fungi, bacteria, insects and other organisms. Microorganisms attack fresh produce easily and spread quickly, because the produce does not have much of a natural defense mechanism, and has plenty of nutrients and moisture to support microbial growth. Post-harvest decay control is becoming a more difficult task, because the number of pesticides available is falling rapidly as consumer concern for food safety increases.

Lack of Market Demand

Poor planning or inaccurate production and market information may lead to overproduction of certain fruits or vegetables which cannot be sold in time. This situation occurs most frequently in areas where transportation and storage facilities are inadequate. Produce may lie rotting in production areas, if farmers are unable to transport it to people who need it in distant locations.

Nobody knows exactly the extent to which harvested fruits and vegetables are lost rather than consumed. Zaldivar (1991) cited several reports which provide loss figures of 25% or 28-42% worldwide, and 15-60% or 15-50% in less industrialized countries. The actual figure changes from one country or one location to another; it also changes from one season or even one day to another. Therefore, any published figures are no more than estimates. While periodic surveys may help us understand the severity and major causes of losses in a specific location and time, frequent extensive investigation for loss figures is generally unnecessary. The figures vary so rapidly that their usefulness is short-lived.

Although many people believe that post-harvest losses are higher in less industrialized countries, this generalization may not be always true. Higher losses may occur in developing countries for lack of good facilities and technologies. However, post-harvest losses may be lower in less urbanized developing countries, where the products need to be transported a shorter distance to market, and there is a shorter time lag period between harvesting and consumption. Consumers in such countries are also more likely to buy lower-grade products. In industrialized countries, on the other hand, produce is shipped for longer distances, the marketing system is more complicated, and consumers demand good quality when they buy food. All these factors contribute to greater post-harvest losses which may not be fully compensated by better facilities and technologies. For instance, Bourne (1986) cited a survey report that losses of produce after arrival in New York City were 1.7 - 14.2%. This includes only losses in wholesale markets, retail outlets and by consumers.

It is safe to say that post-harvest losses occur in every country, but the magnitude and major causes of losses and the effective remedial methods differ greatly from one country to another. In order to solve specific problems in specific areas effectively and economically, a comprehensive knowledge of the nature of post-harvest losses, a grasp of various kinds of technologies, and a tactical selection of strategies is necessary.

EXISTING POST-HARVEST TECHNOLOGIES

Post-harvest technologies which greatly influence the level of post-harvest losses and the quality of produce include grading, packaging, precooling, storage and transportation. Some products also require one or more of the following treatments: trimming, cleaning, curing, disease or insect control, waxing, and ripening. A general description of those technologies adopted in the United States is available in Kader's (1992) book. More detailed but less up-to-date information is also seen in books by Ryall and Lipton (1979), Ryall and Pentzer (1982), and Pantastico (1975). Storage requirements for a wide variety of products are summarized by Hardenburg *et al.* (1986).

Special requirements for each major product are often published in monographs, such as that for citrus fruits by Wardowski *et al.* (1986), and for banana by Stover and Simmonds (1987). Kader (1992) also provides long lists of scientific journals, journals with reviews or abstracts and other periodicals which contain up-to-date information of scientific findings and new technologies related to post-harvest physiology and handling. This Bulletin is not intended to make a comprehensive review of literature, but will give a brief summary of current technology in common use.

Grading

Essentially all fruits and vegetables sold in modern markets are graded and sized. Sophisticated marketing systems require precise grading standards for each kind of product. More primitive markets may not use written grade standards, but the products are sorted and sized to some extent.

Typical grading facilities in large packinghouses include dumpers and conveyors. Produce is graded by human eyes and hands, while moving along conveyor belts or rollers. "Electric eyes" are sometimes used to sort produce by color. In small-scale packing operations, one or a few grading tables may be enough. Dumping, conveying and grasping can cause mechanical injury to some products. Equipment should have a smooth, soft surface, and dumping and grading operations should be gentle, to minimize injuries.

