West Virginia University
Kearneysville Tree Fruit Research and Education Center

DISEASE MANAGEMENT GUIDELINES FOR ORGANIC APPLE PRODUCTION IN OHIO

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Introduction

These Disease Management Guidelines were put together for growers with an interest in the "Organic" production of apples in Ohio. In current organic production systems, growers are not permitted to use conventional synthetic organic fungicides in their disease management program. If fungicides are required in the organic system, growers are limited to the use of "Inorganic" fungicides such as sulfur (elemental sulfur and lime-sulfur) or copper (Bordeaux mixture and basic copper sulfate). There are several problems associated with the use of these inorganic fungicides in modern apple production systems. Among the most important are: 1) phytoxicity, which is the potential to cause damage to foliage, fruit set and fruit finish, and 2) their limited spectrum of activities, which means they may not be capable of providing simultaneous control of the wide range of fungal pathogens that can cause economic damage to the crop.

In a climate like Ohio, environmental conditions during the growing season are generally very conducive to the development of several important diseases, insect pests and weeds. Limitations in relation to which pesticides may or may not be used, present the organic grower with some unique and very demanding challenges.

This Disease Management Program should aid organic growers in achieving an acceptable level of disease control. However, the successful control of diseases **alone** is generally not sufficient to provide a commercially acceptable level of fruit quality in the Midwest and northeastern United States. Unless similar programs are developed and implemented for controlling insects, weeds and other pests (i.e., deer), I strongly question if the organic production of apples on a commercial scale is feasible in Ohio.

Pest management will remain one of the major challenges and constraints facing the organic production of fruit and vegetables in Ohio. In my opinion, growers need to be fully aware of the unique challenges involved, before making any substantial economic commitments.

Objective of the "Organic" disease management program.

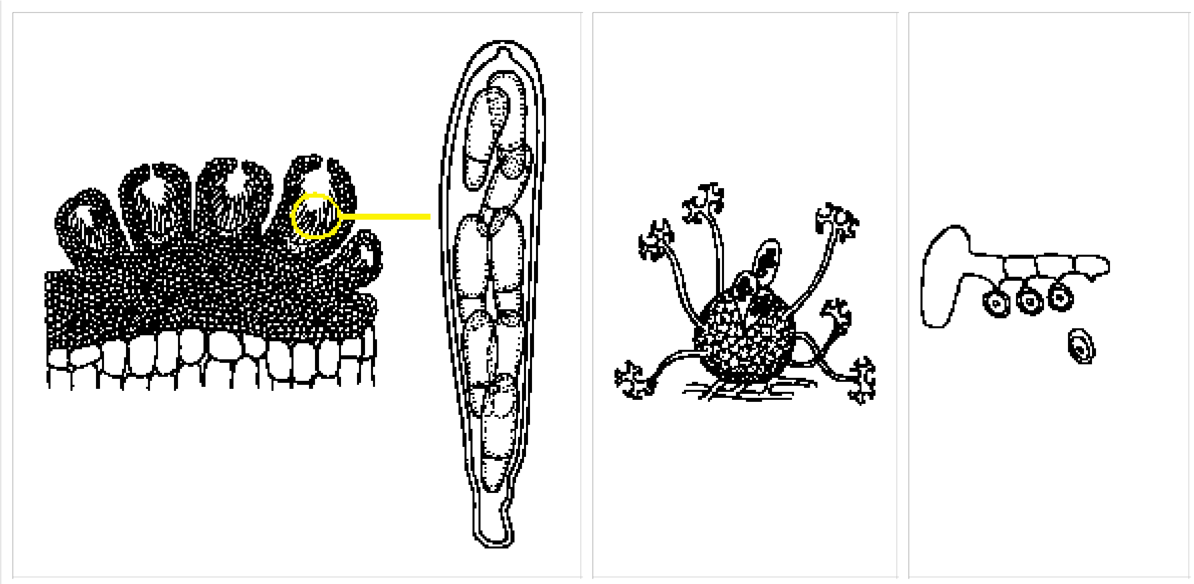
The overall objective of this disease management program is to provide a commercially acceptable level of disease control, with minimal pesticide use. This is accomplished by developing a disease management program that integrates the use of disease resistance, various cultural practices, and knowledge of disease biology to minimize fungicide use. When fungicides are used within the disease management program, they must be acceptable within organic certification programs.

For information on organic production and standards or requirements for organic certification, contact the following organizations: Ohio Ecological Food and Farm Association, 65 Plymouth Street, Plymouth, OH 44865; Phone: 419-687-7665; and Organic Crop Improvement Association, 3185 Township Rd. 179, Bellefontaine, OH 43311

A. DISEASES THAT NEED TO BE CONSIDERED WITHIN THE DISEASE MANAGEMENT PROGRAM.

I. Early Season Diseases:

Apple Scab	Powdery Mildew	Cedar Apple Rust



Unless disease resistant varieties are used, all of these diseases must be controlled with the use of fungicide early in the growing season (from green tip or 1/2 inch green through first to third cover, mid to late June). Failure to control scab and powdery mildew during this period will result in secondary infections occurring throughout the remainder of the growing season. Late season (secondary) infection of scab and mildew will result in increased fungicide usage late in the growing season in order to achieve acceptable control.

II. Late season or "Summer Diseases"

Secondary scab - if primary scab is not controlled.	Black Rot	Sooty Blotch
Secondary mildew - if primary mildew is not controlled.	White Rot	Fly Speck

We need to emphasize early season control of primary scab and powdery mildew so that late season (after mid to late June) fungicide applications for these diseases will not be required. If primary scab and mildew are controlled, then black rot, white rot, sooty blotch and fly speck are the major diseases we need to consider in the late season (end of June through harvest) fungicide program.

III. Other Diseases

Fire blight	Collar Rot

Each of these diseases may require specific control measures and each will be discussed separately.

B. **IDENTIFYING AND UNDERSTANDING THE MAJOR APPLE DISEASES.**

It is important for growers to be able to recognize the major apple diseases. Proper disease identification is critical to making the correct disease management decisions. In addition, growers should develop a basic understanding of pathogen biology and disease cycles. The more you know about the disease, the better equipped you will be to make sound and effective management decisions.

C. UNDERSTANDING THE EARLY SEASON DISEASES (SCAB, MILDEW AND RUSTS)

1. APPLE SCAB BIOLOGY - The importance of early season disease control.

Much of the fungicide spray program for apples in Ohio is directed at the control of apple scab. Therefore, growers that have scab susceptible varieties need to develop a thorough understanding of the apple scab disease cycle before a successful disease management program can be developed.

