Recent Advances in Chemical Control of Postharvest Diseases of Fruit Crops for Domestic and International Markets

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Abstract

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The introduction of disease control chemicals during the 20 th century has been responsible, in part, for human population growth on every continent of earth. Yet, as the 21^{st} century approaches, the lack of food seems to have become more apparent and widespread even in some developed countries. The question before us today, as dictated by public concern, is how to cope with the increased demand for food yet reduce or eliminate the use of fungicides to control plant diseases. Recent advances in chemical control methods have lessened the unpredictability of crop production and marketing. We must accept and realize that without effective fungicide applications (pre-and/or postharvest) there are no guaranteed practices currently available for the marketing of affordable fresh fruit products of high quality. The long term goals of countries appear to proscribe continued overproduction of food and replace it with a more effective long-term storage system. Thus in this discussion we emphasize the need, development, and registration of improved, environmentally compatible, disease control chemicals for integration with non-chemical procedures to prevent sever losses in crops grown for both domestic and international markets. Expanded international cooperative research on postharvest disease control is needed to permit the marketing of fruit crops without excessive regulatrory constraints.

Introduction

The need to control postharvest decay caused by bacteria, filamentous fungi, and yeasts has increased in recent years because of the greater emphasis on mechanical harvesting, bulk handling, tight-fill packaging, long-term storage, and international marketing. These procedures provide for the production of crops at lower cost and with more efficient means for their distribution, yet they also provide new situations for infections by opportunistic pathogens. Furthermore, to increase fruit quality and to protect our environment, standards for percent decay and chemical residues have become more stringent. Fungicide treatments have been essential in controlling the major decay pathogens, but with the complex of multiple decay organisms, pathogens heretofore thought to be minor or secondary are now assuming greater importance. Estimated postharvest losses from diseases range from 10 to 30 percent in developed countries and even higher in third-world nations. Wholesalers, retailers, and consumers are not prone to accept higher tolerances for decay although the public increasingly demands organic (pesticide-free) products.

Natural and synthetic chemicals play an important role in controlling postharvest decay or deterioration of fresh and processed food crops. Properly applied chemical treatments are effective, economical and safe to humans. They help foods retain maximum quality and extend their life for local, national, and international markets. Chemicals continue to be an integral part of disease management programs for effective postharvest disease control. Treatment strategies are based on basic knowledge of host-pathogen-environment interrelationships both in the field and postharvest. The critical points that need to be considered are: 1) the identification of decay causing pathogens; 2) the disease cycle, with reference to such factors as method of infection, presence or absence of quiescent infections, and environmental parameters for infection and disease development; 3) sensitivity of pathogens to specific fungicides; 4) toxicity of chemicals to the crop; 5) compatibility of fungicides with wax or oil mixtures; and 6) acceptance of chemicals in domestic and international markets. The numbers of available fungicides for postharvest application have been limited and they could be further reduced in the future. Our discussion of the recent advances in chemical control of postharvest diseases of fruit crops produced for domestic and international markets is based on our research and on that conducted in other parts of the world.

Fruit Corps for Domestic and International Markets

Fresh fruits provide nutrition for much of the human population of our world by providing energy, protein, fat, carbohydrate, fiber, and vitamins. The common fruit crops in the temperate zone are pome fruits (apple, pear, quince), stone fruits (sweet cherry, peach, apricot, plum, nectarine), grape, berries (strawberry and bushberries), kiwi, and persimmon; subtropical fruits include avocado, citrus (orange, lime, lemon, mandarin, grapefruit), coconut, date, fig, pomegranate, and feijoa); while tropical fruits include banana, papaya, pineapple, mango, lychee, longan, and cashew. Since many of these fruit crops are produced in both hemispheres, with proper marketing and storage techniques they are or could be made available world wide throughout the year. Specific diseases of these crops are given in the reference by Snowdon (12).

