A Grower's Guide to Organic Apples

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A Grower's Guide to Organic Apples

Primary Authors and Coordinating Editors

Gregory M. Peck*. Cornell University, Department of Horticulture, Ithaca.

Ian A. Merwin*. Cornell University, Department of Horticulture, Ithaca.

Contributing Authors and Reviewers

Arthur Agnello*. Cornell University, Department of Entomology, NYSAES, Geneva.

Insecticides; Common Apple Arthropod Pests

Brian Caldwell*. Cornell University, Organic Cropping Systems Project, Ithaca; and farmer of organically managed orchards at Hemlock Grove Farms, West Danby.

Site Selection and Orchard Design; Insecticides; Disease Control Materials

Paul Curtis*. Cornell University, Department of Natural Resources, Ithaca.

Wildlife Damage Management

Ron Gardner, Sr. Cornell University, Pesticide Management Education Program, Ithaca.

Pesticide Regulations; Pesticide Safety

Michael Helms*. Cornell University, Pesticide Management Education Program, Ithaca.

Pesticide Regulations; Pesticide Safety

David Rosenberger*. Cornell University, Department of Plant Pathology, NYSAES, Hudson Valley Laboratory.

Site Selection and Orchard Design; Disease Control Materials; Key Apple Diseases; Harvest and Postharvest Handling

Elizabeth Thomas (New York State IPM Program, Geneva)

Christopher Watkins. Cornell University, Department of Horticulture, Ithaca.

Harvest and Postharvest Handling

**Pesticide Information and Regulatory Compliance*

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The information in this guide reflects the current authors' best effort to interpret a complex body of scientific research, and to translate this into practical management options. Following the guidance provided in this guide does not assure compliance with any applicable law, rule, regulation or standard, or the achievement of particular discharge levels from agricultural land.

Every effort has been made to provide correct, complete, and up-to-date pest management information for New York State at the time this publication was released for printing (December 2009). Changes in pesticide registrations and regulations occurring after publication are available in county Cornell Cooperative Extension offices or from the Pesticide Management Education Program Web site (http://pmep.cce.cornell.edu).

This guide is not a substitute for pesticide labeling. Always read the product label before applying any pesticide.

Always check with your organic certifier before using a new product or material.

Trade names used herein are for convenience only. No endorsement of products in intended, nor is criticism of unnamed products implied.

Updates and additions to this guide are available at: http://www.nysipm.cornell.edu/organic_guide.

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1. INTRODUCTION

Many New York fruit growers have expressed interest in producing for the organic sector, where prices are relatively high and demand is increasing. However, reliable science-based information for commercial organic tree fruit production in cool humid regions such as the Northeastern United States has been difficult to find. This production guide compiles and distills information from university research trials, making the essential elements for organic apple production available to growers, extension agents, crop consultants, researchers, and others who desire to produce organic apples. The goal of this guide is to help growers produce the highest quality fruit possible, utilizing organic techniques and systems.

Few research projects in the Northeast have used organic materials exclusively, and even fewer have been conducted on certified organic farms. This is not surprising, considering that less than 0.5% of NY's apple acreage is certified organic. Nonetheless, much research has been conducted that has direct applicability to organic systems. For example, substantial research efforts have occurred in disease and insect biocontrol, Integrated Pest Management, herbicide-free orchard floor management systems, pheromone mating disruption, and various low-input spray programs. The authors' five years of organic apple research in Ithaca demonstrated that consistent high yields, acceptable fruit quality, and market profitability are possible in a commercial apple orchard. Additionally, apple breeders at Cornell University, the PRI breeding program, and in Europe have worked since the 1940s to develop high quality disease-resistant apples. High quality disease-resistant cultivars that are well adapted to our climate, and with fruit quality similar to mainstream cultivars, are now widely available.

Within this guidebook we attempt to consolidate information specific to organic systems. Growing organic fruit in the Northeast is a challenging and complex operation requiring in-depth knowledge of horticulture, insect and disease management, available cultivars and genetic resources, soil fertility and conservation, and strategic marketing. For this reason, this is not a comprehensive text on apple production. Those who want to learn more about general tree fruit production are referred to one of the many textbooks and/or extension publications available. We focus primarily on commercial orchard systems, but also provide small-scale producers and hobbyists with appropriate information on organic techniques.

Organic apple production requires long-term farm management plans that are based upon proper site and plant selection, managing habitat and natural resources, and may require increased consumer acceptance for blemished fruit. The domesticated apple (*Malus Xdomestica*) is an exotic plant in America, having been introduced from Europe first by Spanish colonialists through Mexico in the early 1500s, and then again by the British settlers in New England during the early 1600s. Apples and other introduced tree fruits were then rapidly and widely disseminated by Native Americans throughout the continent, well in advance of European settlements. Over the last 500 years, many apple diseases and insect pests have also found their way to the New World, joining several indigenous species of insects, fungi and bacteria that adapted from native hawthorns (*Crataegus* sp.) to domesticated apple trees. Today, we know of more than 20 diseases and 50 arthropods (insects and mites) that regularly feed on apples or apple trees in the Northeastern US.

Long-term plans are not only an essential part of the organic certification process, but are necessary for managing soil and crop fertility, as well as controlling pests and diseases without synthetically derived inputs. It will be very difficult to succeed in producing organic apples by simply replacing synthetic inputs with those approved for organics. Throughout this guide we provide information on available management options, but growers will need to develop management plans that best fit their particular operation. There is much more to be learned about organic apple production in the Northeast. If interest in organic production continues to expand we can expect to see an increase in the available products, research, and marketing opportunities.

2. ORGANIC CERTIFICATION

The Organic Foods Protection Act of 1990 required the United States Department of Agriculture (USDA) to develop uniform national organic standards. From this legislation arose the National Organic Program (NOP), which through the 15-member National Organic Standards Board (NOSB) developed regulatory codes that must be followed for selling any products labeled as organic. Since 2002, all organic farming and processing operations are certified by a USDA accredited certification agency (ACA) to assure consumers that all NOP regulations are being followed. The NOP maintains a list of ACAs on their Web site (http://www.ams.usda.gov/NOP), as does NY State Department of Agriculture and Markets (http://www.agmkt.state.ny.us/AP/organic/). The choice of certifier is often dictated by cost, experience with the crops being produced, and familiarity with the targeted marketing outlets. Organic producers with gross sales less than $5000 per year do not need to be certified, but they do need to follow all NOP regulations in order to use the organic label.

The USDA defines organic as a labeling term that refers to an agricultural commodity produced in accordance with the NOP. In other words, the USDA views organic primarily as a marketing category. However, in order to access the organic market the USDA specifically states that an organic production system must be managed to respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity.

Prior to the production of the crops the producer and ACA must agree upon a written organic management plan that includes all aspects of agricultural production and handling as described in the NOP. This agreement is known as the organic system plan (OSP). The process of developing an OSP can itself be valuable in terms of anticipating potential issues and challenges, and fostering thinking of the farm as a whole system. Soil, nutrient, pest, and weed management are all interrelated on organic farms and must be managed in concert for success. ACAs should be able to provide a template for the OSP. Additionally, the National Sustainable Agriculture Information Service, (formerly ATTRA), has produced a guide to organic certification that includes templates for developing an OSP (http://attra.ncat.org/organic.html), as has The Rodale Institute (http://www.tritrainingcenter.org/code/osp_index.php).

Under NOP section §205.202, "any field or farm parcel from which harvested crops are intended to be sold, labeled, or represented as "organic," must have had no prohibited substances, as listed in §205.105, applied to it for a period of three years immediately preceding harvest of the crop." This three-year period is referred to as the transition period. During this time growers will likely assume greater operating expenses, without earning organic price premiums. The transition period will coincide with the time needed for new orchard plantings or top-work grafted trees to come into bearing.

Throughout this guide we refer to the NOP regulations that are relevant to tree-fruit production. For example, the section on pesticide regulations more fully explains how to select materials that are approved for use under the NOP. The entire NOP regulation, as codified by the Federal Government, is available through the NOP Web site (http://www.ams.usda.gov/NOP).

The information in this guide reflects the current authors' best effort to interpret a complex body of scientific research, and to translate this into practical management options. Following the guidance provided in this guide does not ensure compliance with any applicable law, rule, regulation or standard, or the achievement of particular discharge levels from agricultural land. Specific products and practices that are used to produce the crop must be approved by the grower's ACA. Ultimately, it is the producer who is responsible for ensuring that they are following all NOP regulations.

REFERENCES

Riddle, J. 2009. Organic certification of vegetable operations. Available at http://www.extension.org/article/18646.

3. SITE SELECTION AND ORCHARD DESIGN

Site selection and orchard design are some of the most critical decisions that a grower will make, as they will have consequences for the lifespan of the orchard. Many components come into play in selecting or trying to improve an orchard site, including the geographic location of the orchard (at many different scales), the local climate, the site history, potential for future expansion, and the costs of farming a particular piece of land. Each location will need to be evaluated and integrated into the particular business plan and personal preferences of the individual grower.

There is no way to determine or describe the ideal site or design for an organic orchard, but in general, orchard land should have good air movement, have soils with good water drainage, and be located in an area that is not prone to frequent bloom-time frosts. Rootstock and cultivar selection are also key components of the overall design process, and must be evaluated for suitability to each orchard site. Less than ideal sites can sometimes be used if proper rootstocks and scions are selected. Below we outline some general guidelines to assist growers in planting a new orchard, transitioning a producing orchard, or reclaiming an abandoned orchard.

GEOGRAPHY

Proximity to population centers can be viewed as either a positive or negative attribute depending upon the grower's operation and marketing goals. Prime agricultural land that is far enough from population centers may be chosen so that farming operations can occur without upsetting neighbors with traffic from customers, noise, odors, or spray drift. Conversely, sites may be chosen for their proximity to potential customers for direct market sales. Site selection might also be based on the cost of land, proximity to commercial packing and storage facilities, or proximity to abandoned orchards, unsprayed backyard trees and conventional orchards that may pose a risk of drift from materials not approved for organic operations.

In choosing a site, growers should consider how and where they could find farm workers. Many farms in the US struggle to find enough farm labor during peak seasons. Organic orchards typically require additional labor for hand thinning and hand weeding. It should not be expected that workers would travel to remote locations without being compensated for their time. Providing seasonal or permanent worker housing may also be part of the site selection and design process.

Many orchards in NY State benefit from the temperature moderating effects of large bodies of water such as Lake Ontario, the Hudson River, and the larger Finger Lakes. In mid winter, unfrozen bodies of water stay warmer than the air temperatures, thus heating nearby airflows and minimizing winter damage to trees. In the spring, large bodies of water tend to be colder than surrounding air, thus helping to delay bloom until after potential spring frosts have passed. In the summer months through harvest in the fall, large water masses stay cooler than ambient air, moderating high temperatures (>90 ºF) that can reduce photosynthesis or cause heat stress in apple fruit. Additionally, lake effects may delay the first frost in autumn, providing a longer ripening season.

Elevation also plays a critical role in site selection. Cold air being denser than warm air will sink down slopes and build up behind physical barriers such as buildings and wooded areas. For sites in low valley locations, or at higher elevations where spring frosts may be more frequent, selecting later blooming varieties will help to limit frost damage. Planting on gently sloped land, avoiding troughs or "frost pockets", and creating passages for cold air to drain through wooded areas will help to minimize cold temperature damage.

Slopes with an incline greater than 15% will be prone to soil erosion, and may therefore be non-compliant with section §205.203(a) of the NOP, which states that soil erosion must be minimized. Steep slopes are also dangerous for operating mechanical equipment, and difficult for farm workers. Additionally, where slopes and uplands have been cultivated intensively in the past, much of the topsoil on hilltops and ridges has been eroded, reducing soil fertility and tree vigor. Careful groundcover management such as complete sod cover, mulching, and cover cropping can help to minimize erosion and restore soil fertility in these upland sites. In some cases, development of earthen berms and terraces may make a less-than-desirable site more suitable for organic tree-fruit production.

CLIMATE

Climate refers to the weather conditions at a location averaged over long periods of time. Climate classification systems designate the Northeastern US as a humid continental climate, defined by variable weather patterns with large seasonal temperature variations. Growers need to be concerned with and understand their local climate at multiple levels. Macroclimate is determined by large-scale factors, such as the jet stream, prevailing maritime winds or mountain range effects on precipitation, and global North/South latitude. Regional effects, such as lake effect temperature moderation, site elevation, slope or aspect with respect to solar radiation, determine Mesoclimate. Microclimate is determined by small-scale local effects, such as the pooling or movement of cold and warm air through an orchard, the presence of a south-facing building wall that stores solar heat and releases it during the night, or the use of wind machines or sprinklers to prevent frost damage during bloom.

On the macroclimate scale, bud or cambium damage from extreme winter temperatures, and spring frost (i.e., damage caused by temperatures a few degrees below freezing during bloom and fruit set) are the major climatic limitations for fruit growers. For this reason, care should be taken to choose rootstocks and cultivars appropriate for specific orchard sites, considering factors such as their winter hardiness, average bloom dates, and number of days from bloom to harvest. In most of NY and New England (except high mountain elevations) the length of the growing season (between 130 and 210 days without killing frosts) and cumulative Growing Degree Day Units (heat accumulation above a minimum temperature threshold of 50 °F) are adequate for the production of all but the latest ripening cultivars.

Within a single site there are usually several different microclimates, such as the top versus bottom of the hill, and the north versus south side of a slope. Most growers become familiar with the various microclimates on their property after a few years. New growers can gain considerable insight on their property by talking with neighbors, extension agents, or private consultants familiar with other fruit plantings in the region.

Knowing your local climate conditions and selecting the most suitable fruit and rootstock cultivars for those conditions are always the best strategies for avoiding catastrophic damage in your orchard. Most spring frost situations result from radiative cooling, typified by cold, clear nights when there is little air movement to mix cold and warm air masses. These conditions often create inversion layers where cold air accumulates in the orchard, with warmer air massed above. However, the Northeast is also prone to advective freezes, when large cold air masses from the north move swiftly through the region, often resulting in extremely cold temperatures. Advective air masses are typified by moderate to high winds, and little to no inversion layer.

Radiative freeze events can be minimized or avoided through various management strategies such as heat generation in the orchard with propane burners, wind machines, and frost protecting sprinkler systems. Air-mixing wind machines (and helicopters) are particularly effective in areas where inversion layers form, such as in valleys with minimal natural airflow. Sprinkler irrigation can provide up to 5 ºF of protection from frost, if there is adequate water available to keep the sprinklers running continuously from a few hours before the freeze event, until an hour after ambient temperatures rise above the freezing point or lethal temperature threshold. For advective freeze events, moderating temperatures with wind machines, combustion heat sources, or sprinklers is rarely feasible; good site selection is the only practical way to minimize the likelihood of advective freeze damage.

During the mid-winter months, deciduous woody perennial species such as apple trees go into endodormancy (a state of deep rest). In order to emerge from endodormancy, the aboveground tree parts—especially buds—require a specific amount of time at temperatures between 32 and 60 ºF, known as the chilling requirement and measured by "chill units." Several mathematical models have been developed for calculating chill units, but the general principle involves adding the cumulative hours within the temperature range of 32 and 50 ºF, with temperatures above 60 ºF negating some of the accumulated chill units. Under current climatic conditions, NY winters provide adequate chill units for most apple cultivars (>1200 chill units). However, some low-chill cultivars (<250 chill units) are prone to earlier blooming in years with warm spring weather, thus increasing the likelihood of spring frost damage.

CLIMATE CHANGE

As greenhouse gas pollution leads to global warming, most climate models predict that our regional climate will become more variable and extreme (more temperature fluctuation year-round, and [paradoxically] more frequent droughts but also more intense rainstorms). Without abatement of greenhouse gas pollution, by 2050 the NY climate may resemble the present-day climate of South Carolina! This will profoundly affect our regional pest complex, essential processes such as winter chill unit accumulation and dormancy in fruit trees, and the timing and frost damage potential at bloom. Early blooming apple varieties may be especially vulnerable to spring frost damage as the winter and spring temperatures become more variable. On the positive side, growing trees is a good way to sequester carbon and mitigate global warming. Building soil organic matter, using biomass derived fertilizers such as compost or manure, and recycling tree prunings on-site are not only elements of many organic systems, but will also help retain carbon and other nutrients in the orchard agroecosystem.

WEATHER

Weather refers to immediate conditions, such as temperature, humidity, and precipitation at a given location. Weather will vary within a year and between years in NY State. Unseasonably hot or cold weather, and dry or wet weather may occur at any time of the year. These factors will affect plant growth, yields, and fruit quality.

Temperatures, along with prolonged stretches of cloudy weather, can greatly affect fruit production. The period from just before bloom through fruit set until the "June Drop" (a time when apple trees normally self-thin by dropping many of their developing fruitlets) is an especially critical time for fruit trees, when their internal reserves of carbohydrates and essential nutrients such as nitrogen are largely depleted. Prolonged periods of cool, cloudy weather at this time greatly influence the apple tree response to chemical fruit or blossom thinning treatments, and the extent of June Drop. At the other extreme, temperatures above 90 ºF during the summer months can cause heat or drought stress, resulting in sunburn or sunscald injury to susceptible cultivars such as Jonagold, Cox Orange Pippin, Tompkins King, and Priscilla. Heat stress or photo-oxidative sunscald may be reduced through applications of kaolin clay, evaporative cooling with overhead sprinklers, or pruning strategies that increase shade in the fruit zone of susceptible cultivars.

In most growing seasons on typical NY soils, precipitation and stored water in the soil profile will supply sufficient water to support tree growth and fruit production. Prolonged droughts rarely occur in NY, but two- to three-week dry spells occur quite often, and may create significant water deficits that stress fruit trees, especially in the year of planting. If water is available from farm ponds, wells, or municipal water systems, the installation and use of supplemental irrigation is usually worthwhile. This is especially true when establishing new orchards on coarse, textured "droughty" soils, or on dwarfing rootstocks that do not access water from deep in the soil profile. Additionally, sandy or gravelly soils have a lower water-holding capacity than clay soils and will require more frequent irrigation. The addition of composts, mulches, and till-down off-season cover crops will help increase soil organic matter and water holding capacity. The need for supplemental irrigation can be assessed by calculating water-use budgets from pan-evaporation data that are available from regional weather stations, or measured directly with relatively inexpensive tensiometers that are installed into the root zone (approximately 12-inch depth) beneath several reference trees. Apple tree growth and fruit quality are usually optimized when soil water potential is maintained in the 40 to 80 centibar range based upon tensiometer readings.

The amount and frequency of rainfall also affect the development of diseases, the length of time that pesticides reside on fruit and foliage, those pests that spend part of their life cycle underground, and weed germination and growth. For these reasons, production of organic apples is more challenging in the Northeast than in arid climates, such as the inland valleys of West Coast states.

SEASON EXTENSION

Growers of high-value fruit crops are increasingly using hoop-houses or other greenhouse type structures for season extension, protection from hail and spring frost damage, and prevention of disease infection by controlling precipitation or wetting events. As hoop-houses become less expensive to install and more adaptable for different fruit crops, they may offer economical strategies for avoiding weather and pest damage in organic orchards. However, this technology creates some problems for pollination (bee hives must usually be included within the hoop-house), microclimate control (excessive heat can be a problem without adequate ventilation), and recycling or disposal of non-biodegradable plastics that are used to cover these structures.

SOIL CHARACTERISTICS

Agricultural soils are classified into five general management groups on the basis of texture and parental materials (Table 3.1). Percentage of clay, buffering capacity, and potassium availability decrease from group I to V.

A large range of soil types may be acceptable for apple production, but apple roots generally do not perform well in soils that remain saturated during the growing season. Therefore, orchard sites should have adequate soil drainage, either naturally or through the installation of drainage tiles.

TABLE 3.1. Soil management groups.

Soil group	Texture	Comments
I	Clayey soils, fine-textured soils.	These are heavy soils that developed from lake sediments. The will likely require subsurface drainage.
II	Silty loam soils with medium to moderately fine texture.	The better-drained soils in this group can be very productive. Less well-drained soils in this group will benefit from subsurface drainage. Developed from calcareous glacial till.
III	Silty loam soils with moderately coarse texture.	Can be productive soils when pH and nutrients are maintained at adequate levels. Less well-drained soils in this group will benefit from subsurface drainage.
IV	Loamy soils, coarse- to medium-textured soils.	Low in potassium-supplying power. Less well-drained soils can usually be effectively drained with widely spaced tile lines.
V	Sandy soils, very coarse-textured soils.	Very well drained soils that would benefit from irrigation. Will need regular nutrient and organic matter inputs, and supplemental irrigation for sustained yields.
VI	Organic or muck soils with more than 80% organic matter.	This soil group is not recommended for tree fruit production.

If poorly drained sites must be used, they should have tile drainage installed before trees are planted. Also poorly drained sites and heavy soils will benefit from planting trees on berms or raised beds. The latter can be especially useful for enhancing tree growth and avoiding problems with Phytophthora root rots.

EFFECTS ON PEST CONTROL

Orchard design and cultivar selection has long-term impact on pest control. While apple trees are resilient, and can usually survive for decades without human intervention or care, year-round precipitation and in-migration of pests from wild or unmanaged apple trees virtually guarantees substantial pest damage and blemishes to unsprayed fruit. Surveys have shown that more than 95% of the fruit on wild or abandoned apple trees are usually damaged or infested. Beneficial predators or hyperparasites (arthropods or pathogens that parasitize and help to control apple pests) can provide some biological control of arthropod pests and diseases, but in most years they are unable to prevent severe damage. Additionally, in wet seasons apple scab (*Venturia inequalis*) and other diseases can damage the foliage of apple trees severely enough to cause premature defoliation and extensive deadwood.

Managing edge habitats surrounding orchards such as hedgerows, adjacent woods or old successional fields is complicated, and no single strategy can be recommended. Edge habitats are beneficial for wildlife biodiversity, providing habitat for beneficial insects and creating buffer zones to minimize drift. For resistance management of key arthropod pests, such as codling moth (*Cydia pomonella*) and apple maggot (*Rhagoletis pomonella*), it is helpful to have wild-type individuals from surrounding habitat migrate into your orchard and mate with the resident pest population that is subject to chemical controls. Having these two gene pools intermix will help delay the development of pesticide resistance for critical organic pesticides, such as the spinosads (e.g., Entrust®) and pyrethrum (e.g., Pyganic®).

Other pest control activities are more easily accomplished when there are fewer orchard edges bordering natural areas or unmanaged orchards. For example, pheromone mating disruption is much less effective in areas where mated female codling moths, oriental fruit moths (*Grapholita molesta*), or apple maggots can easily fly into the orchard from surrounding areas. Also, cottontail rabbits can become a serious problem in orchards during the winter where surrounding hedgerows, brambles (*Rubus* spp.), or old successional fields provide ideal rabbit habitat during the summer months. When snow cover deprives these rabbits of other food sources, they tend to gnaw on the lower branches and spurs of apple trees, which can cause severe damage. Many species of fruit-eating birds also thrive in hedgerows or woods, and fruit damage by birds in late summer tends to be more problematic where they have ideal habitat around orchards.

In some situations, apple growers may want to selectively remove unmanaged apple and pear trees, crabapple trees, hawthorns, and other alternative host species for apple pests, such as cedar (*Cedrus* sp.), juniper (*Juniperus* sp.), mountain ash (*Sorbus* sp.), cotoneaster (*Cotoneaster* sp.), and quince (*Cydonia oblonga*) trees. Summer diseases are also more prevalent along borders with woodlots and hedgerows than in areas well separated from alternate hosts, such as brambles, oaks (*Quercus* sp.), maples (*Acer* sp.), and wild grapes (*Vitis* sp.). To minimize in-flight of insect pests and the spread of diseases these species would need to be removed within a half-mile of the orchard. Considering the area that might be involved, and the number of potential host species, this can be a daunting task.

Additionally, removing trees from private property will require the permission of landowners, and may not be possible or practical in residential areas where these plants are grown for ornamental landscape purposes.

Cultivar selection and placement will aid in pest management, and disease-resistant rootstocks and cultivars are highly recommended for organic systems (see Rootstock and Cultivar Selection section). Additionally, problems with sooty blotch and flyspeck, a summer disease complex (see Key Apple Diseases section), can be minimized if late-maturing cultivars are kept as far away as possible from hedgerows and woodlots that provide inoculum, whereas early-maturing cultivars are less prone to damage by these diseases. Similarly, cultivars susceptible to cedar rust diseases (see Key Apple Diseases section) should be planted as far away as possible from cedar trees that supply inoculum. Cultivars such as Liberty that bloom early and size fruit rapidly after petal fall appear more susceptible to plum curculio (*Conotrachelus nenuphar*) in some years because this insect invades orchards from perimeter areas at petal fall and often seeks out larger fruit for egg-laying. Similarly, some early maturing cultivars (e.g., Ginger Gold) are especially attractive to apple maggot, another pest that usually invades from orchard perimeters. Keeping these cultivars away from perimeter areas may reduce overall damage from plum curculio, apple maggot, and other pests.

Ideally, organic growers should manage both the surrounding natural areas and the orchard site to optimize the benefits of edge habitat while minimizing some of its potential pest complications. The benefits of hedgerows, woods and other natural areas surrounding organic orchards will probably compensate for the resultant pest management complications in most situations. There is no single design that is appropriate for all orchards, but carefully thinking through the various options for selecting an orchard site and strategically locating cultivars within the orchard will help minimize some pest control problems.

Site topography also affects pest management. Valleys and low-lying sites with poor air drainage allow for a more humid microclimate to exist. These sites will be more prone to summer diseases such as black rot, sooty blotch, and flyspeck. Additionally, synthetic chemicals used in pheromone mating disruption lures are heavier than air and will sink down slope. Pheromone mating disruption tends to works best in large (5 to 10 acres or more) planting blocks that are flat to gently sloping where the pheromone concentration in the air can be maintained at a uniformly high level (see Insecticides section).

LAND AND BUFFER ZONE RECOMMENDATIONS

Apples grown in a mixed operation (i.e., production of both certified organic and non-certified crops on the same farm) or in close proximity to a conventional operation must have a buffer zone to ensure that organic fruit is not contaminated by prohibited synthetic spray drift. As defined by USDA-NOP rule §205.202, a buffer zone has "distinct, defined boundaries and buffer zones such as runoff diversions to prevent the unintended application of a prohibited substance to the crop, or contact with a prohibited substance applied to adjoining land that is not under organic management." If an organic orchard is sprayed with prohibited materials, even accidentally, it must undergo a three-year transition period to regain organic certification.