Note: If scab resistant varieties are used, apple scab requires no other control measures.

a) Primary Disease Cycle

The fungus overwinters in diseased apple leaves on the orchard floor. In late fall and early spring, microscopic, black, pimple-like structures, called pseudothecia, are produced in these dead leaves. Within each pseudothecium are sac-like structures called asci, each with eight ascospores. The ascospores produce the first, or primary, infections on the new growth in the spring.

Apple Scab Disease Cycle

Pseudothecial development in the old dead leaves is favored by alternating periods of wetness and dryness in late winter and early spring. Normally, pseudothecia have mature ascospores when the blossom buds start to open. When the leaves on the orchard floor become wet, ascospores are forcibly ejected into the air. Air currents carry them to the emerging tissues where infection takes place. Maturation and discharge of ascospores usually lasts one to several weeks past petal fall. After this time, there are no ascospores left to cause primary infections.

Environmental conditions that affect ascospore discharge.

Ascospore discharge is induced after dead leaves on the ground have been wetted by at least .01 inches of rain for a least 1/2 hour. After 2 to 3 hours of wetness, the maximum rate of discharge will be reached. After about 6 hours of wetness, 75% of the ascospores that are mature during that wetness period will have been discharged. Some recent research indicates that most ascospore discharge occurs only during daylight.

Ascospore germination begins as soon as a spore lands on young, green leaves or fruit, provided a film of moisture is present. After primary infections occur, lesions are produced in about 1-2 weeks on leaves and fruit. Each lesion (which was caused by a single ascospore) will produce hundreds of thousands of conidia, each of which is capable of causing a new infection. Secondary infections caused by conidia can result in economically damaging levels of fruit scab. The number of hours of wetting required for infection by ascospores varies with temperature. Information on the environmental conditions (leaf wetness duration and temperature) required for scab infection is provided in Table 1.

It is important that growers understand the basic disease cycle for apple scab in order to develop the most successful disease management program.

THE BOTTOM LINE FOR APPLE SCAB CONTROL

In order to effectively control apple scab, you must control primary infections from ascospores. If ascospores are prevented from infecting leaves and fruit early in the season, no further scab control measures are needed after the supply of ascospores is depleted. However, if early-season infections are not controlled, additional fungicide protection is required throughout summer to protect against secondary infections by conidia. The number of conidia produced by just a few early-season scab lesions is much greater than the total number of ascospores produced in an entire acre of leaf litter in most clean, commercial orchards.

Note: Organic growers **should use scab resistant varieties** whenever possible. If scab resistant varieties are used, no fungicides for scab control are necessary.

b) **Secondary Disease Cycle:**

Secondary infections are initiated by conidia produced in primary lesions. Since conidia may develop as soon as 7 to 9 days after infection, secondary infections may be initiated very early in the growing season (prebloom). This is particularly true when ascospores infect the apical portions of sepals and leaves near bud break. Conidia are disseminated by splashing rain and by wind. Conidial germination and infection occurs under about the same conditions as for ascospores.

Although developing fruit become more resistant as they mature, secondary infection to fruit can occur before harvest in the fall but not show up until the fruit have been stored for several months. The disease also can build up on the leaves after harvest. Since the fungus overwinters in these leaves, pseudothecia may be present in sufficient quantity to start the new season even though a good spray program was followed the previous year.

The Bottom Line For Secondary Scab Control is to use a good early season program to eliminate primary infections. Once infections are established in the orchard, the use of additional fungicide sprays throughout the growing season to control secondary scab will probably be required.

Note: If scab resistant varieties are used, no other control measure is required. The use of disease resistance **must be emphasized** within the Organic program.

Get more apple scab info - facts and photos here

II. POWDERY MILDEW BIOLOGY

Powdery mildew (PM) is generally not as severe a problem as scab in most Ohio orchards.

However, under certain environmental conditions and on highly susceptible varieties, powdery mildew can become a major problem.

The conditions required for infection by the PM fungus are very different from those required by the scab fungus. It is important that growers understand these basic differences in order to develop a disease management program for managing both diseases simultaneously.

a) **Powdery Mildew Disease Cycle**

Dormant period

Powdery mildew overwinters as fungal strands (mycelium) in vegetative or fruit buds which were infected the previous season. Infected terminals may have a silvery gray color, stunted growth, and a misshapen appearance, and are more susceptible to winter kill than are healthy terminals. Temperatures near -18 F kill a majority of mildew infected buds and the fungus within them. Unfortunately, even at lower temperatures some PM survives.

The PM fungus produces masses of small black structures called cleistothecia on infected leaves and terminals in the late summer and fall. Although the cleistothecia contain ascospores, their role in the disease cycle is not clearly understood.

Primary Infection

As buds break dormancy, the powdery mildew fungus resumes growth and colonizes developing shoots causing primary infections (Figure 2). The powdery white appearance on infected shoots consists of many thousands of spores which are responsible for spreading the fungus and causing secondary infections. Primary mildew infections may occur on vegetative shoots and blossoms and thereby cause a reduction in yield.

Secondary Infection

Secondary infections are important because they result in the overwintering infected buds and fruit infections. Secondary infections usually develop on leaves and buds prior to terminal bud set in mid-summer and may reduce the vigor of the tree. Young fruit may become infected from about the pink stage of flower development through 1 to 3 week after bloom. Fruit infection results in a weblike russetting on the mature fruit.

b) **Environmental Conditions That Favor Infection.**

Powdery mildew infections occur when the relative humidity is greater than 90% and the temperature is between 50-77 F. The optimum temperature range for the fungus is 66-72 F. Although high relative humidity is required for infection, the spores will not germinate if immersed in water. The high relative humidity that often occurs before and after wetting periods (rainfall or dew) is conducive to powdery mildew development; however, **unlike the apple scab fungus, the powdery mildew fungus does not require leaf wetness for infection**. Under optimum conditions, powdery mildew will be obvious to the unaided eye 48 hr after infection. About 5 days after infection, a new crop of spores is produced. Non-germinated powdery mildew spores can tolerate hot dry conditions and may persist in the orchard until favorable conditions for germination and infection occur.

Note: As a general "rule of thumb" disease pressure from powdery mildew is greater in growing seasons following mild (warm) winters. The critical period for powdery mildew control is from about "tight cluster to pink" through "first" or "second" cover.

