REPORT ON POSTHARVEST PATHOLOGY PROBLEMS AND RESEARCH IN INDIA [a/]

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I. INTRODUCTION AND ASSIGNMENTS

Informed persons generally agree that crop losses from farm to consumer in India and other developing countries of the sub-tropics are excessive in comparison with food losses in countries utilizing advanced technology in storage, transport, and antimicrobial treatment of harvested crops (15). These losses, cited as 30% of the fresh fruits and vegetables grown in India, adversely affect both the farmer and the consumer-- the former through a lowered return on his investment and labor and the latter through a loss in the quantity and quality of food available at a given price. Indeed, international organizations responsible for monitoring food resources have recognized that the most economically feasible and expedient means to increase the world food supply is to reduce losses in food crops that occur after they have been harvested.

The importance of postharvest losses in developing countries is sometimes disparaged by the assertion that there are, in fact, few discarded fruits and vegetables because even low quality or partially decayed produce will be consumed if the price is right. While this observation may be substantially correct, it does not negate the fact that a substantial loss has been suffered both in terms of return to the farmer and nutrition to the consumer.

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a/ Report to Winrock International Institute for Agricultural Development, Subproject on Postharvest Technology for Fruits and Vegetables under the Agricultural Research Project/India.

3/20/89

During the period November 14-December 17, 1988, the writer visited the four institutes responsible for research in the "All-India Coordinated Program on Postharvest Technology of Horticultural Crops" under the direction of the Indian Council for Agricultural Research (ICAR). These institutes are the Indian Institute of Horticultural Research, Bangalore (IIHR); the Central Institute of Horticulture for Northern Plains, Lucknow (CIHNP); the National Research Centre for Citrus, Nagpur (NRCC); the Indian Agricultural Research Institute, Delhi (IARI).

The principle assignments in connection with the visits to the four research centers were:

1. Assess the postharvest pathological problems in the mango, banana, citrus, guava, potato, onion and tomato and evaluate the current research programs related to these crops at the different research centers, providing suggestions for improvement when possible.
2. Identify equipment and infra-structural facilities required, if any, for postharvest pathological work and guide in the effective use of imported equipment.
3. Deliver at least one seminar at each of the four centers about recent advances in postharvest pathological research in horticultural crops with special reference to tropical and subtropical fruits and vegetables.

II. SCHEDULE AND SCIENTISTS CONTACTED

Nov. 11 7 AM Depart Riverside. 11:20 AM Los Angeles - Tokyo - Bangkok

Nov. 12 11:45 PM Arrive Bangkok

Nov. 13 Bangkok. Flight to Delhi delayed 24 hours

Nov. 14 7:45 PM Bangkok to Delhi. Met by Dr. Guy B. Baird (Winrock) and Dr. Ambadan (ICAR).

Nov. 15 Delhi. AM - conferred with Dr. Baird (Winrock)
PM - conferred with Dr. Chadha and Dr. Kaul (ICAR)

Nov. 16 Delhi. Visit IARI - meet with Dr. S. K. Roy, Coordinator P.H. Technol. Hort. Crops
Dr. O. Srivastava, Head, Div. Agric. Econ.
Dr. A. Varma, Head, Div. Mycol. and Pl. Path.
Mrs. V. Krishna-Murthy, Postharvest Pathologist

Nov. 17 Delhi. Visit Azadpur Agricultural Produce Market with Dr. Ambadan, Dr. Atteri and Mrs. Krishna-Murthy. Visit Mother's Dairy retail produce market.

Nov. 18 AM - Fly Delhi to Bangalore
PM - Conferred with Dr. T. R. Subramanyam, Dir. Indian Inst. Hort. Research (IIHR), Bangalore

Nov. 19 Bangalore. IIHR. Conferred with Dr. S. Ethiraj, Coordinator. Research in Food Microbiology. Review postharvest projects IIHR.

Nov. 20 Bangalore. Holiday

Nov. 21 Bangalore. Reviewed postharvest projects at IIHR.
Food Microbiology - Dr. E. R. Suresh
Mango - Dr. S. Krishnamurthy
Food Technol. - Dr. K. K. Ramanjaneya
Onion & Tomato - Dr. K. P. Gopalakrisna Rao
Betel & Tobacco - Dr. N. N. Raghavendra Rao
Postharvest Path. - Dr. B. A. Ullasa
Fruit Crop Path. - Dr. R. D. Rawal
Vegetable Crop Path. - Dr. T. S. Sridhar
Observe field plots - citrus & grapes

Nov. 22 Bangalore. AM - IIHR. J.W. Eckert seminar "Postharvest pathology of fruit and vegetable crops"
PM - Travel to Chethalli, Central Horticultural Expt. Sta. with Dr. R. D. Rawal.

Nov. 23 Chethalli. AM - Central Hortic. Expt. Sta. (CHES). Discuss projects with Dr. A. G. Purohit, Horticulturist and Head. Observe plantings of citrus, mango, papaya, pepper
PM - visit to CHES Gonikoppal laboratory. Discuss citrus pathology with staff. Return to Bangalore

Nov. 24 Fly, Bangalore to Delhi

Nov. 25 Delhi. IARI. Meeting with All-India Postharvest Technology Group. Discussion on achievements and priorities in research on processing and postharvest pathology of fruits and vegetables, led by Dr. Chadha and Dr. Kaul. Presentation of research on individual crops by research staff: Citrus, guava, potato, onion, tomato. Report by Dr. H. T. Chan, USDA, Hawaii, on food processing in India. J.W. Eckert seminar "Recent advances in the postharvest of fruits and vegetables"

Nov. 26 Delhi. IARI. Discussion with staff. Presented lecture to Indian Phytopathological Society "New developments in the postharvest pathology of horticultural crops"

Nov. 27 Holiday

Nov. 28 Delhi. IARI. Discussion with Mrs. V. Krishna-Murthy on her postharvest pathology research program emphasizing latent infection. Conferred with Dr. A. Varma, Dr. J.P. Verma, and Dr. Dharam Vir

Nov. 29 AM - Travel from Delhi to Lucknow
PM - Central Inst. Hortic. for Northern Plains (CIHNP). Conferred with Dr. C.P.A. Iyer (Director), Dr. S. Kalra (USAID Project Coordinator), Dr. I.S. Yadav (Coordinator, All-India Fruit Improvement Project), Dr. Om Prakash (Plant Pathologist).