Guidance for Federal Rule §205.202:
Source: 2009 NOFA-NY Certified Organic LLC Guidance Manual, Version 1

- A minimum 50-foot buffer zone is recommended where a certified field adjoins conventionally managed lands, including both farmland and residential areas. Buffer zones should be under the management control of the certified farmer.
- A minimum of a 250-foot buffer zone is recommended if an air blast sprayer is used on the adjoining non-certified land.
- A minimum of a 660-foot buffer zone is recommended if planting an organic crop next to the same species genetically engineered crop. If wind or insect pollination can occur, testing may be required to ensure the crop has not been genetically contaminated.
- A minimum of an 800-foot buffer zone is recommended if adjoining non-certified land is aerially sprayed.
- Buffers can include windbreaks and living barriers such as a dense hedgerow. A dense hedgerow less than 50 feet may offer better protection from contamination than a 50 ft. open buffer zone. If the buffer is planted to the same crop as the field, documentation of disposal of use of buffer is required, including harvest records.
- Crops grown in the buffer zone area may not be marketed as certified organic, or used for feed or bedding for certified livestock or dairy cattle.
- The buffer zones above are based on research results and are provided as guidance as a way to ensure that the organic crop is not contaminated. Additional information and testing may be required.
- A farmer who maintains organic production in accordance with these Standards, on noncertified fields (i.e., transition fields) adjacent to certified fields, is exempt from a buffer zone provided no prohibited substances are used since January 1 of current year.

LEAD ARSENATE, DDT, AND COPPER SOIL CONTAMINATION

Beginning in the late 1890s, lead arsenate was used as an insecticide for control of many different pests in orchards and vegetable farms throughout the US. By the 1950s, heavy metal insecticides were largely replaced by synthetic insecticides such as DDT (dichloro-diphenyl-trichloroethane). Although the Environmental Protection Agency (EPA) officially banned the use of lead arsenate in 1988 and DDT in 1972, many agricultural soils still contain elevated concentrations of these chemicals. Urban and suburban soils with no history of fruit or vegetable production may also be contaminated with lead from paint dust or automobile exhaust from leaded gasoline. Lead and arsenate bind to soil clays and organic matter and exist mostly as immobile precipitates (of lead) or bound anions (of arsenate) in soil. Similarly, DDT is adsorbed to soil particles and, along with its breakdown products that have similar toxicological effects, can have a decades' long half-life.

Studies have shown that apples grown in lead arsenate contaminated soils do not have significantly higher lead levels than those grown on uncontaminated soil, and the minimal arsenic uptake is sequestered in the seeds of fruit. The primary lead or arsenic ingestion hazard on contaminated sites is from direct ingestion of the soil from unwashed hands, from dropped fruit picked up off the ground, or from dust inhalation during orchard operations. In U-Pick operations there is a risk that young children could be exposed to lead arsenate contaminated soil from direct ingestion or consumption of dirty fruit. Remediation of lead arsenate and DDT contaminated soils is difficult and expensive, but management practices that reduce airborne dust levels, minimize mud and splash contamination of leaf and fruit surfaces, and thoroughly remove soil residues on harvested fruit will greatly reduce the potential for human ingestion of residues on fruit or in the orchard.

Although the NOP makes no mention of maximum allowable lead arsenate or DDT soil concentrations for certification, growers should notify their accredited certification agencies in sites shown to have elevated levels. Soil lead arsenate levels can be tested at reputable labs that completely digest or dissolve the sample using an analytical microwave or by boiling the sample in strong acids. Heavy metals are insoluble and are not extracted by the usual sample processing methods, which were developed for measuring essential nutrient availability for plant uptake, and greatly underestimate the total heavy metal concentrations in soil. Maximum lead levels will also correspond to and depend upon the soil texture and pH; therefore soil test results should be interpreted in consultation with the analytical lab and/or an extension agent who is knowledgeable about heavy metal residues in soil.

Copper usage is permitted with limitations by NOP standards; and in trace concentrations (usually just a few parts-per-million), copper is a micronutrient and non-toxic to plants, humans, and wildlife. However, in higher concentrations, copper can become a serious toxicological hazard, especially to infants and small children, and accumulates in soil over time. Organic fruit growers who rely upon copper applications for disease control should be certain to minimize copper residues on harvested fruit. See Disease Control Materials for further discussion on copper.

APPLE REPLANT DISEASE

Replanting apple trees into land previously planted with fruit trees often results in stunted trees and reduced yields. This disease syndrome, known as apple replant disease, has non-specific causes that often differ from one site to another. Multiple biotic and abiotic factors are involved in replant disease. Organic growers can potentially minimize the negative effects of apple replant disease by avoiding the old tree rows of the previous orchard when planting new trees. Additionally, several rootstock selections from the Cornell-Geneva breeding program, particularly G.41, G.30 and CG.6210, are more resistant to apple replant disease than the Malling rootstocks (see Rootstock and Cultivar Selection section). Preplant cover crops of marigold flowers, certain oilseed rape cultivars, and Sudan grass hybrids, which may provide partial control of apple replant disease in some orchards. Replacing soil from the planting hole with a mixture of fresh soil and compost may also be helpful. Other factors that may alleviate apple replant disease include allowing a fallow period before planting, soil pH adjustment, minimizing soil compaction, improving soil drainage, correcting nutrient deficiencies, and providing supplemental irrigation immediately after nursery trees are planted in the orchard.

ORCHARD TRAINING AND TRELLIS SYSTEMS

Orchard training and trellis systems that are well exposed and promote good airflow through the tree will reduce disease incidence by facilitating quicker drying after rain or irrigation, allowing better pesticide coverage, and increasing light penetration into the canopy. These are especially important features in organically managed orchards. Dozens of different orchard systems exist for growers to choose from, and no one system can be recommended for all growers. Although there are many different tree-training systems in use around the world, the best systems share one common trait—they maintain a tree form where no part of the canopy is farther than four feet from full sunlight. This basic feature ensures that every part of the tree receives enough sunlight to maintain healthy spurs and flowers, highly colored and full-flavored fruit, and adequate annual shoot growth.

TRELLIS POSTS

Most orchards on size-controlling rootstocks use trellis systems consisting of large posts that support steel wires or smaller stakes for supporting individual trees. The smaller stakes are sometimes attached to the steel wire for support. For organic growers, NOP certification regulation §205.205(f) stipulates that, "the producer must not use lumber treated with arsenate or other prohibited materials for new installations or replacement purposes that comes into contact with soil or livestock." None of the currently available pressure treated lumber products are allowable under the National List; however, some manufacturers are seeking organic approval for pressure treated lumber that does not contain prohibited materials. According to NOFA-NY's policy, "the prohibition for treated wood applies to lumber used in direct contact with organically produced and handled crops and livestock and does not include uses such as lumber for fence posts or building materials, that are isolated from production. The prohibition applies to lumber used in crop production, such as the frames of a planting bed, and for raising livestock, such as the boards used to build a farrowing house, or bunk silo." However, treated lumber in an orchard transitioning to organic may be allowed by some accredited certification agencies. Black locust (*Robinia pseudoacacia*), white cedar (*Thuja occidentalis*), or catalpa (*Catalpa speciosa*) fence-posts, dried bamboo stakes, metal, and plastic are alternatives to pressure-treated pine (*Pinus* sp.) fence and trellis posts.

RECLAIMING ABANDONED ORCHARDS

Throughout the Northeast, there are a substantial number of unmanaged apple trees in backyards and abandoned orchards. Older orchards offer the allure of discovering antique cultivars that may have regional or family significance, and they provide bucolic landscapes for picnics and the like. However, bringing these trees back into production is a formidable challenge. Older orchards were not planted on size-controlling rootstocks (the advantages of which are discussed elsewhere in this publication), and these trees tend to be large and overgrown, with many missing, dead, or diseased branches. While there is intrinsic value in a venerable old apple tree, it is often easier to remove an abandoned orchard and start anew than to renovate an abandoned one.

It usually requires three or more years of intensive pruning to reshape and restore old apple trees for production. This intensive pruning often stimulates a great amount of vegetative growth that requires continued thinning and is highly susceptible to diseases such as fire blight (*Erwinia amylovora*). By comparison, apple trees on size-controlling rootstocks will come into production within three years, and are much easier to manage than large old trees. While it does take considerable capital to plant new high-density orchards, over the long-term it might be more cost effective to start anew. Scion wood from cherished heirloom trees can readily be grafted onto a different rootstock, preserving the genetics of the cultivar without investing in the reclaimation of an entire orchard.

Another approach is to cut down older trees and graft to more desirable cultivars, particularly those that are disease resistant. Abandoned trees with healthy trunks larger than 8 to 10 inches in diameter probably need limb grafts rather than whole-trunk grafts, but any tree where darkened xylem (commonly called heartwood) extends to within 2 inches of the bark would probably not be a good candidate for top-working.

In some instances, it might be worthwhile to rejuvenate older trees for their aesthetic value, and maintain a heritage block of old trees within a modern high-density orchard, which may be desirable for historical or marketing reasons in U-Pick orchards.

A MULTI-YEAR STRATEGY FOR RENOVATING NEGLECTED AND OVERGROWN APPLE TREES

Year one: Most abandoned apple trees are densely overgrown at the top and lack healthy bearing wood in the lower two-thirds of the canopy. The first task is to open up the treetop so that sunlight reaches lower branches. Prune out dead, dying, diseased, or otherwise damaged wood. Remove up to 6 large branches to strategically open up the middle of the tree to sunlight and air circulation. The goal is to have 3 to 5 main scaffold branches emerge from the lower central trunk, spaced equidistantly. A lower tree height should be established in the first year. Because the tree will be overgrown for several more years, do not spend too much time detail pruning (removing spurs or fine wood) at this time.

Year two: Make additional aggressive cuts (perhaps 2 to 4) to allow light into the center of the tree and even out the distribution of main branches within the canopy. The goal is to reshape the tree. Assess the amount of new growth achieved in year one. If the tree has not responded with a flush of new growth, more pruning will be acceptable. But if the tree responded to the previous year's pruning with abundant new growth, a more conservative approach may be needed. Branches that are growing from the outer part towards the center of the canopy should be removed. Some detail pruning should be done to remove old spurs and downward growing branches, and to redirect new growth outward from the trunk.

Year three: At this point the basic structure of the tree should have been reformed. Any branches that are misplaced should now be removed. Detail pruning should be done on as much of the tree as is practical.

Year four and on: Maintain annual pruning that renews vegetative growth and flower bud development. The amount of pruning will be determined by the variety and vigor of the tree.

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4. Rootstock and Cultivar Selection

Rootstocks

The wide-range of rootstock genotypes allows apple growers to select the best rootstock for tree size, soil adaptability, and disease resistance. Most commercial growers now use size-controlling "dwarfing" rootstocks planted at high density (often 500 to 1000 trees per acre but sometimes more than 2000 trees per acre) that bring the grafted scion into fruit production within one to three years after planting. When dwarf apple trees are properly pruned and trained, sunlight penetration into the center of size-controlled trees is much greater than in larger trees. Greater light penetration will increase tree health and precocity, return bloom, and fruit size and quality. Smaller trees on dwarfing rootstocks also make orchard operations such as pesticide sprays, pruning, fruit thinning, and harvesting easier, safer and more efficient. In U-Pick operations it is safer and much less expensive to obtain liability insurance when ladders and tree climbing are not necessary. Furthermore, less crop protectant per acre is required and better coverage is obtained when spraying smaller trees.

The combination of dwarfing rootstock and high-density planting also provides a faster return on investment for commercial growers, and has been shown to be highly profitable for NY growers. However, the initial costs associated with planting and establishment can be quite high. In backyard plantings, dwarfing rootstock will bear fruit much sooner than larger rootstocks, thus providing short-term enjoyment.

Some organic apple growers prefer larger trees on vigorous rootstocks, assuming they will be more competitive with weeds, insects, and diseases, and therefore minimizing the amount of pest intervention needed. Other than the fact that deer-browsing is less problematic above five feet (when larger trees are established), there is little evidence to support the assumption that large trees are more suitable for organic orchards. In fact, insect and disease control is more difficult with larger trees. There is more competition between vegetative growth and fruit production within these trees, and their internal self-shading makes them more vulnerable to fungal diseases such as powdery mildew (*Podosphaera leucotricha*) and apple scab (*Venturia inaequalis*). It is often assumed that trees on vigorous rootstocks will be longer lived, but that has not been substantiated. A dwarf apple tree that has good support (with a pole, trellis or pergola) will endure just as long as the big old apple tree on a seedling rootstock. In Europe, there are healthy and productive apple orchards on Malling 9 rootstocks that are approaching their 100th year. The only likely or compelling reason to plant or renovate an orchard of old-style big trees on seedling rootstocks is to maintain pasture and cut hay or graze livestock beneath the fruit trees. In this situation the trees will require some physical protection (e.g., wire mesh guards) around the trunks up to the browse line, and the grower will need to pay close attention to NOP and EPA rules about pesticide use intervals required before cutting forage or allowing livestock to enter the treated area.

A wide-range of clonal rootstocks from different breeding programs is currently available. The most common apple rootstocks are: Budagovsky (abbreviated B or Bud), Cornell/Geneva (CG or G), Malling (M), Michigan Apple Rootstock Clones (MARK), Malling Merton (MM), Ottawa (O), and Poland (P). Clonal lines of M and MM series rootstocks that are designated EMLA (East Malling/Long Ashton) are certified virus-free. The EMLA rootstocks tend to be slightly more vigorous (5 to 10% more growth) than the standard M and MM series with the same identification numbers (e.g., M.9 vs. EMLA.9), but will otherwise perform similarly.

TABLE 4.1. Apple rootstocks.

Rootstock	Percent of Standard Tree Size[1]	Yield Efficiency[2]	Yield Precocity	Need for Support?	Fire Blight Resistance	Collar and Root Rot Resistance	Replant Disease Resistance	Cold Damage Tolerance	Comments
P.22	< 30	High	High	Required	Susceptible	Resistant	Unknown	High	Suckers profusely
M.27	< 30	Medium	High	Required	Susceptible	Variable	Low	Fair	Limited availability
G.65	< 30	Very	High	Required	Moderate	Moderate	Low	Fair	Limited availability
Bud.146	< 30	High	High	Required	Susceptible	Unknown	Unknown	High	Limited availability
Bud.491	< 30	High	Low	Required	Susceptible	Susceptible	Unknown	High	Limited availability
P.16	< 30	High	High	Required	Susceptible	Resistant	Unknown	High	Extensively planted in Eastern Europe
MARK	< 30	Low	Low	Required	Susceptible	Moderate	Susceptible	Fair	Not recommended. Trees fail due to massive burr knots
M.9	< 30	High	High	Required	Susceptible	Moderate	Susceptible	Fair	Most common full-dwarf rootstock
Bud.9	< 30	Very	High	Required	Resistant	Moderate	Susceptible	High	Increasing popularity among US growers
P.2	30-55	Very	High	Required	Susceptible	Unknown	Unknown	High	Limited availability
G.16	30-40	High	High	Required	Resistant	Resistant	Susceptible	High	Virus sensitive
O.3	30-40	High	High	Recommended	Susceptible	Resistant	Moderate	High	Virus sensitive
G.11	30-40	High	High	Required	Resistant	Resistant	Moderate	Good	Limited availability
G.41	30-40	High	High	Required	Resistant	Resistant	Resistant	Good	Limited availability
M.26	40-50	High	High	Recommended	Susceptible	Moderately susceptible	Low	Good	Does not tolerate droughty or poorly drained soils
G.30	50-60	High	High	Required	Resistant	Resistant	Moderate	Good	Weak graft unions
M.7	55-65	Fair	Low	Not required	Resistant	Moderate	Moderate	Poor	Can be overly vigorous on fertile soils; Useful for low-vigor cultivars; Suckers
CG.6210	55-65	High	High	Recommended	Resistant	Resistant	Resistant	Good	Limited availability
MM.106	65-85	Good	Medium	Not required	Susceptible	Susceptible	Moderate	Poor	Requires well-drained soils and long, mild growing season
Bud.490	65-85	Low	Low	Not required	Susceptible	Susceptible	Moderate	Good	Vigorous!
MM.111	65-85	Low	Low	Not required	Susceptible	Susceptible	Moderate	Good	Drought resistant; extensive rooting; Vigorous!
Bud.118	65-85	Low	Low	Not required	Resistant	Susceptible	Moderate	Good	
P.18	65-85	Fair	Low	Not required	Resistant	Resistant	Moderate	Good	Does well in poorly drained soils
Seedling/ Standard	100	Poor	Poor	Not required	Variable	Variable	Variable	Variable	Seedling trees highly variable due to genetic differences in seeds

[1] Based upon a standard seedling rootstock being equal to 100%. Ultimate tree size will depend upon scion variety, height of bud union above the soil line, and environmental factors such as soil fertility and water supply.
[2] Yield efficiency is ratio of expected fruit production (lbs) to tree size (trunk cross-sectional area)

CULTIVAR SELECTION

Deciding between mainstream commercial, disease-resistant, or antique apple cultivars will depend upon the grower's market destination for their apples. However, given the limited number of materials approved for disease management in organic systems, and the potential negative effects of repeatedly applying materials such as sulfur and copper, organic growers should seriously consider planting disease-resistant cultivars (DRCs) that can be grown with minimal fungicide applications.

Growers must also consider where they obtain their planting stock. According to USDA-NOP regulation §205.202, "the producer must use organically grown seeds, annual seedlings, and planting stock. The producer may use untreated nonorganic seeds and planting stock when equivalent organic varieties are not commercially available, except that organic seed must be used for the production of edible sprouts. Seed and planting stock treated with substances that appear on the National List may be used when an organically produced or untreated variety is not commercially available. Non-organically produced annual seedlings may be used when a temporary variance has been established due to damage caused by unavoidable business interruption, such as fire, flood, or frost. Planting stock used to produce a perennial crop may be sold as organically produced planting stock after it has been maintained under a system of organic management for at least 1 year. Seeds, annual seedlings, and planting stock treated with prohibited substances may be used to produce an organic crop when the application of the substance is a requirement of Federal or State phytosanitary regulations." With the limited availability of organically certified fruit-tree stock, growers will likely be able justify the use of non-organic sources to their certifying agency.

There are more than 100 modern apple varieties, and several dozen antique varieties, that have been selected in part for their disease resistance. They offer a broad range of flavors, appearance, taste profiles, storage potential, and harvest dates from mid summer to early winter. Although many of the DRCs are not well known among consumers, this novelty can provide an advantage for organic marketing as they gain a reputation as the preferred organic apples. This approach has already been successfully implemented in Europe. As noted in the organic pest management sections of these guidelines, apple production in the Northeast US requires a complex disease management strategy. Additionally, many of the NOP-permitted materials for controlling apple diseases pose potential problems with phytotoxicity (oils and sulfur-based compounds), environmental toxicity (copper-based compounds), or potential resistance effects on human pathogens (streptomycin antibiotics). For all these reasons, it makes good sense for organic growers to choose DRCs that require minimal disease-control sprays.

The disease resistance of most modern DRCs was achieved by hybridization with other species of Malus that developed resistance to significant diseases, such as apple scab, through natural selection. *Malus floribunda* (also known as Japanese flowering crabapple) provided a group of closely linked genes for scab resistance known as the *Vf* gene. *Malus micromalus* (also known as the Kaido crabapple from Korea) provided the *Vm* scab-resistance gene. These two genes are present in most modern DRCs, and confer qualitative resistance or immunity against common races of the apple scab pathogen (*Venturia inaequalis*). However, scab resistance has repeatedly broken down over the long term as the fungus evolved to be able to overcome the two common resistance genes. A cold-hardy Russian apple known as Antonovka has a suite of other genes that provide quantitative (incomplete) but more durable scab resistance in some of its offspring (e.g., Freedom apple). The early ripening cultivar Akane also has quantitative polygenic resistance to the scab fungus. Whether growing scab-immune or scab-resistant varieties, it is advisable to apply a few protective fungicides during the primary scab infection period (mid April to mid June in NY) to avoid selecting for virulent races of the scab fungus in your orchard.

LIST OF DISEASE-RESISTANT CULTIVARS

(All are resistant to apple scab, but other disease susceptibilities vary as noted.)

Akane (Jonathan x Worcester Pearmain): Developed Tohoku Station, Japan. Bright red, round, mid-sized fruit ripens with Gala, early September. Tree is sprawling, leaves often speckled with yellow, not highly productive but reliably annual. Fruit hang well and are very tart, aromatic, fine crisp flesh, juicy. Can be stored for a month or two. Durable multigenic resistance to apple scab. Susceptible to powdery mildew, tolerates cedar apple rust and fire blight.

Ariane ((Florina × Prima) × Golden Delicious seedling): Quickly becoming a popular cultivar in France. Excellent fruit quality and storage life but needs to be aggressively thinned to obtain good fruit size and annual bearing. Resistant to powdery mildew and fire blight.

Belmac (Spartan × Ottawa 521): Matures in late September. Resembles McIntosh, skin smooth and glossy with up to 90% red, slightly striped over a green background color. Flesh is white, medium to coarse texture, mild sub-acid. Stores for three to four months. Cold hardy. Moderately resistant to powdery mildew.

Britegold: Matures in mid September. Yellow, medium size, sweet, flesh creamy yellow, slightly coarse, tender, and juicy. Bruises easily. Resistant to powdery mildew and fire blight; susceptible to rusts. Suggested for homeowner use.

Co-op 27 (Illinois #2 × PRI 1042-100): Late season, dark red apple comparing favorably to Winesap and matures one week after Delicious. Fruit have moderately thick skin, with firm, crisp to slightly tough flesh texture. Fruit ripen uniformly, but may be slightly woody at harvest, mellowing after four months in storage. Tree has moderate vigor, upright habit similar to spur-type Delicious. Resistant to rust and fire blight; susceptible to mildew.

Co-op 28 (PRI 1982 × Prima): Matures with Mclntosh. Variable but medium-sized red apple. Tree is vigorous, upright and spreading, somewhat limber with blind wood in basal portions of branches. Fruit are oblate-round to round or short conic, slightly striped 50-90% medium red over yellow ground color; hang well on tree while ripening. Flesh is cream-colored, very crisp and crunchy, with medium to slightly coarse grain, moderately juicy, mildly subacid to sweet, slightly spicy. Flavor, flesh, and appearance are similar to Prima but with less acid. Fruit retains firm crisp texture throughout storage. Susceptible to fire blight and has a tendency toward biennial bearing.

Co-op 31 (Rock 41-112 × PRI 841-103): Late-season apple with rustic appearance but nice spicy flavor and good storage potential. The fruit may be splashed, striped, or mottled medium-red to purple-red with green ground color. Scarf skin has been noted some seasons. Resistant to fire blight and powdery mildew; susceptible to cedar apple rust.

Co-op 34: Medium-sized red apple maturing one week after Delicious. Annually productive tree. Conic-shaped fruit has Jonathan-like quality and is well adapted to the mid-west. Resistant to rust and fire blight; susceptible to mildew.

Co-op 35: Medium-sized conic yellow apple maturing with Golden Delicious. Flavor is mild and pleasant with crisp and breaking flesh. Fruit size smaller than Golden Delicious but storage life is superior. Resistant to mildew and fire blight; susceptible to cedar apple rust.

Co-op 36: Mid-sized yellow-green apple maturing with Golden Delicious. Flavor is mild and pleasant with crisp and breaking flesh. Heavy but biennial producer requires aggressive thinning. Keeps well three to four months. Resistant to mildew and fire blight; susceptible to rust.

Co-op 37: Yellow fruit matures with Rome. Flavor is full, rich and complex with crisp breaking yet melting flesh. Fruit size smaller than Golden Delicious but storage life is superior. Tree is moderately vigorous, semi-spur type. Resistant to fire blight and mildew; susceptible to rust.

CrimsonCrisp™ (formerly Co-op 39; PCFW2-134 × PRI 669-205): Fruit matures middle to end of September and hangs well on the tree. Medium to dark red apple with cream-colored, mildly acidic, coarse flesh. Best quality at harvest. Fruit retains texture for about six months in regular storage, but flavor may weaken. Moderately vigorous, upright tree, standard bearing habit with some blind wood at base of branches. Moderate productivity and tendency to bear single, uniform-sized fruit suggesting that fruit thinning will probably not be required. Moderately resistant to rusts and powdery mildew; susceptible to fire blight.

Dayton (formerly Co-op 21; NJ 123249 × PRI 1235-100): Early-season red apple maturing in the Paulared season—about four weeks before Red Delicious. Medium fruit size, 80-90% attractive glossy red over yellow background color. Flesh pale yellow, crisp, juicy, firm, fine-grained, and moderately acid. Fruits are large with a glossy red color. Fruit quality considered mediocre. Reports indicate that maximum storage may only be one month. The tree is vigorous, with strong, upright-growing branches. Some reports suggest it is not cold hardy enough for northern growing areas. Resistant to mildew, moderate resistance to fire blight; susceptible to rusts.

Ecolette (Elstar × Prima): Developed in the Netherlands. Moderate fruit size and yield. Tart fruit with good firmness and keeping quality. Low susceptibility to powdery mildew under European growing conditions.

Enterprise (formerly Co-op 30; PRI 1661-2 × PRI 1661-1): Fruit matures two to three weeks after Red Delicious, mid to late October. A smooth, glossy, 90-100% red apple with yellow-green ground color. Fruit are round to elongated in shape, occasionally lopsided. Lenticels can be conspicuous. Flesh color is pale yellow to cream. Flavor is spicy, rich and sprightly acid at harvest, improves after one month in storage. Relatively thick skin makes this apple more palatable when peeled. For this reason, Enterprise might be most suitable for processing, juice, or cider. Retains flesh texture and quality for six months or more in refrigerated storage. Fruit hang well on the tree even when overripe. Tree is spreading, round topped, vigorous, with a standard bearing habit. Lenticel breakdown of unknown cause (possibly bitter pit) has been a problem on fruit from young trees in some locations. Prone to corking. Late maturity may limit its northern adaptability. Resistant to fire blight and cedar apple rust; moderately resistant to powdery mildew. Suggested for both homeowner and commercial growers.

Freedom (NY 18492 × NY 49821-46): Mid-season (end of September) apple that ripens a week before Delicious. Medium- to large-sized, orange to red fruit with 80% red stripes on a yellow background. Fruits are large, but their external appearance is rough because of prominent lenticels and somewhat muddy coloration. When grown without fungicides fruit may have numerous superficial blemishes and some black rot infections at lenticels. Flesh is creamy, juicy, firm, medium fine-grained, tender, and moderately acid. Fruit ripen unevenly on the tree and do not store well. Storage scald is a major problem when picked too early. Suggested for home plantings only. Resistant to rust, mildew, and fire blight. Not a mainstream variety, but some like its unique spicy flavor.