Currently, with fungicide treatments, apples, pears, and grapes can be held in storage up to 8 months. Citrus and kiwis are stored up to 3 months, while stone fruits are stored only about one month. Highly perishable produce such as strawberries and figs should be consumed within a week. Modified atmosphere storage rooms are becoming increasingly common and has considerably extended the storage period for some crops. At present the effective worldwide distribution of fruit crops is dependent on the control of decay with chemicals.

Only with utmost care to prevent injuries (i.e. bagging) during production and handling can fruit be are held for an extended period without chemical treatment. For example, apples produced in Japan are treated with chemicals in the field but not postharvest. Yet they can be held for as long as 6 months under cold storage. To obtain decay-free fruit with limited chemical treatment, it is necessary to consider such factors as: 1) Appropriate cultivars for the region so as to obtain fruit without defects such as suture cracks, excessive skin peeling at the stem-end during harvest, and uneven ripening; 2) resistance of blossoms and fruit to disease; 3) environment of the region with reference to requirements for disease and insect control; 4) method of harvesting - hand or mechanical; 5) distance of field from packing house; and 6) distance of domestic and international markets. These factors are important in relation to the development of decay in either the orchard or postharvest or in both.

Decay Pathogens

The most common decay pathogens on these crops are fungi. Bacteria appear to play a minor role and research efforts on bacterial pahtogens have been minimal. Examples of bacterial pathogens of importance are species of *Erwinia* on pineapples, avocados, and papayas, *Pseudomonas* on pineapples, avocados, and apples, and *Xanthomanas* on stone fruit. The major fungal organisms on fruit crops are *Monilinia, Rhizopus, Colletotrichum, Mucor, Botrytis, Alternaria, Gilbertella, Penicillium, Botryodiplodia,* and *Aspergillus.* The minor fungal organisms include *Cladosporium* and *Phytophthora.* Pathogen identification may be difficult for people not familiar with postharvest pathogens because the appearance of fungi growing on stored products often is different from that observed in the field or on a synthetic medium. Also, environmental conditions during storage affect mycelial growth and sporulation. Furthermore, the symptoms and signs expressed by a disorder often vary among host crop because of their differences in pathogenic reaction. It is not uncommon to confuse *Monilinia* with *Botrytis* on the decaying fruit. Differentiation among mucoraceous fungi requires thorough microscopic examination combined with determination of the optimum growth temperature. Species identification in *Phytophthora* requires the use of special growth media and knowledge of the morphological characteristics of the genus. *Rhizopus* species vary markedly in their sensitivity to chemicals: for example DCNA (dichloran, Botran) controls *R. stolonifer* but is not effective against *R. circinans* and *R.arrhizus*.Thus, identification of the pathogen is critical in the integration of chemical control with other handing and storage procedures.

Decay Control Strategies

The chemical treatment most commonly used for sanitation is chlorinated water as a drench or in a hydro-cooler to kill contaminating fungal propagules and bacteria on the fruit surface. Protective fungicides such as benzimidazoles, iprodione, and dichloran are used alone or in combination with waxes as spray, drench, or brush applications. Sulfur dioxide used as a fumigation treatment for fresh grapes, acts as a suppressant. Chemicals used as surface disinfestant of storage houses and packing shed equipment are chlorinated water and chlorine dioxide foam. Physical biocides (heat and gamma radiation) have also been tested on fruit but with limited results. The influence of mineral nutrition on decay of apples was shown after postharvest treatment with calcium chloride. The basis for resistance is attributed to increase in calcium levels in the middle lamella and cell wall which makes their degradation by fungal pectic enzymes more difficult.

a. Eradicants/disinfestants (chlorine, ozone, chlorine dioxide, ethanol,hot water,hot air,steam,and gamma irradiation): Of these treatments, chlorinated water, using chlorine gas or hypochlorite of sodium or calcium is most commonly used as a disinfestant. Chlorination of the dump tank or hydrocooler effectively reduces the population of decay causing pathogens. Micro-organisms on the healthy surface are essentially eliminated and those on the injured surface are reduced. Established infections are not eradicated or suppressed by exposure to chlorinated water. The concentration of chlorine used is 50 μg/ml or higher. In the preparation of chlorine water, the pH of the solution determines the concentration of the hypochlorous acid (active ingredient) with a neutral or slightly basic solution preferred. Acidic chlorine solutions have a tendency to release chlorine gas, and basic solutions are less effective as the concentration of hypochlorous acid is reduced.