Many products are sized according to their weight. Automated weight sizers of various capacity are used in packinghouses. Round or nearly round fruits are often sized according to their diameter, using automated chain or roller sizers or hand carried ring sizers. An inefficient sizing operation can also cause significant injuries.

Packaging

There are two very different types of packaging. The first is when produce is packed in containers for transportation and wholesale. The second is when produce is packed into small retail units.

Ideal containers for packing fruits and vegetables should have the following attributes. They are easy to handle, they provide good protection from mechanical damage, they have adequate ventilation, and they are convenient for merchandising (i.e. they can easily carry printed information and advertising about the product etc.). They should also be inexpensive, and easily degradable or recyclable. Many kinds of containers have been used, but the "ideal" is yet to be found. Users often put economic considerations first in selecting containers. Fancy containers such as fiberboard boxes, or wooden or plastic crates, are often used for high-value products. Inexpensive containers such as bamboo baskets or nylon net sacs are used for low-priced produce.

Methods of packing can affect the stability of products in the container during shipping, and influence how much the container protects their quality. In fiberboard boxes, for example, delicate and high-priced products are often packed in trays, while other products are simply all put in the box together.

Prepackaging or consumer packaging generally provides additional protection for the products. It is also convenient for retailers as well as customers, and therefore adds value to produce. However, over-use of non-biodegradable plastic trays and wrapping materials, as often seen in modern supermarkets, creates an extra burden of waste disposal and damages the environment.

Precooling

Good temperature management is the most effective way to reduce post-harvest losses and preserve the quality of fruits and vegetables. Desirable storage and transportation temperatures for major fruits and vegetables have been identified and published (e.g. Kader 1992, Hardenburg *et al.* 1986, McGregor 1987). Temperatives which are low, but not low enough to cause chilling-injury, slow down physiological activity and hence the rates of senescence of the products. Low temperatures also reduce microbial growth rates and the rate of decay.

Products harvested from hot fields often carry field heat and have high rates of respiration. Rapid removal of field heat by precooling is so effective in quality preservation that this procedure is widely used for highly perishable fruits and vegetables. Currently used precooling methods include room cooling, forced-air cooling, watercooling, vacuum cooling, and package icing. Cooling equipment and technologies for large-scale operations in the United States are well described in Kader's (1992) book. Smaller capacity equipment can be made using the same principles. Liu (1991) has made a brief summary of cooling principles and methods.

Room cooling is a relatively simple method which needs only a refrigerated room with adequate cooling capacity. The produce is packed in containers which are loosely stacked in the cooling room, leaving enough space between containers for each one to be exposed to circulating cold air. The rate of cooling is rather slow compared to other methods of cooling, because the heat inside each container needs to be transferred to the surface of the container by means of conduction before being carried away by the refrigerated air. It may take hours or even days to cool a product, depending on what kind of product it is, the size and nature of the container, and the temperature and velocity of the circulating air.

Forced-air cooling is a more rapid way of using air to cool produce. Cold air is forced to flow through the inside of each container, so that it carries away heat directly from the surface of the produce rather than from the surface of the container. The air flow is produced by creating a pressure difference between the two perforated sides of each container. The containers are stacked inside a covered tunnel with an exhaust fan at one end. Highly perishable and high-value products such as grapes, strawberries and raspberries may be cooled in less than an hour using this method.

Water cooling (also known as hydrocooling), is a rapid and less expensive method. Produce is exposed to cold water by means of showering or dipping. The required cooling time is often a matter of minutes. However, not all kinds of products tolerate hydrocooling. Hydrocooled products inevitably have a wet surface, which may encourage decay in some kinds of produce.

Vacuum cooling is the most efficient way to cool leafy vegetables, particularly headed ones such as head lettuce, cabbage and Chinese cabbage. The produce is placed inside a vacuum tube in which air pressure is reduced. When the pressure is lowered to 4.6 mm Hg, water "boils" off at • 0°C from all over the leaf surface. The boiling effect draws heat for vaporization, and hence cools the produce. The cooling time is usually in the order of 20 to 30 minutes. Unfortunately, the equipment needed for vacuum cooling is very expensive, and may not be a good choice for small-scale farming systems.