Florina (Querina®): Fruit 50% red on yellow ground color, firm, small to medium size, sweet flavor. Whitish-yellow flesh, very crisp, low acid. Moderately resistant to fire blight. Deserves further evaluation.

Galarina (Gala × Florina): Developed in France. The medium size fruit matures one to two weeks after Gala. Skin color is 65-100% orange-red over greenish-yellow with flesh that is yellowish-white. The stem end of fruit is prone to russeting. Flavor is aromatic and slightly tart. Trees are moderately vigorous. A Gala-like apple that is resistant to apple scab and can be stored for longer periods.

GoldRush (formerly Co-op 38; Golden Delicious × Co-op 17): Medium-sized yellow-bronze apple maturing after Rome and three to four weeks after Delicious. Late maturity may limit its northern adaptability, but it hangs very well and ripens adequately after a few frosts. Fruit are ovate and regular, greenish-yellow at harvest turning to deep yellow in storage, sometimes with a fine net-like russet. Skin is non-waxy, tender, thin to medium in thickness with conspicuous russeted lenticels. Flesh is pale yellow, medium coarse-grained, firm, very crisp with a complex, spicy flavor; high in both sugar and acid levels; slow to brown when sliced. Develops a red blush on sun-exposed cheek. Eating quality is good at harvest and superb after a period of two months in storage. Stores at least seven months in refrigeration. High humidity during storage is recommended because non-waxy fruit surface makes it susceptible to shriveling. Must be thinned aggressively to achieve satisfactory size. Trees are slightly upright, with low vigor, limited branching, semi-spur bearing habit, and slight biennial tendency. Moderately resistant to powdery mildew and fire blight; susceptible to cedar apple rust. Suggested for both homeowner and commercial growers. Recommended for cider and juice as well.

Jonafree (formerly Co-op 22; PRI 855-102 × NJ 31): This mid-season red apple ripens with Jonathon and Delicious. Fruit color well and trees are annually productive. Flavor similar to Jonathan but less acid. Fruit are 75-95% medium red; medium-grained, light yellow to cream colored, firm, crisp and slightly breaking flesh, slightly tough until fully ripe; moderately acid, mild flavor, and juicy. Skin is thick, tough, and waxy. May be more acceptable in areas where Jonathan is a preferred cultivar. Off-flavors develop after two to three months of storage. Usually requires two pickings. Small fruit size if not properly thinned. Can be difficult to train and manage due to bushy growth habit and extensive bare wood. Susceptible to powdery mildew and to cedar apple rust; moderately susceptible to fire blight.

Juliet™ (formerly Co-op 43; PRI 1018-101 × Viking (PRI 1033-5)): Mid- to late-season harvest. Skin 60-90% striped light to medium red on yellow-green at harvest, yellow ground color at maturity. Finish smooth and waxy. Flesh is white to light straw, crisp, breaking, very fine textured and juicy. Flavor sub-acid to mild. Maintains firmness and crisp texture in refrigerated storage for over six months. Flavor becomes bland after nine months in storage and will develop off flavors after one year. Heavy and annual crops. Tree moderately vigorous, spreading, sturdy wood, heavy semi-spur type, with very little blind wood. Desirable growth and bearing habit. Leaves are moderately susceptible to rust, but fruit are resistant; field resistance to fire blight. Grown in France under organic production and licensed as an exclusive to Benoit ESCANDE (www.juliet.eu).

Liberty (PRI 54-12 × Macoun): Mid-season, somewhat striped, dark red apple maturing with Empire. Trees are consistently productive (equal to Empire) with good winter hardiness. Flesh is yellowish, moderately acid, juicy, crisp, aromatic and fine textured. Flavor and quality are excellent when picked at the right time, but harvest window is narrow. Requires multiple pickings for best quality. Fruit soften rapidly, develop off-flavors, and drop if left too long on tree. After hot growing seasons, fruit are very acid at the optimum harvest date but eating quality improves after several weeks of storage. Requires aggressive thinning to maintain adequate fruit size. Loses quality after several months in regular cold storage, but keeps longer if picked pre-climacteric and held in low-oxygen cold storage. Recommended scab-resistant cultivar for McIntosh growing regions for both homeowner and commercial production. Recommended for hard cider and juice.

Macfree (McIntosh × PRI 48-177): Mid-season red over greenish-yellow background apple. Fruit coloring is a problem in southern areas, just as with McIntosh. Flesh is juicy, white with a slight green tinge. Firm, moderately coarse, pleasant, moderately acid. Fruit size is medium to small. Biennial tendency. Susceptible to mildew and cedar apple rust.

McShay (McIntosh × PRI 612-4): Fruit mature in early September. The fruit are attractive with a green undercolor and a dark red blush covering 70% of the surface. The skin has a light bloom and polishes to a bright shine equivalent to that of McIntosh. Fruit lenticels are white and moderately conspicuous. No russeting has been observed. The skin is thin and the flesh is fine-textured, moderately firm, juicy, and light green with a good balance of sugars and acids. The fruit retains its flavor and texture for two to three months in refrigerated storage, then softens in a manner similar to McIntosh. Trees are vigorous, with an upright growth habit and a tendency to develop spurs. McShay produces good annual crops. Susceptible to powdery mildew.

Moira (McIntosh × DG22-81): Late-season dark red apple maturing after Delicious. Released from the Agriculture Canada breeding program in Trenton, Ontario. Fruit are McIntosh type, moderate in size, round to round-conic, lightly ribbed, medium to dark red over a greenish-yellow ground color. Flesh is cream-white and slightly coarse. Tree is moderately vigorous. Resistant to cedar apple rust; susceptible to mildew, fire blight, and quince rust.

Murray: Early McIntosh type, red, medium-sized. Flesh is soft, juicy, white, and fine textured. Suggested for home garden use.

Nova Easygro (Spartan × PRI 565): Early to mid-season, large, dark red fruit matures with Mclntosh. Fruit coloring is a problem in southern areas, similar to Mclntosh. Flesh is cream-colored with medium coarse texture. Some fruit russeting noted in older trees. Flavor is tart (like Jonathan). Eating quality improves with storage. The tree is very vigorous and ripens somewhat unevenly. Moderately productive. Moderate resistance to cedar apple rust, mildew and fire blight.

Novamac (McIntosh × PRI 1018-3): Early mid-season red apple maturing with Mclntosh and sharing its flavor, texture, and premature drop characteristics similar. Flesh is creamy white, fine, tender, moderately crisp, juicy, and moderately acid. Trees can be very precocious and consistent croppers. Considered only fair quality in NY. Limited potential as a commercial cultivar.

Nova Spy (Nova Easygro × NY-44411-1): Developed in Nova Scotia. The fruit are attractive with red blush or stripes on greenish to yellow background. The fruit mature between Delicious and Northern Spy. High quality with good storage potential (similar to Northern Spy). Flesh is creamy yellow, fine-grained, very firm, crisp, juicy, and moderately acid. The tree is well spurred but bears terminally; it tends to droop under crop-load, and is not vigorous. Moderately resistant to mildew and susceptible to rusts. It has excellent processing (pie slice) traits comparable to Northern Spy with fewer problems, and has potential as a commercial cultivar.

Otava (Sampion × Jolana): Developed in the Czech Republic. The globose and ribbed fruit matures with, and resembles Golden Delicious. Yellow skin with a slight red-orange blush. The flesh is yellow to cream with fine-grained texture, and has juicy, sweet, subacid flavor. Field tolerance to powdery mildew. Particularly susceptible to sooty blotch.

Pixie Crunch™ (formerly Co-op 33; PRI 669-205 × PCF 2-134): Matures in mid-September. The blushed skin is 75-90% red to purple-red over a light green ground color at harvest, developing to deep yellow, and producing a somewhat orange cast after maturity. Flesh is yellow, crisp and breaking, yet melting; medium- to fine-grained; juicy; mildly acid, rich, spicy, full-flavored; short storage potential. Quality is maintained up to two months in refrigerated storage; then flavor, not crispness, substantially declines. Fruit tends to be small (2.5 inches diameter). Standard spreading growth habit with some bare wood and leggy branching. Branches are thin and more dense than most varieties—a difficult growth habit. Moderate to heavy cropping with biennial tendencies, if over-cropped. Susceptible to powdery mildew and fire blight. Small fruit size and poor growth habit not suited for commercial plantings, but might fill a niche in U-Pick operations. Offers a scab-immune alternative to Lady apple.

Priam (PRI 14-126 × Jonathan): Red fruit maturing one to two weeks before Delicious. Fruit is moderate to large in size, round-conic, with a moderately tough skin, flush red over a greenish-yellow ground color. Flesh is fine-textured, crisp, and very acid. Eating quality is better after storage. Fruits can be stored in refrigeration for at least three months. The tree is moderately vigorous, somewhat spreading, with regular and heavy yields. It shows slight mildew susceptibility, similar to Golden Delicious, but much less than its parent, Jonathan.

Prima (formerly Co-op 2; PRI 14-510 × NJ 123249): Early season red-orange apple, matures with Jonamac. Fruit is round to short conic and irregular, green yellow to yellow ground color; bright finish; slightly striped, 50-90% medium to dark red; medium-grained, cream-colored, crisp and breaking flesh at harvest, reduced firmness after three to four weeks in storage; slightly spicy, moderately to spritely acid, and rich in flavor, juicy. Very good dessert quality. Moderate to large fruit size. Retains quality for one month or more in refrigerated storage. Fruit hang on tree until overripe. Requires multiple harvests. Susceptible to cedar apple rust. Fruit quality is better in northern climates but lacks winter hardiness for the coldest areas. Suggested for commercial plantings for early entry into fresh market, especially in areas where Jonathan is grown but where winter injury is not a severe problem.

Primevère (Graham × 597NJ1): Developed by Agriculture and Agri-Foods Canada in Quebec. Ripens in mid October. Skin is bright, glossy, and dark cardinal red; slightly conical. Flesh is moderately coarse-grained, pale green to white, firm, crisp. Susceptible to rusts. Has commercial potential but limited field testing in US.

Priscilla (formerly Co-op 4; Starking Delicious × PRI 610-2): Mid-season dark red apple matures with Empire. Fruit develops 70-90% red blush over pale yellow background. Flesh is pale, creamy colored, crisp, medium-grained, and juicy, with mild flavor, low acid, and can have licorice flavors and aromas. Fruit size can be small, if not properly thinned. Annual cropping. Fruit hangs on the tree until overripe. Retains quality for two to three months or more in refrigerated storage, if properly handled. Very prone to watercore. Resistant to rust, mildew, and fire blight. Suggested for home garden use and small scale commercial plantings where the unique flavor can be used as an advantage in specialty markets.

Pristine™ (formerly Co-op 32; Co-op 10 × Camuzat): Matures with Lodi in late July to early August. Medium-sized, pale green-yellow at harvest, maturing to deep yellow, with moderate orange blush. Smooth, glossy, non-russeted finish with inconspicuous lenticels, very attractive. Thin skin develops greasy cuticle after six to eight weeks in refrigerated storage. Flesh is pale yellow, crisp and slightly breaking yet melting, medium- to fine-grained. Mildly acid to sweet, slightly spicy, moderately rich, full-flavored. Retains quality and texture after four to six weeks in refrigerated storage; edible for at least 12 weeks, quite remarkable for an apple of this season. Prone to scald and bruising in storage. Heavy preharvest drop in some years. Quality and shelf-life are better than Lodi or Yellow Transparent. Wood is limber, resulting in drooping tree habit. Reports have been mixed for Pristine's resistant to fire blight and cedar apple rust. Suggested as an early niche market apple.

Redfree (formerly Co-op 13; Raritan × PRI 1018-101): Early season red apple with light green to pale yellow ground color. Matures with Paulared mid to late August, but is sweeter and less acid than Paulared. Unusually crisp for a summer apple, though quality may vary from year to year. Flesh is firm, light cream, medium-grained, crisp, juicy, mild flavor, and low acid. Storage life is about two months. Trees are low in vigor, weepy, and prone to bare wood, which may contribute to small fruit size. Branches are brittle and weak. Tends to be a tip bearer. Annual cropping. Resistant to cedar apple rust; moderately resistant to mildew and fire blight. Recommended as an early season apple.

Richelieu (Ottawa 521 × 11-51): Matures one week before McIntosh. Medium-sized fruit, 50-65% red on light green background. Fruit are oblong conical with crisp, juicy, white flesh, mild to sub-acid with high sugar and aroma. Tree is medium vigor, spreading, precocious, and annually productive. Moderately resistant to mildew and fire blight; susceptible to cedar apple and quince rusts.

Rouville (52-05-312 × 69-52): Matures in early September. Large, 75-80% medium red fruit, lightly striped, over pale green to yellow ground color. Fruit are oblate, symmetrical, somewhat ribbed with white to cream-colored, juicy, slightly coarse flesh. Flavor is sub-acid with high sugar and tannin content. Fair quality, dual purpose-fruit. Tree is vigorous, semi-spreading, precocious, annually productive, and cold hardy. Has become susceptible to some strains of apple scab.

Rubinola (Prima × Rubin): Matures about ten days before Golden Delicious. The fruit are medium to large, flat, globose, and with a skin that is bright red over most of the surface, although some russeting can occur. The flesh is yellow, firm, fine textured, juicy, and has a sweet aromatic flavor. The trees are vigorous. Resistant to powdery mildew.

Sansa (Gala x Akane): Ripens late August, several weeks ahead of Gala. Fruit are medium-sized, conical, pale yellow with orange blush, lightly russeted. Aromatic and full-flavored, subacid, granular texture with pleasant astringency. One of the few highly flavored late summer apples. Its resistance to apple scab is polygenic and may be more durable than most other DRCs. Tolerant to mildew. Susceptibility to fire blight and rust not determined.

Santana (Elstar × Priscilla): Developed in the Netherlands. Produces good-sized fruits with good color and a sweet yet sharp flavor. Trees are productive annual bearers. Susceptible to powdery mildew in Europe and may defoliate. Found to be low in proteins that cause allergic responses in humans.

Scarlet O'Hara™ (formerly Co-op 25; PCF 2-134 × PRI 669-205 (669NJ5)): A mid-season red apple that ripens one week before Delicious. The fruit are round to slightly conic. The overcolor is 75-95% medium red to orange with a green-yellow to yellow undercolor. The flesh is yellow to cream colored, firm, and crisp. The flavor is sweet and mildly subacid. Somewhat bland at harvest, flavor improves after one to two months in storage. Fruit hang on the tree very well, and retain eating quality in refrigerated storage for six months or more but tend to develop moldy core. Tree moderately vigorous, spreading with flat crotch angles, somewhat thin, slightly weeping branches with moderate bare-wood toward the base; fruit tend to be borne on long spurs, with some tendency for tip-bearing, and fruit borne in clusters; slight biennial tendency. The tree and fruit are moderately resistant to powdery mildew, resistant to cedar apple rust, and susceptible to fire blight.

Sir Prize (Formerly Co-op 5; Tetraploid Golden Delicious × PRI 14-152): Late mid-season yellow apple that matures with Delicious. Yellow fruit, with an occasional slight red blush, and smooth, conic shaped, very attractive fruit, but may russet. Flesh is fine-grained, lemon yellow-colored, crisp yet very tender; moderately to spritely acid, and rich in flavor with distinctive aroma; very juicy; very good dessert quality. Large-sized fruit; triploid. Annual cropping. Retains quality for six months in refrigerated storage. Fruit hangs on the tree very well. Susceptible to cedar apple rust but moderately resistant to mildew and fire blight. Bruises easily and is therefore unsuitable for standard commercial packing. Suggested for limited use in U-Pick operations and as a home grower cultivar. Sir Prize is one of the few scab resistant apples in Golden Delicious season with a yellow peel.

Sundance (formerly Co-op 29; Golden Delicious × PRI 1050-201 (1050NJ1)): Matures two weeks after Delicious. Large and attractive fruit has pink blush over pale yellow smooth skin. They have moderate stem-end russet, which can extend over the side of the fruit. The flesh is medium to coarse, cream-colored, and has a very firm and crisp texture. Retains flesh texture and quality for five months or more in refrigerated storage. Flavor intensifies after a month in storage. Fruit hangs well during extended harvest. Tree is moderately vigorous, slightly upright, with leggy branches and some blind wood. Moderate yields, and prone to biennial bearing if not properly thinned. Tolerant of powdery mildew; resistant to cedar apple rust and fire blight.

Topaz (Vanda × Rubin): Developed in the Czech Republic. Medium to medium-large fruit matures about one week after Golden Delicious. The skin color is yellow overlain with a red and crimson blush. May develop some stem-bowl russet. The flesh is crisp and cream-colored. Fruits are prone to bitter pit and have a short storage life. The trees are moderately vigorous and very precocious. Resistant to apple scab; moderately resistant to powdery mildew. Considered one of the better DRCs from Europe.

Trent: Dark red, very late maturing cultivar from the Agriculture Canada program in Ontario. Fruit are moderate to large, round to slightly conic, medium to dark red with faint striping over a greenish-yellow ground cover. Flesh is firm, juicy, cream-colored with greenish tinge, and slightly coarse. Prone to bitter pit. Good storage potential. Tree is vigorous and upright; susceptible to cedar apple rust and quince rust.

Williams Pride (formerly Co-op 23; PRI 1018-101 × NJ 50): Early-season, red-purple apple ripens in mid-August, about one week after Lodi. Medium- to large-sized fruit, texture similar to Macoun. Flesh is light cream, medium-grained, mildly acid, very crisp and firm initially but soften quickly when ripe. Multiple pickings are required. Fruit are prone to water core and quality will vary with the summer growing conditions. Annual cropping with slight biennial tendencies. Retains quality and crisp flesh texture for one to two months in refrigerated storage. Tree has willowy growth habit. Resistant to cedar apple rust, mildew and fire blight. Not recommended on MM.111 rootstock or under high nitrogen conditions. Suggested for homeowner use and direct market sales.

ANTIQUE OR HEIRLOOM APPLES

Because it is relatively difficult and expensive to control the pest complex in Northeastern organic orchards compared with organic orchards in arid growing regions, it will be difficult for commercial fruit growers in the Northeast to compete head-to-head with organic growers of mainstream cultivars in arid regions. As noted above, growing DRCs is one way to achieve market differentiation for organic apples from the Northeast because organic growers in the Western states are mostly producing conventional apples such as Red and Golden Delicious, Gala, Fuji, etc. Growing antique apples is another good way to develop niche markets for Northeastern apple growers. Many of these old-time favorite apples are well adapted to cool humid climates, and they offer distinctive flavors, unusual appearance, and historical cachet that identify them as local and unique in the increasingly competitive organic market. There are hundreds of antique apples available from USDA Malus collections, or from commercial nurseries, and it would be beyond the scope of this guidebook to describe many of them, but some references on antique apples are listed at the end of this section.

CIDER APPLES

Another strategy to minimize disease problems in organic orchards is to grow apples for processing uses such as applesauce, and sweet or fermented ciders. There are many advantages to producing cider from organic orchards. There are usually more culls or blemished fruit from organic orchards in the Northeast, and most of that fruit is well suited for sweet or hard cider. Culled fruit of almost any variety can provide bulk juice for cider sales, but generally a mix of aromatic sweet and tart varieties produces the most highly flavored ciders. Many antique apples are excellent for cider blends because in the past that was an important use for these apples.

Fermenting ciders can add substantial market value to this product, and the market for hard ciders is expanding and diversifying in the US. The best hard ciders can fetch prices comparable to fine wines, but they usually require adding special varieties called "bittersweets" and "bittersharps" (apples with high tannin or polyphenolics content) to the fermentation blend. Tannins have relatively high antioxidant activity and provide important health-promoting benefits in the diet. They also contribute complex textures and enhanced flavors to the finished ciders, and make the high-tannin-content cultivars relatively resistant to insect pests such as the codling moth. There are few commercial sources for bittersweet or bittersharp apples in the US, and demand has been strong for them as the number of amateur and commercial cider-makers grows.

French and English cider-makers have developed recommended lists of apples that produce consistently good yields and ciders. Their juice yields, tannin type and content, titratable acidity, soluble solids, disease resistance or susceptibility, and horticultural traits have been characterized and summarized in extension publications. Characteristics of cider apples that affect fermentation and quality are their yield of juice per bushel of fruit, the total content and traits of their tannins, acidity, sugar content, and aromatic qualities.

TABLE 4.2. The standard European classification system for cider apples.

Classification	Percent tannin (w/v)	Percent malic acid (w/v)
Bittersweets	> 0.2	< 0.45
Bittersharps	> 0.2	> 0.45
Sharps	< 0.2	> 0.45
Sweets	< 0.2	< 0.45

Classification traits have been quantified for most of the European cider apples and for many of our North American varieties. The following is a short list of European and American cider varieties, especially bittersweets and bittersharps that are suitable for organic growers in the Northeast:

From England: Ashmead's Kernel, Dabinett, Ellis Bitter, Ashton Bitter, Brown Snout, Fillbarrel, Margil, Major, Kingston Black, Porter's Perfection, Tremlett's Bitter, Hereford Redstreak, Somerset Redstreak, Chisel Jersey, and Yarlington Mill.

From France: Douce Coetligne, Kermerrien, Douce Moen, Binet Rouge, Locard Vert, Petit Juane, Avrolles, Bedan, Michelin, Medaille D'Or, Frequin Rouge, Moulin a Vent, Bisquet, Calard, Noel de Champs, St. Aubin, St. Martin, Germaine, Rouge Duret, Rambault, Rene Martin, Guillevic, and Peau de Chien. Many of these are currently available as budwood for grafting from the USDA Malus collections.

American varieties prized for ciders: Golden Russet, Roxbury Russet, Northern Spy, Liberty, Tompkins King, Pound (Tolman) Sweet, GoldRush, Geneva Red, Geneva Trembletts, Mutsu, IdaRed, Gravenstein, Newtown Pippin, Cortland, Jonagold, Winesap, Esopus Spitzenberg.

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5. SOIL FERTILITY AND CROP NUTRIENT MANAGEMENT

In organic systems soil fertility, crop nutrient status, and groundcover management are closely linked. As specified under the NOP (§205.203), organic producers must rely upon animal manures, compost (organic matter of animal and/or plant origin that has been decomposed by microorganisms), and cover crops to supply some, if not all, of the required nutrients for healthy crops. Furthermore, the producer must select and implement tillage and cultivation practices that maintain or improve the physical, chemical, and biological condition of soil, and minimize erosion.

Besides supplying nutrients, soil amendments can increase soil organic matter, balance pH levels, increase microbial activity, improve soil structure and tilth, improve drainage in clayey soils, improve water-holding capacity in sandy or gravelly soils, and help to suppress some root diseases. However, naturally derived soil amendments have variable nutrient levels depending upon the sources from which they were derived. Therefore, soil nutrient availability from composts and cover crops will be specific for the soil type, input, and crop demand on each farm.

SOIL ANALYSIS

Soil sampling and chemical analysis are especially useful for determining lime requirement and mineral nutrient availability in soil before orchard establishment. For existing orchards, a soil test every three years provides useful information for interpreting leaf analysis results and modifying fertilization programs.

The collected soil sample should be representative of the soil type and conditions within an orchard. Generally, the area included in any one-sample collection should not exceed 10 acres where soils are relatively uniform (or from smaller blocks where soils are highly variable). Scrape away the surface inch of soil, then collect samples from the 1 to 8 inch depth, and separate samples from 8 to 16 inches. In a 10-acre orchard, a minimum of 10 to 20 subsamples are recommended; but if there are known differences in soil type or drainage characteristics within the orchard, it is a good idea to collect separate sample sets from each different area. Thoroughly mix the 1- to 8-inch subsamples together to provide a representative sample of the topsoil, and treat the 8- to 16-inch subsamples similarly to get a representative sample of subsoil. Providing background information on the soil type, intended crops, and site history with the soil sample will enable the analytic lab to provide a more detailed and useful report on specific nutrient requirements for fruit trees on that soil.

Recently, Cornell University began offering Soil Health Tests that include biological and physical soil measurement along with the traditional chemical analyses for soil nutrients. Soil health describes the capacity of a soil to be used productively without adversely affecting its future productivity, the agroecosystem, or the environment. This holistic soil test may be especially useful in organic farming systems that rely upon organic matter inputs. Currently, recommendations based upon the Soil Health Test are limited to annual cropping systems. However, several research teams are working to develop perennial fruit crop recommendations. More information on this topic can be found at the Cornell Soil Health Web site:
http://www.hort.cornell.edu/soilhealth/about/index.htm.

LEAF TISSUE ANALYSIS

Leaf analysis indicates the concentration of nutrients that are actually present in the tree foliage, where photosynthesis and carbohydrate production take place. If leaf samples are taken correctly and the results are interpreted properly, they provide a good tool for developing an effective fertilization program. Recommendations for leaf analysis sufficiency ranges for fruit trees are listed in Table 5.1.

Leaf samples should be collected about 60 to 70 days after petal fall, which generally corresponds to late July or early August. Undamaged mid-shoot leaves about twelve nodes downward (toward the subtending branch) from the terminal end of non-bearing current season extension shoots on the periphery of the tree will provide the most representative sample. Sampled trees should represent the general conditions of the orchard in terms of vigor, crop load, soil conditions, etc. Each sample should consist of about 100 leaves collected from several trees in the sample area. Do not mix leaves from different varieties, soil conditions, tree vigor, or crop load. Record observations on terminal shoot length, thickness, crop load, and fruit size, because these will enable meaningful interpretation of the observed nutrient concentrations in tree leaves.

However, 60 to 70 days after petal fall may be past the point in the season when mineral deficiencies can be corrected and therefore an annual maintenance program should be developed to address any nutrient losses from harvested fruit, fallen leaves, and pruned branches. Nutrient maintenance programs often include nitrogen, potassium, boron, zinc, magnesium, and calcium for cultivars susceptible to disorders such as bitter pit.

Under NOP regulations, many commercial fertilizers are permitted, but for most nutrients supplemental fertilizers are allowable only after documenting a deficiency. Both soil and leaf samples can be used for documentation, and growers will need to work with their accredited certifying agent to develop an acceptable nutrient program that prevents rather than corrects nutrient deficiencies.

TABLE 5.1. Leaf analysis standards for tree fruits (dry weight basis; from Stiles and Reid, 1991).