Nov. 30 Lucknow. CIHNP. Discuss research project with staff.
Dr. S. K. Kalra - Processing
Dr. Om Prakash - Plant Pathologist
Dr. B. P. Singh - Postharvest Handling
Dr. S.E.S.A. Khader - Plant Physiol.
Dr. D. K. Tandon - Postharvest Technology

Dec. 1 Lucknow. CIHNP. Observe field experiments at Rehmankhera Exptl. Farm - mango, guava, anola.
J.W. Eckert Seminar "Pathological problems in postharvest technology".
Visit guava plantation and roadside retail produce market.

Dec. 2 Lucknow. CIHNP. Continue review of postharvest research projects with staff.

Dec. 3 Lucknow. Visit central (wholesale) produce market with Dr. Om Prakash. Local guava plantations. Potato cold storage facility.
Group discussion and review with CIHNP staff.
Discussion with entomologist, Dr. R. P. Srivastava.

Dec. 4 Holiday. Fly from Lucknow to Nagpur

Dec. 5 Nagpur. National Research Centre for Citrus (NRCC).
AM - Introduction to NRCC staff and laboratories
Dr. H. Dass, Director
Dr. R. R. Kohli, Horticulturist
Dr. S.A.M.H. Naqvi, Plant Pathologist
PM - visit Kalmana market to observe citrus auction and packing. accompanied by Dr. Naqvi and Dr. V.S. Rao

Dec. 6 Nagpur. AM - visit to Kalmeshwar and Katol areas to observe citrus culture and problems. Anthracnose and gummosis
PM - Discuss equipment needs with NRCC research scientists. Discuss postharvest physiology with Dr. M.S. Ladenya

Dec. 7 Nagpur. AM - NRCC. Continuation of discussion of research with Dr. Naqvi (Plant Pathologist) and Dr. V.S. Rao (Food Processing).
PM - visit Kalmana market to observe citrus packing.

Dec. 8 Nagpur. AM - visit Central Food Technology Research Institute Nagpur Experiment Station to discuss their research on fruit waxes, fungicides, and sour rot (a serious problem on late oranges). Dr. S.D. Bhale Rao, Laboratory Head Dr. M.S. Laul
PM - NRCC. J.W. Eckert seminar "Postharvest diseases of citrus fruits" followed by group discussion with staff.

Dec. 9 Nagpur. NRCC. Continue discussions with staff on research projects and equipment needs. Report to Director Fly from Nagpur to Delhi

Dec. 10 Delhi. Worked on report.

Dec. 11 Delhi. Holiday

Dec. 12 Delhi. IARI. AM - Div. of Mycol. & Plant Path. Discussion with Mrs. V. Krishna-Murthy on her postharvest research program
PM - Horticulture Division Dr. S. K. Roy, Dr. D. S. Kurdia, Dr. Vijay Sethi, Dr. Vidya Ram. Vegetable crops - Dr. V. S. Seshadn

Dec. 13 Delhi. Visit to Azadpur Agricultural Produce Market. Mr. Yadav, Mr. Baradwaj - market representatives.

Dec. 14 Delhi. Worked on report

Dec. 15 Delhi. AM - worked on report
PM - conferred with Dr. Chadha & Dr. Kaul conferred with Dr. S. K. Roy

Dec. 16 Delhi visit Nuclear Research Laboratory. Dr. J. P. Gupta and colleagues. J.W. Eckert seminar

"Recent developments in postharvest fungicides". Observe facilities and discuss fungicide research.

Dec. 17 Depart Delhi for Riverside, California

III. OBSERVATIONS ON COMMERCIAL HANDLING PRACTICES AND POSTHARVEST PROBLEMS IN INDIA

Mango

India accounts for almost two-thirds of the world's mango production, yet exports less than 1% of that production. Over 40% of the Indian acreage is in Uttar Pradesh; 14% each in Andhra Pradesh, Bihar; and important production also in the states of Kerala, Gujarat, and Tamil Nadu (3). Most of the fruit matures in late May, June and July, although fruit is available as early as February-March in Kerala and as late as September in West Bengal. Markets are flooded with mangoes in June and many fruit (20-40%) rot in the warm humid environment at that time of the year (3,27). The principal causes of decay are anthracnose (arising from latent infections of Colletotrichum gloesporioides in the peel) and stem-end rot caused by Botryodiplodia theobromae attacking the cut peduncle of the fruit (3,16,17). Rhizopus and Aspergillus, high temperature wound pathogens, cause a serious problem in fruit shipped from Bangalore to New Dehli and in fruit awaiting processing at the cannery . Generally, postharvest decay is most serious on fruit produced in the south because of mild winters which favors growth and survival of the pathogens. Anthracnose is serious in fruit produced in the coastal districts of Goa and West Bengal. The fruit are packed with newspaper in 8-16 kg wood boxes. About two weeks are required to market fruit produced in Karnataka in New Dehli. Fruit produced in the north can be marketed in a shorter period of time. Most of the mangos do not receive a postharvest treatment and are shipped and marketed at ambient temperatures. Mature green fruit of the Alphonso variety have a maximum three week postharvest life under these conditions (27). Ripening can be hastened by treatment of the fruit with ethylene generated from calcium carbide or by dipping the fruit in a solution of 500 ppm Ethrel in 52°C water (3). Fruit should be ripened at 22-25°C for best flavor development. Few Indian mangos receive these postharvest treatments at the present time.

There appear to be exceptional opportunities for exporting mangos, especially to the Persian Gulf states. Handling practices and packaging would have to be improved considerably in order to export successfully. Mangos harvested in a mature green state can be stored for 2-3 weeks at temperatures of 8-15°C before ripening, depending upon the chilling sensitivity of the variety and the production area. Anthracnose can be controlled during storage/shipping by fungicides applied before harvest or by a postharvest heat/fungicide treatment (11,24,25). Stem-end rot caused by Diplodia is more difficult to control, but some very encouraging results have been obtained with heated solutions of benomyl, imazalil, and prochloraz (13,14,25,26).

Banana

Bihar, Tamil Nadu, Gujarat and northwestern Maharashtra are the major banana production areas of India. Heaviest production is from August to December. Mature green bananas are shipped on stem from the production areas to the New Dehli central wholesale market in railroad cars. In the New Dehli market, I observed steel railroad cars loaded with stems of bananas piled about five feet high. The cars had natural ventilation and banana leaves had been piled on top of the cars to provide some insulation from the sun. After arrival at the market, the bananas are kept in the shade until they are ripened with etnylene generated from calcium carbide or charcoal embers. In winter, green bananas can be held at the wholesale market for 10-14 days, then ripened by holding them in a room with ethylene for 24 hours. Small-fingered varieties are ripened on stem, whereas Cavendish varieties are separated from the stem as hands before ripening. This is intended to reduce finger-drop. The ripening rooms I observed at the Lucknow and Dehli wholesale markets were primitive; there was no temperature control and no provision for the introduction of fresh air during the ripening process. The burning charcoal must increase the fruit temperature, perhaps too much since the optimum fruit temperature for ripening is 14-20^{o}C. The accumulation of CO_2 and CO in the room atmosphere should retard the ripening process, however. Since the national preference is for very ripe bananas (over-ripe by western standards) the traditional ripening methods in India probably have little impact on marketability of the fruit.