Package-icing or top-icing is the simplest way of cooling. Adding crushed ice, flake-ice or slurry of ice in containers can cool the produce. However, this method is not suitable for produce which is very sensitive to ice-cold temperatures. Cooling by ice also inevitably wets both the produce and container, and generates water which needs to be drained. Fancy equipment is used in large-scale package-icing operations in the United States (Kader 1992), but many vegetable packers in Taiwan simply add ice flakes to each container, either by hand or by shovel.

Storage

Many horticultural crops have a relatively short harvesting season. Storage is needed to extend the marketing period. Various storage methods have been used on a commercial scale (Liu 1991). Air-cooled common storage houses are often used, or underground or cave storage using natural cold air. Storage humidity is sometimes regulated by controlled ventilation and dehumidifiers. Refrigerated storage (cold storage) controls temperature and humidity precisely by mechanical means. Controlled atmosphere (CA) storage controls the concentrations of oxygen and carbon dioxide, in addition to temperature and humidity. Modified atmosphere (MA) storage also controls oxygen and carbon dioxide concentrations, although not as precisely as in CA, by using semipermeable polymeric films. Ethylene may be scrubbed for products responsive to it, regardless of the storage system used. A good control of temperature, humidity and atmospheric composition maximizes the storage life span of a product.

Air-Cooled Common Storage

This is widely used for storing horticultural products, particularly those which have good keeping quality even without a precise low temperature. However, its use is generally limited to cool seasons in temperate and sub-tropical regions, or high altitude areas where there are low ambient temperatures at night. An ideal storage room is adequately insulated and has a good ventilation control system which pulls cool air in at night and keeps warm air out during the day. Booth and Shaw (1981) and Hallee and Hunter (undated) have given comprehensive descriptions of how to construct and ventilate air-cooled common storage, but this technology has not been adopted in many parts of the world. For instance, hundreds of thousands of tons of citrus fruits are stored in common storage in Taiwan each winter, but ideal common storage facilities are still at their trial stage. Lack of technical knowledge, and the need for a large investment to build new facilities, delay adoption of this new technology.

Large commercial-scale storage of horticultural products in *caves and underground cellars* are seen only in northern and central China. The major crops stored are apples, pears and citrus fruits. Underground or cave storage often provides better temperature control than above-ground air-cooled storage. This method is most useful in areas where there is a long, cold winter, a dry climate, and a thick layer of fine heavy soil. The construction and management technologies developed in China do not yet seem to have spread to other countries. Some modification of Chinese technologies to suit different climatic and soil conditions might well make this technology useful in many parts of the world.

Refrigerated Storage

Refrigerated storage is a well-established technology widely used for storing horticultural crops all over the world. Its application is limited only by cost and benefit considerations. Essentially, all crops can benefit by being stored at a suitable low temperature which extends the storage life and preserves quality. However, these benefits sometimes do not cover the cost of refrigeration, if the price of the products is too low.

Another problem is how to make full use of refrigerated storage for a long period each year. Many horticultural crops have storage life spans ranging from less than one month to several months when refrigerated. Therefore, refrigerated storage can be used continuously only if several different crops with different harvesting seasons can share the facility.

There are other important reasons why this method is not used in many tropical and sub-tropical countries, where refrigeration is needed most. The initial investment cost is too high and its energy consumption too large for many countries. As to the technology itself, many books (eg. Ryall and Pentzer 1982, Kader 1992) have given detailed discussions. A very practical and concise reference of the subject has been written by

Bartsch and Blanpied (1984).

SA Storage (Controlled Atmosphere)

Commercial application of *CA storage* is limited to only a few crops, apples and pears being the most popular ones. It is not used for other crops because the benefit is too slight to cover the cost. The technologies involved (Bartsch and Blanpied 1984) are complicated and sophisticated. The cost of building, facilities, and management for CA storage is considerably higher than for refrigerated storage. It should not be recommended for any crop without a thorough cost and benefit analysis.