Element	Crop	Desired level
Nitrogen	Young nonbearing apples and pears	2.4-2.6%
	Young bearing apples and pears	2.2-2.4%
	Mature soft apples and pears	1.8-2.2%
	Mature hard apples and processing	2.2-2.4%
	Cherries, plums, prunes	2.4-3.4%
	Peaches	3.0-4.0%
Phosphorus	All crops	0.13-0.33%
Potassium	All crops	1.35-1.85%
Calcium	All crops	1.3-2.0%
Magnesium	Apples and pears	0.35-0.50%
	Stone fruits	0.40-0.60%
Boron	Apples and pears	35-50 ppm
	Stone fruits	30-40 ppm
Zinc	All crops	30-50 ppm
Copper	All crops	7-12 ppm
Manganese	All crops	50-150 ppm
Iron	All crops	50+ ppm

SOIL PH

Orchard soils should be maintained in the pH range of 6.0 to 6.5 throughout the soil profile to optimize plant growth and nutrient availability. Because of widespread acid precipitation and soil geological history, most NY soils have pH values lower than optimum and need liming to raise the pH prior to planting a new orchard. This also helps to ensure adequate calcium and magnesium supplies in the soil during the orchard lifespan. For preplant soil preparation, topsoil pH (0–8 inch depth) should be adjusted to 7.0, and subsoil to 6.5. The amount of lime required to adjust topsoil pH to 7.0 and subsoil pH to 6.5 is determined by soil pH values and the buffering capacity of the soil, i.e., exchange acidity or cation exchange capacity (CEC) (determined by soil analyses). If soil magnesium is below the desired level, an application of dolomitic or oyster-shell lime is recommended because they also provide both calcium and magnesium.

Before planting an orchard, lime should be thoroughly disked or rototilled into the surface soil, then plowed to work it in as deeply as possible into the soil. If large amounts of lime are required, split applications are recommended, working one-half or two-thirds of the total amount of lime into the soil as indicated above, plus thoroughly tilling the remainder into the topsoil after plowing.

NUTRIENT INPUTS

COMPOST

NOP regulation §205.203 specifies that: "Compost must be produced through a process that combines plant and animal materials with an initial C:N ratio of between 25:1 and 40:1. Producers using an in-vessel or static aerated pile system must maintain the composting materials at a temperature between 131 °F and 170 °F for [at least] 3 days. Producers using a windrow system must maintain the composting materials at a temperature between 131 °F and 170 °F for 15 days, during which time, the materials must be turned a minimum of five times." Animal manures may also be used in organic orchards, but they must be incorporated into the soil at least 90 days prior to harvest (assuming the fruit does not come into direct contact with the soil surface or soil particles).

Most commercial compost suppliers will provide a nutrient content analysis report to help calculate application rates for their composts as formulated. Growers should also verify that the compost supplier is following all of the current NOP regulations, and that the accredited certifying agency will approve that compost for organic production. Compost must be free of non-compliant materials such as herbicides that can contaminate composts made from animal bedding or municipal green waste. Unlike mineral fertilizers, the elemental nutrients in biomass-based fertilizers are released gradually over several years. Usually about one-third of the nutrients in manure or compost are available to the crop during the year of application. The remaining nutrients are bound in soil humus, and released slowly over the next two to four years, at a rate that plant roots can take up relatively efficiently. Since compost is often expensive to purchase, apply, and incorporate, tree-fruit growers may want to limit applications to the tree row planting strips.

Growers can also make compost on-site, which may be more cost effective but is also labor intensive. During the composting process, temperature ranges must be monitored to ensure that they reach the appropriate range for thermophilic microorganisms. Poorly made compost can become anaerobic, allowing weed seeds, plant diseases, and potential human pathogens to persist and survive the composting process. Such composts may also be in violation of NOP rules. To estimate the nutrients supplied by different manures, see Table 5.2 for approximate values of nitrogen, phosphorus, and potassium from common sources.

COVER CROPS

Preplant cover cropping can improve soil conditions, and provides nutrients and organic matter. Other benefits of cover crops include reducing soil erosion, attracting beneficial insects, and improving site aesthetics, which are especially important in U-Pick orchards. Nitrogen-fixing legume cover crops are often seeded along with one or more species of annual grass. Nutrient availability will depend upon the growing conditions, species used, seeding rates, and prior soil nutrient status. Some examples of cover crops that have been successfully used in the Northeast US are shown in Table 5.3.

Typically, the cover crops are mowed/chopped and then incorporated into the soil prior to tree planting. Organic growers can also maintain cover crops or permanent grass covers in bearing orchards (see Groundcover and Weed Management section).

TABLE 5.2. Nutrient content of common animal manures.

Nutrient Source	Nutrient content lb/ton			Available nutrients lb/ton in first season			
	N	P_2O_5	K_2O	N1	N2	P_2O_5	K_2O
Dairy (with bedding)	9	4	10	5	2	3	9
Horse (with bedding)	14	4	14	7	3	3	13
Poultry (with litter)	56	45	34	23	16	36	31
Compost (from dairy manure)	12	12	26	3	2	10	23
Composted poultry manure (no litter)	80	104	48	40	40	104	48
Swine (no bedding)	6	7	7	2	2	5	6

N1= incorporated within 12 hours of application, N2 =incorporated after 1 week or more.
Adapted by Vern Grubinger from "Using Manure and Compost as Nutrient Sources for Fruit and Vegetable Crops" by Carl Rosen and Peter Bierman.

TABLE 5.3. Estimated biomass yield and nutrient accruement by selected cover crops. Actual amounts will vary.

Crop	Biomass* lbs/ac	Nitrogen lbs/ac	Potassium lbs/ac	Phosphorus lbs/ac	Magnesium lbs/ac	Calcium lbs/ac
Annual ryegrass (*Lolium multiflorum*)	5,608	89	108	17	8	22
Crimson clover (*Trifolium incarnatum*)	4,243	115	143	16	11	62
Field pea (*Pisum sativum*)	4,114	144	159	19	13	45
Hairy vetch (*Vicia villosa*)	3,260	141	133	18	18	52

*Dry weight of above ground plant material.
Adapted from Sullivan, 2003. Overview of Cover Crops and Green manures. ATTRA.

COMMERCIAL FERTILIZERS

Any material, including fertilizers, that is used in a certified organic system must be approved under NOP regulations by your certifier. Fertilizers and soil amendments that are commonly used in organic systems are listed in Table 5.4. Many companies now make custom organic fertilizer blends. These products tend to be more expensive than purchasing the materials in bulk and blending them on-site prior to application. There are also numerous companies making liquid nutrients for foliar applications. These can be useful for correcting deficiencies, making maintenance applications for return bloom (e.g., boron and zinc) and improving fruit quality (e.g., calcium).

To convert nutrient percentages to application rates, simply convert the percentage into a fraction of "1" and divide the desired rate by this fraction. For example, if you would like to supply nitrogen at a rate of 40 lb/ac and the fertilizer (or compost) contains 5% nitrogen:

5% = 0.05

40 lb/ac ÷ 0.05 = 800 lb/ac would be needed.

To calculate for areas measured in square feet, divide the square footage to be treated by 43,560 sq ft per acre, and then multiply that fraction by the desired rate. For example, if your orchard is 20,000 square feet:

800 lb/ac * (20,000 sq ft ÷ 43560 sq ft per ac) = 367 lb

Oregon State University has published a useful online "Organic Fertilizer Calculator" tool (http://smallfarms.oregonstate.edu/organic-fertilizer-calculator) to assist growers in selecting composts, cover crops, and commercial fertilizers. The calculator provides nutrient supply and current cost information on numerous compost types and commercial fertilizers. There are versions for "acre" and "square foot" calculations.

FOLIAR FERTILIZERS

Applying nutrients to leaves in a spray solution can provide the plant with nutrients such as calcium and zinc that are taken up poorly by the root system, as well as to help correct immediate nutrient deficiencies. Under NOP regulations many of these products are only allowed if there is a documented nutrient deficiency. Growers should contact their certifier to learn how to best document deficiencies, but soil and leaf analyses as well as visual symptoms will likely need to be documented.

Organic sources of foliar nitrogen are derived mostly as a byproduct of seafood processing, and come in the form of fish emulsions, fish powders, and fish oils. Rates will depend upon the specific product. Several companies make chelated foliar fertilizer products that are compliant with the NOP. However, there are few replicated trials comparing different organically allowed foliar fertilizer products in orchards. Solubor is a good source of foliar boron, and has proven to be an effective material for increasing leaf boron levels in NY orchards.

In NY, it is recommended that growers apply at least two "spring tonic" sprays that contain boron, zinc, and nitrogen in order to stimulate fruit set and flower bud initiation. Also recommended are two to three applications of Epsom salt (for magnesium) at 15 lb/100 gallons of spray, starting at petal fall and continuing for several cover sprays. Additionally, repeated calcium sprays from the end of shoot growth to harvest have been shown to help improve fruit storage duration. Calcium chloride is typically used as a calcium source, but other formulations may also be acceptable under NOP regulations. The above foliar fertilizer recommendations are based upon trials in non-organic orchards, and it is not known whether recommendations for organic systems would be different.

MICROBIAL STIMULANTS

Numerous microbial-based products are marketed with claims that they stimulate soil biological activity. While these products may be acceptable under NOP regulations, there is little independent scientific confirmation of the manufacturers' claims. Well-managed organic orchards that include regular organic matter inputs (e.g., cover crops, manures, mulches, composts) typically already have relatively high soil organism biomass and activity, and additional microbial "stimulation" should not be necessary and is unlikely to be cost-effective.

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TABLE 5.4. Organic fertilizers and soil amendments. Read product label for application rates. Check with your certifier about the acceptability of specific products and name brands.

Material	Nutrient content Percent by weight of N-P-K or other minerals as noted. Diamond between N-P-K concentrations denotes different product formulations.	Comments
Alfalfa meal or pellets	2.5-1-1 ♦ 5-1-2	Slow release nitrogen source; also a moderate source of calcium
Azomite (powder or pellets; also called "rock dust")	0-0-2.5; plus magnesium, 5% calcium, and 67 other trace minerals	Mined aluminosilicate from an ancient marine deposit in Utah; name is derived from the phrase: "A to Z of Minerals Including Trace Elements"
Bat guano	0-7-0 ♦ 3-10-1 ♦ 8-4-1 ♦ 10-3-1	Rates vary depending upon guano source; quick release nitrogen and phosphorus; highly soluble
Blood meal	12-0-0 ♦ 13-0-0 ♦ 13-1-0	Readily available nitrogen source; by-product of meat rendering
Bone meal	2-11-0; 22% calcium ♦ 3-15-0; 24% calcium ♦ 3-22-0; 30% lime l 5-10-0	Readily available phosphorus source; also a calcium source; can increase soil pH
Canola meal	5.5-0-0 ♦ 6-2-1	Slow release nitrogen source; recovered from canola oil pressing
Corn gluten meal	10-0-1	Some pre-emergent herbicidal activity
Cottonseed meal	6-2-1	Slow release N-P-K; somewhat acidic
Epsom salts	9.9% magnesium; 12.2% sulfur	Magnesium sulfate
Feather meal	13-0-0	Slow release nitrogen; hydrolyzed ground feathers
Fertibor	15% boron	Natural, mined, and purified boron; slow release; can be phytotoxic if over-applied
Fish bone meal	3-16-0; 14% calcium	Can be used as bone meal
Fish emulsion	3-1-1 ♦ 4-2-1 ♦ 5-1-1	Liquid fish protein that has been enzymatically digested and then stabilized with phosphoric or sulfuric acid; concentrations vary depending upon source and manufacturer
Fish meal	10-4-0 ♦ 10-6-2	Slow release
Fish oil		Spreader sticker; purported UV stabilization
Fish powder	11-0.25-1 ♦ 12-1-1	Enzymatically hydrolyzed fish protein; usually applied to foliage or through irrigation systems
Glacial rock dust	Ca, Fe, Mg, K, plus trace elements and micronutrients	Mined material from Canadian moraines; readily available; purportedly can increase phosphorus availability and improve cation exchange capacity
Granite meal	0-0-5	Potassium in the form of potash; does not alter pH
Greensand	0-0-3 ♦ 0-0-7; 20% iron oxide	Slow release potassium; derived from glauconite (70-80 million year old marine deposits) in New Jersey; contains more than 30 other minerals

Gypsum	84% $CaSO_4 \times 2 H_2O$ (equivalent to 23% calcium and 18% sulfur)	Adds calcium without altering soil pH; helps loosen clayey soils; can correct high soil sodium levels
Iron sulfate (ferrous sulfate monohydrate)	17% sulfur; 31.5% iron	Derived from ferrous sulfate
Kelp and seaweed extracts	0.1-0-1 ♦ 0.2-1-1 ♦ 1-0-4	Liquid formulations usually applied to foliage or through irrigation systems; contains growth hormones and enzymes with purported plant growth benefits; concentrations vary depending upon source and manufacturer
Kelp meal	1.1-2.5-2	Contains growth hormones and enzymes with purported plant growth benefits; concentrations vary depending upon source and manufacturer
Limestone (Dolomite)	46-49% $CaCO_3$, 36-39% $MgCO_3$ (equivalent to 22% calcium and 12% magnesium)	Mined material; used to increase soil pH; slow release magnesium source; used in soils with low magnesium levels
Limestone (Hi-Cal)	0-0-0; 95% $CaCO_3$	Mined material; increases soil pH; calcium source; used in soils with high magnesium levels
Manganese sulfate	32% manganese	Readily available manganese
Oyster shell lime	96% $CaCO_3$	Increases pH; similar to limestone; by-product of seafood industry; a calcium source; use in soils with low magnesium levels
Peat moss		Used to lower soil pH; harvested from peat bogs that may be depleted and threatened
Rock phosphate (also called colloidal phosphate)	0-3-0	Mined material; very slow release phosphate (contains 27% P_2O_4); also a calcium source
Seabird guano	1-10-0 ♦ 12-12-2.5 ♦ 13-8-2	Readily available phosphorus or nitrogen depending upon product; concentrations vary depending upon source and manufacturer; can be applied to foliage
Shellfish meal	2.5-3-0.5; 15% calcium	Slow release; derived from crab and/or shrimp shells as a by-product from shellfish industry; high carbon content from chitin, which may stimulate soil microbial activity
Sodium nitrate (also called Chilean nitrate or Natural Nitrate of Soda)	16-0-0	This product is prohibited under NOP rule §205.602(h), unless use is restricted to no more than 20% of the crop's total nitrogen requirement per year; highly soluble nitrogen source—may leach through the soil profile; also a source of sodium; mined material from Chile
Solubor boron	20% boron	Usually applied to foliage or through irrigation systems
Soybean meal	7-0.5-2.3 ♦ 7-2-1	Slow release nitrogen and potassium
Sulfate of Potash (also called potassium sulfate)	0-0-50; 18% SO_4	Readily available potassium; mined material from Utah
Sulfate of potash magnesia (K-Mag)	22% K_2O; 27% sulfur; 18% MgO (equivalent to 22% sulfur; 22% potassium; and 11% magnesium)	Naturally occurring source of potassium, sulfur, and magnesium; mined material
Sulfur, granular	90% sulfur	Fast acting material for decreasing pH

6. GROUNDCOVER AND WEED MANAGEMENT

Managing orchard understory vegetation is important for weed suppression, attracting and sustaining beneficial arthropods that prey upon foliar and fruit pests, and protecting the soil surface beneath trees from erosion, weathering and organic matter loss. However, planted groundcovers and weeds in the tree row can also compete excessively with trees for water or nutrients, and provide habitat for voles (*Microtus sp*.) and other rodents. Weed management is often cited as one of the main challenges in organic production.

Under NOP regulation §205.206(c), weed problems may be controlled through:

(1) Mulching with fully biodegradable materials
(2) Mowing
(3) Livestock grazing
(4) Hand weeding and mechanical cultivation
(5) Flame, heat, or electrical means; or
(6) Plastic or other synthetic mulches—provided that they are removed from the field at the end of the growing or harvest season.

When weeds are allowed to grow in the tree row they can stunt tree growth, especially during orchard establishment, as well as reduce yields and fruit size. The optimal area for weed management around trees is determined by soil type, tree age, and irrigation availability. In dwarf and semi-dwarf plantings, weeds should be controlled from the tree trunks out to 2 to 4 feet in all directions. Smaller weed-free areas may be sufficient in orchards with irrigation or very fertile soils. In Northeast orchards the most critical months for weed competition with fruit trees are May, June and July; during autumn and the winter months tree requirements for soil nutrients are reduced. Therefore, groundcovers and weeds during nine months of the year have minimal competitive effects on fruit trees, and can provide beneficial protection for soil quality.

The drive-lane (the area between the tree-rows) is usually planted with a turfgrass, although it is possible to plant different species in that area. In most orchards there is an endemic seed bank of clovers (*Trifolium* spp.), plantain (*Plantago* sp.), dandelions (*Taraxacum officinale*), and other herbaceous broadleaf plants that will naturally establish within a mowed grass lane. Drive-lane vegetation improves traction for orchard equipment, reduces soil rutting and compaction, minimizes dust and mud, and can provide biodiversity for the orchard agroecosystem, while being relatively non-competitive with fruit trees. The drive-lane is usually mowed regularly during the growing season to minimize water needs, suppress voles and other rodents, and facilitate routine orchard operations. During bloom time in the orchard, close mowing of flowering groundcovers such as dandelion or yellow rocket (*Barbarea vulgaris*) and other spring blooming Brassica weeds will encourage bees and other pollinators to visit the tree flowers instead of the groundcover bloom.

Orchard groundcover management is an active area of research and there are no generic recommendations that are appropriate for all sites. Most organic apple growers integrate mulch, compost, or dormant-season cover crops in combination with mechanical cultivation in the tree-rows during the growing season. Below is a description of some of the more common groundcover management methods used in organic orchards.

COVER CROPS

Integrating cover crops under apple trees offers important benefits. However, it is difficult to find the right balance between beneficial cover-crop impacts and the negative effects of cover crops as "weeds" that compete with trees for water and nutrients, and may provide ideal vole and rodent habitat. The ideal cover crop should be low growing, non-competitive with trees, and non-invasive. Both perennial and annual cover crop species have been tested in orchard situations, as have legumes, other broadleaf plants, and grasses. Research has shown that it is difficult to keep tree-row cover crops at a high plant density and weed free.

The best choices for perennial groundcover within tree rows and drive lanes of orchards where mowing will be the primary weed management practice, or livestock will be pastured, are probably cool season fine-leaf fescues such as hard fescue (*Festuca duriuscula*), sheep fescue (*F. ovina*), or red fescue (*F. rubra*). These grasses hold up well under machinery and foot traffic, and tend to cease growth during hot weather in mid-summer when water and nutrients are most limiting for fruit trees. The fine-leaf fescues are also low in stature, and do not provide as much protective cover for meadow voles as other more vigorous cover crops and grasses.

BIOMASS MULCH

Mulch has many positive attributes that make it an attractive option for organic operations. It can stabilize and protect the soil surface, increase organic matter content in the soil, act as a slow release fertilizer, conserve soil moisture, moderate soil temperature, and stimulate biological activity in the topsoil.

A layer of wood chips, bark, straw, or other organic material applied to a depth of three to six inches can help suppress many weeds by blocking sunlight from hitting the soil surface, thus preventing seed germination and slowing weed growth. When applied onto a weed-free soil, a thick layer of mulch may effectively control weeds for one to two years. When mulch is applied onto a weedy soil, weed suppression will not be as effective. Eventually some weeds (particularly deep rooted perennials and grasses) will emerge through the mulch, and may then become very aggressive. This poses a management challenge–how to suppress weeds without disturbing the mulch. Incorporating a large amount of woody (high C-to-N ratio) mulch into the topsoil can tie up soil nitrogen in the short-term, therefore making nutrients less available to apple trees. Flame and steam, or hand weeding, or undercutting mechanical tools are potential options discussed below, but further research is needed in this area.

Numerous research trials conducted in NY and elsewhere have shown that partially composted hardwood bark-chip mulch (obtained from local sawmills) is an effective biomass mulch that decomposes very slowly and provides physical and biological mulch benefits for two or three years after each application. Additionally, meadow vole populations increase much less under wood-chip mulches than under other mulches. However, the initial installation cost for wood-chip mulch can be quite high. In one recent trial, mulch applications cost $700 per acre, not including labor and machinery installation costs. However, this cost can be prorated over two or three years, making it more comparable to mechanical cultivation costs on a per-year basis. On farms with low soil pH, repeated applications of hardwood bark mulch can also neutralize soil acidity, substituting for lime applications. Side discharge row mulchers, such as those made by Millcreek Manufacturing CO (Leola, PA; http://www.millcreekmfg.com/) can significantly reduce the amount of time needed to mulch large orchards. On farms with woodlots, composted wood chips may also be available on-site.

Mulching with compost for weed control can be even more expensive than hardwood bark chips, and will likely add more nitrogen and provide less weed suppression than is desirable for most orchards.

Mow and Blow

One approach to building a mulch layer in the tree-row is to mow the drive-lane with a side-discharge mower that blows grass clippings beneath the trees. In practice, it is difficult to obtain a thick enough mulch layer to discourage weed growth this way, except when cover crops that generate a large amount of biomass are grown in the drive-lane. However, in groundcover management systems that use other methods for weed control, the mow and blow approach will provide sustained inputs of organic matter and nutrients to the soil around the trees. This can improve soil quality, staying compliant with NOP soil management regulations.

Geotextile and Fabric Mulches

Under NOP regulations, weed problems can be controlled through mulching with fully biodegradable materials or other synthetic mulches, provided they are removed from the field at the end of the growing or harvest season. These mulches are usually pinned to the ground with long metal staples; however, wind and orchard machinery can dislodge the material, making frequent maintenance necessary. Material and installation costs can be quite expensive (over $1000 per acre), especially if annual installation and removal are needed. Key features to look for in geotextile or fabric mulches include good water infiltration, light reflectance (depending upon location this can be a highly desirable feature possibly increasing fruit size, red color, and yields), and durability so that the same material can be reused over several years.

Mechanical Cultivation

Off-set tractor-mounted tillage implements can suppress weeds under the tree canopy, without disturbing the vegetation in the drive-lane. Mechanical cultivators can be ground-driven (meaning that the weed control action comes from implements rolling alongside or behind the tractor), powered directly through the tractor's engine with the PTO (power take-off), or powered by hydraulic pumps. There are many different types of mechanical cultivators available for use in orchards, and each has its pros and cons. The most important features for tree-row cultivators are a low vertical profile (to minimize damage to low-hanging branches and fruit), and shallow soil penetration (to avoid damage to tree roots in the upper soil layer).

Under NOP regulation §205.203(a), the producer must select and use tillage and cultivation practices that maintain or improve the physical, chemical, and biological condition of soil and minimize soil erosion. However, numerous research trials have shown that all mechanical cultivation causes soil disturbance, and inevitably degrades soil organic matter and quality unless it is combined with cover crops, compost, or manure amendments to the soil. Therefore, organic growers need to balance the use of mechanical cultivators with other practices that can improve soil conditions. Additionally, tillage often brings buried dormant seeds to the soil surface, allowing them to germinate and causing a flush of new weeds to emerge soon after cultivation.

Repeated mechanical tillage will often lead to dominance by weed species such as dandelion, foxtails (*Setaria sp.*), crabgrass (*Digitaria sp.*), quackgrass (*Agropyron repens*), common groundsel (*Senecio vulgaris*), and ground ivy (*Glechoma sp.*), that produce abundant seed during the summer months, or re-grow from rhizome pieces after tillage. Increasing fertilizer rates to compensate for resource competition by these weeds is usually not very helpful, because weeds can usually exploit fertilizer nutrients more readily than fruit trees. Fertilization may actually increase weed biomass and competition for water and sunlight.

Of the ground-driven implements, both Lilliston rolling cultivators (also known as spiders) and discs have been successfully used in Northeastern orchards. Lilliston spiders have shown some advantage over other implements because they effectively cultivate at a fairly shallow depth, thus causing minimal soil inversion and tree-root damage. They tend to either pull weeds out of the soil where they desiccate, or bury weeds underneath soil. Lilliston spiders reportedly conserve soil aggregates more than some other cultivating equipment, but more testing in orchard situations is needed to verify this claim.

One cultivator that the authors have tested extensively is the Wonder Weeder® from Harris Manufacturing (Burbank, WA; http://www.wonderweeder.com). This is a ground-driven rolling cultivator that uses Lilliston spiders, mounted to a frontal 3-point hitch, with a tool bar that extends from the front of the tractor on the driver's right side. Two gangs of Lilliston rolling cultivators are mounted behind the tool bar. A spring-steel shear bar is used to suppress weeds in the centerline between the trees. This cultivator provided satisfactory weed control in an established high-density research orchard in NY when used at least three times (May, June, and July) per season. Some additional hand weeding was necessary to remove weeds in the tree-row centerline that were missed by the shear bar. More passes may be needed in high weed-pressure situations. In new plantings, growers may want to remove the shear bar altogether to avoid hitting young trees. The Wonder Weeder® was difficult to operate in wet soils (especially clays) and on slopes, and we found it difficult to operate at ground speeds in excess of 5 mph. However, it caused considerably less soil disturbance and tree-root damage than the other available rotary cultivators, and provided effective weed control in most situations. It requires a tractor of at least 30 hp, and 4-wheel drive will improve its operation.

Several manufacturers have developed mechanical cultivators based upon other modes of action. Many of them use a trigger bar to pull the device around tree trunks and posts, allowing weeding in the tree-row. The Weed Badger® (Town & Country Research & Development, Marion, ND; http://www.weedbadger.com), is mounted to a side frame or rear 3-point hitch and uses tractor-powered hydraulic pumps to spin a disc with attached tines that face downward. The device is mounted on the right side of the tractor, providing operator visibility. The Weed Badger® can also be outfitted with other implement heads, such as sweeps, discs, and rakes making it a versatile piece of machinery for orchard operations. However, this cultivator tills a relatively narrow strip and can cause deep soil disturbance in many orchard situations. It also requires slower tractor operating speeds than some other cultivators, and the rotary head is subject to fouling when tilling tall weeds.

Rinieri (Forli, Italy; http://www.rinieri.com) makes a number of rear mounted orchard and vineyard cultivators. In trials conducted in NY on a silt loam soil, the horizontal side-sweep subsurface cultivators did not provide effective weed control, allowing many weeds to re-root after cultivation. In these trials, a sod layer formed in the weed control area over the course of two growing seasons. In coarse-textured soils, or in low weed pressure situations, these side-sweep subsurface cultivators may provide more effective control.

Rototillers tend to have more aggressive action than the above-mentioned cultivators. Rototillers can effectively remove weeds from the orchard understory, but the speed at which rototiller tines spin through the soil tends to destroy soil aggregates. It is also difficult to keep rototillers operating at a shallow depth, and this can lead to root damage or hardpan formation in the soil sub-surface. Rototiller attachments can be purchased for devices such as the Weed Badger® and Rinieri, or tines can be removed from larger rototillers to keep tillage directly under the tree.