The principal postharvest decays of bananas in India are caused by Colletotrichum (anthracnose and wound infection) and Botryodiplodia (wound infection). Rough handling and shipment at ambient temperature, and the national preference for very ripe bananas aggravate the decay problem. On the other hand, shipment on stem should minimize crown rot, which is the scourge of bananas shipped from Central America as hands in corrugated cartons. Crown rot is caused by infection of the cut crown of the hand by a complex of Botryodiplodia, Fusarium, Thielaviopsis and other pathogens. For the most part, bananas offered for sale in local markets were of poor quality by U.S. standards, showing extensive bruising, scarring and wound anthracnose, all of which can be attributed to rough handling during harvesting and ambient temperature shipment. Any serious effort to develop an export market would have to involve a substantial improvement in the quality and handling of the fruit. It is interesting that banana producers of Central America have developed a substantial market for their fruit in the Persian Gulf states. Banana hands in Central America and Africa are treated with thiabendazole or imazalil (7) to prevent crown rot and shipped in polyethylene film lined corrugated cartons at 13^{o}C. An extraordinary effort is made at all stages of postharvest handling to minimize bruising.

Citrus

The greatest concentration of citrus production is in the states Maharashtra, Karnataka, and Andhra Pradesh. The high quality of the Nagpur orange and Coorg orange (both mandarin type fruit) is recognized throughout the world. Two crops are produced in Coorg and Nagpur, but not on the same trees. In Coorg, the main bloom in March produces a high quality crop of fruits that are harvested October-February. A secondary bloom in November-December gives rise to a poor quality monsoon crop harvested in June-August. In Nagpur, the analogous crops are harvested in October-December and April-June. The fruit is generally harvested by snap picking (twist and pull) at color break and some tearing of the peel at the stem-end was evident. In Punjab, the Kinnow mandarin is harvested in October-January by clipping and several varieties of sweet orange are harvested later in the season. Few, if any, of the fruit receive a postharvest fungicide treatment or a wax coating, although experiments with benomyl, thiabendazole, and imazalil have reduced green mold on coorg mandarine (18). Ninty-eight percent of the citrus production is consumed fresh domestically. Processing and export are essentially undeveloped. Several diseases of the tree are constraints on production and are poorly controlled today: greening, anthracnose, and Phytophthora gummosis in mandarins and sweet oranges and bacterial canker in limes.

I observed fruit handling at the Nagpur (Kalmana) central market. The fruit was delivered to the market loose in the bed of a truck and displayed in mounds on the auction floor. The buyers/shippers graded and packed the fruit for truck shipment to New Dehli. Nagpur mandarins were place-packed by count with cushioning of grass straw and newspapers in sturdy wood boxes. Sweet oranges were weighed into burlap sacks. The protection of the mandarins offered by the wood cases during shipment was almost excessive, whereas the handling of sweet oranges in sacks must have caused considerable damage. The packages of fruit were shipped by truck under ambient conditions to the primary markets of New Dehli, Bombay, and Calcutta. Later on, in the New Dehli central market, I observed the repackaging of mandarins for shipment to secondary markets. I was surprised by the low incidence of decay in the fruit (not more than 5%) which I would attribute to the mild dry weather at that season of the year.

The principal postharvest decays of citrus fruit in India are caused through wound infection by Penicillium and Aspergillus, and stem-end rots caused by Diplodia, Phomopsis, Alternaria, and Colletotrichum. In India, Penicillium has been controlled well experimentally by postharvest dip treatments with thiabendazole, benomyl, and imazalil (5,18). Diplodia and Phomopsis have been controlled by post-harvest treatment with the same fungicides and Colletotrichum stem-end rot by preharvest sprays of prochloraz and benomyl (5).

Guava

The major areas for commercial production of guavas are Uttar Pradesh, Madhya Prapesh, and Bihar, but the fruit is grown on a smaller scale throughout India. Two distinct crops are recognized: the winter crop, which is harvested from November-January and the rainy season crop, which is harvested in July-August. The winter crop is the major commercial crop. Postharvest disease is minor in the main crop because of the cool dry winter weather. Typically, anthracnose does not appear for fifteen days after harvest unless the fruit is overripe at harvest. No fungicide program is necessary for control of anthracnose in this crop. In contrast, the rainy season crop is plagued with fruit flies attacking several weeks before harvest. In addition to decay initiated at sites of fruit fly ovaposition, the prevailing hot humid conditions result in heavy decay due to a number of pathogens-- Colletotrichum, Gloeosporium, Phytophthora, Pestalotia, Phomopsis Phoma, Botryodiplodia, and Rhizopus. The fruit ripens within a few days after harvest due to the high temperature and decays quickly. Although the quality of the rainy season crop is poor, it could be saved for processing by application of insecticides and copper fungicides to the crop before harvest and perhaps by storage of the harvested fruit at 10-13°C in case of a delay in processing. Several postharvest fungicides have been effective for control of guava decays (1,30).

Potato

Potatoes are grown in several states with about one-third of the total production concentrated in Uttar Pradesh. Two crops are produced each year. New potatoes are planted in September and harvested in December and consumed as a fresh vegetable. Storage potatoes are planted in December and harvested in February-March. The tubers are stored at a low temperature (values of 2°C and 10°C were quoted) until September, when most of the remaining storage potatoes are used as seed. About one-half of the storage capacity is used for seed potatoes. Curing potato tubers before storage is not a commercial practice, nor are sprout inhibitors and fungicides commonly used.

Common storage diseases of potatoes (22) have been identified in India-- bacterial soft rot, Fusarium dry rot, Phytophthora rot, Pythium leak-- but the incidence of these rots is not known. A survey of potato storage diseases in Uttar Pradesh is in progress.

Potato production could be increased if additional storage capacity was developed. Capital investment and energy requirements seem to limiting factors. Research on storage could develop new technologies involving curing, sprout inhibitors, and fungicides that would permit storage at a higher temperature than traditional. Curing and chemical treatments could reduce water loss and decay (4), which would be expected to be the major limiting factors in higher temperature storage. The International Potato Center has a project on low energy storage of potatoes in Northern Thailand.