Note: Several scab resistant varieties also have good resistance to powdery mildew. The use of disease resistance must be emphasized within the Organic Program.

Get more powdery mildew info - facts and photos here

III. **RUST DISEASES**

Rust diseases and causal fungi include: 1) cedar apple rust, caused by *Gymnosporangium juniperi-virginianae*; 2) quince rust, caused by *G. clavipes*; and 3) hawthorn rust, caused by *G. globosum*. All three fungi spend part of their life cycle on red cedar and are problems only when red cedar is found close to the orchard. The life cycles and control of these diseases are similar.

Cedar-apple rust is the most important rust disease in Ohio and the disease is generally more severe in the southern portion of the state. In Ohio, the rust diseases are generally not a serious problem to apple production; however, if the disease is established on cedar (juniper) within a 2-mile radius of the orchard, serious losses can result.

a) **Cedar-Apple Rust Disease Cycle**

The disease cycle is very similar for all three rusts and is very complex. For the purposes of this discussion, cedar-apple rust will be used as an example. Two plants (apple and cedar) and three fungal fruiting structures (telia, aecia and pycnia) are involved. The pathogen requires 2 yr. to complete its life cycle.

The cedar-apple rust and hawthorn rust fungi overwinters in reddish-brown galls or "cedar apples" in the cedar tree. The quince rust fungus overwinters in elongated galls in cedar branches. When galls become wet during spring rains, they extrude gelatinous tendrils or "horns" consisting of microscopic two-celled teliospores, each of which produces four basidiospores. Air currents carry the basidiospores to the apple leaf and fruit where they infect under favorable conditions. Leaves are most susceptible when they are 4 to 8 days old. Apple leaves and fruit can only be infected by the basidiospores of the rust fungus from cedar trees. Thus, when the basidiospores have all been discharged from the spore hornes on cedar trees, the danger from infection on apple is past. There is no secondary cycle or infections on apple. Once the lesions form on leaves or fruit, they will not spread or cause additional infections on apple. Instead, another type of spore (aeciospore) is produced and during July and August, these aeciospores are carried by wind back to the cedar trees where they cause infection and complete the life cycle of the fungus.

Note: The basidiospores that infect apple are produced and released from galls on cedar trees from about the "Pink" stage of apple bud development, until about "First" to "Second" cover. If fungicide is required to control this disease, this period is most critical for timing sprays.

Note: Apple varieties differ greatly in their susceptibility to rusts. Many scab resistant cultivars also have good resistance to cedar-apple rust, which is the most common rust disease in Ohio. It is important to realize that the resistance reported to rust in the disease resistant apple varieties is for cedar-apple rust. **The varieties may not be resistant to quince rust.** Due to the lack of effective fungicides for rust control, if quince rust is a serious problem in the area, organic production may not be feasible unless you can eliminate cedar trees within at least a 1/2 mile radius. The use of disease resistance must be emphasized in the Organic disease control program.

b) **Bottom Line For Rust Control.**

Use rust resistant varieties and eradicate the alternate host within at least a 1/2 mile radius of the orchard.

Get more cedar-apple rust info - facts and photos here

Get quince rust info - facts and photos here

D. **UNDERSTANDING THE LATE SEASON OR "SUMMER" DISEASES (SOOTY BLOTCH, FLY SPECK, BLACK ROT, WHITE ROT)**

I. **SECONDARY SCAB -** This should not be a problem if primary scab in controlled or scab resistant varieties are used. See previous section on apple scab biology.

II. **SECONDARY MILDEW -** This should not be a problem if powdery mildew is controlled early in the season or mildew resistant varieties are used. See previous section on powdery mildew.

III. **SOOTY BLOTCH AND FLY SPECK -** These two diseases are caused by different fungi, but the environmental conditions that favor their development and the management strategies for this control are very similar. Sooty blotch and fly speck are common names of two diseases often found on apple and pear fruit at the same time. Sooty blotch is caused by *Gloeodes pomigena* and fly speck by *Microthyriella rubi*. They do little or no actual damage to the fruit, but their presence on the fruit's surface lowers quality and the subsequent market value. The diseases occur throughout the eastern apple-growing areas of the United States, but are most severe in the southern fruit-growing regions. Both fungi also occur on the bark, stems and leaves of many other plant species with waxy cuticles.

a) **Disease Cycle**

Both pathogens overwinter on twigs of many woody plants. *Gloeodes pomigena* is spread from these overwintering hosts by waterborne conidia or mycelial fragments. Spread of *M. rubi* is by airborne ascospores, which are discharged during rain periods or by airborne or waterborne conidia. Fruit infection can occur anytime after petal fall but is most prevalent in mid- to late-summer. Both diseases are favored by moderate temperatures, high humidity and abundant rainfall. The diseases are most severe in orchards where fog or heavy dews are common through the mid-to-late growing season. *Gloeodes pomigena* and *M. rubi* are primarily restricted to the fruit's cuticle. Fruit severely affected with sooty blotch may shrivel more readily in storage.

b) **Environmental Conditions That Favor Disease Development.**

Both diseases are favored by temperatures between 65^0 and 80^0F and by high humidity (greater than 90% relative humidity for sooty blotch and greater than 95% relative humidity for fly speck). Conditions such as these occur frequently when nighttime temperatures remain above 65^0 to 70^0F during summer, or during extended warm rainy periods. Sooty blotch and fly speck symptoms can develop within 14 days from infection under ideal conditions, but symptom development is arrested by high temperatures and low relative humidity. Thus, the period between infection and symptom development ranges from 25 to more than 60 days in the Northeast. Sooty blotch and fly speck infections not yet visible at harvest can develop during cold storage.

Note: All varieties, including scab resistant varieties are susceptible to sooty blotch and fly speck.

BOTTOM LINE FOR SOOTY BLOTCH AND FLY SPECK CONTROL

i) Emphasis must be placed **on cultural practices that increase air circulation** and reduce drying time of fruits and foliage.

CULTURAL PRACTICES THAT AID IN CONTROL OF SOOTY BLOTCH AND FLY SPECK

Any management practice which improves air movement and reduces relative humidity within the orchard and tree canopy will aid in reducing the incidence of sooty blotch and fly speck. Management strategies that encourage good air movement and speed drying include dormant and summer pruning, keeping orchards well mowed, and removing hedgerows or adjacent woodlots that obstruct air flow. Removing hedgerows will also remove some of the inoculum sources.