Other types of mechanical cultivators utilize different tine or disc designs in an attempt to minimize soil degradation. Comprehensive tests of these tools have not been conducted in the Northeast. Some other mechanical cultivator manufacturers include: Clemens GmbH & Co. (Wittlich, Germany; http://www.clemens-online.com/); Gearmore Inc. (Chino, CA; http://www.gearmore.com); The Green Hoe Company (Portland, NY; http://www.greenhoecompany.com/); and Kimco (Ukiah, CA; http://www.kimcomfg.com).

SWISS SANDWICH SYSTEM

Researchers at the Research Institute for Organic Agriculture (FiBL) in Frick, Switzerland have developed an integrated approach to weed control, called the "Sandwich System". This system was developed in part to accommodate mechanical cultivators that were unable to remove weeds in between trees. The researchers saw this difficulty as an opportunity, and started to experiment with narrow strips (in line with the tree trunks) planted with species that added biodiversity and attracted biocontrol predator insects. On each side of the planted strip, the soil was cultivated with a tractor-mounted implement to a width appropriate for the tree size.

Results from research projects in several different apple-growing regions have found that trees grown in the Sandwich System perform similarly to full tree-row tillage systems, except in shallow soils or where drought conditions exist. As with other cover crops, there has been difficulty in maintaining the desirable cover crop species and excluding weeds in the planted area. The planted strip has also been found to provide habitat for rodents. While many studies have shown that flowering groundcovers provide pollen and nectar that attract beneficial insects such as lacewings (Neuropterans) and syrphid flies (Syrphidae), there is little evidence that these beneficials provide economically significant biocontrol of direct fruit pests, or compensate for the increased resource competition that flowering herbaceous perennials pose for the adjacent fruit trees.

MOWING

Cutting down weeds under the trees is a useful practice for keeping weeds from reseeding or growing into the tree canopy, but mowing does not significantly reduce groundcover competition with the trees. Mowing should be done only if other weed control methods are unavailable. Several manufacturers make multi-deck "batwing" mowers that can be adjusted to go underneath trees. Hand mowers can also be used, but tend to be inefficient and energy intensive in large orchards. Care should be taken when using string trimmers, to avoid damaging tree bark.

THERMAL WEED CONTROL

Both direct flame and steam weeders have been used in commercial organic orchards. The goal with these devices is not to incinerate weeds, but instead to denature enzymes and burst cells eventually causing the weeds to desiccate and die. It may take up to 24 hours to see the effects of thermal weed control. Since there is no soil disturbance, thermal cultivation leaves soil structure intact. Additionally, weeds are killed in-place where they can add organic matter to the soil.

Liquid petroleum gas (LPG) (propane) is most commonly used to fuel the burners. Flame burner units can produce 3,000,000 BTU per hour and temperatures over 1600 ºF. The more powerful flame weeders can be operated at speeds up to 5 MPH. Studies have shown that as long as burners are kept moving there is minimal damage to older bark over the course of one to two seasons, but it is unclear what happens over the life of an orchard that utilizes repeated flame weeding. Furthermore, these devices can damage young trunks and branches, and leaves and fruit are sensitive to high heat and flames. Shrouds can be used over the burners to protect the lower canopy, and will also keep heat on weeds for a longer period of time. Flame weeding poses some risk to the tractor operator and to wildlife in the orchard. It is also advisable to have a fire extinguisher or water source nearby in case of unintended fires.

Companies that manufacture commercial units include Flame Engineering, Inc. (LaCrosse, KS; http://www.flameengineering.com); Thermoweed (North Yorkshire, UK; http://www.thermoweed.co.uk/); and Weed Control BV (Waalwijk, Netherlands; http://www.weedcontrol.nl/engels/uk_home.html).

HAND WEEDING

Using hoes or other hand tools to weed under trees is effective but extremely labor intensive and only practical in small orchards (or with large amounts of labor). Hand weeding can be accomplished with any number of different tools, but generally hoes with a heavy blade, such as a grape hoe, work best to uproot larger weeds. Some hand weeding may be necessary to clear areas that were either inaccessible or missed when using other weed control approaches.

HERBICIDES

Several herbicide products are available for organic production. These include acetic acid (concentrated vinegar) used at 5-20% concentrations in 30 gallons per acre, citric acid, essential oils (e.g., clove, pine, thyme, and citrus, among others), and various combinations of these with different surfactants (e.g., molasses and yucca extract). These products all have one thing in common: they are contact burn-down herbicides, meaning that direct contact with plant tissue must be made. They do not translocate within the plant, or cause systemic injury. For the most part, approved organic herbicides will only kill very young broadleaf plants that have just a few leaves. It is possible to stunt larger broadleaf weeds and grasses by burning off the leaves, but most weed species, especially perennials, will outgrow that damage. The leaves of grasses grow from nodes that are often at or below the soil surface, thus grass weeds can be damaged by contact herbicides, but they will quickly re-grow after each treatment. Only minimal weed control has been obtained by using organic herbicides in orchards.

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7. CROP-LOAD MANAGEMENT

Adjusting the number of harvested fruit, either up or down, is referred to as crop-load management. Key elements of crop-load management include: 1) pollination and fruit set; 2) thinning (removing) set fruit in order to increase fruit size and color of the remaining fruit, as well as to prevent branches from breaking under excessive weight; and 3) ensuring that the orchard is cropping annually by breaking the natural tendency for many apple cultivars to produce biennially (this is also referred to as alternate bearing). Organic growers need to manage crop load on their apple trees for all three of these reasons. Doing so will help maintain high yields and adequate fruit size, and keep the trees in a good vegetative/fruiting balance.

Proper crop-load adjustment also helps with pest control. Fruit that are spaced on the tree so that they are not touching will receive better spray coverage and minimize favorable feeding locations for pest insects, such as leaf roller (Tortricid) caterpillars. Additionally, during manual thinning of excess fruit, organic growers can selectively remove apples that have been damaged by early season pests.

Crop-load management takes place over the course of the entire year. During the 30 to 45 days following petal fall, the current season's apple fruit undergo cell division and then begin cell expansion. Large fruit size is best achieved when all thinning has been completed by the end of this period. Thinning fruit later in the season may help increase color and remove infested fruit, but it will have little impact on final fruit size or return bloom the following year.

The 30 to 45 days after petal fall is also the time when flower buds are initiated on spurs and bearing terminals in apple trees. If properly managed these bud meristems will become the flowers that produce fruit the following spring. If too much fruit is left on the tree one year, then flower bud initiation for the following year will be suppressed by carbohydrate limitation and internal hormonal regulation. This will decrease the yield potential for the next growing season.

Maintaining adequate nutrient levels is also critical for flower-bud initiation. Low nitrogen status in the tree can be corrected through soil amendments or, when deficits are severe and immediate, through foliar sprays. Boron and zinc aid in flower-bud formation and are usually applied as a foliar spray in the early part of the growing season. Nutrient analysis of mid-summer leaf tissue should be used as an indicator of tree nutrient status (see Soil Fertility and Crop Nutrient Management section).

Pruning and training are also used to manipulate crop load. In most cases branches that grow vertically tend to produce fewer flower buds than branches growing at or below a 45º angle above the horizontal plane. Pruning and training systems that balance vegetative and fruit bud formation, as well as growing precocious rootstocks and cultivars, will help to ensure annual crops. Pruning and training also provide opportunities to select branches that have the best chance for producing high quality fruit.

Apple fruit buds contain up to six individual flowers, each of which is capable of producing an apple. The king bloom is the centermost flower in the apical meristem. It opens earlier than the surrounding lateral flowers and tends to produce the largest fruit. Many thinning strategies are targeted at preserving the king bloom, or keeping fruit that set from the king bloom, while removing lateral flowers or fruit.

For fruit to fully form and size, most apple cultivars require cross-pollination with a different cultivar that blooms around the same time. While some cultivars are fully or partially self-fruitful (meaning that they can pollinate their own flowers) cross-pollination is recommended in most commercial plantings. In orchards where many different cultivars are planted in close proximity and their flowering times overlap, pollinizers (trees planted specifically for pollination) may not be needed. Bees can also transport viable pollen (and possibly fire-blight inoculum) from feral apple trees and crabapples or backyard apple trees in neighboring homesites into the orchard. An inexpensive orchard pollination strategy is to intersperse within the main cultivars some ornamental crabapples that produce an abundance of flowers coinciding with bloom of those cultivars. One crabapple per 20 main cultivar trees will usually be sufficient in orchards with low cultivar diversity. Multiple crabapple cultivars may be needed to cover early through late blooming cultivars. Crabapple branches can be grafted onto commercial apple cultivars if insufficient pollination is a problem in an existing orchard. Many disease-resistant crabapple cultivars are available for use in organic orchards.

Cultivars with an extra chromosome set (triploids) do not produce viable pollen and cannot be depended upon for pollinizing other cultivars. Well known triploids include Mutsu (Crispin), Jonagold, and Winesap.

Apple tree pollen is transferred to receptive flowers by a wide-variety of insects including many species of wasps, flies, solitary bees, ground-dwelling bees, bumblebees, and European honeybees (*Apis mellifera*). Hedgerows that contain undisturbed soil areas and plants which flower throughout the growing season will help to conserve wild pollinators by providing alternate pollen sources as well as nesting habitat. In commercial plantings, European honeybees are often employed to pollinate apple flowers, primarily because they are easily transported in hives that can be placed within orchards. In addition, European honeybees tend to visit only one flowering species during individual foraging trips, increasing the chances of pollen transfer between apple trees. Apples contain up to ten seeds per fruit, therefore each flower requires multiple pollinator visits.

Orchardists may choose to rent hives from commercial beekeepers or maintain their own hives. In either case, care must be taken to ensure that pesticide sprays do not harm bees. Bees should be placed in the orchard right before the king blooms open, and should be removed immediately after petal fall. One strong hive (six or more frames of brood and at least eight combs of bees) will be sufficient to pollinate one to three acres of apple trees if weather conditions are suitable (sunny, warm, and not too windy) during bloom time. Large orchards and orchards with low populations of wild pollinators should use higher hive densities.

Frost at bloom can damage fruitlets and reduce seed set, which will result in increased natural drop and a greater chemical thinning response. Frost can also damage spur leaves, resulting in greater uptake of chemical thinning materials, and thus a greater thinning response. Wherever flowers and leaves have been damaged by frost, extreme caution should be used with chemical thinners. Typically, lower chemical thinner rates would be appropriate in such cases.

There are three main periods during which apples naturally drop from the tree through self-thinning mechanisms. The first drop occurs right around petal fall and is usually a result of incomplete pollination or abnormal flower development. Some fruit will continue to drop over the next four to six weeks, culminating in the "June drop" when a substantial amount of fruit will naturally fall from the tree. The third fruit-drop period occurs shortly before harvest, and may be a result of over-cropped and stressed trees, or a tendency for some cultivars to attain physiological maturity before they are at an appropriate maturity for commercial harvest. The final preharvest drop is most detrimental, and usually more severe on short-stemmed cultivars that often set multiple fruit on the same spur, such as Liberty or Macoun.

In cultivars that set a heavy crop, up to 90% of the fruit that initially set may need to be removed to obtain sufficient fruit size and return bloom. While it seems counter-intuitive to overset an apple crop only to have to remove a significant percentage of the remaining fruit a few weeks later, unpredictable weather events such as frost or hail can damage the developing fruit during the intervening time, so it is desirable to have a margin of safety in excess of the ultimate intended fruit load on the trees. Also, poorly pollinated apples will often be misshapen. Hence most growers prefer to set an abundant crop by providing bee pollinators and maintaining good tree nutrition, and then selectively thin that initial fruit set down to a more optimal crop load when the danger of frost is past, and fruit can be selectively thinned down to an optimal load.

Studies have shown that to produce apples of good size and color there should be about 30 leaves for each apple. In most spur-bearing cultivars this equates to apples spaced 4 to 6 inches apart, and ideally one apple on every other spur because the resting spurs without fruit are more likely to produce flowers and fruit the following year. However, many cultivars have specific thinning requirements. For example, Liberty and Macoun will annually set a large crop with multiple apples per spur. If not thinned to a single apple per spur, the fruit will be quite small at harvest.

There are a number of ways to remove apples from the tree, including the use of thinning chemicals, tractor-driven mechanical tools, and hand thinning. Each method has strengths and weaknesses, and thus multifaceted approaches may be needed.

CHEMICAL THINNING

In non-organic orchards, chemical thinning is usually accomplished with the use of carbaryl in combination with one or more synthetically derived plant growth regulators, including auxins and cytokinins. However, these materials are not allowed for use in certified organic orchards. Starting in the late 1990s, organic growers in Washington State began experimenting with rates and timing of several organically approved materials that were known to cause fruit drop in apples. From these trials, a combination of liquid lime sulfur (LLS) and fish oil was found to provide a thinning response similar to the conventional carbaryl and plant growth regulator combinations. Both organic and non-organic growers in Washington State now use the LLS-oil combination.

The apparent mode of action for LLS is to depress photosynthesis for a period of time (at least a week and up to several months in some studies). This puts the tree under stress during a time of year when carbohydrate and nitrogen reserves are usually low, causing the trees to abort developing fruitlets. When used during bloom, LLS may also cause direct injury to the reproductive organs within the flower, preventing successful pollination and fertilization of the ovules. When crop oil is tank-mixed with LLS it acts as a leaf penetrant, increasing the uptake and efficacy of LLS. For unknown reasons, fish oil has proven to have marginally greater efficacy than petroleum or plant-based oils. Crocker's Fish Oil (Quincy, WA) was the specific product used in most US based trials. It is unclear whether this particular product has greater efficacy than other fish oil products. High rates of LLS (for example a 10% solution) may cause a similar thinning response as a lower rate that is combined with oil. However, these higher LLS rates will cause more leaf tissue damage and may cause blemish russet on the fruit.

In Washington State, thinning trials with LLS and oil were primarily aimed at thinning flowers to reduce pollination and fruit set. In the Northeast, chemical thinning usually starts at petal fall when a better assessment of the potential crop load can be made and the danger of frost damage has passed. With limited production of organic apples in the Northeast, few replicated trials have been conducted using LLS and oil, or other combinations of organically approved materials during the post-bloom thinning window. However, limited success has been reported using a 2% solution of LLS in combination with a 2.5% solution of fish oil applied at petal-fall and then again four to seven days later. Timing of the second application (and possibly a third application), as well as adjusting the LLS rate (from 2 to 4% is a reasonable range), will be dependent upon weather conditions, fruit set, and overall tree health. Higher LLS rates will cause a greater thinning response, but this needs to be weighed against the possibility of increased LLS toxicity and damage to foliage, fruit, or tree.

Dark, cloudy weather for two or more days either before or after application of non-organic chemical thinners has been shown to increase the fruit thinning response, and it can be expected that a similar increase would occur with LLS and oil applications. Therefore, growers should reduce the LLS rate if cloudy weather precedes or is predicted following the application. Furthermore, high night temperatures (>60 °F) and high day temperatures (>85 °F) after application of thinners will also increase thinning response; thus, growers should critically examine the weather forecast for the 3- to 5-day period following application of thinners, adjusting the rates used based on forecasted night and daytime temperatures and sunlight levels.

The repeated use of LLS and oil from bloom through petal fall and the fruit set period may have unfavorable consequences besides fruit thinning. First, LLS is phytotoxic (i.e., poisonous to plants) and its excessive use can cause leaf burn and fruit russet, reducing final fruit size and overall tree health. Some organic growers apply a foliar nitrogen supplement soon after the desired fruit thinning effect has been realized, in an attempt to increase photosynthesis, but no replicated research has been conducted to show that this approach has the intended benefits for tree health or fruit quality. LLS may also have a negative impact on beneficials, especially predatory mites. However, LLS used for thinning will aid in disease control, particularly for apple scab and powdery mildew, and therefore minimize the need to apply other fungicides during this period.

Not all LLS products are labeled for thinning, and LLS is somewhat caustic and corrosive to sprayer tanks and pumps, irritating to the skin and eyes, and results in unpleasant rotten-egg odors that may persist for weeks and cause complaints from neighbors or U-Pick customers on other parts of the farm. Growers must follow all LLS product labeling to ensure that they are in compliance with federal, state, and organic regulations.

Other thinning chemicals researched for use in organic apple production include salts (e.g., table salt, NaCl), a calcium-magnesium brine solution (NC-99; G.S. Long, Yakima, WA), vinegar solutions, and various oils; but none of these have provided the efficacy obtained with LLS and fish oil. As with other chemical thinners not approved for organic production, the rates, timing, and selection of materials will vary depending upon the specific situation in each orchard.

MECHANICAL THINNING

Several machines have been devised that physically remove flowers or fruit from trees, including trunk shakers, low-frequency electrodynamic limb shakers, high pressure water streams, rotating rope curtains, spiked drum canopy shakers, and rotating string thinners. These devices can be divided into two general groups—those that shake the tree or individual branches causing fruit to fall, and those that physically dislodge fruit from the tree. Several research groups in the US and in Europe are currently evaluating different approaches, timing, and machines. In apples, physically knocking off fruit appears to be a more promising approach than tree shakers, which are used for thinning stone fruit, and often remove the best (largest) apples, as well as damage trunks.

One recent report investigated the Darwin 300 string thinner (Fruit-Tec, Deggenhausertal, Germany; http://www.fruit-tec.com/), a string thinner that consists of a tractor-mounted square frame with a 10-ft. tall vertical spindle in the center of the frame. Attached to the spindle are 36 steel plates securing a total of 648 plastic cords each measuring 20 inches long. The speed of the clockwise rotating spindle is adjustable with a hydraulic motor. The height and angle of the frame is adjustable to conform to the vertical inclination of the tree canopy, and the intensity of thinning is adjustable by changing the number of strings and the rotation speed. When used between tight cluster and first pink on GoldRush apple trees the researchers found that this device provided better thinning (lower overall yields with larger fruit at harvest) than LLS and oil. They note that chemical thinning is dependant upon numerous environmental factors, and that mechanical thinning might be a more predictable method for organic orchards.

However, mechanical thinning devices tend to be non-selective in the fruit that are removed from the tree. For this reason it will be difficult to selectively remove the lateral bloom fruit. Also, improperly calibrated mechanical thinners can over- or under-thin the trees, and possibly damage branches. This could potentially lead to catastrophic spread of "trauma" fire blight if there is any of this disease inoculum present in the orchard. Tree shape and size may have to be manipulated to accommodate the orientation of mechanical thinners. As with chemical thinning, additional hand thinning may be necessary to remove small, infested, or otherwise undesirable fruit.

HAND THINNING

Hand thinning apples involves manually removing fruit with fingers or small snips. While this approach can give exact spacing and fruit selection throughout the tree, it is also expensive due to the labor involved. In research trials conducted in NY, after two applications of LLS and oil, labor costs for hand thinning Liberty apple trees ranged from $200 to 400 per acre. In this trial, there were 622 trees per acre, some ladder work was needed to reach the top of the 9-ft. tall trees, and workers were paid $11 per hour. Without the aid of other thinning approaches, hand thinning labor costs will be significantly greater.

Hand thinning provides an opportunity to remove infested fruit from the orchard, possibly reducing future pest pressure and increasing marketable yields at harvest. If not pest- or otherwise damaged, the largest apple from each spur (usually from the king bloom) should be retained when hand thinning. In some long stemmed cultivars such as Gala or Jonagold, two apples can be kept per spur, but additional space to the next apple may be needed. Hand thinning should be completed within 45 days of petal fall to achieve maximum fruit size and return bloom.

SHADING

Covering trees with fabric, plastic, or other materials that block sunlight will cause a depression in photosynthesis, and therefore a thinning response. Research has shown that blocking 75% of light for three days during the post-bloom period with shading nets can effectively thin apple trees. While this offers a non-chemical thinning method, there are not enough data to make commercial recommendations on timing, amount of shading, or other variables. Additionally, significant costs may be incurred in purchasing and installing the shade cloth.

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8. PESTICIDE REGULATIONS

Every pesticide label provides detailed instructions for a pesticide's safe use that must be followed at all times. Mishandling pesticides could lead to applicator or consumer injury, crop and environmental damage, legal action, and economic losses that affect the entire fruit industry or region. The label is the law!

ORGANIC PESTICIDE REGULATIONS

The Organic Foods Production Act of 1990 stipulates that synthetic substances are prohibited, and non-synthetic substances are allowed for use in organic food production. Furthermore, it established a National List of Allowed and Prohibited Substances that identifies certain synthetic substances that may be used (e.g., pheromones), and other non-synthetic substances that cannot be used (e.g., nicotine extracts), in organic production and handling operations. The National List is available through the National Organic Program (NOP) Web site at: (http://www.ams.usda.gov/nop).

It is the responsibility of each certifying agency to review products for acceptability with the National List. However, the NOP allows accredited certifying agencies (ACA) to recognize reviews conducted by other ACAs and competent third-party reviewers. For example, the Washington State Department of Agriculture (an ACA) maintains a materials list with many fruit-tree specific products at: http://agr.wa.gov/FoodAnimal/Organic/MaterialsLists.aspx.

Many ACAs use the Organic Materials Review Institute (OMRI) for third-party reviews of products intended for use in certified organic production, handling, and processing. OMRI is a 501(c)(3) nonprofit organization that publishes a *Generic Material List* and a *Name Brand Products List*, with the former available for free from their Web site: http://www.omri.org. A testing fee is charged for companies to have their products reviewed by OMRI. The EPA allows companies to print the "OMRI Listed® Seal" on product labels, making these products easily recognizable as having approval for organic operations. However, growers should double-check each product's status before use, because products can be removed from the OMRI list if they are found to be no longer compliant with the NOP rules. Additionally, an ACA must approve all materials applied for pest management or fertilization. OMRI approves products in accordance with NOP regulations, but their review process does not include product efficacy.

Check with your certifying agent, who along with you is responsible for verifying all inputs used in your operation to make sure they comply with the regulations, including the National List of Allowed and Prohibited Substances. You should also verify with your certifier before applying any pest control products that have not already been approved through your Organic System Plan. Maintaining good communication with your certifying agent is absolutely essential for successful organic production and marketing of fruit.

FEDERAL PESTICIDE REGULATIONS

All pesticides and repellents used for agricultural production (including organic production) must be registered by the Environmental Protection Agency (EPA), or meet a specific exemption as "minimum risk" pesticide under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) regulations. The EPA pesticide registration process involves evaluating data supplied by the pesticide manufacturer to determine that using the pesticide according to label directions will not cause unreasonable risks to people and/or the environment.

The EPA classifies registered pesticides as either general-use or restricted-use. Most pesticides approved for organic production are general-use. In most cases, general-use pesticides may be purchased and used by anyone. Restricted-use pesticides may only be purchased and used by certified applicators or used by persons working under the direct supervision of a certified applicator. See New York State specific information below.

"Minimum-risk pesticides," also referred to as 25(b) pesticides, are exempt from EPA registration because their ingredients, both active and inert, are demonstrably safe for the intended use. These pesticides must meet specific criteria to achieve the "minimum risk" designation. The active ingredients of a minimum-risk pesticide must be on the list of exempted active ingredients found in the federal regulations (40 CFR 152.25). Minimum-risk pesticides must also contain inert ingredients listed on the most current List 4A published

in the Federal Register
(http://www.epa.gov/opprd001/inerts/section25b_inerts.pdf).

In addition to meeting the active and inert ingredient requirements above, a minimum-risk pesticide must also meet the following:

- Each product must bear a label identifying the name and percentage (by weight) of each active ingredient and the name of each inert ingredient.
- The product must not bear claims to either control or mitigate microorganisms that pose a threat to human health, including, but not limited to, disease-transmitting bacteria or viruses, or claim to control insects or rodents carrying specific diseases, including, but not limited to, ticks that carry Lyme disease.
- The product must not include any false or misleading labeling statements.

Biopesticides, or biological pesticides as defined by EPA, are certain types of pesticides derived from natural sources such as animals, plants, bacteria, viruses, and naturally occurring minerals. These include microbial pesticides (which contain bacteria, fungi, virus, etc., as the active ingredient); plant pesticides (i.e., pesticidal substances produced by genetically engineered plants such as corn that are modified to produce *Bacillus thuringiensis* endotoxins); and biochemical pesticides comprised of naturally occurring substances that control pests by nontoxic mechanisms (such as pheromones or some insect growth regulators). Like other pesticides, biopesticides must also be registered with the EPA. More information on biopesticides is available at:
http://www.epa.gov/pesticides/biopesticides/.

Some organic certifiers may allow "home remedies" to be used to manage pests. These materials are not labeled as pesticides, but may have properties that reduce the impact of pests on production. Examples of home remedies include the use of beer as bait to reduce slug damage in strawberries or dish detergent to reduce aphids on plants. Home remedies are not mentioned in this guide, but in some cases, may be allowed by organic certifying agencies. Maintaining good communication with your certifying agent cannot be overemphasized in order to operate within the organic rules.

Adjuvants (substances added to pesticide formulations to increase their efficacy) do not have to be registered with EPA, though a few states do require registration. Be sure to follow any pesticide label instructions when using adjuvants.

NEW YORK STATE PESTICIDE REGULATIONS

In addition to EPA registration, pesticides used in New York State must also be registered with the New York State Department of Environmental Conservation (NYS DEC). NYS DEC pesticide registration policy exempts minimum-risk (25(b)) pesticides from product registration requirements. Policies may differ in other states; some states require minimum-risk products to carry a state registration number.

Before a pesticide can be sold and/or used in New York State, it must be currently registered with the NYS DEC. One way to determine the New York registration status of a pesticide is to use the Pesticide Product, Ingredient and Manufacturer System (PIMS). This database is designed to aid those seeking current pesticide product information. Listings of currently registered pesticides and images of NYS DEC-approved pesticide labels can be accessed through this system at: http://magritte.psur.cornell.edu/pims/.

PESTICIDE APPLICATOR CERTIFICATION

All states operate EPA approved certification programs for pesticide applicators. The NYS DEC maintains this responsibility in New York. Under FIFRA, pesticide applicators are divided into two groups: private and commercial. Private applicators purchase, use, or supervise the use of restricted-use pesticides used to produce agricultural commodities on land owned or rented by themselves or their employer. (Applicator certification is not needed if a general-use pesticide is used to produce an agricultural commodity.) A commercial applicator uses or supervises the use of pesticides for any purpose or on any property not covered by the private applicator classification. In New York, a commercial applicator must be certified to purchase or use any pesticide, whether it is general- or restricted-use. Detailed record keeping and annual reporting of all pesticide applications are required for commercial applicators.