MA Storage

This is a much simpler method than CA. Theoretically, it is possible for MA storage to generate a result similar to that of CA. However, practical experience seems to show that MA storage is usually less reliable and less effective than CA, in terms of extending storage life and preserving quality. Its biggest advantages are that it is easy to use and not expensive. Therefore, commercial trials and application are becoming more common. Although many research papers have been published on trials using different polymeric films for wrapping or bagging different products, many new experiments are still conducted each year to try and get better results. This method is unlikely to replace CA for crops which are stored in large quantities over long periods, but it is often useful for small-scale and short-period storage of products which benefit from an atmosphere with a low oxygen and high carbon dioxide content.

Transportation

Inland transportation of horticultural crops is usually by rail or way truck. Overseas transportation is by sea or by air. A limited amount of high-valued produce is sometimes transported overland by air. The basic requirements for conditions during transportation are similar to those needed for storage, including proper control of temperature and humidity and adequate ventilation (except in the case of MA). In addition, the produce should be immobilized by proper packaging and stacking, to avoid excessive movement or vibration. Vibration and impact during transportation may cause severe bruising or other types of mechanical injury.

CA containers are not used much for transporting fruit and vegetables. Only a small number of CA containers are used for long-distance shipping of highly perishable, high-value products in the United States and for international trade. Refrigerated containers and trailers are more often used for long-distance shipping, whether by sea, rail or truck. Modern technologies for the refrigerated transportation of horticultural produce have been well described by McGregor (1987).

Shipping by refrigerated trucks is not only convenient, but also effective in preserving the quality of product. However, both the initial investment and the operating costs are very high. Another possibility is insulated or properly ventilated trailer trucks. Precooled products can be transported by well insulated non-refrigerated trucks for up to several hours without any significant rise in product temperature. There are considerable cost savings without any sacrifice of quality if trucks are only insulated, rather than refrigerated, for short-distance shipping. If the product is not precooled or if the shipping distance is long, a ventilated truck is a better choice than an insulated truck without ventilation and without refrigeration. Ventilation alone does not usually provide a uniform cool temperature, but it may help dissipate excessive field heat and respiration heat, and thus avoid high temperature injury.

DIFFICULTIES IN APPLYING WESTERN TECHNOLOGY IN ASIA

Modern post-harvest technologies developed over the past twenty or thirty years are now widely used in North America and Europe. Japan is the only Asian country which uses technologies of comparable sophistication.

Although there are many Asian postharvest horticulturists who have been trained in the United States, Europe, or Japan and returned to their home countries, technical improvement in many Asian countries has been slow. There are several reasons why Western technologies cannot be applied quickly in Asia. Firstly, Western technologies use sophisticated equipment and facilities which are too large for the small-scale farming systems of Asia. There is some small-scale equipment manufactured in Europe or Japan, but it is too expensive for most Asian countries. Secondly, advantages of applying Western technologies are less obvious in traditional marketing systems than in the supermarkets which dominate retail in western countries.

Large capacity coolers, waxers, grading and packing line facilities, etc. manufactured in the United States are designed for use in large packinghouses. Asian farmers not only have small-scale operations, but also grow diverse crops. Their products are either packed by the growers themselves, or in small packingsheds operated by farmers' cooperatives. The volume each grower or cooperative packs each day is too small for large equipment. Although smaller equipment is often made in European countries and Japan, it is always sold at high prices.

The manufacturers have good reason to ask high prices, because the number of units sold is so small. Reputable manufacturers of farm machinery are reluctant to compromise the quality of their products for the sake of lower prices, so they make only sophisticated, expensive equipment. Since user countries cannot even afford to buy the first unit for trial, it is not possible for them to order many units at once for a bargain price.

Modern supermarkets have refrigerated display cabinets and temporary cold storage. They can keep produce cool continuously, provided it has been properly cooled before arrival. In contrast, traditional markets do not usually have refrigeration. They make every effort to sell produce quickly to reduce display time and avoid quality loss. Even if the produce has been cooled before and during shipping, the "cold chain" breaks at the retail markets and hence reduces the benefit of cooling. Even worse, many consumers mistakenly believe that cold produce has been stored, while warm produce means it is "fresh". This misconception further discourages cooling, which is the most effective way to prevent rapid deterioration of the produce.