Pruning is the **most important cultural practice** for improving air movement and reducing drying time in the tree canopy. The combination of good dormant and summer pruning will aid greatly in controlling sooty blotch and fly speck.

Dr. Dan Cooley (University of Massachusetts) reported that summer pruning alone resulted in a 50% decrease in the incidence of flyspeck in an orchard that received no summer fungicides. Summer pruning and traditional dormant pruning also opens tree canopies so that in addition to providing increased air movement, better spray coverage of fruits during late summer is also accomplished.

Adequate fruit thinning is also important for minimizing the incidence of Sooty Blotch and Fly Speck. If fruit are clustered (more than two fruit per spur), it becomes virtually impossible to maintain adequate fungicide coverage in the center of the clusters as fruit mature. Clustered fruit often have flyspeck on their inner faces even where an adequate fungicide program has been used.

Growers wishing to minimize the need for summer fungicides in new orchards should recognize that site selection and tree spacing will ultimately impact on incidence of summer diseases in these orchards. High density orchards may provide a faster return on investment, but tight spacings will also result in dense canopies and poor air movement between trees as the plantings mature.

ii) If fungicide is required, sulfur or Bordeaux mixture are the only choices. During wet growing seasons or on problem sites, fungicide application may be required. Sulfur is at best only "fair" for controlling these diseases. Bordeaux mixture is much more effective than sulfur and will provide longer residual activity. See "Comments" on copper in the suggested spray schedule.

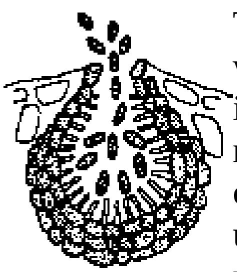
iii) **Chlorine Dip for Removing sooty Blotch and Fly Speck.**

Research at the University of Georgia by Dr. Floyd Hendrix Jr. has shown that a 5-7 minute dip in 500 ppm chlorine in the dump tank of a commercial packing line, followed by brushing and a fresh water rinse was effective in removing both diseases from apple fruits. For severely infected fruit, the longer time period may be required. Dr. Hendrix saw no phytotoxicity on red delicious fruit soaked for 15 min in a 4100 ppm chlorine solution (personal communication). Pennwalts liquid Sodium Hypochlorite is labeled for use in this post harvest dip.

Note: Before using any chemical in the organic program, first check to see if it is acceptable for use in organic production.

Get more sooty blotch and fly speck info - facts and photos here

IV. **SUMMER ROTS -** Black Rot, Bitter Rot and White Rot



There are three summer fruit rots that can occur in Ohio: black rot, bitter rot and white rot. Of these diseases, black rot, and white rot can be commercially important problems. The rather intensive fungicide program that is generally maintained to control our other major diseases probably adds greatly to the control of the summer rots. Where conventional fungicides such as captan are used, summer rots seldom occur as a significant problem. As we develop new programs and strategies that reduce our overall fungicide use, these rots may become more important.

Note: There is good potential for these diseases to become serious problems in organic production systems. Sulfur is not effective in controlling any of the summer rots. In organic systems any cultural practice (primarily sanitation) that aids in controlling these diseases **must be emphasized.**

Black Rot

Black rot of apple fruit is caused by the fungus *Botryosphaeria obtusa*. It also causes frog-eye leaf spot. In addition, the fungus causes a limb canker. The limb canker phase is most important in the northeastern and north central apple growing regions of the United States, and leaf spot and fruit rot phase is most important in the southeast.

a) **Disease Cycle**

Botryosphaeria obtusa overwinters in dead bark, twigs, cankers and mummified fruit. Ascospores and conidia are released during rainfall throughout the growing season and are washed or blown onto fruit and foliage. Ascospores are generally more common during the spring than summer months. Sepal infection can occur any time during the growing season. Leaf infection is most common just after petal fall. Black rot infection of leaves and fruit commonly develops in cone-shaped areas on the tree beneath black rot mummies or old fire blight cankers. Early-season infection may result in fruit drop. Severely diseased fruit may mummify and remain attached to the tree.

b) Environmental Conditions That Favor Disease Development

The optimum temperature for leaf infection (frog-eye leaf spot) is 80^0F; at this temperature, 4.5 hours of wetting is required for light infection. No infection occurs at 46^0F, even with 48 hours of wetting. The optimum temperature for fruit infection ranges from 68^0F to 75^0F, and 9 hours of wetting is required for fruit infection to occur.

Get more black rot info - facts and photos here

White Rot

White rot is also referred to as Botryosphaeria rot or Bot rot. The disease is most severe in trees weakened by drought, winter injury, sunscald, poor pruning, low or unbalanced nutrition, and other plant diseases. White rot can be sporadic in appearance, being serious one season and difficult to find in the following season. The Botryosphaeria fungus attacks a wide range of woody plants that are common in Ohio.

Dutchess, Golden Delicious, Grimes Golden, Gallio Beauty, Rome, and Yellow Transparent apple varieties are all very susceptible to white rot. Jonathan and Red Delicious are less affected than other varieties. In addition to fruit rot, the disease can also result in cankers on twigs and limbs.

a) Disease cycle

The fungus overwinters as black pycnidia and perithecia in a wart-like stroma on living and dead cankered limbs and in rotted or mummified fruits. The fungus is also commonly found on fire-blighted twigs or cankers. Wounds or breaks in the epidermis are necessary for the fungus to penetrate. Spores (ascospores) are forcibly discharged from the perithecia during spring rains. Another type of spore (conidia) is produced within pycnidia and ooze out in tremendous numbers. They are then washed and rain-splashed to other parts of the plant throughout the summer. Apple fruits may become infected fairly early in the season, but the rotting does not develop much until the fruit is almost mature. At temperatures above 75^0F (24^0C), mature fruit may rot completely within a few days after infection. The development of Botryosphaeria canker and fruit rot is favored by any condition that reduces tree vigor.

b) Environmental Conditions that Favor Disease Development

The optimum temperature for germination of ascospores and conidia is 82 to 90^{0}F. Germination can occur in as little as 90 min at 82^{0}F. Germination is greatest in free water, but some can occur in the absence of free water at relative humidity as low as 96%. Wounding is not necessary for fruit infection, but entry through wounds is probably the most important means of infection. Infection of wounded fruit can occur in as little as 2 hours at 82^{0}F.