In New York State, a certified commercial applicator may only apply pesticide products that are registered with the NYS DEC or those that are exempt from registration by the EPA (25b pesticides). Since a home remedy is neither a registered nor exempted pesticide, a commercial applicator is prohibited from applying any home remedy.

More information about pesticide applicator certification is available from your Cornell Cooperative Extension office, regional NYS DEC pesticide control specialist, or the Pesticide Management Education Program at Cornell University.

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9. PESTICIDE SAFETY

(Adapted from Cornell Pest Management Guidelines for Commercial Tree Fruit Production, Agnello (ed.), 2009)
Using any pesticide imparts great responsibility on the users to protect their own health, as well as the habitat and well-being of other humans and wildlife. Keep in mind that there is more to "pesticide use" than the application. Pesticide use also includes mixing, loading, transporting, storing or handling after the manufacturer's seal is broken, cleaning of pesticide application equipment, and any preparation of a container for disposal. All of these actions require thoughtful planning and preparation; they are also regulated by state and federal laws that are intended to protect the user, the community, and the environment from any adverse effects that pesticides may cause.

PLAN AHEAD

Many safety precautions should be taken *before* you begin applying pesticides. Too many applicators are dangerously and unnecessarily exposed to pesticides while they are preparing to spray. Most pesticide accidents can be prevented with informed and careful practices. Always read and understand the label on the pesticide container before you use it. Make sure that you understand everything you need to know about the pesticide ahead of time so that you are a responsible user. Carefully follow all the directions and precautionary advice on the label. Be sure that you are prepared to deal with an emergency exposure or spill before you begin using pesticides. Be sure to know the first aid procedures for every pesticide you use.

SPRAYER CALIBRATION

Whether using a backpack sprayer or tractor-mounted air-blast sprayer, proper calibration is essential in order for pesticides to be effectively delivered to the target. Few organic crop protectants have systemic activity, which makes uniform and thorough spray coverage especially critical for effective pest management. Additionally, many organic pesticides have short residual activity. For these reasons, organic growers need to ensure that full and uniform spray coverage is achieved by using recommended spray rates and accurately calibrated equipment that targets the key crop locations that need to be protected. Detailed information on pesticide application technology is available at http://www.nysaes.cornell.edu/ent/faculty/landers/pestapp.

MOVE PESTICIDES SAFELY

Carelessness in transporting pesticides can result in broken containers, spills, and contamination. Once pesticides are in your possession, you are responsible for safely transporting them. Accidents can occur, even when transporting materials a short distance. If a pesticide accident occurs, you are responsible. Do all you can to prevent a problem when transporting pesticides. Be prepared in case an emergency should arise.

PERSONAL PROTECTIVE EQUIPMENT

The need for personal protective equipment depends mainly on the pesticide being handled. Personal protective equipment requirements are printed on pesticide labels. These requirements are based on the toxicity, route of exposure, and formulation of that pesticide. The personal protective equipment (PPE) requirements listed on each label are the **minimum** that must be worn during the pesticide use. A pesticide user always has the option of wearing more protection than the label requires.

The activity, the environment, and the handler also influence the choice of PPE. Activity-related factors include the mode of pesticide activity, duration of the activity, the equipment being used to apply the pesticide, and the pesticide deposition pattern with respect to the applicator. Mixing and loading procedures often require extra precautions when the pesticide is in concentrated form. Studies show that applicators are at greater risk of accidental poisoning when handling pesticide concentrates. Pouring pesticide concentrates from one container to another is the most hazardous activity. A closed mixing/loading system can reduce this risk.

AVOID DRIFT, RUNOFF, AND SPILLS

Pesticides that deposit anywhere but on the target area can harm people, crops, wildlife and the environment. Choose weather conditions, pesticides, application equipment, pressure settings, droplet size, formulations, and adjuvants that minimize drift and runoff hazard.

AVOID EQUIPMENT ACCIDENTS

Properly maintained and carefully used equipment contributes to safe pesticide application:

- Be sure to turn off your machinery before making any adjustments.
- Do not allow children, pets, or unauthorized people near the pesticide equipment.
- Between jobs, depressurize tanks or systems.
- Always return equipment to appropriate areas for cleaning and storage when pesticide applications are completed.

PESTICIDE STORAGE

Most pesticide applicators use existing buildings or areas within existing buildings for pesticide storage. Whether you choose a site to build a new storage area or use existing buildings, you need to consider several points:

- The site should be in an area where flooding is unlikely.
- It should be downwind and downhill from sensitive areas such as houses, ponds, and play areas.
- There should be no chance that runoff or drainage from the storage site could contaminate surface or groundwater.

Storage facility checklist:

- ❑ Is the facility separated from offices, workshops, and livestock areas?
- ❑ Is the facility separated from wells, streams, lakes, ponds, and wildlife?
- ❑ Is the facility separated from food and feed?
- ❑ Is the facility made of fire resistant building materials?
- ❑ Does the facility have impermeable flooring?
- ❑ Does the facility have liquid spill containment (berms to hold 25% of liquid storage)?
- ❑ Can the doors be locked?
- ❑ Is the facility fenced in?
- ❑ Are warning signs posted?
- ❑ Is a spill kit readily available?
- ❑ Are fire extinguishers readily available?
- ❑ Is personal protective equipment readily available?

PROTECT HONEY BEES FROM INSECTICIDES

Honeybees, wild bees, and many other insects are essential for pollination of tree-fruits. Poor pollination results in small or misshaped fruit, as well as reduced yields. Each flower must be visited by pollinators many times for adequate pollination to occur.

To avoid harming bees with insecticide treatments, remember these points:

- Do not spray when trees are in bloom
- Mow blooming weeds before treatment, or spray when the blossoms are closed
- Make applications in the early morning or late evening when bees are not foraging
- Always read the label before use, and use the pesticide least toxic to pollinators

If pesticides that are highly toxic to bees are used in strict accordance with label directions, little or no harm should be done to bees. Label statements on pesticides that are highly toxic to honeybees will include a caution statement such as: "This product is highly toxic to bees exposed to direct treatment or residues on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds if bees are visiting the treatment area."

EPA WORKER PROTECTION STANDARD (WPS) FOR AGRICULTURAL PESTICIDES

The Worker Protection Standard (WPS) contains requirements designed to reduce the risks of illness or injury resulting from occupational exposures to pesticide handlers and agricultural workers. Accidental exposure of agricultural workers and other persons to pesticides used in the production of agricultural plants on farms, nurseries, greenhouses, and forests are included under these regulations. WPS requirements include the following:

- Restricted-entry intervals (REIs) for most pesticides.
- Personal protective equipment (PPE) for handlers and early-entry workers.
- Decontamination supplies and emergency assistance.
- Pesticide safety training and posting.
- Revised labeling that includes specific WPS instructions.

For more complete information on reentry and farmworker protection standards, please contact your local Cornell Cooperative Extension office or the Pesticide Management Education Program, Comstock Hall, Cornell University, Ithaca, NY 14853, 607-255-1866. Online WPS information can be found at: http://www.epa.gov/agriculture/twor.html

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10. INTEGRATED PEST MANAGEMENT

(Adapted from Cornell Pest Management Guidelines for Commercial Tree Fruit Production, Agnello (ed.), 2008)

The goal of integrated pest management (IPM) is to maximize crop yields and value while minimizing risks of undesirable environmental impacts from pest management—an especially important goal for organic growers. Orchard design and decision-making steps that are included under IPM include selection of the most pest-resistant cultivars and rootstocks available for your region and market, understanding pest biology, monitoring pest populations, assessing the need for pest control, and reducing pest populations to acceptable levels through cultural, biological, mechanical, and chemical techniques that keep pest populations below economically injurious levels (the pest damage threshold). Pesticides are just one control tactic employed in IPM, and should only be used when other methods of control are impractical or unavailable. Pesticide use is thus minimized without jeopardizing crop quality or yield. Applying multiple control tactics also minimizes the chance that pests will adapt (acquire resistance) to any one tactic, while allowing growers to choose the most environmentally sound, efficacious, and economical pest control program for their situation.

Rather than total eradication of a pest, IPM stresses suppression of insect and disease populations to threshold levels that do not cause economic damage. For this to happen, it is essential that pests and natural enemies are accurately identified and their abundance is properly assessed in relation to established damage thresholds. In the case of insect pest biocontrol by natural enemies, a large enough pest population must exist in order to encourage their natural enemies to remain in the orchard and thereby suppress subsequent pest infestations. Achieving biocontrol therefore requires patience, some tolerance of risk, and continuous monitoring of both pests and beneficials during critical times of the growing season.

Furthermore, the biology and ecology of the pest(s) attacking a fruit crop will influence pest infestations and control tactics. For example, a lag time usually exists between the initial pest infestation and the response of beneficial predators that can suppress that specific pest. Additionally, factors such as weather and natural enemies often change from year to year, and therefore the choice of appropriate management tactics may need to be adjusted each season.

IPM COMPONENTS

MONITORING (SCOUTING). Scouting includes detecting, identifying, and determining the level of pest populations on a timely basis. Insect traps that involve mating (pheromones) or feeding attractants can often be used to detect pests and identify times when scouting should be intensified or control measures should be taken. Monitoring individual orchard blocks throughout the season is the most effective way of assessing the insect, disease, and weed situation and the need for chemical treatment in that block. Scientifically based, accurate, and efficient monitoring methods are available for many pests on fruit crops in NY. Brief descriptions of the recommended techniques follow.

FORECASTING. Daylength, precipitation, and accumulated temperatures above metabolic thresholds (known as growing degree days or heat units) are the driving factors in annual life cycles or phenology (developmental stages) of fruit trees and most pest species that depend upon fruit trees for their sustenance. Weather data and related information are essential to predict when specific pests will most likely occur, and how likely they are to cause crop damage locally or regionally. Weather-based pest forecast models for diseases and insects of many crops have been developed for NY. Local weather records are available through the NYS Network for Environment and Weather Awareness (NEWA) at http://newa.cornell.edu/.

However, while access to a computer network to obtain weather, regional insect, and disease forecasts is useful it is not essential. Simple and inexpensive weather monitoring equipment such as min-max thermometers, hygrometers, and rain gauges placed in orchards can be combined with established models to predict pest outbreaks quite reliably. Information on the potential for pest outbreaks generally can also be obtained from local Cooperative Extension offices, newsletters, and regional crop advisors. A simple internet search using the pest name will often yield multiple university sponsored Web site links with detailed pest identification and damage pictures, life-cycle and key control-point information, and predictive models for many orchard pests.

THRESHOLDS. Economic injury levels or damage thresholds are defined empirically as pest populations at a level that could cause crop or yield losses equivalent to the costs of control measures. Researchers determine damage thresholds through extensive field observations, by monitoring pest population levels in relation to observed crop damage and treatment costs. In mainstream (non-organic) orchards, using IPM thresholds as decision-making tools can reduce pesticide use by as much as 50%, cutting costs proportionally for growers. However, published thresholds from mainstream orchards may not be reliable in organic orchards. Organically approved materials tend to be more expensive and less effective than the synthetic pesticides used to develop threshold cost/benefit ratios. There is also a greater reliance upon biocontrol in organic systems. Even in non-organic orchards, suggested thresholds are not always applicable; nonetheless, they represent the best guidelines available to commercial growers concerned with effective and efficient management of tree-fruit pests. Knowledge of site-specific orchard factors and potential pests will help in applying damage thresholds.

MANAGEMENT TACTICS. Appropriate management tactics to control pests include cultural, biological, and physical controls, as well as chemical controls when needed. Taking advantage of some relatively simple and inexpensive pest management advice offered in this guide can result in significant savings to growers in terms of both pesticide use and crop loss. Often a thoughtful preventive measure taken before the pest becomes a problem can result in significant savings. In organic production there are few rescue treatments that can save a crop if initial controls fail.

RECORDKEEPING. Records kept from year to year on pest occurrence in orchards can be valuable tools for avoiding or anticipating pests in the future. They are also useful in justifying pesticide use in the organic system plan required by certifying agencies.

IPM TACTICS

A definitive trait of IPM is to integrate available pest management options. Some pests are problematic every year and usually require pesticide treatment either preventively or in response to observed threshold numbers during the season. However, infestations by these pests and the need for pesticide treatments can often be reduced through a combination of control tactics described below.

RESISTANT VARIETIES. The use of disease-resistant or tolerant cultivars and rootstocks is an essential component of organic orchard systems. It may be the simplest way to reduce costs and negative environmental impacts during the growing season. Detailed lists of disease-resistant cultivars and rootstocks are provided elsewhere within this guide.

CULTURAL AND PHYSICAL CONTROLS. Remove sites where pests overwinter, such as discarded fruit piles, mummified fruit on trees, suckers and damaged branches or trees, empty wooden bins, and alternate hosts for key pests (such as hawthorn, cedars, and wild apple trees), to minimize damage by insects and diseases.

Use techniques that expose pests to natural enemies or environmental stress, or that make the crop less susceptible to insects or diseases.

Ensure vigorous crop growth through proper nutrition and weed control to avoid stress that may predispose crops to attack by insects, diseases, or physiological disorders. Conversely, avoid over-fertilization that produces excessive new growth on trees, making them more likely to suffer aphid, mite, and fire-blight damage.

When irrigating, manage irrigation schedules based on soil water or pan-evaporation monitoring, to avoid long periods of leaf wetness, saturated soil, or high relative humidity that encourage disease development; avoid over-irrigation, to minimize Phytophthora root disease.

Actively promote healthy root development and function by improving soil drainage, correcting soil pH problems, and minimizing soil compaction by deep-ripping of compacted zones and keeping heavy machinery out of the orchard after heavy rains.

Avoid planting trees into areas of known, high pest pressure.

Orient and locate orchards to provide maximum air drainage and circulation.

BIOLOGICAL CONTROL. Conserve natural enemies of insect and mite pests by using fungicides and insecticides only when absolutely necessary. Whenever possible, use narrow-spectrum pesticides that are selective for specific pests and least disruptive to beneficial organisms.

CHEMICAL CONTROL. Use pesticides only when pest pressure, monitoring, economic thresholds, or disease forecasts indicate a need.

For more information, consult the Fruit IPM Web site at http://nysipm.cornell.edu/fruits/.

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11. INSECTICIDES

Organic pest control is based upon cultural, physical, and biological practices, combined with the use of NOP allowed pesticides as specified on the National List. Growers are encouraged to manage habitat to enhance natural enemies of pests and to safeguard and release biological control agents whenever feasible.

However, apples and other tree-fruits in the cool humid Northeast face arthropod and disease pressures that are much greater than most other crops, or than apple orchards in the arid Northwest. In a NY apple orchard the dynamic equilibrium between biocontrol agents and pest populations does not provide sufficient natural control of pests that infest the fruit (known as **direct** fruit pests). Surveys of abandoned orchards in the Northeast show that—in addition to fungal and bacterial disease damage to foliage and fruit—more than 95% of the apples in these orchards are severely damaged by pests such as plum curculio (*Conotrachelus nenuphar*), tarnished plant bug (*Lygus lineolaris*), apple maggot (*Rhagoletis pomonella*), codling moth (*Cydia pomonella*), oriental fruit moth (*Grapholita molesta*), and leafrollers (Tortricidae). When they are not disrupted by broad-spectrum pesticides, natural biological controls such as predatory wasps, syrphid flies, coccinellid beetles, and insectivorous birds can usually provide adequate control of insects and mites that infest the leaves and shoots of fruit trees (known as the **indirect** foliar pest complex). In a commercial setting these beneficial predators rarely provide suppression of direct fruit pests adequate enough to produce marketable fruit. For these reasons, pesticide applications are almost always necessary in Northeast organic apple orchards.

Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. The registration status of pesticides can and does change. Those pesticides meeting requirements in EPA Ruling 40 CFR Part 152.25(b) (also known as 25(b) pesticides) do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) Web site: http://magritte.psur.cornell.edu/pims/. **ALWAYS CHECK WITH YOUR CERTIFIER BEFORE USING A NEW PRODUCT.**

BOTANICALS

(Adapted from Kain and Kovach, 1997)
Naturally occurring pesticides that are derived from unmodified (not genetically engineered) plants or plant parts are commonly referred to as "botanicals". Botanicals have been used in agriculture for centuries. Along with arsenicals (lead arsenate insecticides) and other inorganic pesticides, botanicals were used extensively before the advent of the synthetic insecticides such as DDT and the organophosphates rendered these naturally derived pesticides "obsolete". Except for copper-based fungicides that are still used in fruit production (including certified organic crop production), heavy metal-based pesticides are now illegal for use in orchards. However, the botanical insecticides are still of interest and useful for organic pest management for a variety of reasons. Most botanicals are less toxic to humans, wildlife and the environment, and they degrade more rapidly than synthetic pesticides into harmless components in the orchard. For these reasons many botanicals are allowed in organic food production.

Because botanicals generally break down quickly after application, they may also be of use near harvest when insect control is needed but other materials should not be applied because of pre-harvest interval (PHI) restrictions. Rapid degradation also means that botanicals are less likely to cause environmental problems. However, botanical insecticides are not without concerns. They are usually broad-spectrum poisons that can be hard on beneficial insects. And, unlike "biological" pesticides and pheromones, some botanicals (e.g., rotenone) are acutely and chronically toxic to humans and other mammals. Moreover, the fact that botanicals break down rapidly in the environment also means that they provide very short-term pest control, so that sprays must be timed precisely to coincide with pest events, or be applied at lower pest populations, or be applied more frequently. The botanicals also tend to be relatively expensive. For all of these reasons, the use of botanical pesticides should be a last resort, not the first choice for controlling problematic pests that exceed their damage threshold after other more benign means of pest management have been employed in the orchard.

When botanicals are applied to crops as pesticides they are subject to the same federal, state, and organic regulations as all other pest control materials.

BACILLUS THURINGIENSIS VAR. KURSTAKI (*BT*)

A microbial insecticide derived from the *Bacillus thuringiensis* bacterium specifically for the control of Lepidoptera caterpillars. Both resting spores and a crystalline protein (an endotoxin) produced by the bacterium are considered to have insecticidal properties. To be effective, *Bt* must be ingested by the insect larvae. After the protein binds to the insect's gut, a pore is created through which the gut contents leak into the pest's body cavity and bloodstream. The insect ceases to feed and dies within a few days.

Bt is particularly useful for control of the obliquebanded leafroller, as well other leafroller (Tortricid) species. When applied repeatedly (i.e., every 7 to 14 days), it also provides some control of codling moth and other internal Lepidopteran apple pests. It is also useful for control of tent caterpillars (*Malacosoma americanum*) and green fruitworms (e.g., *Orthosia hibisci* and *Lithophane antennata*).

Since *Bt* must be eaten by the insect to be effective, it is very important to spray the undersides of leaves and concealed parts of the plant where larvae tend to feed. As with most insecticides, young larvae are generally more susceptible than older larvae. Early detection of a pest is critical for good control. The spray deposit may only last one to two days before it is washed off by rain or broken down by sunlight. Sticker substances that promote adherence to leaf surfaces and UV light inhibitors that protect *Bt* from photo-degradation may enhance efficacy.

Bt is harmless to humans, animals, and most beneficial insects (except certain butterflies), including the honeybee.

Some *Bt* products are manufactured by using genetically modified organisms and/or contain inert ingredients that are prohibited for use on organically certified farms. Organic growers must check the acceptability of specific *Bt* products prior to use.

Other *Bt* subspecies include:
- *Bt* var. kurstaki: used against caterpillars
- *Bt* var. aizawai: used against caterpillars
- *Bt* var. tenebrionis (also called *Bt* san diego): used against beetle larvae
- *Bt* var. israelensis: used against fly larvae (including fungus gnats, blackflies, and mosquitoes)

BEAUVERIA BASSIANA

Derived from the fungus, *Beauveria bassiana*, this microbial pesticide causes white muscardine disease of insects. It is a contact insecticide that germinates from spores on the exterior of the insect; the fungal hyphae penetrate through the insect cuticle and then grow rapidly inside the body. Insects die within 3 to 7 days, depending upon the number of spores in contact with each insect, its age and susceptibility, and environmental conditions. Insects may become infected by spray droplets that adhere to their bodies, by moving on a treated surface, or by consuming plant tissue treated with the fungus (although not a major method of uptake). Infected insect cadavers may serve as a source of spores for additional infections.

Beauveria spores are sensitive to sunlight, making them short-lived once sprayed. This pesticide is most effective when temperatures are cool to moderate, humidity is high, and water droplets are present. Good coverage is essential, with a large number of droplets containing high concentrations of spores. Care should be taken to apply the material to the undersides of the leaves or wherever the pest species is usually found. Applications should be made during the early growth stages of the insect, as it may take several days for the insect to die.

Numerous strains have been isolated, with differing efficacy. Commercial products are commonly labeled for a large number of pests including thrips, whiteflies, aphids, caterpillars, weevils, grasshoppers, ants, Colorado potato beetle, and mealybugs. However, in recent research trials *B. bassiana* products have not shown consistent efficacy against most tree-fruit pests.

***CYDIA POMONELLA* GRANULOSIS VIRUS** (Carpovirusine, CYD-X®, Virosoft[CP4])
Cydia pomonella granulovirus (CpGV) is an insecticidal baculovirus specific to the larval stage of the codling moth. The virus occurs naturally at sub-lethal levels within codling moth populations, but when virulent stains are applied at high rates significant population control may be obtained. The insect must ingest this biological insecticide. Once in the mid-gut, the viral occlusion bodies dissolve and release infectious virions. These enter cells lining the larval digestive tract, where they replicate and infect other tissues. This causes larva to stop feeding and die, usually within 3 to 7 days. After death, the larva disintegrates, releasing billions of new occlusion bodies that may infect other codling moth larvae.

Applications should take place around egg hatch prior to larval penetration of fruit. Coordinating spray timing with biofix (determined by pheromone trap monitoring) and degree-day modeling will provide the greatest efficacy. Best results are seen with repeated applications for each generation during the growing season. One manufacturer recommends at least two applications per codling moth generation—the first application at a high rate and subsequent applications at reduced rates. The virus can persist in soil, leaf litter, and in plant surfaces, allowing a local buildup of the virus for control of subsequent generations and possibly over the long-term. Because it may take several days from infection to larval death, superficial entry wounds ("stings") on the fruit may still occur after CpGV treatments. These small punctures usually heal over, sometimes with small round corky tissue.

Laboratory assays have shown that CpGV can infect closely related Lepidopteran species (caterpillars) including oriental fruit moth, but field applications have not shown CpGV to be an effective control for these other pests. The product contains live virus and should be stored under refrigeration. No adverse effects on fish, wildlife or beneficial organisms have been observed; it has a low bee-poisoning hazard.

GARLIC
Extracted from garlic (*Allium sativum*) cloves, these products are usually formulated into oil for use as a pest repellent. Although they may be labeled for a wide-range of insect pests, in research trials they have not been found to provide adequate control for key apple pests such as aphids, leafminers, mites, plum curculio, tarnished plant bug, obliquebanded leafroller, and internal Lepidoptera. Garlic extracts do not appear to interfere with beneficials such as *Typhlodromus pyri* and *Aphidoletes aphidimyza*. Garlic extracts may provide some bird repellency. Highly concentrated formulations and frequent (weekly) applications may be required.

HOT PEPPER (no products currently approved by OMRI)
Derived from fruits in the genus *Capsicum*, these products are used as an insect repellent. In research trials, they have been largely ineffective against most apple insect pests. However, the active compounds, capsaicinoids, appear to have some self-protective anti-fungal properties in pepper fruit that have been damaged by insects. Manufactured hot pepper materials may not have the same efficacy. Hot pepper may deter deer and other mammals if applied frequently, but it is not active against birds.

KAOLIN CLAY (Surround® WP)
A naturally occurring aluminosilicate clay mineral that is processed into uniformly sized particles for use as a plant protectant. Commercial formulations are applied in a water suspension. After the water evaporates, a dry white particle film layer is left on plant surfaces. Several modes of action have been suggested for insect control, including: 1) direct death by interfering with insect feeding or respiration; 2) physically blocking insects from reaching vulnerable plant tissue; 3) repelling or deterring insects by creating an unsuitable surface for feeding or egg-laying; 4) disrupting host-finding capability by masking plant tissue color and reflecting light; and 5) acting as an irritant to the insect, triggering an excessive grooming response. In regions with intense sunny days and high temperatures (e.g., Washington), kaolin clay may also reduce environmental stress caused by solar radiation and high temperatures, thereby reducing fruit sunscald and potentially increasing overall fruit size and yields. In the Northeast, these effects would only occur during abnormally hot and dry years. Kaolin clay is also used as an inert carrier in pesticide formulations, including many synthetic and microbial products. Non-agricultural uses of kaolin clay include use as an additive in food, medicine, cosmetics, and toiletries, use in ceramics and coated paper manufacturing.

In apple orchard research trials, kaolin clay has shown preventive efficacy against plum curculio, internal Lepidoptera such as codling moth, tufted apple bud moth (*Platynota idaeusalis*), lesser appleworm (*Grapholita prunivora*), and oriental fruit moth, leafrollers, leafhoppers, and apple maggot. In pears, it can suppress pear psylla (*Cacopsylla pyricola*). Kaolin clay has a low bee-poisoning hazard. However, research trials also show that repeated kaolin applications are harmful to beneficial species—particularly predatory mites, and therefore can bring about outbreaks of European red mites (*Panonychus ulmi*) and San Jose scale (*Quadraspidiotus perniciosus*).

Kaolin clay can be applied using most commercially available spray equipment, including tractor-powered airblast or hydraulic sprayers, and backpack units. The material must be well mixed prior to and during application, and inhalation of dust during mixing and application can cause lung damage. Use a respirator when handling. Before adding kaolin clay to spray equipment that has poor or no agitation it may be useful to pre-mix it in a 5-gallon bucket using a paint mixer driven by a power drill. Kaolin clay can be tank mixed with most pesticides, including soaps; it should not be mixed with copper, sulfur, or Bordeaux mixtures. Precipitation, curdling, uneven film formation, and changes in viscosity are signs of incompatibility.

Two to four applications at the maximal labeled rate may be required to establish a thorough coating on leaves and fruit; once that is accomplished, lower rates can be used. Frequent applications (5 to 14-day intervals, depending upon rainfall) are advised while there is active foliar and fruit growth, and during frequent rainfall. Applications can start prior to full bloom to suppress insects that emerge from bud scales or bark cracks, such as pear psylla. Spraying kaolin clay during bloom may adversely affect bee activity and interfere with pollination, and is therefore not recommended. The commercial formulation is partially rain-fast once dry; however, applications should not be made when leaves are wet or when the clay residue cannot adequately dry prior to rain.