Solutions containing chlorine dioxide and ozone have been less effective than chlorinated water. With both of these chemicals, concentrations over 2 μg/ml are difficult to establish and maintain. Furthermore, the release of chlorine and ozone, both highly toxic to humans, makes the use of these materials in enclosed packing sheds questionable. Currently, chlorine dioxide in foam for sterilisation of packing house equipment shows promise. Solutions of ethanol alone at 30 percent concentration and in combination with fungicides have been used to reduce decay in stored peaches. Of serious concern, however, is the formation of chloroform in dump and hydrocool tanks containing chlorinated water. This highly toxic compound is formed when chlorine reacts with organic material that accumulates in these tanks. Attempts are being made to destroy the chloroform molecule with ozone.

Other practices include hot water to sterilize dump tank water and to suppress quiescent infections of pathogens such as *Colletotrichum* on papayas and mangoes. Hot air treatment has been used to control brown rot decay during ripening of peach fruit, while steam is sometimes used to decontaminate fruit boxes and bins . Gamma irradiation has been tested also for eradication of incipient infections but because of phytotoxicity it appears to offer little promise.

b. Protectants by suppressive action of chemicals applied in liquid treatments: Dichloran (DCNA,Botran)was initially introduced to control *Botrytis,* but its effectiveness in control of *Rhizopus stolonifer* had a major impact on the postharvest treatment of stone fruit crops. Yet DCNA is ineffective against other *Rhizopus* species. Today, there are no alternative fungicides reported which effectively controls *R. stolonifer.* Iprodione (dicarboximide) however, applied as a suspension in water reduces Rhizopus decay. Further research is in progress to find an effective control of both *R. stolonifer* and other mucoraceous fungi, including *Mucor piriformis, Gilbertella persicaria, R. arrhizus, R. oryzae,* and *R. circinans.* The benzimidazoles (benomyl, thiophanate methyl, thiabendazole) effectively control *Monilinia, Botrytis, Penicillium,* and *Colletotrichum* but not *Alternaria* or *Rhizopus.* Their limited systemic action and high activity (less than 1 μg/ml to suppress mycelial growth) are important factors in their effectiveness. However, their mode of action has resulted in the selection of resistant pathogen strains which, in turn, have restricted their use on some crops.

c.Suppression by fumigations: Fumigation with sulfur dioxide for control of Botrytis decay is essential to long term storage and marketing of table grapes. Instead of weekly high-dosage applications, current recommendations suggest more frequent treatments with smaller doses. Also slow release pads containing sodium bisulphite are used directly in the packed boxes. Methyl bromide fumigation to kill insects does not suppress decay organisms.

d. Reduction of moisture loss: Waxes and oils are applied to reduce loss of moisture and retain the fresh quality of fruit. Initially, waxes were applied after a fungicide treatment but recent procedures commonly incorporate the chemicals directly in the wax or mineral oils.

e.Prevention of senescence: For citrus, reducing button infections on the fruit can be accomplished by keeping them from senescing. The use of minute quantities of 2,4-D keeps them alive and less prone to *Phomopsis* infection.

f.Cultural methods: On grapes small quantities of 2,4-D or gibberelic acid can elongate the cluster stems and reduce *Botrytis* infection of the berries. After harvest, quiescent infections are difficult to suppress. On pineapples, *Botryodiplodia* infections occur through the cut stems ends of the fruit. Harvesting the fruit with one shoot attached to the stem retains the life of the stem and prevents spread of the infection into the fruit.

g.Mineral nutrition: Nutrient balance in the soil affects plant growth and crop quality. The role of nutrients, especially that of calcium, has been attributed to increasing the storage period of fruit crops with increase in resistance to decay. Postharvest treatments with calcium chloride has been shown to increase resistance to decay in apples but this treatment has not replaced the current fungicide treatment recommendations.