Get more white rot info - facts and photos here

C. CULTURAL PRACTICES THAT AID IN BLACK ROT AND WHITE ROT CONTROL

a) Maintain trees in a healthy vigorous condition. Prune trees annually and maintain good soil fertility based on foliar and soil analysis.

b) Sanitation is probably the most important cultural practice that aids in control of these diseases. Piles of prunings are an important source of inoculum and should be removed from the perimeter of the orchard or burned. Prunings can be left on the orchard floor if they are chopped with a flail mower, which removes much of the bark. All dead, cankered, or infected twigs and limbs should be carefully pruned, then removed from the orchard and destroyed (preferably by burning) during the winter. This will reduce the carryover of the fungi. Old, weak, and diseased trees should be destroyed.

Removal of mummified apples in the tree is important for reducing the inoculum within the tree. Pruning out current-season shoots infected with fire blight is also important, because they can be colonized and serve as an inoculum source during the same growing season.

c) Handle fruit very carefully while picking, sorting, and packing to avoid bruises and cuts which are quickly colonized by the fungi.

d) Refrigerate fruit promptly after harvest. Although rot can develop in cold storage, disease development is greatly reduced at temperatures below 40^{0}F.

E. DISEASE MANAGEMENT OPTIONS FOR ORGANIC PRODUCTION SYSTEMS.

I. Options:

Option 1) Do not use Fungicides

Use Disease Resistant Apple Cultivars and Emphasize the Use of Good Cultural Practices. The use of scab resistant or "immune" varieties will greatly reduce the need for early season fungicide use. In fact, by using a variety such as "Liberty" that has resistance to scab, mildew and rust, the need for early season fungicide application is essentially eliminated. Several new varieties have multiple resistance to the early season diseases. These varieties are not resistant to the summer diseases. However, the diligent use of good cultural practices that have been described will greatly aid in controlling these diseases. If the use of disease resistant varieties combined with good cultural practices does not provide an acceptable level of disease control, the use of fungicide will be required.

Note On The Use of Fungicides in Organic Production Systems: The use of disease susceptible varieties that require the intensive use of fungicides to control diseases **is strongly discouraged** within an Organic Production System. In fact, this approach is probably doomed to failure in the long run. The use of disease resistant varieties and rootstocks that require no or minimal fungicide use must be emphasized in organic systems.

Option 2) **Use Inorganic Fungicides (copper and sulfur) In a Protectant Fungicide Program.**

This program requires a 4-7 day interval between fungicide sprays from green tip to 1/2 inch green through first or second cover (through primary scab) for control of the early season diseases **on susceptible varieties,** then a 10-14 day interval between the remaining cover sprays through harvest for control of summer diseases. During wet growing seasons, the shorter interval will probably need to be used, and during dry growing seasons the interval can usually be extended.

If used in conjunction with good cultural practices, this program should provide acceptable disease control, but it requires an intensive use of fungicides. The only fungicides currently acceptable for use within organic programs in Ohio are elemental sulfur, lime sulfur, Bordeaux mixtures (copper plus lime), and basic copper sulfate. Although these are actually "inorganic" compounds (contain no carbon atoms) they are often referred to as "organic" fungicides. The following is intended to provide some general information about these fungicides.

a) **Copper Fungicides**

In general, copper fungicides are very effective against most apple diseases and provide good residual activity, thus increasing the time interval required between sprays. However, copper fungicides have some very important disadvantages that growers need to understand before they use them.

When different formulations of copper are dissolved in water, copper ions are released into solution. These copper ions are toxic to fungi and bacteria because of their ability to destroy proteins in plant tissues. However, because copper can kill all types of plant tissues, the use of copper fungicides carries the risk of injuring foliage and fruit of most crops. Factors promoting this injury include: 1) the amount of actual copper applied, and 2) cold, wet weather (slow drying conditions) that apparently increases the availability of copper ions and, thus, increases the risk of plant injury. Because of the potential to injure plants, the use of copper fungicides for fruit disease control has largely been replaced with the synthetic, organic fungicides that are safer to plant tissues and often more effective. The use of copper fungicides on apple after the 1/2 inch green stage of bud development through about 4 to 5 weeks past bloom will probably result in some level of fruit russet.

Several terms are used when discussing copper as a fungicide. The original material used was copper sulfate (also known as blue vitriol or bluestone). When this material was combined with lime in French vineyards, the combination became known as Bordeaux mixture.

Bordeaux Mixture

Bordeaux mixture is a mixture of copper sulfate and hydrated lime in water. The formulation of Bordeaux mixture is usually expressed by using three numbers, such as 8-8-100 or 6-8-100. The first number is the amount of copper sulfate in pounds; the second is the amount of hydrated (spray) lime in pounds and the last number is the gallons of water they are mixed in. For example, an 8-8-100 Bordeaux mixture is 8 lbs. of copper sulfate plus 8 lbs. of spray lime in 100 gallons of water. The addition of lime to copper sulfate makes it safer for use on plants. The lime reacts with the copper ions making them more stable. Thus, copper compounds in the presence of lime will generally produce lower, more uniform concentrations of free copper ions, which in turn is less likely to injure plant tissues. Bordeaux mixture has long residual activity and has been used to control fire blight and apple scab. The use of copper (Bordeaux Mixture) in the later cover sprays (mid-to late-summer) may result in acceptable fruit finish and good disease control; however, I feel that the use of copper on apple anytime after bud break is risky and may result in damage to fruit and foliage. Bordeaux mixture is available as a wettable powder or it can be made on the farm (see below). Bordeaux mixture is approved for use in organic production in Ohio.

Fixed Copper Fungicides

Following the discovery and use of Bordeaux mixture, several relatively insoluble copper compounds or fixed coppers were developed. Fixed copper formulations may be less injurious to plant tissues than Bordeaux mixture, but their use is still limited because of their potential to injure plants and lack of compatibility with other pesticides. Some of the more common formulations of fixed copper include C-O-C-S, Kocide 101, Tribasic Copper Sulfate, and Tenn-Copp 5E. There are many copper fungicide formulations on the market.

Note: Before using any form of fixed copper fungicide, check to make sure it is approved for use in organic production in Ohio (see note page 4). It must be emphasized that these copper containing compounds are fungicides and must be labeled for use on apple before they can be used. Label instructions must always be followed.

b) **Sulfur Fungicides**

Sulfur is available as liquid lime sulfur, dry wettable powders, and in liquid or flowable formulations. The following are some of the more common and readily available types.