Onion and Tomato

These crops were observed only in wholesale and retail markets and were not discussed in any detail with researchers, so the comments here are limited to general experience world-wide (2,4).

Postharvest losses in onions in India are reputed to run as high as 60% of the crop. Onions observed at Azadpur Produce Market in Dehli were bagged in large burlap sacks (50-60 lbs.) and were in sound condition, as were other samples observed in road-side markets.

The principal postharvest diseases of onions are Botrytis neck rot, Fusarium basal rot, Aspergillus rot, and bacterial soft rot (2,4). The incidence of decay is influenced by several factors: 1) seed treatment with a fungicide to prevent systemic infection of the onion plant with *Botrytis*; 2) allowing the onion bulb to reach full maturity before harvest; 3) curing the mature onions in the field, if weather permits, or curing in storage by forcing heated air (25-35°C) through the onions in storage for 48 hours. The cured bulbs can be stored at 0°C or 30°C and 65-70% RH for several months. Storage temperatures between 5° and 20°C lead to sprouting and decay. The onion plants may be treated with maleic hydrazide in the field to reduce sprouting of the bulbs in storage. The principal factors leading to excessive decay are rough handling during harvest, insufficient curing (drying), and improper temperature and high humidity in the storage environment.

Tomatoes were observed in wholesale markets in Dehli, Lucknow, and Bangalore. Generally, the fruit had good color and few defects except for small size. The fruit were well-protected in wood packing boxes. The principal microorganisms involved in postharvest decay of tomatoes are *Botrytis*, *Alternaria*, *Erwinia*, and *Phytophthora*. *Geotrichum*, *Rhizopus*, and *Mucor* are important if the crop has been handled roughly and held at a relatively high temperature (>25°C).

Tomato plants should be staked or surrounded by a surface mulch to prevent the fruit from contacting the soil, which is a reservoir for several pathogens. Fungicide sprays should be applied to the plants when required to protect the fruit from infection by *Botrytis*, *Phytophthora infestans* and *Alternaria*. Several fungicides applied postharvest have provided effective control of several postharvest diseases in small scale experiments. Sodium *o*-phenylphenate and dicloran are permitted for postharvest use on tomatoes in the U.S. Active chlorine is commonly added to wash water to prevent inoculation of fruit with bacterial soft rot. Details of the fungicide treatments for use on tomatoes has been given elsewhere (6).

IV. MAJOR STRATEGIES FOR CONTROL OF POSTHARVEST DISEASES

Four general approaches are used to control postharvest diseases of fresh fruits and vegetables: 1) inoculum reduction (sanitation); 2) Prevention and eradication of infections initiated in the field; 3) Prevention and abortion of wound infections; 4) Suppression of disease development and spread. The most effective, economical, and convenient strategies should be deduced after a thorough investigation of the disease cycle and the vulnerability of each stage of the cycle to control measures. The major strategies are discussed herein as background for the commentary on postharvest research projects in India covered in Section V.

1) Inoculum reduction. The pathogen inoculation level in the plantation determines the density of latent infections (eg., anthracnose) on subtropical fruits and vegetables. The inoculum concentration in the postharvest environment (atmosphere, water for cooling, cleaning, antimicrobial treatment, etc.) determines the probability of infection of a susceptible injury, stomate, lenticel, etc.

Thus, a substantial reduction in the pathogen inoculum in contact with the fresh fruit/vegetable will reduce the level of postharvest decay, all other factors being equal. Removal of dead wood (bearing pathogen fructifications) and diseased plant materials (potatoes, fruits, foliage) from the plantation will reduce latent infections and wound infection on harvested fruits/vegetables. Usually, it is beneficial to remove developing fruits from inoculum sources, eg, the use of plant mulches and plastic films to prevent contact of tomatoes and strawberries from soil, a major reservoir of pathogen inoculum.

Fungicides applied in the field may exert a highly beneficial anti-sporulation action that significantly reduces the amount of pathogen inoculum arriving at the host surface. Finally, picking containers and packing equipment should be sanitized as required with formaldehyde, steam, or quaternary ammonium compounds so they do not become a source of inoculation of recently harvested fruits and vegetables.

2) Prevention and eradication of field infections. Fruits, vegetables, and potatoes are often inoculated or infected during their development in the field. Due to the inherent or induced resistance of the host tissue, or to some morphological barrier, the pathogen is unable to produce an active disease lesion, but rather enters a quiescent state on or in the host. The pathogen persists in this condition until the resistance of the host declines with advancing maturity or until the pathogen is activated, either by a wound to the host tissue or by some other mechanism that weakens the host defenses.

In tropical and subtropical areas, latent infections of *Colletotrichum* are common on bananas, mangos, papayas, avocados, and citrus fruit at harvest time (5). Spores of the pathogens are carried to the immature fruit on the plant by rain-splash; the spores germinate in a few hours and form appressoria. Some of the appressoria germinate to form infection hyphae. By mechanical force aided by the enzyme cutinase, these penetrate the cuticle and develop to a limited extent in the epidermal layer of the fruit. Continued growth of the pathogen is prevented by the resistance of the immature host tissue. However, most of the appressoria do not germinate immediately, but remain firmly attached to the host surface where they function as the latent stage of the pathogen.

Stem-end rots of citrus fruits caused by *Botryodiplodia* and *Phomopsis* are the major postharvest diseases when these fruits are grown in humid subtropical areas. These diseases arise from quiescent infection in the stem button (calyx + disc). Infections are initiated at all stages of fruit development when rainfall is adequate for dispersal of pycnidiospores of the pathogen. Propagules of the pathogen remain quiescent under the sepals of the fruit and do not become active until the buttons become senescent and begin to separate from the fruit. Several other pathogens may establish quiescent infections on developing fruit if sufficient rain falls late in the growing season: Botrytis cineria on grapes, Monilinia on stone fruits, Phytophthora spp. on citrus fruits.

Infections that are well established or latent at the time of harvest are difficult to eradicate by postharvest application of protective fungicides. The traditional approach to this problem has involved field applications of fungicides to the developing fruits to prevent spore germination and formation of appressoria or deep-seated infection in the lenticels or in the floral remnants on the fruit. Protective sprays on a 7-14 day schedule have been widely used to prevent anthracnose on mangos (3,17), papayas, avocados, and bananas. Fungicides applied to strawberries and raspberries in the field on a 7-14 day interval during the period of flowering and fruit development control Botrytis rot after harvest. Chlorothalonil, dichlofluanid, and benomyl are the most effective fungicides for this purpose. Benomyl sprays applied to oranges more than one month prior to harvest prevented the postharvest development of stem-end rot arising from quiescent infections of Botryodiplodia and Phomopsis in the button of the fruit. Brown-rot of peaches after harvest caused by Monilinia fructicola has been controlled by orchard sprays of benomyl applied 2-3 weeks before harvest, a treatment that eradicates quiescent infections. Currently the best control of Phytophthora brown rot of citrus fruit has resulted from sprays of fixed copper compounds applied to the lower skirt of the tree in the late fall before the onset of the rainy season.