Strategies for Delaying Problems of Pathogen Resistance

The use of benomyl as a postharvest treatment on stone fruit has been canceled in the United States because of development of resistant strains of postharvest decay fungi. Thiophanate methyl is still registered for use on stone fruit and thiabendazole on citrus and pome fruit. Pathogen resistance is a major problem, especially in the control of decay in citrus and pome fruit. Monitoring for resistant pathogens in citrus packing sheds has led to the proper use of fungicides, such as thiabendazole, 2-aminobutane, and imazalil, with different modes of action. On pomefruit, the use of benomyl has been restricted in some regions to postharvest use to prevent selection of resistant isolates in the orchard. To prevent build of resistant strains of *Monilinia* in the orchard, the number of applications of certain fungicides has been limited. In the United States, although dicarboximide-resistant *Botrytis* has developed in strawberry fields such resistance in *Monilinia* has not been detected in fruit orchards. Mixtures of fungicides were initially suggested by a number of researchers to prevent or delay the development of resistant strains. This strategy, however, has had little success. Today the number of applications of certain fungicides is limited to prevent the rapid selection of resistant strains. With the fungicides used for postharvest treatment, resistance has not been a problem with eradicant type chemicals such as chlorinated water, but those which permit germination but not mycelial growth such as benzimidazoles, diphenyl, sodium orthophenylphenate, and DCNA, appear to be quite prone to the selection of resistant strains. This suggests that if new fungicides are developed whose mode of action is to kill the spores or mycelium resistance problems could be minimized. However, experience in insect control indicates that lethal compounds have permitted selection for resistance.

Domestic Versus International Marketing Programs

For international markets, acceptance of fungicide treatment with chemical residue tolerances set within the current limits of the importing nations would make exportation realistic. Yet pesticide tolerance requirements for domestic markets are usually based on needs of local conditions for crop production and domestic use. Thus pesticides are registered on a crop in one country but not in another, but international travelers certainly consume products which are treated with a chemical not allowed on that crop in their own country. The current trend in international marketing is to require crops with no chemical residues or established tolerances. Some regulations appear to be protectionist while others are based on demands of the consumer or a lack of knowledge of the involved chemical. Most serious is the lack of adequate data on a particular pesticide, and its elimination is often due to the high cost of obtaining the needed information. Chemicals used only for postharvest treatment are likely to be eliminated because of insufficient funds to obtain the chemical and biological data required for registration. Of special concern could be minor crops grown for international markets but which require chemical protection from decay. More rapid inexpensive distribution systems could be the answer for some crops, but for produce with established infections, suppressive chemicals would be required. With the increasing diversity of the population in many nations, we expect that demands will increase for a wider variety of foods. Historically, only the well-to-do were thought to be able to afford the riches (special crops) of the world, but in the 21st century we should endeavor to make foods of choice available to the public as a whole.