Modification of High-technology Facilities to Suit Local Needs

If the capacity of a packing shed is small, only small-scale equipment is needed. If a country cannot afford to buy expensive equipment, cheaper equipment should be developed. In order to lower the price, it may be necessary to sacrifice quality in terms of appearance, convenience, mobility, durability and/or user friendliness. Sacrificing one or more of these attributes might be acceptable at the initial stage of development, provided that the equipment still functions well. In order to encourage users to purchase, the equipment must be sold at an affordable price. Therefore, sophisticated equipment and facilities developed in Western countries may need substantial modification to suit local needs in Asian countries.

This is best done in the user countries. The equipment and facilities needed for post-harvest handling of horticultural crops are relatively simple. The principles involved have been widely published, and are readily available to farm machinery specialists, while few or no patents are involved. The fundamental need for developing modified equipment of this kind is good cooperation among post-harvest horticulturists, farm machinery specialists and end users, plus sufficient support from government policies. Several Asian countries have made significant progress in this area in recent years. For example, locally made small-scale forced-air coolers, crushed-ice makers, and small refrigerated storage facilities are often seen at cooperative shipping points in Taiwan today.

INTEGRATION: THE KEY TO SUCCESS

A typical route for a horticultural product to follow from harvest to arrival in the consumer's hands includes grading, packaging, transportation, wholesaling and retailing. Additional processes which might be added en route are trimming, curing, precooling, storage, waxing, disease and insect control treatments, and prepackaging. Improper procedures at any step en route may ruin all the efforts made during other steps to preserve the quality of the product. In other words, the final quality of the product is often determined by the worst procedure, which acts as a limiting factor.

Since no post-harvest technology can remedy quality which is already damaged, a mistake at one point may not be compensated by extra care in other steps. Therefore, an integrated program covering all post-harvest procedures is necessary to guarantee success. For instance, if three steps in the post-harvest handling system need to be improved, they all have to be improved simultaneously. Improving only one or two steps may not be any improvement at all.

Taiwan had at least two bad experiences in the past, when it made fragmentary effort to improve postharvest technology. One was to import two hydrocoolers from the United States in the 1970s for cooling vegetables produced in central Taiwan. The government subsidized more than half the cost of the equipment, but the users (Farmers' Associations) still could not justify the operational costs for the very limited benefits from using the coolers.

There were no suitable transportation and storage facilities to protect hydrocooled products at that time. The products rewarmed rapidly. Precooled and then rewarmed wet vegetables often decay faster than those which have not been cooled at all. The ultimate fate of the hycrocoolers was to be dismantled and sold as waste metal.

The second failure was the subsidizing of small refrigerated trucks to transport fresh vegetables from eastern Taiwan to Taipei in the 1980s. Since no precooling facilities were available at the shipping point, the warm vegetables remained warm or became warmer inside the "refrigerated" truck, because the cooling capacity of the truck was enough to keep cool vegetables from warming but not enough to precool warm products.

After these costly lessons of failure, post-harvest workers realized that improvement programs should be integrated rather than fragmentary. The people who formulate and supervise a program must have a comprehensive knowledge of the subject. They should understand all procedures involved, and be able to identify all problems and choose remedial strategies.

The first successful program in Taiwan began with vegetables in the suburbs. Harvested vegetables were trimmed, hydrocooled, prepackaged, stored in refrigerated rooms until needed, and then shipped to supermarkets in Taipei by insulated small trucks, with or without refrigeration. The hydrocoolers, refrigerated storage, and shipping trucks used were all small and were locally made.

Encouraged by the favorable response of growers and consumers, the program was extended to major vegetable production areas in central and southern Taiwan. As the volume of vegetables handled under the project increased and shipping distance lengthened, larger coolers, refrigeration storage rooms and shipping trucks came into use.