Liquid Lime-Sulfur or Lime-Sulfur Solution is a 29% solution of calcium polysulfide. It is rather caustic material and smells like rotten eggs but it is a good fungicide and is accepted within many organic certification programs. The labels I have seen do not mention its use on apple past petal-fall or first cover. In addition, if it is used past tight cluster it may result in poor fruit finish (russet).

Dry Wettable Sulfurs

Dry wettable sulfurs are available under many trade names. The microfine wettable sulfurs are usually much less injurious to foliage and fruit than liquid lime sulfur, but their use during hot weather (above 80 F) may result in some leaf burning and fruit russeting.

Flowable Sulfurs

Flowable sulfurs are also available from several manufactures. The most common formulation I have seen is the 6F which contains 6 pounds of sulfur per gallon. Due to smaller particle size, flowable sulfurs may be a bit more efficacious than wettable powders. Flowable sulfurs are often preferred to wettable powders because they do not create dusts that can be inhaled during loading and measuring operations.

Various other forms of sulfur such as dispensable granules are also available.

Note: Elemental sulfur and lime sulfur are approved for use in organic production systems in Ohio.

General Comments on Sulfur

Sulfur is highly effective for control of powdery mildew. It is "at best" only fair for control of apple scab and summer diseases and provides no control of rusts. A major problem with the use of sulfur as a fungicide is the lack of residual protectant activity. Sulfur only provides about 3-5 days of protection. When sulfurs were the only fungicides being used in the past, up to 25 applications per season were necessary to obtain satisfactory control.

Growers should also note that sulfur is toxic to many beneficial insects, spiders and mites. These beneficial insects are natural predators of harmful insects and mites that affect fruit crops. Killing these beneficial insects may increase certain insect problems, especially with mites.

II. A Suggested Fungicide Spray Schedule for Organic Production Systems In Ohio (Option 2).

Important Note:

The following spray schedule is only intended to provide guidelines for organic growers that need to use fungicide in order to obtain satisfactory disease control. Organic growers **must understand** that it may not be feasible to use "organic" fungicides on a strict calendar schedule with a precise number of days between sprays. Calendar spray schedules are feasible with some of the conventional synthetic, organic fungicides such as captan because they provide enough residual activity to allow a specific number of days between sprays. Sulfur, on the other hand, only provides 3-5 days of protective activity and needs to be applied just prior to rains that are infection periods (Table 1). Thus, the timing of fungicide sprays within an "organic" spray schedule will be largely dictated by weather conditions.

Growers should pay close attention to the "Comments" sections within this spray schedule.

Timing	Disease Controlled	Fungicide and (Rate/100 gal)

Green tip to 1/2 inch green	Scab	Copper fungicide (see label) or Lime-Sulfur (1.5-2 gal) or Microfine Wettable Sulfur (6 lb.) or Flowable Sulfur 6F (5 qt.)

Comments

If scab was a problem in the orchard last year, copper or lime-sulfur should be the fungicide of choice. Lime-sulfur is incompatible with oil and should not be applied within 3 weeks of an oil spray. The use of a copper fungicide past 1/2 inch green is not recommended due to fruit finish problems (russet) and potential damage to foliage and overall tree health.

If sulfur is used, it should be re-applied after every rain, and may need to be re-applied after each additional 1 inch of rain during long wetting periods until the danger of primary scab infection is past.

Timing	Disease Controlled	Fungicide and (Rate/100 gal)
Tight Cluster (5-7 days after 1/2 inch green	Scab Powdery Mildew	Lime-Sulfur (1.5-2 gal) or Microfine Wettable Sulfur (6 lb.) or Flowable Sulfur 6F (5 qt.)

Comments

The use of lime-sulfur past tight cluster may result in fruit finish problems and damage to leaves; however, if scab is established in the orchard or disease pressure is severe, lime-sulfur would be the fungicide of choice.

The labels I have seen for lime-sulfur recommend its use up to petal-fall or first cover, depending upon the manufacturer.

If sulfur is used, it should be re-applied after every rain, and may need to re-applied after each additional 1 inch of rain during long wetting periods until the danger of primary scab infection is past.

Timing	Disease Controlled	Fungicide and (Rate/100 gal)
Open Cluster to Pink (5-7 days after tight cluster)	Scab Powdery Mildew Rust	Lime-Sulfur (1.5-2 gal) or Microfine Wettable Sulfur (6 lb.) or Flowable Sulfur 6F (5 qt.)

Comments

This is an important period for disease control. See comments on lime-sulfur and sulfur above, under tight cluster.

Timing	Disease Controlled	Fungicide and (Rate/100 gal)
Bloom (5-7 days after previous spray)	Scab Powdery Mildew Rust	Microfine Wettable Sulfur (6 lb.) or Flowable Sulfur 6F (5 qt.)

Comments

See comments on lime-sulfur under tight cluster. Sulfur sprays will probably need to maintained on a 5-7 day schedule.

Timing	Disease Controlled	Fungicide and (Rate/100 gal)

Petal Fall (When last petals are falling or 5 -7 days after previous spray)	Scab Powdery Mildew Rusts Sooty Blotch Fly Speck Black Rot White Rot	Microfine Wettable Sulfur (6 lb.) or Flowable Sulfur 6F (5 qt.)

Comments

Fruit Finish: The time from bloom to about second cover (4 to 5 weeks past bloom) is thought to be the most critical time for fruit russet due to pesticides. Sulfur is probably the safest material available. Unfortunately, it is also the least effective. Sulfur applications need to be maintained on a 5-7 day schedule until the danger of primary scab infection is over. (See page 6, Environmental conditions that favor ascospore discharge.)

Lime-Sulfur: The labels I have seen for lime-sulfur solution state that applications can be made up to petal fall or first cover, depending upon the manufacturer. My interpretation of the label is that lime-sulfur is not labeled for use in the cover sprays. Thus, other labeled formulations of sulfur must be used to control summer diseases in the cover sprays past petal fall.

Copper: I have not found a label for a copper fungicide (other than Bordeaux Mixture, Tri-basic copper sulfate, and Tenn-Cop 5E) that is registered for use on apple past petal-fall. The Bordeaux Mixture I have seen is sold in small packages primarily intended for homeowner use. I feel that the use of copper during the period from 1/2 inch green through 4 to 5 weeks past bloom will probably result in serious fruit finish (russet) problems. However, copper fungicides should provide good control of the summer diseases in the later cover sprays when temperatures are higher and if they are not applied under slow drying conditions. If growers decide to use Bordeaux Mixture for summer disease control, they should consider avoiding its use from bloom through second or third cover which is considered to be the critical period for russet. Remember that there is always some risk of fruit and foliar damage anytime copper is used during the growing season. Check labels of products to verify their registrations for use on fruit after petal-fall.