In recent years, several systemic fungicides have become available that can eradicate quiescent infections as well as protect against their establishment. Preharvest sprays of these materials can prevent the establishment of quiescent infections before harvest and reduce disease pressure, thereby improving considerably the effectiveness of postharvest fungicide treatments. The cost effectiveness of preharvest fungicide treatments to control postharvest diseases depends on the unit value of the crop and the ability to time a limited number of sprays to inactivate the inoculum present during the period of crop susceptibility. In some cases, a few well-timed sprays of a systemic fungicide can prevent infection or eradicate inoculum of the pathogens responsible for postharvest diseases. A major problem in this approach to postharvest disease control is that selective fungicides such as benomyl may cause a proliferation of fungicide-resistant variants of the pathogen that cannot be controlled by postharvest treatment with benomyl or related fungicides.

Several fungicides have been developed over the past 15 years that can inactivate quiescent infections if they are applied to fruit after harvest (2,5,6). These systemic fungicides have the ability to inhibit development of latent infections of Colletotrichum spp. and to penetrate through the host cuticle to reach quiescent infection hyphae of Alternaria and Botryodiplodia and Phomopsis.

3) Inactivation of Wound Infections

Many microorganisms responsible for postharvest diseases are unable to penetrate the surface barriers of the host. Mechanical and physiological injuries created during and after harvest are the usual sites of invasion by these "wound pathogens" which, as a group, cause the most devastating postharvest diseases. The strategy for controlling these diseases seeks to (a) eradicate incipient infections or pathogen propagules in susceptible injuries and (b) protect the surface of the perishable product against infection through superficial wounds created after application of the fungicide treatment. For many years, incipient infectons on several fruit crops have been eradicated by the postharvest application of fungicides, usually water-soluble compounds that diffused into the injured tissue to inhibit the development of the pathogen there. Protection of the uninjured host tissue, on the other hand, requires a fungicide that can penetrate the plant cuticle to establish a deep-seated defense zone beneath the host surface.

Two potential infection sites are common on harvested crops-- the injury created by severing the crop from the plant, and natural openings such as lenticels and stomates. Natural openings in the host surface are a frequent route for infection, especially if the crop is handled or washed in water after harvest. Infection of the cut stem gives rise to crown rot of banana hands; black rot of pineapples; and stem-end rots of mangos, papayas, avocados, pears and green peppers.

Some random mechanical damage to the surface of perishable crops is inevitable in the course of harvesting, handling, and packaging, even when these operations are carried out with reasonable care. The severity of postharvest diseases induced by wound pathogens is proportional to the damage inflicted to the crop by rough handling after harvest. Many fresh fruits and vegetables have physiological mechanisms (lignification, periderm formation, and phytoalexin production) for reducing the susceptibility of slightly injured tissue to invasion by pathogenic microrganisms. If wounded tissue and root crops are placed in an environment conducive to these reactions, the wounded tissues become highly resistant to infection within days or even hours. Therefore, it is not essential that a postharvest fungicide persist at an injured site, but only that fungistatic action be exerted during the period when the wound is susceptible to infection.

Several investigators have demonstrated that sprays of dicloran applied to peach orchards one week before harvest reduced wound infection by Rhizopus after harvest. Oranges sprayed with benomyl, thiophanate-methyl, and thiabendazole 30 days before harvest showed substantially less Penicillium mold two weeks after harvest. Sprays of benomyl and thiabendazole in pear and apple orchards reduced decay due to Penicillim and Botrytis in harvested fruit. Although postharvest treatment is usually more effective and efficient, preharvest treatment is an appropriate strategy in situations where considerable harvest injury is anticipated (e.g. mechanical harvesting) and handling practices make postharvest treatments difficult to apply soon after harvest. Orchard sprays may be the best means to reduce decay of peaches or mangos that will be subjected to controlled ripening after harvest and oranges that will be degreened, since these practices often increase decay by wound pathogens. Fungicides applied to the crop in the field before harvest should be selected with care since there is a significant risk that residues from the preharvest treatment will encourage the build-up of fungicide-resistant variants of the pathogen, and these will nullify all benefits of a postharvest treatment with the same or related fungicides.

4) Suppression of disease development and spread. Although several postharvest fungicides have effectively controlled latent infections on tropical crops, lenticel infections on apples, and stem-end rots on citrus fruits, opportunities for suppressing the development of progressive infections by postharvest fungicide treatment are limited because superficially applied chemicals generally do not penetrate a significant distance into the infected host. Nonetheless, dicloran applied to peaches several days after inoculation retarded the expansion of established infections of Rhizopus. Following a dip treatment, the fungistatic action of dicloran against Rhizopus was evident at a depth greater than 1 cm in the flesh of a peach. Fungistatic residues of benomyl have been measured several millimeters below the surface of superficially treated peaches, pears, and oranges. The degree of penetration of surface-applied chemicals appear to be determined by the surface characteristics of the crop, its maturity, and the lipophilicity of the applied compound. For example, benomyl penetrated pears better than thiabendazole and oranges better than carbendazim.

Treatments involving cold, heat, irradiation, plant growth regulators, and modified storage atmospheres (high-CO_2, low-O_2, ethylene-scrubbed) that inhibit the onset of plant tissue senescence have successfully suppressed the progress of deep-seated fungal infections. These treatments have been discussed in detail elsewhere (4).

The value of fresh fruits and vegetables may be reduced significantly by superficial fungal growth or by visible contamination by spores and other debris from adjacent diseased plant material, even though palatability and nutritional value are not affected. Soiling of citrus fruits with Penicillium spores, superficial fungal growth on melon rinds, and moldy sepals on apples are devaluating conditions that can be controlled by postharvest fungicide treatments. Botrytis, Rhizopus, Trichoderma, Sclerotinia, Phytophthora, and other fungi can spread by contact from diseased to sound fruit during storage and long-distance transit. In fact, contact spread may account for the major losses caused by these pathogens. Incipient infections of Botrytis on grapes at the time of harvest may develop into pockets of decayed berries during long-term cold storage. The standard commercial practice is to fumigate grapes with SO_2 at ten-day intervals in order to suppress growth of Botrytis on the surface of diseased berries. Paper wraps impregnated with fungistatic chemicals have been used for many years to control spread of Botrytis and Rhizopus on several fruits and vegetables during long-term storage. Recently, fruits have been individually wrapped in a heat-shrinkable polyethylene film that prevents the spread of diseases as well as the transfer of spores and debris from fruit to fruit in the same container.