In order to avoid wetting vegetables, forced-air cooling gradually replaced hydrocooling for some kinds of vegetables and fruit. More and more shipping points adopted the new technology, and precooled products were not only shipped to supermarkets, but also to large institutional users, and sometimes wholesale markets. Post-harvest losses were reduced, and product value increased.

In order to provide shippers, extension staff and marketing personnel with the essential technical knowledge, a number of short training courses were offered. At the beginning of the program, Government agencies begged users to try the new technology. Nowadays, it is the users who beg government agencies for newer technology and more technical advice.

RESEARCH INTO NEW TECHNOLOGIES

Existing technologies for cooling, storage, and transportation of horticultural crops are generally adequate at present. New research should aim at improving equipment, facilities and methods, to make them more efficient and less costly. Applied research for solving specific problems is likely to be more fruitful than basic research in developing countries.

Different crops often need different post-harvest treatments. Post-harvest horticulturists must establish the requirements for each major crop. Even if optimum conditions and best treatments are known, it is often worthwhile to study the crop's response to less than optimum conditions, since the best treatment is not necessarily the most economic one. For instance, a study was made of optimum storage conditions for Taiwan citrus fruits.

This was followed by experiments in refrigerated storage, improved common storage, and "traditional" common storage. Cave storage is also going to be studied. When these experiments are completed, we shall be able to make recommendations for growers, depending on their specific location and the duration of the storage.

Since improved handling methods often rely heavily on improvements in equipment and facilties, close cooperation between post-harvest horticulturists and agricultural engineers is necessary.

An area which is urgently in need of new technology is post-harvest disease and insect control. Effective fungicides for post-harvest application have become fewer and fewer, since many previously used fungicides are now banned for fear of health hazards. Control of post-harvest decay must rely on new, safe chemical treatments and practical physical methods, in addition to improved sanitary conditions. Recent findings, such as the use of acetic acid fumigation, (Moyls *et al.* 1996) and UV-C light (Wilson *et al.* 1997) indicate the feasability of finding new chemical and physical methods.

Many countries wish to export their quality products, but have difficulty in fulfilling the quarantine requirements imposed by importing countries. Current quarantine procedures are either chemical or physical (Paull and Armstrong 1994). Many tropical products cannot tolerate any form of cold treatment. Heat treatment is expensive, and often damages the quality of products. Irradiation is a possibility (Lalaguna 1998 Miller and McDonald 1998), but still needs further development. New and safe chemical treatments are yet to be found.

COORDINATION AND COOPERATION

More About Taiwan's Experience

Although our past experiences of making improving post-harvest handling of horticultural crops in Taiwan have not all been successful, significant progress has been made in recent years. In the early stages, even a small success could be realized only after many trials and frustrations. Projects which began in the 1970s ended in almost total failure, because every program tackled only part of the post-harvest system programs were also technically unsound, according to current knowledge. More projects, were launched in the 1980s and some small progress made, but many projects still failed. Eventually the stage was reached in the late 1980s when there were enough high-caliber postharvest scientists, while both industry and government agencies were aware of the importance of postharvest handling. Taiwan was then able to carry out more effective programs.

Recent progress has been based on good cooperation between postharvest scientists, government coordinators, extension staff, and decision makers at shipping points and terminal markets. Full coordination and cooperation were made possible after repeated discussions and debates. Once the major funding agencies were convinced that an integrated national program should replace individual fragmentary small projects, the program really took off.

This type of integrated programs quickly generated fruitful results. Each year we were able to see some improvement in the quality of fresh produce at the markets, and growers and shippers began to enjoy the benefits of reduced postharvest losses and increased profit margins for higher value-added products.

Several steps were crucial in changing programs from initial failure to recent success.

- A few high-level postharvest scientists were trained to serve as program leaders, while more than a hundred middle-level technical workers were trained to implement projects.
- Key persons were organized into a strong working group.
- Problems, priorities, and programs were discussed, to generate a consensus within the group.
- Fragmentary projects were integrated into a national program.

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