Mid- to late-season kaolin clay applications may leave an unsightly white residue on harvested fruit. The residues may transfer to hands and clothes of fruit pickers, and although they are not toxic, pickers may find them disagreeable. Residues on the fruit will reduce marketability if not removed. Hand-wiping fruit with a damp cloth, or using commercial brush rollers with overhead water jets will physically remove most of the residue, except from the calyx basin and stem cavity of apples. Lowering dump tank water pH, adding detergents, and longer soaking periods may also aid in residue removal. Another approach that works best for late ripening apples is to discontinue kaolin clay applications several months prior to harvest, allowing for natural weathering of the residue.

NEEM (azadirachtin, neem oil, neem oil soap)
Neem products are botanicals derived from the neem tree (*Azadirachta indica*). The neem tree is native to southern Asia and can grow in most arid sub-tropical and tropical areas of the world. For centuries humans have used neem for medical, cosmetic, and pesticidal purposes. Neem tree seeds are crushed, and the pesticidal constituents are then extracted with water or a solvent such as alcohol. Azadirachtin is considered to be the primary active ingredient, although it is one of more than 70 compounds identified from neem trees. Neem acts primarily as an insect growth regulator, but also has anti-feedant, oviposition (egg-laying) deterrent, and repellent activity.

Neem pesticide products can be grouped into three classes: 1) azadirachtin-based products; 2) neem oil; and 3) neem oil soap. Neem cake is the residual seed meal remaining after extraction of oil from seeds, and is often sold as a fertilizer product. Neem products produced with different extraction techniques may result in different biologically active chemicals (or amounts of chemicals) present in a product. Thus, product efficacy may vary from one lot to another, as with other botanicals.

Neem has been tested for control of a large number of insect and mite species. On fruit crops, neem has shown some efficacy against aphids, including rosy apple aphid (*Dysaphis plantaginea*), woolly apple aphid (*Eriosoma lanigerum*), tarnished plant bug, some leafhoppers, pear psylla, and spotted tentiform leafminer (*Phyllonorycter blancardella*). Results have been mixed against white apple leafhopper (*Typhlocyba pomaria*), the internal Lepidopteran complex, and mites. Neem has little efficacy for control of beetles, flies, leafrollers, psyllids, and scale. Neem has also been reported to have nematode repellency.

Repeated applications at short intervals are necessary for acceptable control of susceptible pests. Neem products are relatively expensive, and the cost will be amplified by the need for repeated applications. Azadirachtin is short-lived in the orchard agroecosystem and its mammalian toxicity is low. It is relatively nontoxic to beneficials (including the predatory mite *Amblyseius fallacis*), but it is highly toxic to fish and aquatic invertebrates, as well as to bees that are directly exposed. Neem is relatively non-toxic when dried, and is therefore categorized as having a moderate bee-poisoning hazard.

NICOTINE COMPOUNDS
This botanical insecticide is derived from the tobacco plant, and was once widely used by organic and conventional growers. It is a potent carcinogen and under NOP regulations, may **not** be used in organic crop production.

OILS: DORMANT, SUMMER, AND STYLET (including petroleum derivatives, fish oil, vegetable oils, and essential plant oils)
Pesticidal petroleum oils are derived when crude oil is refined by fractionation in a distillation tower. Under the NOP, only oils with a narrow range of distillation (i.e., half of the material has a boiling point between 415 °F and 440 °F) may be used. These highly refined oils have a unsulfonated residue content greater than 92%, which decreases their phytotoxicity. Most such oils can be used during the dormant and/or growing season for insect or disease control.

Organically permitted oils can also be derived from vegetable and fish sources. Plant and fish oils are chemically classified as lipids containing fatty acids, alcohols, glycerides, and sterols. The chemical and physical properties of plant and fish-derived spray oils are determined largely by the structure of their fatty acids. Plant oils are primarily derived from seeds (e.g., soy and canola) while fish oils are by-products of the fish processing industry. Although there is interest in using botanical and fish oils as pesticides, compositional variability has limited their use and made reliable application guidelines difficult to implement.

Essential plant oils, including those derived from wintergreen, clove, pine needles, and rosemary may be exempt from EPA label registration because they are defined as minimum risk pesticides. These products are generally pressed or otherwise extracted from leaves, stems, or flowers rather than seeds, and are often formulated with mineral oil. Little reliable information is available regarding the modes of action or efficacy of these products. Manufacturer's efficacy claims for control of a wide-range of insect, disease, and weeds have not been substantiated in research trials of most essential plant oils.

Oils are physical pesticides, effective only when they form a film over eggs, spores, or soft-bodied insects. Thus, their mode of action is usually suffocation, by which respiratory or gas-exchange channels of pests is blocked. In some cases, oils may also act as poisons, interacting with insect fatty acids and interfering with normal metabolic functions. They can also be disruptive to feeding insects, a mechanism that is particularly important in controlling aphids, which often transmit plant viruses. Plant- and fish-derived oils have similar physical modes of action. Oils are often added to other pesticide products to improve uptake, retention, or efficacy. For example, a 1% (v/v) dormant oil solution will improve the retention and uptake of copper when used as a bactericide, fungicide or plant micronutrient in prebloom orchard sprays. In this context, oils can be considered spray adjuvants, even though they have pesticidal activity on their own. Thorough spraying and complete coverage of the whole tree are necessary for oils to provide effective pest control.

Petroleum-based oils are applied in the dormant and/or prebloom period to control certain scales and other insects, as well as the European red mite. A prebloom oil is recommended at 2% (v/v) solution ratio for the half-inch green to tight cluster growth stage of apple bud development. A concentration of 1% (v/v) is advised for the tight cluster to the pink growth stage because mite eggs are more susceptible to the effects of petroleum-based oils as they approach hatch, and the potential for oil phytotoxicity to flowers and foliage also increases. In apple orchards that have been sprayed with a prebloom dormant oil spray, mite populations can be effectively managed when the oils are applied at petal fall and in subsequent cover sprays at rates of 1 to 2% (v/v). However, different apple cultivars vary in their sensitivity to foliar damage from summer oil sprays. Oils may also provide some control of San Jose scale, spotted tentiform leafminers, pear psylla, and a few Lepidopteran pests. Oil has a low bee-poisoning hazard. Mites and insects are generally unable to develop resistance to oil.

Follow label recommendations to minimize oil phytotoxicity. Slower oil evaporation will increase the chance of phytotoxicity. Oil applications are not recommended on very humid days (>65% relative humidity), or at temperatures above 90 ºF and below 40 ºF. Oil should **never** be mixed with fungicides containing sulfur or copper when foliage is present. Do not apply oil within two weeks of a sulfur application. Apple cultivar, moisture stress, and spray drying conditions should be taken into account to minimize possible damage to foliage and fruit finish. Summer oils can increase the incidence of scarf-skin, especially for Red Rome, Jonathan, and Stayman.

To avoid phytotoxicity problems with oil on apples:

- Use oil in a dilute application, not in tank-concentration mixtures
- Do not exceed an oil concentration of 1% (v/v) after the tight cluster growth stage
- Do not apply oil when temperatures exceed 90 ºF
- Adjust sprayer nozzles to avoid large droplet sizes when applying oil
- Ensure good tank agitation while mixing and applying oils
- Make sure oil is completely emulsified in the spray mixture

In recent years, fish oil has been used in combination with liquid lime sulfur (LLS) for chemical apple fruit thinning (see section on Crop Load Management). It is likely that any oil used in combination with LLS will cause some thinning response.

PIPERONYL BUTOXIDE (PBO)

This botanical insecticide, derived from the Brazilian sassafras plant, may **not** be used in organic crop production under the NOP because it is considered a synthetic material as formulated. It is often added to products such as rotenone and pyrethrum because it has synergistic effects. These products would therefore also be prohibited under the NOP. Acutely, it has minimal toxicity but it may be chronically toxic to humans and wildlife in high doses.

PHEROMONES FOR MATING DISRUPTION

Some synthetic pheromones are NOP and OMRI approved, although growers will need to check product labels and with their certifier to ensure that specific products are compliant with NOP rules. Pheromones can be used to disrupt the chemical communication and behavior of certain insect pests, which prevents them from mating and producing offspring that injure the crop. Pest-specific pheromones are released from dispensers or microcapsules placed or sprayed in the orchard before the initiation of flight, and can reduce or in some cases eliminate the need for supplementary insecticidal sprays. When applied in sufficient numbers and locations, pheromones prevent male and female insects of the same pest species from locating one another and mating within the orchard, thus minimizing oviposition and egg hatch. This approach works best in large (5 acres or more), rectangular plantings, where the pheromone concentration in the air is more uniform and can be maintained at a high level. Pheromone mating disruption is difficult to implement in Northeastern orchards because there are many alternate hosts plants in the surrounding woods or abondoned orchards which can support target pest populations. Females that have mated outside the orchard will then still be able to find their way into the orchard. Border sprays are often necessary in orchards adjacent to sources of adult immigration, or in other high pressure situations.

Pheromones can also be mixed with an insecticide in a paste or gel to "attract and kill" specific pests. As of this writing, no such materials have been approved for organic orchards. Synthetic pheromone lures are also used in traps for monitoring purposes, and this practice is generally permitted under NOP rules.

PYRETHRUM/PYRETHRIN
Produced in pyrethrum daisy (*Chrysanthemum cinerariaefolium*) flowers, and closely related species (e.g., *C. coccineum and C. marshalli*), this botanical contains a mix of six active pyrethrin ester compounds. Pyrethrum is the forerunner to the widely used synthetic pyrethroid insecticides, but the latter is not approved for use in organic production. The pyrethrum daisy is native to Europe, and is also commercially grown in West Africa, Southeast Asia, and Oceania. Pyrethrum is a fast-acting broad-spectrum contact insecticide that paralyzes insects by stimulating repetitive nerve discharges and convulsions. Some insects are able to recover after the initial knockdown if the dose is low.

The label for one organic formulation claims that the product controls more than 100 different insect species. Used correctly, pyrethrum is moderately to highly effective against aphids, apple maggot, European apple sawfly (*Hoplocampa testudinea*), leafhoppers, Lepidoptera larvae (including codling moth), mealybugs, pear psylla, plum curculio, many of the true bugs (Hemiptera), and flower thrips (*Frankliniella tritici*). However, frequent repeat applications of pyrethrum are required because of its rapid photo-degradation and short residual activity in the orchard. This product is potentially very useful in the years when the trees are first establishing, when foliar pests are most problematic and can stunt tree growth.

Pyrethrum is a non-discriminating insecticide and therefore lethal to many beneficial insects, including honeybees and natural biocontrol agents of foliar pests such as aphids and phytophagous (leaf-damaging) mites. Both target and non-target effects of pyrethrum need to be carefully considered prior to use. However, because of its shorter residual activity period, pyrethrum is considered less harmful to beneficials than the related synthetic pyrethroids.

Pyrethrins (the active chemicals) are rapidly broken down by sunlight. Therefore, it is recommended that pyrethrum be applied before dawn or in late evening when the target pests are active and present in the orchard, and UV light is minimal. Use of UV-inhibiting adjuvants may allow for a longer period of residual activity. Pyrethrum is broken down rapidly by both acid and alkaline conditions in the spray mix water, and should not be tank mixed with liquid lime sulfur, sulfur, or soap solutions. Pyrethrum breaks down quickly in the environment and has negligible residual activity in soil or groundwater. It has low chronic toxicity to humans and other mammals; however, it is toxic to fish and birds.

QUASSIA (no products currently approved by OMRI)
The active ingredient, quassin, is derived from plant species in the Simaroubaceae family, particularly the Caribbean species, *Quassia amara* and *Picrasma excelsa*. It has been reported to have very good efficacy against European apple sawfly, but further testing is needed.

ROTENONE (no products currently approved by OMRI)
Rotenone is derived from the plant roots of numerous species in the *Derris* and *Lonchocarpus* genera from Southeast Asia, and Central to South America. In the past, organic growers used rotenone extensively, and it is still allowed under the NOP rules. However, rotenone has greater acute mammalian toxicity than many synthetic insecticides, and chronic exposure to rotenone can cause neurotoxic symptoms similar to Parkinson's disease. For these reasons, US organic growers have discontinued use of rotenone, and OMRI does not list any approved formulations.

RYANIA (no products currently approved by OMRI)
Ryania is derived from the roots and stems of *Ryania speciosa*, a plant native to northern South America. The active ingredient, ryanodine, acts as both a stomach and nerve poison on target insects. In research trials it has provided excellent control of the internal Lepidoptera complex (codling moth, oriental fruit moth, and lesser appleworm), as well as aphids, white apple leafhopper and spotted tentiform leafminer. It does not appear to be effective against plum curculio or apple maggot. It is more persistent than rotenone or pyrethrum, and is more selective. It is generally not harmful to pest predators and parasites, but it is somewhat toxic to insect predators *Atractotomus mali* and *Diaphnocoris* spp. It is also toxic to fish.

SABADILLA (CEVADILLA) (no products currently approved by OMRI)
Sabadilla is derived from the seed of a Mexican lily, *Schoenocaulon officinalis*. The active ingredient, veratrine, acts as a nerve toxin and is sometimes used for control of external parasites on humans and domesticated animals. In apples it may control potato leafhopper and is somewhat effective against tarnished plant bug. It is extremely toxic to the predatory mite *Typholdromus pyri*, but appears to have minimal effect on other beneficial insects. Sabadilla is toxic to honeybees on contact, but has minimal residual activity. Sabadilla is less acutely toxic to mammals than rotenone or pyrethrum.

SOAPS (INSECTICIDAL)

Insecticidal soaps are concentrates of long-chain fatty acids manufactured to provide some insect control without causing phytotoxicity. Not all soaps have these properties, thus homemade soap sprays are not recommended. Insecticidal soaps smother soft-bodied pests and disrupt their membrane function on contact. After insecticidal soaps dry on the plant surface, they become ineffective. Uniform drying conditions are required to prevent droplet residues on the fruit surface. Early morning or evening applications, when air temperatures are cool, provide the best drying conditions. Soaps may also function as a wetting agent or surfactant, reducing the surface tension of water, and allowing other spray materials to better cover plant surfaces by penetrating into small crevices with less "beading up". Under NOP regulations some soaps are permitted as adjuvants, but none are currently permitted for use as a fungicide or herbicide.

Insecticidal soaps are most effective against soft-bodied arthropods such as aphids, mealybugs, and psyllids. They can also provide some suppression of pear psylla when used in a season-long spray program, but their residual activity may be less than a day. Soaps have little efficacy against insect eggs. Soap products can be toxic to soft-bodied beneficial insects, some predatory mite species, and ladybeetle larvae that are directly covered with the spray, but soaps have a low bee-poisoning hazard.

In organic systems, soaps might have the greatest utility during tree establishment when moderate to severe aphid infestations can stunt the growth of young trees. For mature trees, under organic management, natural predators usually can suppress aphid populations.

Under NOP regulations ammonium salts of fatty acids can be used as a mammal repellant, provided there is no contact with edible portion of the crop, or with soil. They slowly release an ammonia smell that may deter deer and rabbits.

SPINOSAD (Entrust® Naturalyte® Insect Control, GF-120® NF Naturalyte® Fruit Fly Bait)

Spinosad is a naturally derived insecticide composed of spinosyns in alpha and delta stereoisomer forms, produced by aerobic fermentation of the actinomycete species, *Saccharopolyspora spinosa*. This rare bacterium was originally found in soil samples collected outside a Caribbean rum distillery. Spinosad acts as both a contact and stomach poison by over-activating the insect's nervous system and causing loss of coordination. Insects die of exhaustion within one to two days. Without a penetrating adjuvant, there is minimal movement of spinosad into the leaf surface. Depending upon light conditions and rain, spinosad residues will last from 2 to 14 days. The use of a UV protecting adjuvant will extend its effective period.

Spinosad is a fast-acting, somewhat broad-spectrum material that has greatest activity against insects in the Lepidoptera (caterpillars), Coleoptera (beetles), Thysanoptera (thrips), and Diptera (flies) orders. It is highly effective for obliquebanded leafroller control, but also has some activity against the internal Lepidoptera complex. When a leaf penetrant is used, spinosad can control spotted tentiform leafminer. It is also effective against apple maggot and cherry fruit fly, and formulations with attractant bait (e.g., GF-120) can be used at very low rates to provide good control of fruit flies. Spinosad is not effective at controlling mites at normal use rates.

Spinosad is minimally toxic to birds, fish, aquatic invertebrates, mammals, and most beneficial insects, but spray droplets can harm *Trichogramma* wasps and other parasitoids. It has a low bee-poisoning hazard once dried. Allow three hours of drying before bees are active. It can be tank mixed with lime sulfur.

Populations of diamondback moths (*Plutella xylostella*), flower thrips, and houseflies have recently become resistant to spinosad. The extensive and repeated use of spinosad by organic fruit growers in arid regions may eventually lead to pest resistance to this very useful insecticide in US orchards. It is therefore important to use resistance management practices such as avoiding applications on consecutive generations of the same pest, using alternate pesticides for control, implementing cultural controls, and following manufacturer's recommendations for maximum yearly application rates and frequencies.

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12. COMMON APPLE ARTHROPOD PESTS

The many arthropod (insect and mite) pests that feed on apple trees or apple fruit can be categorized into internal fruit feeders, external fruit feeders, trunk and branch feeders, and foliar feeders. Organic apple growers will likely encounter some of these pests on an annual basis. Other pests will need to be controlled on an irregular basis. There are also some locations where certain pests may exist in greater numbers because of unmanaged trees nearby. Early detection through scouting and monitoring will help the organic grower take appropriate control measures before the damage becomes severe.

Below we synthesize the available information on organic control strategies, which may work for each pest or type of pest. However, given that only a limited number of replicated experiments have been conducted in organic orchards, and that even fewer studies have attempted to implement multifaceted approaches to pest control, the information provided here should be used only as a guide while developing a control strategy appropriate for your situation.

Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. The registration status of pesticides can and does change. Those pesticides meeting requirements in EPA Ruling 40 CFR Part 152.25(b) (also known as 25(b) pesticides) do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) Web site: http://magritte.psur.cornell.edu/pims/. **ALWAYS CHECK WITH YOUR CERTIFIER BEFORE USING A NEW PRODUCT.**

The following information should be used in conjunction with other resources that contain more detailed information about the identification, biology and IPM strategies of these arthropods, such as the NYS IPM Fact Sheets available at http://www.nysipm.cornell.edu/factsheets/treefruit/default.asp, the Pest Management Guidelines for Commercial Tree-Fruit Production, and the *Tree Fruit Guide to Insect, Mite, and Disease Pests and Natural Enemies of Eastern North America*.

INTERNAL (DIRECT) FRUIT FEEDERS

APPLE MAGGOT *(Rhagoletis pomonella)*

IPM strategy: Sticky red sphere or yellow board traps can be used for monitoring adults to detect potentially damaging numbers. Monitoring should begin on or before July 1 in NY.

Biological: Biological control is usually not effective against apple maggot, and little work has been done to conserve or augment natural enemies. Several species within the parasitic wasp family Braconidae may suppress apple maggot populations in native habitats on hawthorn, but they are ineffective in apple orchards. This is possibly because these parasitoids have small ovipositors that are unable to reach larvae burrowed deeply inside apple fruit.

Cultural: Intensive trapping to reduce numbers to acceptable levels may be practical in smaller plantings. Using this strategy, traps usually consist of a sticky red ball placed in close proximity to a small vial of apple fruit essence (a mixture of esters such as butyl hexanoate, hexyl butyrate, and others). The sticky balls need to be cleaned every 7 to 10 days, and the sticky material (e.g., Tanglefoot, Grand Rapids, MI) should be periodically reapplied. For small orchards, 1-2 traps per tree may suffice. For larger plantings, traps should be placed about every 30 feet around the orchard perimeter of the orchard in the upper two-thirds of the canopy. Branches should be cleared at least one foot around the trap. Perimeter trapping can reduce the influx of apple maggot but probably will not completely halt the invasion. Other cultural methods include removing infested fruit from the orchard floor and removing unmanaged apple trees, as well as host plants such as hawthorns and dogwoods within 350 feet of the orchard. Apple maggot flies can travel more than 2000 feet, but it is usually not practical to remove all plant hosts from such a large area.

Pesticidal: Kaolin clay (complete plant coverage is required prior to infestation and reapplication will be needed every 5 to 14 days depending upon rainfall; residue from these late season sprays may remain on fruit until harvest); pyrethrum; spinosad; spinosad with bait.

EUROPEAN APPLE SAWFLY *(Hoplocampa testudinea)*

IPM strategy: Prior to bloom, monitor adults with non-UV reflective white sticky boards that mimic blossom color.

Biological: As this is a non-native species, few natural enemies exist in Northeastern orchards.

Cultural: Remove infested or dropped fruit. Trap out with white sticky boards.

Pesticidal: Kaolin clay; pyrethrum; spinosad (there are no OMRI approved spinosad products currently labeled for European apple sawfly). Many insecticides used for European apple sawfly will also adversely affect honeybees, which are closely related to sawflies.

PLUM CURCULIO *(Conotrachelus nenuphar)*

IPM strategy: Once daytime and evening temperatures exceed 60 ºF, regularly monitor fruit for fresh damage. Placing Tedders pyramid traps baited with plum essence or benzaldehyde at the orchard border where previous damage has been noted may provide an early warning of plum curculio emergence. A degree-day model can be used to predict the oviposition period when insecticide protection will be required. However, this model assumes that applied pesticides reduce plum curculio populations in the orchard to levels below damage thresholds, and that the final insecticide spray has 10 to14 days of residual activity. These assumptions are not usually valid in organic orchards.

Biological: In research trials, the entomopathogenic fungus *Beauveria bassiana*, and nematodes such as *Steinernema carpocapsae* and *S. riobrave*, have shown some efficacy against plum curculio, but delivery methods, application timing, and seasonal variability are still uncertain. Additionally, the currently available commercial products or biocontrol inoculations are prohibitively costly for larger orchards. Livestock animals known to consume plum curculio include chickens and pigs. However, grazing animals in an orchard may not be compatible with NOP manure management regulations. These livestock pest control systems for curculio require further study.

Cultural: Remove damaged apples from the orchard floor, because they may contain viable eggs that will emerge as adults in late summer. Eggs laid in apples that remain on the tree have a low survival rate. A high density of baited traps around the orchard perimeter may reduce the number of plum curculio entering the orchard. Due to the expense involved, trap-out may be best suited to smaller orchards.

Pesticidal: Kaolin clay (full plant coverage is needed from insect emergence through the end of the oviposition control period); pyrethrum (repeated applications required). One approach is to obtain full kaolin clay coverage and then apply pyrethrum to the entire orchard on the first few warm (>70 ºF) evenings to decrease the plum curculio populations. Another approach, where plum curculio is pushed from the inner area of the orchard with kaolin clay and pulled toward exterior rows with a chemical attractant, has been termed the "push-pull" strategy. Under this program, pyrethrum applications are carefully timed to coincide with the aggregation of plum curculio in border rows. Spraying intentionally planted "trap" plants near the orchard has not shown significant reductions in plum curculio damage. The success of these cultural tactics is still under study and will depend upon the specific orchard conditions, pest populations, and weather in each season.

INTERNAL LEPIDOPTERA, INCLUDING:
CODLING MOTH *(Cydia pomonella)*
LESSER APPLEWORM *(Grapholita prunivora)*
ORIENTAL FRUIT MOTH *(Grapholita molesta)*

IPM strategy: Monitor adults with pheromone traps and use degree-day developmental models to precisely time control measures. Specific pheromones and developmental models are available for each species.

Biological: Mass-released parasitoid *Trichogramma* wasps (e.g., *Trichogramma minutum* and *T. platneri*) have been shown to reduce codling moth damage in West Coast apple orchards. However, *Trichogramma* releases have not been cost-effective for internal Lepidoptera under East Coast conditions. Likewise, the entomopathogenic nematodes (*Steinernema feltiae* and *S. carpocapsae*) have shown potential for control of overwintering cocooned larvae in other apple production regions, but technical advances are needed to make them a viable option in the Northeast.

Cultural: Remove damaged apples from trees and the orchard floor, as they may contain viable larvae that emerge later in the season.

Pesticidal: *Bt*; *Cydia pomonella* Granulosis Virus, kaolin clay, pheromone mating disruption (there are species-specific products, as well as some products that contain the pheromones for multiple species), summer oils. Kaolin clay will provide some deterrence of the first generation, but will not likely be sufficient as a stand-alone measure in high-pressure orchards. Likewise, *Bt* will only provide control of internal Lepidoptera in low to moderate population densities. Along with careful monitoring, a combination of sprays, pheromones, biological controls, and sanitation will likely be necessary to control this pest group.

EXTERNAL (DIRECT) FRUIT FEEDERS
OBLIQUEBANDED LEAFROLLER *(Choristoneura rosaceana)*

IPM strategy: Monitor adults with pheromone traps and use degree-day developmental models to time control measures. Specific pheromones and developmental models are available for this and other leafroller species.

Biological: Numerous species of parasitic wasps (e.g., *Trichogramma platneri*), tachinid flies, and other species have limited ability to control leafrollers in apple orchards through controlled releases and habitat conservation. However, when used alone biological control only provides partial reduction in leafroller populations.

Cultural: Reduce feeding sites by thinning fruit and removing water-sprouts in midsummer.

Pesticidal: *Bt*, pesticidal oil, pheromone mating disruption, spinosad. For *Bt* products, greater efficacy against summer brood larvae has been achieved with 2 to 4 sprays at low rates on a 7-day interval, starting 10 to12 days after first adult catch. *Bt* products are more effective when consumed by smaller larvae.

TRUE BUGS, INCLUDING:
MULLEIN PLANT BUG *(Campylomma verbasci)*
TARNISHED PLANT BUG *(Lygus lineolaris)*
GREEN STINK BUG *(Acrosternum hilare)*
BROWN STINK BUG *(Euchistus servus)*
DUSKY STINK BUG *(Euchistus tristigmus)*
BROWN MARMORATED STINK BUG *(Halyomorpha halys)*

IPM strategy: In apples, thresholds have been developed for tarnished and mullein plant bugs, but scouting and identification are useful for all species. White sticky cards can be used to trap tarnished plant bugs. For mullein plant bugs, during bloom, tap two-year-old flower-bearing shoots over a black beating tray, especially in problem spots and those in proximity to areas containing mullein (*Verbascum* spp.) and evening primrose (*Oenothera* spp.) plants. Plant bugs are difficult insects to control in organic systems because: 1) organically approved pesticides for this group of insects are unable to reduce pest populations below economic injury levels for more than a few days after application; 2) different species of this insect group will emerge throughout the growing season, and many will remain active for the entire season; 3) they have numerous alternate hosts, many of which are commonly found in the orchard ground cover; 4) they are highly mobile; and 5) they are predacious on other apple pests such as aphids and mites, thus their control may contribute to other pest problems.