V. COMMENTS AND RECOMMENDATIONS ON THE POSTHARVEST RESEARCH PROGRAM OF ICAR

1. Indian Agricultural Research Institute, New Delhi (IARI)

Two projects directly related to postharvest pathology at the IARI are 1) the development of the Zero Energy Cool Chamber under the direction of Dr. S. K. Roy, Department of Horticulture and 2) postharvest diseases of mango, tomato, and guava, with the emphasis on latent infections and their role in disease development.

The Zero Energy Cool Chamber is a well-conceived project to reduce deterioration of fresh produce for several days to one week after harvest. The chamber, which is easily constructed with inexpensive and readily available materials, generates an atmosphere that is cooled and humidified by water evaporated into air circulated through the chamber by gravity. Dr. Roy has demonstrated that the postharvest life and quality of twenty vegetable crops is enhanced by placing them in the Zero Energy Cool Chamber immediately after harvest. The shelf life of mature mangos was increased from 6-15 days (in July) and oranges from 10-60 days (in February). The beneficial effects of the chamber are attributed to the relatively cool, humid atmosphere (compared to the ambient environment) which reduces respiration and water loss from the produce. Wound-healing of root and tuber crops, as well as fruits and vegetables, is encouraged in the high humidity atmosphere environment. Onions are one of the few crops that would not store well in such a humid environment.

Dr. Roy pointed out that the high humidity environment encouraged mold growth on the inside of the chamber and on the surface of stored fruits and vegetables. This problem might be overcome by introducing a volatile fungicide in the form of a mist delivered over the stored fruits and vegetables. The following substances are suggested for evaluation in this connection: acetaldehyde, ethanol, propionic acid, calcium hypochlorite, ammonium carbonate, sodium bisulphite, CO_2 (generated by acid treatment of calcium carbonate). Ammonium carbonate and sodium bisulphite may be injurious to some fruits and vegetables. Ammonium carbonate has been used extensively on citrus and apples and sodium bisulphite is effective on grapes and some berry crops without injury. Acetaldehyde has been shown to reduce decay of apples, strawberries and several other fruit crops. More expensive fungicides with remarkable vapor action are: sec-butylamine, imazalil, dicloran, and propiconazole. Reprints and literature describing these products have been sent directly to Dr. Roy.

The project directed by Mrs. Krishna-Murthy on the role of latent infections in the development and control of postharvest diseases is important to the development of rational control measures. Latent infections are difficult to control by postharvest treatments and are responsible for heavy losses in crops that mature during the monsoon season such as mangos, tomatoes, and guavas. In this research project, latent infections are recognized by incubating fruits and vegetables after they are surface sterilized to kill superficial microorganisms. Microorganisms that give rise to green or ripe fruit rots are isolated and identified. Further experiments characterize the host range, latent structures, and effectiveness of fungicides applied in the field and postharvest.

Mrs. Krishna-Murthy and I discussed the research on latent infections that might be appropriate during her visit this year to the University of California, Riverside. We agreed that the behavior of appressoria in response to fruit volatiles and other stimuli, involving the scanning electron microscope and other techniques, would contribute significantly to her research capabilities at the IARI. The research program would also include an investigation of the relative sensitivity of conidia and appressoria of Colletrichum to protective and systemic fungicides.

The facilities available at IARI to support Mrs. Krishna-Murthy's research program appeared adequate with the exception of laboratory space and fruit storage facilities. These are woefully inadequate for the research program assigned to her there. I recommend that Mrs. Krishna-Murthy and her assistant be assigned the entire laboratory/office space that is now shared with a colleague in an unrelated research program.

Mrs. Krishna-Murthy has access to most of the equipment of the Division of Mycology and Plant Pathology. The following items on the POSTHARVEST TECHNOLOGY EQUIPMENT LIST are essential to her research program and should be placed in her laboratory or close nearby.

POSTHARVEST TECHNOLOGY EQUIPMENT LIST.
ITEMS RECOMMENDED FOR POSTHARVEST PATHOLOGY LABORATORY

Import items

1 *Research microscope, binocular, 10X eyepieces, 10, 45, 100X objectives. Tube for mounting 35mm camera.

1 Microwave oven

1 Spectronic 21 spectrophotometer

1 Top loading Mettler balance (PE 166) 0.01 X 1600 g

Local items

1 Disecting microscope with accessories

1 Incubator for microbial cultures, 0-50°C

1 Refrigerator

1 Transfer chamber (for microorganisms), laminar air flow (typical spec sheet enclosed)

1 Walk-in cooler for fruit storage (Blue Star PC 600 or PC 1050)

25 Plastic fruit boxes (specifications can be furnished by Dr. S. A. M. Naqvi, NRCC, Nagpur)

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*Microscope, phase contrast, fluorescence (PHT-13 #6) on the Postharvest Technology Equipment list appears to be a much more sophisticated microscope than is required currently in Mrs. Krishna-Murthy's research project. Hopefully, a binocular research microscope for Mrs. Krishna-Murthy's laboratory can be made available in exchange for the floures-cence/phase contrast microscope which should be shared by all researchers associated with the Postharvest Technology project.

2. Indian Institute of Horticultural Research (IIHR), Bangalore

The major postharvest programs at IIHR deal with the physiology of mango fruit with emphasis on prolonging the shelf life (Dr. S. Krishnamurthy, in charge) and the postharvest pathology of the mango, banana, tomato, and onion (Dr. Ullasa, in charge). Dr. Krishnamurthy has initiated studies on shrink wrap film to delay ripening and to protect mango fruits. One film caused a few days delay in ripening, but with some adverse effect on flavor and color of the fruit. In a small test in Florida, film wrapped mangos did not ripen properly and developed excessive decay (26). Films of other compositions, various thicknesses and perforation should be evaluated at IIHR. Other potential treatments to delay the climacteric will be tested also: modified atmospheres, wax coatings, and ethylene absorption from the atmosphere.

Dr. Krishnamurthy found that bananas can be stored four weeks at 12°C and then ripened in 3-4 days at ambient temperatures without ethylene. Purafil slowed down the rate of ripening, but Semperfresh coating was not promising, possibly because it didn't wet the fruit well. I suggested experiments holding banana hands in closed polyethylene bags. This is a commercial practice in Central America for fruit shipped long distances at 12°C. Bagging is also utilized in Australia to delay ripening of fruits shipped at ambient temperatures (20).