Timing	Disease Controlled	Fungicide and (Rate/100 gal)

First Cover (5 -7 days after Petal Fall)	Scab Powdery Mildew Rusts Sooty Blotch Fly Speck Black Rot White Rot	Microfine Wettable Sulfur (6 lb.) or Flowable Sulfur 6F (2.5 qt.)

Timing	Disease Controlled	Fungicide and (Rate/100 gal)
Second and Third Covers (10 - 14 days after First Cover)	Scab Powdery Mildew Rusts Sooty Blotch Fly Speck Black Rot White Rot	Microfine Wettable Sulfur (6 lb.) or Flowable Sulfur 6F (2.5 qt.)

Comments

Sulfur is not very effective in controlling the summer diseases. The use of good cultural practices must be emphasized if sulfur is expected to provide acceptable control. During wet growing seasons a shorter interval between sprays may needed.

Timing	Disease Controlled	Fungicide and (Rate/100 gal)

Remaining Covers (10 - 14-day intervals through harvest)	Sooty Blotch Fly Speck Black Rot White Rot	Microfine Wettable Sulfur (6 lb.) or Flowable Sulfur 6F (2.5 qt.) or Bordeaux mixture (see label)

Comments:

If summer diseases are a persistent problem in the orchard, growers may want to consider the use of Bordeaux mixture in the later cover sprays (after third cover). Although the risk of damage to fruit finish and foliage still exists, it is minimized during these later sprays. Copper should not be applied during cool temperatures or under wet, slow drying conditions. The 14 day interval should be satisfactory for copper fungicides and during dry growing seasons the interval could probably be extended to 21 days.

Do not apply sulfur if the temperature is warmer than 80^{0}F. If summer diseases are a problem, the spray interval for sulfur should not exceed 10-14 days. Regardless of the fungicide being used, the use of good cultural practices to aid in summer disease control must be emphasized.

F. **APPROACHES TOWARD REDUCING THE USE OF FUNGICIDES FOR SCAB CONTROL.** ⬆

1) Use scab resistant cultivars. This eliminates the need for fungicides to control scab.

2) Reduce scab inoculum levels in the orchard.

a. After leaves drop in the fall, pulverize them with a mower. This will speed up their decay. Obviously, if leaves do not overwinter in the orchard, they can't serve as a source of primary inoculum in the spring.

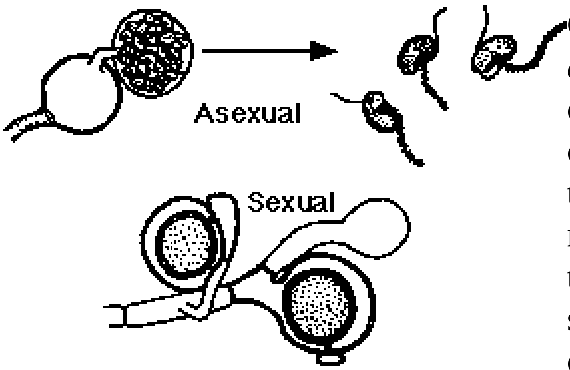
b. Apply nitrogen to leaves on the ground or in the tree just before they drop to speed up their degradation. Some tests in North Carolina have used 5 lbs. of urea per 100 gal of water (personal communication: Dr. Turner Sutton). In theory this sounds good, and some discussion about this approach surfaces from time to time; however, I would not recommend this approach until more research has been conducted and specific recommendations are available.

3) Good pruning practices (both summer and dormant pruning) to open up the tree canopy will be beneficial in increasing the efficacy of the fungicide spray program. Open canopies result in better air circulation and light penetration that aid in reducing the length of wetness periods, in addition to providing for better spray penetration and coverage.

4) Properly calibrate the sprayer and make sure that you are getting complete coverage of all susceptible plant parts.

G. **OTHER IMPORTANT DISEASES THAT NEED TO BE CONSIDERED.**

a) **Collar Rot (Crown Rot) of Apple**



Collar rot, caused by the soil borne fungus *Phytophthora cactorum* is a chronic problem in midwestern apple orchards, several other *Phytophthora* species can also cause collar rot on apple. Collar rot is especially severe on trees that are grown on Malling Merton 106 (MM.106) rootstocks. The disease is most frequently associated with those areas of the orchard having heavy, poorly-drained soil. Phytophthora collar rot attacks the lower trunk just at or below the soil surface. One of the first indications of a collar rot problem is the production of smaller, chlorotic (yellowish) leaves in spring or early summer, and reddish or bronze colored leaves in late summer. This is soon followed by general stress symptoms which include poor terminal growth, small off-colored leaves, and numerous, small, brightly colored fruit. Cankers at the base of the main trunk can be recognized by the dark, sunken appearance of the bark. Tissue beneath the bark has a reddish to dark brown to black marbled appearance.

Collar Rot Control: Good water management and site selection are the most important factors for control of collar rot. Orchard soils should have good internal as well as surface drainage and should be leveled before planting. If collar rot occurs after trees are planted, improve drainage in the vicinity of the "saucer" around the base of the trunk. If subsurface drainage is a problem the only solution may be the installation of drainage tile through the area in which trees are planted, a task much more easily done before trees are planted! Select rootstocks that are not highly susceptible to collar rot. Although no rootstock is immune to collar rot, some are much more resistant than others.

Get more info on collar rot - facts and photos here

b) **Fire Blight**

Fire blight of apple and pear is a very serious disease on susceptible varieties. The disease is caused by the bacterium *Erwinia amylavora*. Incidence varies from year to year and severity is influenced by cultivar susceptibility, tree age, succulence of tissues and spring climatic conditions. The disease is most serious when temperatures during pre-bloom and bloom are warmer than average. Warm rainy periods at this time are particularly conducive to rapid spread of the pathogen resulting in blossom blight. Secondary blight of twig terminals occurs in late May through June during wind driven rains. Hail and wind damage provide openings that the pathogen enters. Insects with sucking mouth parts such as aphids and leaf hoppers may also be capable transmitting the disease to twig terminals. However, the role of insects in twig or shoot blight development is not clearly understood. Hot July weather generally slows disease progress. The bacterium overwinters in cankers on infected trees.