Discussion

The marketing strategy for fruit crops is to provide consumers with a high quality, decay-free product, with minimal or no chemical residue. These products are sold fresh, processed or dired. Both preharvest cultural practices and postharvest handling techniques are critical to the longevity of the produce in storage and on the shelf. To prevent postharvest decay, a knowledge of the biology of each decay pathogen involved alone or in combination for each crop, both before and after harvest, is essential. In the orchard, pathogens such as *Monilinia, Botrytis,* and *Colletotrichum* can infect noninjured immature fruit and produce decay, or the infections can remain quiescent until the fruit approaches maturity. Organisms such as *Rhizopus, Mucor,* and *Penicillium* are naturally ubiquitous in temperate zones where fruit crops are produced and infect injured fruit at maturity. When ripe, fruit should be held at cold temperatures because at this stage they are most susceptible to infection and decay. Low storage temperature limits spore germination, mycelial growth, and decay. The limits for mycelial growth are 4°C for *Rhizopus* and 1-2°C for *Monilinia* and *Botrytis,* while *Mucor piriformis* can decay fruit at 0°C. Thus decay control strategies involve: 1) limiting the contamination and infection of fruit by pathogens in the orchard, 2) rapid removal of field heat to slow the ripening process and reduce the growth of most pathogens; 3) prevention of mechanical injuries (including those caused by insects) to fruit in the orchard and during their transportation to the packing shed; 4) postharvest treatments for eradication of contaminating fungal spores; protection of fruit from new infections; and suppression of established infections; 5) appropriate packaging to reduce additional injuries; and 6) transportation in refrigerated containers. Too often, once the retailer has bought the fresh product little or no effort is made to properly refrigerate it. Thus on the market, decaying fruit was often a common sight, with losses up to 50 percent, until the introduction and use of protectant fungicides such as DCNA (Botran 50 W), benzimidazoles (Benlate 50 W, Topsin M 70 W), triforine (Funginex 50 W), and iprodione (Rovral 50 W). Fungicides and other chemicals (waxes, hormones) are essential today in reducing decay during storage, transit, and marketing. For the future, new environmentally safe formulation should be developed and used on fruit corps grown under conditions that minimize contamination and infection by pathogens. Expanded research is needed on all aspects of the postharvest decay problem.

الملخص

أوغاوا، ج م وإنكلش، هـ و مانجي، ب،ت. 1992. تطورات حديثة في المكافحة الكيميائية لأمراض ما بعد الحصاد التي تعتري ثمار الفاكهة الموجهة للأسواق المحلية والأسواق الدولية. مجلة وقاية النبات العربية 10 (1): 58-62

يعتبر ادخال الكيماويات لمكافحة الأمراض مسئولاً ولو جزئياً ـ عن النمو السكاني الذي حدث في معظم انحاء العالم إبَّان القرن العشرين. ومع اقتراب القرن الحادي والعشرين، ستصبح مشكلة نقص الغذاء أكثر وضوحاً وانتشاراً حتى في الدول المتطورة. والسؤال الذي يطرح نفسه: كيف يمكن تلبية الطلب المتزايد على الغذاء مع تقليل الإعتماد على مبيدات الفطور أو حتى استعمالها؟ لقد قللت التطورات الحديثة في طرائق المكافحة الكيميائية من عدم الإستقرار في إنتاج المحاصيل وتسويقها. ولا بد لنا من القبول بحقيقة عدم توافر معاملة مضمونة لتسويق المنتجات الطازجة لثمار الفاكهة القابلة للتلف وبمواصفات عالية سوى باستخدام مبيدات فطور فاعلة قبل و/أو بعد الحصاد. ويبدو أن الهدف البعيد الأمد للدول هو تحريم الإنتاج الزائد للمنتجات الغذائية واستبداله بنظام تخزين طويل الأمد أكثر فاعلية. وسنناقش في هذه المقالة الحاجة إلى تطوير وتسجيل مواد كيميائية لمكافحة أمراض النبات لا تضرّ بالبيئة، والعمل على مكاملتها مع طرائق مكافحة غير كيميائية في محاولة لتقليل الفاقد الكبير في غلة المحاصيل المزروعة والمعدّة للأسواق المحلية أو الدولية. وهناك حاجة ملحة لتطوير بحوث دولية مشتركة عن مكافحة أمراض ما بعد الحصاد، تسمح بتسويق ثمار الفاكهة دون أية قيود تنظيمية زائدة.

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