Dr. Ullasa's research emphasizes the application of fungicides in plantations of mangos and bananas to reduce latent infections of anthracnose and wound infection by <u>Botryodiplodia</u> after harvest. Sprays of carbendazim and thiophanate methyl applied every 10-15 days beginning 30 days before harvest, have given good results. The same fungicides applied as dip treatments postharvest have shown promise also. Dr. Ullasa plans to survey orchards for <u>Colletotrichum</u> strains that are resistant to benzimidazole fungicides. Postharvest heat treatments (52-55°C for 5 minutes and 50-55°C for 15 minutes have given good control of anthracnose. Lower temperature treatments can be used most effectively with thin-skinned varieties such as Alphonso. To reduce the hazard of heat injury, I suggested a postharvest treatment of benomyl or imazalil at 52°C, a treatment extensively tested in Florida and Australia (13,24,25,26). Some newer systemic fungicides, eg. prochloraz (Shering Co.), have provided excellent control of anthracnose and should be tested in the connection (10,14). <u>Rhizopus</u> is a major problem during ripening and holding mangos for processing. A field spray or postharvest dip in a solution of iprodione (Rovral) or dicloran (Botran) have been used on peaches to control Rhizopus rot.

POSTHARVEST TECHNOLOGY EQUIPMENT LIST

Items recommended for postharvest pathology laboratory at IIHR, Bangalore

<u>Import items</u>

1 Microwave oven

1 Spectronic 21 spectrophotometer

1 Portable digital hydrometer/thermometer

1 Bench top sterilizer/dispenser for agar medium

<u>Local items</u>

1 Disecting microscope with accessories

2 Incubators for microbial cultures 0-50°C

1 Refrigerator

1 Transfer chamber (for microorganisms), laminar air flow (typical spec sheet enclosed)

25 Plastic fruit boxes (specifications can be furnished by Dr. S. A. M. Naqvi, NRCC, Nagpur)

The laboratory and facilities (cold rooms, evaluation space, etc.) now available or under construction at the IIHR are impressive. I believe the capabilities for post-harvest research will be first-class after installation of the shrink wrap equipment on order. In addition, I would urge the procurement of a small scale fruit cleaning/waxing/fungicide treatment line for oranges, mango, tomatoes, etc. to support research on first-quality export produce.

3. <u>Central Institute of Horticulture for Northern Plains (CIHNP), Lucknow</u>

This institute possesses an excellent research farm (Rehmankhera) with large plots of mangos, guavas, and other fruit crops which are available for both field and postharvest research. On the other hand, the temporary office/laboratory facilities in Lucknow are old and crowded and not conducive to the best efforts of a well-trained and energetic staff.

Since Uttar Pradesh is the major mango producing area of India, it is not surprising that most of the postharvest research of the CIHNP is directed to the improvement of the market quality of this fruit. The station has a major research responsibility for the guava and potato also. Dr. Om Prakash has a detailed survey underway to identify and quantify postharvest losses from all sources.

Major missions of the research station are 1) Reduce postharvest losses due to diseases, insects, and handling; 2) Develop export-quality fresh mangos; 3) Improve processing technology; 4) Develop efficient methods to dispose of processing wastes.

Physiological/processing research are conducted by Dr. S.E.S.A. Khader, Dr. B.P. Singh and Dr. S.K. Kalra. Research is directed at increasing the shelf-life of the mango. Gibberellin field sprays 10 days before harvest reduced the degree of ripeness of the fruit evaluated six days after harvest. A postharvest dip in gibberellin delayed ripening also. Fruit that were dipped in gibberellin solution and stored at 20°C were high in quality after 19 days storage. These results suggests that gib berellin (and other growth regulators) might be combined with evaporative cooling to give affordable storage of mango for a few weeks by the farmer or wholesaler.

Although mango maturity is usually appraised by fruit age (from time of bloom) or fruit shape, there is interest in developing a more objective, non-destructive method based on bouyancy in water. Additional studies are planned on low temperature storage to delay the climacteric; e.g. hydrocooling, gradual cooling, and low temperatures with intermittent warming.

Tests of preharvest and postharvest fungicides/hot water should continue at the CIHNP since the behaviour of the Dashehari and other varieties of the north may be quite different than the Alphonso. Wax formulations for mangos have been developed by the Brogdex Co., Pomona, California and have improved fruit appearance considerably in tests conducted in Israel. New fungicides are introduced annually with superior activity against anthracnose, stem-end rot and other postharvest diseases of the mango.

The utilization of the rainy-season guava crop for juice and products could be improved if the fruit fly population could be reduced by insecticide baits and the control of Colletotrichum (anthracnose) and stem-end rot improved by fungicide sprays in the plantation.

Several items of equipment that are essential to the research of postharvest pathologists, but not readily available at the CIHNP are listed below.

POSTHARVEST TECHNOLOGY EQUIPMENT LIST

Items recommended for postharvest pathology laboratory at CIHNP, Lucknow

Import items

1 Microwave oven

1 Spectronic 21 spectrophotometer

1 portable digital hygrometer/thermometer
1 top-loading electronic balance Mettler 1600

1 Refrigerated centrifuge Sorvall RC50

1 Bench top sterilizer/dispenser for agar medium

Local items

1 Dissecting microscope with accessories

1 Walk-in cooler (Blue Star PC1050)

25 Plastic fruit boxes (specifications can be furnished by Dr. S. A. M. Naqvi, NRCC, Nagpur)

Development of the Rehmankhera Experimental Farm into a research institute conceptually similar to the IIHR, Bangalore, would require additional cold storage space and practical-size equipment for heat treatment, waxing, fungicide application, handling, packing, and pre-cooling fruit. The shrink-film wrapping equipment ordered will be an integral part of this proposal. I believe that it would be wise to plan for the upgrading of the the laboratory/research facilities at Rehmanhera in view of the plans to increase mango exportation and potato production and storage in the area.

4. <u>National Research Center for Citrus, (NRCC) Nagpur</u>

This research center was established in very recent times (within the past year or so) in recognition of the fact that Nagpur is the main center for mandarin growing in India and many unique problems in cultivation and postharvest technology exist. Maharastra is an important banana growing area also; thus this center will ultimately be involved in postharvest research on this crop.

The basic office and laboratory structures, previously occupied by a soil survey, are adequate for the immediate needs of the NRCC, but considerable renovation will be required to bring this institute up to its potential as a world-class citrus research center.