Fire Blight Disease Cycle

Fire Blight Control: Completely reliable control methods for blight are not available. Control strategies for this disease must include all aspects of fruit production. Resistant varieties of both apple, including scab-resistant varieties, and pear are available and should be planted wherever possible. Avoidance of blight susceptible rootstocks (M26, M9) especially when grafted to susceptible scions is encouraged. Cultural conditions should be modified if susceptible varieties are grown. Cultural practices which minimize rapid growth and succulent tissues should be practiced. Annual pruning with avoidance of major cuts will help minimize tree vigor. Similarly, limiting the amount of nitrogen fertilizer will reduce twig terminal growth. Fertilization should be based on the results of foliar and/or soil nutrient analysis. Other cultural practices which will help control fire blight include careful pruning of trees during dormancy to remove overwintering cankers.

Note: Certain years are "blight years" and even well-managed trees may be severely blighted. Organic growers should avoid varieties that are highly susceptible to fire blight.

Cutting Out Infected Twigs In The Growing Season

When large blocks of trees are severely affected by fire blight, it is difficult to determine whether removing fire blight strikes as they appear during summer is cost effective. In mature apple orchards that are not overly vigorous and do not include trees on M.9 or M.26 rootstocks, fire blight can often be left to run its course without endangering the tree. Older, nonvigorous trees will wall off the cankers before they spread very far in larger limbs. There is less risk of spreading the blight bacteria if pruning is delayed until winter, and winter pruning can be accomplished more efficiently because pruning tools need not be disinfected between cuts if pruning is done when trees are fully dormant. Generally, remove fire blight strikes during summer only if the following conditions exist:

1. The infections are in young, vigorous trees, where significant damage to the central leader and scaffold limbs will often occur if blight is not removed as it develops.

2. The infections are in dwarfing trees on highly sensitive rootstocks, such as M.9 or M.26, in which case the entire rootstock may die if exposed to inoculum from scion infections.

3. The number of infections in older trees is limited and can easily be removed.

4. Summer rot diseases such as black rot, bitter rot, or white rot have been a problem in the orchard. The removal of dead, blighted twigs is an important sanitation measure to prevent the increased development of these diseases.

Remove infected shoots during the growing season only on dry, sunny days. Make the cuts 8" to 10" below the visible canker. Disinfect the cutting tools between each cut, using 70% alcohol, 10% bleach, or 5% Lysol to avoid spreading the bacteria. When blight appears in an orchard, sucking insects should be controlled as long as the trees continue growing, to minimize secondary spread to new terminal shoots. Aphids and leafhoppers transmit fire blight, but their efficiency as disease vectors has not been determined. The usual control thresholds for aphids and leafhoppers are based on their feeding damage to trees and are not valid when they may be transmitting fire blight.

Get more info on fire blight - facts and photos here

Chemical Control of fire blight

Sprays of copper sulfate during dormancy and fixed copper or Bordeaux mixture (8-8-100) during early growth (no later than 1/2 inch green) may help reduce inoculum from cankers in the spring.

Recommended Spray Schedule For Fire Blight
DORMANT TO SILVER TIP
Before growth starts in the spring and when temperatures are above 45º F.

Pest/Problem	Material	Rate/100 gal	Low volume rate/acre	Comments
Fire blight	Bordeaux mixture OR Copper sulfate plus Superior oil (70 sec vis.)	8-8-100, plus oil (see comments) OR 5 lb. plus 1/2 gal.	not recommended not recommended	If fire blight was severe last year, a Bordeaux or copper spray at silver tip is suggested. Use a dilute Bordeaux spray of 8 pounds copper sulfate, 8 pounds spray lime, and 1 gallon miscible superior oil per 100 gallons of water. To mix, dissolve the copper sulfate in one-half tank of water. Once completely dissolved, add the spray lime with constant agitation as the tank fills. Add the oil last but before completely filling the tank. The mixture must be agitated continuously or the mixture will gel plugging nozzles, etc. Do not apply after 1/4 inch green leaf stage or when drying conditions are slow, as severe injury can occur. Bordeaux mixture and its residue have many compatibility problems with other pesticides. Do not apply copper sulfate plus oil past silver tip. It will burn any green tissue.

HALF INCH GREEN STAGE

Pest/Problem	Material	Rate/100 gal	Low volume rate/acre	Comments
Fire blight Scab	Bordeaux mixture	8-8-100, plus oil (see comments)	not recommended	See comments above. Do not apply copper during the period between 1/2 inch green and second or third cover or severe fruit finish problems may result. This spray may be beneficial for fire blight control and will also control apple scab. Some people have reported fruit finish problems, when copper fungicide was applied at 1/2inch green. The use of copper any time during the growing season is risky.

Note: Before using any copper compound, make sure that it is approved for use in Organic programs in Ohio or in other locations where fruit may be sold (see note page).

Some Links for Organic Insect and Disease Management:

- MSU Organic Apple Spray Program, by Mark Longstroth
- Organic Apple Production Guide for Nova Scotia, by G. Braun

Additional Resources:

The following literature contains color photographs of disease symptoms on apple, as well as information on pathogen biology and disease development.

"Compendium of Apple and Pear Diseases", is published by The American Phytopathological Society, 3340 Pilot Knob Rd., St. Paul, MN 55121, Phone: 612-459-7250. This is the most comprehensive book on apple diseases available. It has excellent color photos and all commercial apple growers should have a copy. Cost including shipping is $35.00 within the U.S.

"Management Guide For Low-Input Sustainable Apple Production", is a publication of the USDA Northeast LISA Apple Production Project. For detailed information about disease resistant cultivars, growers should obtain a copy of this publication from: Dr. David Rosenberger, Box 727, Highland, NY 12528. Make checks payable to: New York State Agricultural Experiment Station, Cost: $10.00 plus $2.00 shipping = $12.00.

"Diseases of Tree Fruits in the East", North Central Regional Publication No. 45, by Alan L. Jones and Turner B. Sutton. The publication has excellent color photos and is available for $10 from Michigan State University, Bulletin Office, 10-B Agriculture Hall, East Lansing, MI, 48824-1039, telephone (517) 355-0240 for more information.

Fruit Tree Books

West Virginia University
Kearneysville Tree Fruit Research and Education Center