The experimental citrus plantings are being planned but, for the present, research on cultivation, nutrition, and pest control are carried out cooperatively in commercial groves. Dr. H. Dass, Director of the Center, is proceeding very cautiously in setting out the center's experimental plantings to avoid the introduction of the Greening disease, which earlier decimated the sweet orange industry of Punjab and Karanataka. Rootstock selection is also a major priority. Traditionally, the rough lemon was the preferred rootstock for the Nagpur orange because of compatability, tree vigor, and large fruit size. However, Phytophthora gummosis is a serious problem with this combination, especially since the trees are budded close to the soil.

Dr. S. A. M. H. Naqvi, plant pathologist at NRCC, has proposed an ambitious research program consisting of five parts: 1) Survey of postharvest diseases of the Nagpur mandarin from farm to retail market; 2) Identity of the disease-causing microorganisms and their interaction in mixed infections; 3) The role of latent infections in postharvest disease; 4) Control of postharvest disease by preharvest fungicide sprays and postharvest treatments; 5) Pilot demonstrations of practical control measures. The program is well thought-out and workable, provided adequate support is available. The following items of equipment should be readily available for postharvest pathology research:

POSTHARVEST TECHNOLOGY EQUIPMENT LIST-
Items recommended for postharvest pathology laboratory at NRCC, Lucknow

Import items
1 Microwave oven

1 Spectronic 21 spectrophotometer

1 Portable digital hygrometer/thermometer

1 Bench top sterilizer/dispenser for agar medium

Local items
1 Dissecting microscope with accessories

3 Walk-in coolers (Blue Star PC 1050)

Dr. Naqvi and I discussed short-term research projects that might be carried out during his period of training in my laboratory this spring. We plan to study latent infections of *Colletotrichum gloeosporioides* on several varieties of citrus fruits. On most varieties of oranges, latency continues until the fruit becomes overripe or injured whereas young green Nagpur oranges are aggressively attacked by the same pathogen species but perhaps by unique aggressive strains.

Dr. M. S. Ladaniya, postharvest physiologist, was engaged in a research program for fruit quality consisting of: 1) growth regulator treatments to improve the storage life of mandarins; 2) Comparison of shipping containers (wood boxes, wire-bound, corrugated fiberboard, bamboo baskets), wrapping, and cushioning materials on fruit injury and shelf life; 3) fruit cooling, including precooling and the application of the Zero Energy Cool Chamber. In my opinion, the research of Dr. Ladaniya is likely to pay back early returns in improved fruit quality. Poor handling appeared to be a major cause of losses in Indian fruit crops. I was shown a returnable wire-bound wood box with excellent design characteristics for citrus and the fruit crops. The productivity of this practical project would be stimulated by the availability of a small scale fruit cleaning/waxing/fungicide treatment line and shrink film wrapping equipment. Several large adjoining rooms at the NRCC appeared to be an excellent location for a demonstration-scale fruit handling line and shrink-wrapping equipment.

VI. SPECULATIONS AND CONCLUSIONS

The methodology of handling fresh fruits and vegetables in India appears to be in a state of transition. The local open-air market with its labor-intensive conventions and high turnover of goods can offer fresh, high quality produce, but invariably with large price fluctuations and substantial wastage. Clearly, this simple method of merchandising produce becomes less efficient when the goods must be transported long distances, and completely unacceptable when fresh fruits are marketed overseas.

The problem of supply and price fluctuations is inherent in the typical local market, comprised of many small independent grower/merchants. Major fluctuations result from the seasonality of crops; to a certain degree, research in crop production and postharvest handling can help smooth out these cycles. In India, the supply of certain fruits, e.g., mango, citrus, and guava is spread over a harvest season of several months due to geographical location and horticultural variety. The supply is further influenced by the harvest of two distinct crops from the same plantation in some climatic zones, and the use of horticultural practices such as pruning, irrigation, and plant growth regulators to control flowering and the time of harvest. After harvest, the supply of produce offered to the market can be manipulated by storage under conditions that maximizes the storage life -- low temperature, modified atmospheres, anti-transpirant fruit coatings, fungicides, and growth regulators. One of the main problems in utilizing these technologies to control supply and market price is rewarding all of the contributors. There is little incentive for a farmer or a wholesaler to treat mangos with hot water for anthracnose control. So, who will bear the cost of modified atmosphere cold storage for several months? Perhaps this problem could be solved by the formation of farmer cooperatives which participate in all levels of marketing the crop.

The local open-air markets will continue to serve the needs of Indian consumers for many years in the future. However, government planners should begin to look beyond: Chain produce markets such as Mother's Dairy in New Delhi are probably the Indian fore-runners of supermarkets which dominate produce marketing in industrial countries today.

The principal demands of consumers regarding produce in road-side markets is freshness and price; minor superficial defects are usually of lesser, if any, significance. Therefore, fungicide programs required to eliminate superficial infections are hardly justified by the value of the crop in the local market. Research efforts to support local marketing should be directed to the adoption of practices which may be more labor-intensive, but require less expensive imported materials such as fungicides, growth regulators, synthetic coatings and fiberboard containers. The most obvious research agenda to support local marketing would include improved picking techniques, low-cost packaging, gentler handling to reduce injuries, and sanitation to reduce postharvest diseases. In the local market context, affordable cooling will probably be limited to shading and evaporative cooling; control of anthracnose by a single pre-harvest spray or by a post-harvest dip in hot water. While these recommendations are elementary, they do match the consumer expectations and the farmer's capabilities with respect to quality of fresh fruits and vegetables. Picking of Nagpur mandarines by pulling; transport of bananas with constant rubbing of the fingers are examples of substantial injury which could be remedied by modification of current commercial practices.

For long range shipment of perishables to more-sophisticated markets in the major cities of India and abroad, and the development of strategies to deal with surpluses and shortages, modern methods of packing, fungicide treatments, and low temperature storage will be required. The benefits for big-city markets would be reduced losses due to deterioration, availabilty of high quality produce over a longer season, decrease handling costs associated with repacking at the wholesale market. A foreseeable increase in numbers and locations of retail produce stores, such a Mother's Dairy, should increase consumer's awareness of quality produce and quality merchandising. Increased export of fruits such a mangos, bananas, and citrus and export specialties such as exotic fruits and organically-grown produce would demand a large input of technology in the production, refrigerated storage, and packaging of minimum-defect produce. The technology required cannot simply be lifted from the published research and experiences in Europe and North America, but must be tailored to fit the needs, limitations, and resources available in India. This will require the development of additional agricultural research centers with a practical focus, and facilities, equipment, and expertise for development of postharvest technologies that will be required to complete the transition in India from the local open-air markets to the air-conditioned supermarkets of the future.

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