Cultural: Elimination of alternate host broadleaf weeds such as legumes, mullein, common chickweed (*Stellaria media*), dandelion (*Taraxacum officinale*), pigweeds (*Amaranthus* spp.), common lambsquarters (*Chenopodium album*), plantains (*Plantago* spp.), goldenrods (*Solidago* spp.), and asters (*Aster* spp.) is not practical in organic systems. However, keeping hay (alfalfa or clover) and strawberry fields away from orchards might help reduce plant bug populations. Also, avoid mowing the orchard groundcover from bloom to petal fall because this might force adult plant bugs into the trees.

Biological: *Peristenus digoneutis*, a parasitic wasp native to northern Europe, has been introduced to the Northeastern US by USDA staff with the primary intent on reducing tarnished plant bug damage in alfalfa fields. It appears that tarnished plant bug populations in apple orchards have also been reduced by this introduced beneficial. It is very difficult to rear *P. digoneutis*, so commercial availability of this parasitoid is unlikely. However, it is evidently dispersing naturally, and most suitable areas may eventually benefit from self-sustaining, natural populations of this parasitoid. Two related native species, *P. pallipes* and *P. pseudopallipes*, have also been found to inhabit NY apple orchards and may contribute to natural biocontrol.

Pesticidal: neem; pyrethrum.

ROSY APPLE APHID *(Dysaphis plantaginea)*

See aphids below.

TRUNK AND BRANCH FEEDING PESTS
BORERS, INCLUDING:
DOGWOOD BORER *(Synanthedon scitula)*
AMERICAN PLUM BORER *(Euzophera semifuneralis)*

IPM strategy: Flying adults can be monitored with pheromone traps. Inspect graft unions and burr knots for larvae and frass fecal pellets.

Biological: The larval stage of these insects is usually well protected within the tree. However, research is currently evaluating the placement of entomopathogenic nematodes near expected sites of borer activity with the use of pastes and trunk wraps.

Cultural: Minimize trunk damage caused by mechanical implements such as mowers or cultivators. Exclude borer larvae by mounding soil around the graft union to cover burr knots and other preferred entry sites (but not so high as to allow scion rooting); install mosquito netting around the trunk, or cover the trunk with white latex paint or clay. Keep the area around tree trunks weed-free and open to sunlight to decrease burr-knot formation. A small diameter soft metal skewer (e.g., 14-guage single strand bare copper wire) can be inserted into the borers feeding tunnels to manually kill larvae in small plantings.

Pesticidal: Pheromones for these borer species have been difficult to manufacture without antagonistic chemicals; however work currently being done in this area could make pheromone mating disruption or attract-and-kill products available in the near future.

WOOLLY APPLE APHID *(Eriosoma lanigerum)*

See aphids below.

FOLIAR FEEDING
APHIDS, INCLUDING:
GREEN APPLE APHID *(Aphis pomi)*
ROSY APPLE APHID *(Dysaphis plantaginea)*
SPIREA APHID *(Aphis spiraecola)*
WOOLLY APPLE APHID *(Eriosoma lanigerum)*

IPM strategy: Thresholds have been developed for green apple aphid and rosy apple aphid. Check for woolly apple aphid colonies on pruning scars and on interior and upper branches beginning in early to midsummer. Scouting and identification can be done for most species.

Biological: Aphids have numerous natural predators, including species of lady beetles, hover flies, gall midges (*Aphidoletes* sp.), and glassy-winged mirid bugs (*Hyaliodes vitripennis*). In organic orchards, these biocontrol agents can be adversely affected by pyrethrum, sulfur, lime sulfur, and copper applications. However, when properly conserved this natural enemy complex will keep aphid populations at acceptable levels in most years. Biocontrol agents tend to move toward preferred food sources; therefore intentional localized releases of lady beetles or other insects for aphid control may not result in sustained populations of these biocontrol insects on the target plant.

Cultural: Remove alternate hosts for rosy apple aphid, especially narrow-leaved plantain and dock (*Rumex* spp.). Use woolly apple aphid resistant rootstocks (see rootstock table).

Pesticidal: Insecticidal soap, neem, pesticidal oil, pyrethrum (will also reduce natural predator populations).

JAPANESE BEETLES (*Popillia japonica*)

IPM strategy: Pheromone traps can be hung in the orchard in early July to detect Japanese beetle presence. However, these insects are easily detected without traps. Except on newly planted or weakly growing apple trees, Japanese beetle feeding will rarely cause sufficient leaf damage to seriously harm tree health or productivity.

Biological: Milky spore disease caused by soil-dwelling bacteria *Paenibacillus popillae* and *P. lentimorbus* is often promoted as a biocontrol agent against Japanese beetle larvae. However, cool fall and spring soil temperatures—when larvae are present in the soil—reduces the efficacy of milky spore bacteria. Most NY orchards are above the northern geographic range for obtaining effective Japanese beetle control with applied milky spore products. Additionally, it may take up to five years to build up an effective milky spore population in the soil. Commercial milky spore products have generally not been effective against Japanese beetles in NY. Other biocontrol agents, nematodes in particular, have shown promise under controlled conditions for Japanese beetle suppression, but commercially available products have not been consistent in formulation or efficacy under field conditions.

Cultural: Trapping out Japanese beetles with pheromone traps is generally not effective, because the traps tend to attract beetles from the surrounding area. Some cultivars (e.g., Liberty) appear to be preferred hosts for Japanese beetles.

Pesticidal: Kaolin clay; pyrethrum (will only provide temporary population reduction).

LEAFHOPPERS, INCLUDING:

POTATO LEAFHOPPER (*Empoasca fabae*)

WHITE APPLE LEAFHOPPER (*Typhlocyba pomaria*)

IPM strategy: Monitor the populations on leaves, especially for young trees.

Biological: There are many natural enemies of leafhoppers, but none adequately control these pests in orchard situations. Controlled releases of beneficials including green lacewings (*Chrysopa* spp.) have not provided satisfactory control in research trials.

Cultural: Potato leafhoppers will migrate into orchards from recently cut hay fields, so attempt to keep these farming operations in separate locations. Potato leafhoppers are not usually a serious problem except on newly planted or otherwise stressed apple trees.

Pesticidal: Kaolin clay or pyrethrum (the latter provides only temporary control).

MITES, INCLUDING:

EUROPEAN RED MITE (*Panonychus ulmi*)

TWO SPOTTED SPIDER MITE (*Tetranychus urticae*)

IPM strategy: Sequential monitoring schemes have been developed with specific thresholds for June, July, and August sampling periods. Avoiding excess vegetative tree growth due to high nitrogen supply will reduce mite fecundity and population increase.

Biological: The predaceous mite *Typhlodromus pyri* is native to apple-growing regions in western NY, and when managed correctly it can successfully control populations of European red mite in commercial apple orchards. Other predatory mites (including *Amblyseius fallacis*, *T. occidentalis*, *T. vulgaris*, and *A. cucumeris*), glassy-winged mirid bugs (*Hyaliodes vitripennis*), the spider mite destroyer (*Stethorus punctum*), and several other species of lady beetles are also natural enemies of phytophagous mites. When predator mite populations are encouraged and properly conserved, additional applications of miticides may not be required after the delayed dormant oil application.

Cultural: Make use of "seeding" releases of predator mites; refer to NYS-IPM Pub. 215, *Achieving Biological Control of European Red Mite in Northeast Apples: An Implementation Guide for Growers* available at http://www.nysipm.cornell.edu/factsheets/treefruit/pests/erm/erm.asp.

Pesticidal: Pesticidal oils (starting with a delayed dormant application); kaolin clay will usually suppress both phytophagous and predatory mites possibly increasing pest mite populations.

SPOTTED TENTIFORM LEAFMINER (*Phyllonorycter blancardella*)

IPM strategy: Populations can be monitored with pheromone traps. Degree-day phenological development models are available to estimate the emergence of the second generation. Thresholds are based upon sampling leaves for mines, and vary as the growing season progresses.

Biological: Parasitoid wasps, particularly *Pholetesor ornigis*, are very effective at controlling spotted tentiform leafminer populations. If natural enemies are conserved, biological control of this pest may be sufficient.

Cultural: Maintain healthy trees and avoid over-cropping trees, because stressed trees have a lower threshold for leafminer damage.

Pesticidal: Neem, or spinsosad (with the use of a leaf penetrant).

TENT CATERPILLARS, INCLUDING:
EASTERN TENT CATERPILLAR (*Malacosoma americanum*)
FOREST TENT CATERPILLAR (*Malacosoma disstria*)

IPM strategy: Scout for caterpillar emergence and silken tents starting just before bloom and continuing through the summer.

Biological: Tachinid flies, parasitic wasps, birds, viruses and fungi all prey upon tent caterpillars in natural settings. These organisms help prevent tent caterpillars from sustained widespread annual outbreaks. However, localized infestations are a possibility each year.

Cultural: Remove web-nests and larvae from the tree. Remove egg masses when detected while pruning. Use local intervention on the most severely infested trees.

Pesticidal: *Bt*, spinosad, or pyrethrum. Young tent caterpillars are susceptible to low rates of *Bt*, but as the insects develop larger doses are needed until *Bt* is no longer as effective.

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13. DISEASE CONTROL MATERIALS

Controlling diseases in organic orchards begins with proper site, cultivar, and rootstock selection, as discussed elsewhere in this guide. With the limited number of effective fungicides available for use in organically managed orchards and the large number of diseases that infect apple trees and fruit, planting disease-resistant cultivars (DRC) is the most important recommended disease control practice, and should be the foundation for disease management.

Even when using DRCs, growers will need to apply some fungicides to control certain diseases. Most DRCs were selected primarily for apple scab resistance, and secondarily for fire-blight, cedar-apple rust, and powdery mildew resistance. Many of these cultivars have limited resistance to other diseases. Further discussion and descriptions of DRCs can be found elsewhere in this guide.

In humid growing regions such as the Northeast, organic growers using susceptible mainstream cultivars such as McIntosh, Red Delicious, Golden Delicious, Honeycrisp, Cortland, Macoun, and Fuji will need to apply fungicides from before bloom until the end of the primary scab season, in order to harvest marketable fruit during most growing seasons. Additional fungicide treatments will also be needed to control summer diseases. For these disease-susceptible cultivars, fungicide sprays will likely be needed every 5 to 14 days—and even more often during rainy growing seasons.

Under USDA NOP regulations (§205.206) disease problems may be controlled through management practices which suppress the spread of disease organisms, or application of nonsynthetic biological, botanical, or mineral inputs. When these practices are insufficient to prevent or control crop pests, weeds, and diseases, a biological or botanical substance, or a substance included on the National List of synthetic substances allowed for use in organic crop production may be applied to prevent, suppress, or control diseases, provided that the conditions for using the substance are documented in the organic system plan.

The most commonly applied fungicides included on the NOP list are sulfur, liquid lime sulfur (LLS), and copper formulations. These inorganic (i.e., not carbon based) fungicides have a long history; some have been used for many centuries. Sulfur is still one of the most used fungicides in the world. Research trials with inorganic fungicides for controlling apple diseases in the Northeast reached a peak sometime around 1940. After that time, effective synthetic fungicides became widely available and are now used extensively by mainstream fruit growers in humid regions. More recently, with the renewed interest in organic farming, the best practices for sulfur, LLS, and copper use in apple orchards are being re-examined. Both organic and mainstream growers still rely upon sulfur for powdery mildew control in grapes and stone fruit.

Various orchard management practices will help to minimize disease problems and reduce the need for fungicides. Complete rotary mowing of the orchard floor after leaf drop will reduce the overwintering inoculum for scab by promoting decomposition and earthworm consumption of scab infected leaves. Light manure applications after harvest will provide nitrogen for decomposer microorganisms to promote leaf decomposition. Pruning out mildew-infested shoots will also reduce the infection potential. Maintaining good canopy structure with light penetration and air circulation throughout the tree will substantially reduce the infection potential for summer diseases of apple. And of course, growing the most disease-resistant apple cultivars available is usually the best line of defense.

Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. The registration status of pesticides can and does change. Those pesticides meeting requirements in EPA Ruling 40 CFR Part 152.25(b) (also known as 25(b) pesticides) do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) Web site: http://magritte.psur.cornell.edu/pims/. **ALWAYS CHECK WITH YOUR CERTIFIER BEFORE USING A NEW PRODUCT.**

BORDEAUX MIXTURE

Bordeaux mixture was developed in France during the late 1800s for use against downy mildew in wine-grape vineyards. It is a mixture of copper sulfate (bluestone), calcium hydroxide (hydrated spray lime or slaked lime), and water that can be used as both a bactericide and fungicide on apples, pears, and some stone fruits. Bordeaux mixture prevents pathogen growth by disrupting enzyme function. It works as a preventative measure and has no systemic activity, so applications need to be made prior to infection. Bordeaux mixture can be purchased pre-mixed, but is more effective when freshly prepared. Bordeaux mixture concentration is designated by three numbers (e.g., Bordeaux 2-6-100). The first number is the pounds of copper sulfate, the second is the pounds of spray lime, and the third is the gallons of water. Bordeaux mixture can be made by dissolving copper sulfate "snow" (not fixed copper) in a spray tank half filled with water. Once the copper sulfate is completely dissolved, the calcium hydroxide is added slowly with constant agitation (to prevent settling) and then the appropriate final volume of water is added. The lime produces a solution that has a more uniform and stable copper ion concentration than copper sulfate alone, thus minimizing phytotoxicity and improving retention on trees following application. The recommended ratio of Bordeaux ingredients varies by crop, plant phenological stage, and weather conditions.

Copper regulations imposed by the NOP are discussed in the fixed copper section below.

Bordeaux mixture can be used to control fire blight (*Erwinia amylovora*), peach leaf curl (*Taphrina deformans*), and black knot of plums and cherries (*Apiosporina morbusa*). As a delayed dormant or postharvest spray it helps to control cherry leaf spot (*Blumeriella jaapii*) and bacterial (*Xanthomonas campestris pv. pruni*) leaf spot of stone fruits and bacterial canker (*Pseudomonas syringae*) of plums and cherries. The risk of fruit russet and leaf burn make Bordeaux mixture generally unsafe to use on apples after the quarter-inch green stage. Fruit russet may even result from applications made before the quarter-inch green stage if there is insufficient rain to weather the residues prior to the tight cluster bud stage when copper that redistributes to flower parts can cause fruit russetting. Warm temperatures or rain soon after application will exacerbate phytotoxicity of applications made after quarter-inch green. Pear trees are somewhat more tolerant of copper than apple trees, and Bordeaux mixture can be used during bloom for fire-blight control provided that the disease pressure is only moderate to light. Bordeaux mixture has long residual activity and gives good control of bacterial leaf spot when applied to tart cherries in a postharvest spray.

Due to its spray lime content, Bordeaux mixture has a high pH that creates compatibility problems in tank combinations with other materials that can be degraded by alkaline hydrolysis. When used in combination with other pesticides, the labels of the pesticides involved should be read thoroughly to verify their compatibility with Bordeaux mixture. It is also corrosive to spray equipment. See the following discussion of fixed coppers for general toxicity information.

FIXED COPPER

Fixed copper is a term that refers to several relatively insoluble formulations of copper that are somewhat less phytotoxic and are more convenient to use on fruit crops than Bordeaux mixture. There are four basic types of fixed copper: 1) copper oxychloride with copper sulfate (COCS); 2) copper hydroxide; 3) complexed forms of basic copper sulfate; and 4) copper dust preparations. The activity and potential phytotoxicity of these formulations are proportional to the amount of actual metallic copper each contains, the rate and timing of application to the crop, the phenological stage of the plant and pathogen, and the weather conditions after application. Copper-based materials work by disrupting enzyme function after copper ions contact bacterial or fungal cells. Once dried on the plant surface, copper will be reactivated by rain until it is completely washed off, usually after 2 to 4 inches of accumulated rainfall following application. Copper has only preventative or protectant activity, so applications need to be made prior to infection.

Under NOP regulations, copper products are considered synthetic, but may be applied to prevent, suppress, or control diseases when the use of preventative, mechanical, physical, and other management practices is insufficient for disease control. Under these rules copper products may not be used as an herbicide, and must be used in a manner that minimizes accumulation in the soil. Several copper products have recently lost OMRI approval because they contain non-compliant inert ingredients, so growers should check products with their certifier prior to application.

Applications at quarter-inch green will reduce fire-blight inoculum, but other controls should also be implemented if the orchard has a recent history of fire-blight infection. Copper does not completely suppress the bacterium that causes fire blight, but it creates unfavorable conditions for bacterial growth on plant surfaces. Copper applied between half-inch green and bloom can cause fruit russeting, and copper applied between petal fall and early July can cause blackened lenticels on fruit.

Copper may also control summer rot diseases (e.g., black rot (*Botryosphaeria obtusa*), white rot (*B. dothidea*), and bitter rot (*Glomerella cingulata*) from mid-July through September, but due to phytotoxicity risk only a few formulations are labeled for use during this time. Post petal-fall applications of copper and oil made within a few weeks of each other can be highly phytotoxic. Yellow-skinned apples are more prone to skin discoloration from summer copper sprays than red-skinned apples. Copper hydroxide spray solutions should be above pH 6.0 to minimize phytotoxicity.

In trace concentrations copper is an essential plant and animal nutrient; at higher concentrations it is toxic to plants, animals, and other organisms. Acute exposure to copper can cause burning to skin, eyes, and nasal passages, and induce vomiting in humans. Copper hydroxide is less acutely toxic than copper sulfate and Bordeaux mixture. Over time, humans can bio-accumulate copper, which may lead to numerous chronic health problems involving the brain, heart, blood, liver, kidneys, stomach, intestinal tract, and reproductive organs. Copper can also harm birds, fish, and honeybees. Copper residues accumulate in the soil, and are harmful to beneficial organisms such as earthworms, nitrogen-fixing bacteria, and microbial biocontrol agents.

In soil, copper will bind (adsorb) to organic matter, clay, and mineral surfaces. The degree of adsorption depends on soil pH, decreasing copper availability as soil pH becomes more alkaline. Because copper sulfate is highly water soluble, it is considered one of the more mobile heavy metals in soils. However, because of its binding capacity, its leaching potential is low in all but sandy soils. Although copper is always present in soils at low background levels, with repeated applications copper can become a serious soil contamination problem. Agricultural soils are reported to have average background levels of 20 to 30 ppm, with average overall US levels around 15 ppm. In some vineyard soils of Europe that have received frequent copper fungicide applications for more than a century, soil copper concentrations up to 1500 ppm have been observed. Maximum concentration rates for copper in NY soils have been recommended based on soil type, and range from 40 ppm (for sandy soils) to 60 ppm (for silt loam) to 100 ppm (for clay soils). Some agronomic crops are sensitive to copper toxicity from root uptake, and with frequent copper spray applications toxic soil levels could be reached in a matter of decades. Organic certifiers may request that growers determine a baseline soil copper level, and then regularly test soil to track changes over time.

LIME SULFUR, LIQUID LIME SULFUR (LLS)

Lime sulfur was first used to control powdery mildew in grape vineyards during the mid 1800s. It is a mixture of calcium polysulfides formed by adding elemental sulfur to a boiling water slurry of calcium hydroxide. It is usually in a liquid formulation. The active compound, hydrogen sulfide, gives lime sulfur an unpleasant rotten egg smell that may remain in the orchard for over a week. The alkalinity and salinity of lime sulfur, along with the hydrogen sulfide make lime sulfur more aggressive and phytotoxic than elemental sulfur materials, but the calcium hydroxide moiety reduces the long-term soil acidification effects of repeated sulfur applications.

Liquid lime sulfur (LLS) can provide up to 72 hours of "kick back" activity meaning that this material has the ability to stop disease activity after infection has taken place. Kick back activity can be particularly useful when a preventative sulfur application to control apple scab (*Venturia inaequalis*) was missed. LLS has activity against apple scab, powdery mildew (*Podospheara leucotricha*), and the sooty blotch/flyspeck (SBFS) fungal complex. LLS applications are only minimally effective against late-summer black, white, and bitter rot infections.

Fruit russeting and yield reduction may result after repeated applications of LLS, especially if it is used during high-temperature conditions (>80 ºF). LLS applications within 14 days of an oil application are potentially phytotoxic. However, applications of LLS with oil have become a common method of chemically thinning apple fruit in organic systems (see Crop-Load Management Section). LLS is incompatible with many other pesticides, especially oils and other emulsified materials. It is considered a dermal, respiratory, and eye irritant, but has minimal chronic toxicity when properly handled.

POTASSIUM BICARBONATE (AND SODIUM BICARBONATE)

The use of baking soda (sodium bicarbonate) as a fungicide has been noted since at least 1933. It has been suggested that the bicarbonate disrupts potassium or sodium ion balance within fungal cells, causing cell walls to collapse. Bicarbonates need to be applied prior to an infection because they do not have post-infection activity. The material has very short residual period on plant surfaces, and repeated applications (7 to 14 days and more often after rains) are recommended. Combining oil and potassium bicarbonate is thought to provide better anti-fungal activity than either substance used alone. Bicarbonates have minimal negative impacts on beneficials, soils, humans or wildlife.

Bicarbonate products may provide some partial control of powdery mildew. This material has provided very limited suppression of SBFS and is unlikely to provide sufficient control in wet years. In several studies, potassium bicarbonate has provided partial control of other diseases, such as gray mold (*Botrytis cinerea*), black rot, Phomopsis (*Phomopsis viticola*) on grapes, and strawberry leaf spot (*Mycosphaerella fragariae*). However, other trials have found that bicarbonates provide poor control of anthracnose and Phomopsis on blueberry, brown rot (*Monilinia fructicola*) and cherry leaf spot (*Blumeriella jaapii*), Botrytis bunch rot on grapes and strawberries, and powdery mildew on strawberry. The variable performance of this material may be due to differences in pathogen morphology, spray timing and frequency, application concentrations, and use of adjuvants such as oil.

SULFUR

Sulfur has been used as a fungicide for at least 2000 years, but elemental sulfur dusts were first formulated for agricultural use in the late 1800s. Elemental sulfur is obtained from volcanic rocks, underground deposits, natural gas refineries, or crude oil distillation. The latter two are the most common sources today. Sulfur is a non-systemic contact and protectant fungicide, making it only effective in a protective or preventative schedule based upon predicted infection periods. It also has some secondary acaricidal (mite suppressive) activity. Sulfur becomes toxic to fungal cells by inhibiting respiration, disrupting proteins, and chelating heavy metals.

Current sulfur formulations include dusts, wettable powders, dry flowables, and liquids. Granular sulfur can be used at high rates to lower soil pH for blueberry and other crops. Other sulfur formulations are available for use as foliar nutrient sprays. Wettable sulfurs contain a wetting agent that facilitates the emulsion of insoluble powder with water, maintaining particle suspension during spray applications. Dry flowables and liquid sulfur formulations tend to have lower dust content, are effective at lower rates, and have better leaf retention. Micronized sulfurs are refined to have a particle size between 1 to 6 microns, with 95% of the particle diameters between 2 and 3 microns. This small particle size helps minimize sulfur phytotoxicity, lengthen its residual activity, and increase contact area and adhesion on plant surfaces. However, finer particle-size materials may be more phytotoxic under light rain conditions, subjecting the plant to an excessive sulfur dose. Micronized products can have lower sulfur content without losing activity. Both wettable powders and flowables (dry and liquid) products may contain micronized sulfur. Micronized wettable powders are most commonly used for tree-fruit production.

The most effective micronized sulfur products are formulated with bentonite clay or other particulate carriers to improve their resistance to rain wash-off. Depending upon the brand and formulation used, sulfur products may contain up to 95% sulfur; but when fused with bentonite clay they have either 30% or 80-85% sulfur content, depending upon the formulation.

In organic orchards sulfur is used primarily against apple scab and powdery mildew. It does a poor job of controlling cedar apple and quince rusts, and provides minimal control of late-summer black rot, white rot, or bitter rot infections. Sulfur can be used on stone fruits to control cherry mildew, cherry leaf spot, and brown rot. It is not effective against Rhizopus rot. It can be used during bloom without substantially reducing set. Fruit russeting and yield reduction may result if sulfur is used during high-temperature conditions (>80 ºF), especially in post-bloom sprays. Sulfur applications within 14 days of an oil application are potentially phytotoxic. It is compatible with most other orchard spray products.

Sulfur is considered a dermal, respiratory, and eye irritant, but has minimal chronic toxicity when properly handled. Orchards recently sprayed with sulfur will retain the sulfur odor for several weeks, and that odor will permeate clothes of anyone entering the orchard. Sulfur residues on leaves can become a serious eye irritant for workers involved in hand thinning, summer pruning, or harvesting if the residues are not diminished by rainfall before workers enter the orchard.

BACTERICIDES

STREPTOMYCIN (Agri-Mycin® 17**,** FireWall™ 17 WP)
Derived from the actinobacterium *Streptomyces griseus*, streptomycin was first isolated in the 1940s when it was found to be an effective antibiotic to cure tuberculosis in humans. Agricultural uses for streptomycin started in the 1950s. It is a bactericide used to control fire blight of apples and pears, as well as blister spot (*Pseudomonas syringae* pv. *papulans*) on Mutsu (Crispin) apples. Recent estimates suggest that only 0.1% of all antibiotic use in the US is for control of plant diseases. Nonetheless, because of the importance of this antibiotic for human and domesticated animal health, many European countries limit or prohibit streptomycin for tree-fruit production. The NOP may remove all antibiotics, including streptomycin, from the list of allowable materials for organic crop production by 2012.

In the US, resistance to streptomycin is widespread among populations of the blister spot bacterium. Resistant strains are also common among populations of the fire-blight bacterium in Pacific Northwest and Midwest fruit-growing regions, and streptomycin resistance has recently been detected on a very limited scale in NY. Indiscriminate use of streptomycin outside of bloom-time fire-blight infection periods will hasten the further development of antibiotic resistance. It is therefore discouraged in organic production, except following hailstorm damage.

Streptomycin is commonly used during bloom at the rate of 0.5 lb per 100 gal solution for fire-blight control, formulated as streptomycin sulfate in a 17% wettable powder form. It can be applied to pears up to 30 days before harvest, and to apples until 50 days before harvest.

***PANTOEA AGGLOMERANS* STRAIN E325** (Bloomtime Biological™)
A biopesticide labeled for control of the blossom-blight phase of fire blight. Bloomtime Biological is a wettable powder formulation of the bacterium *Pantoea agglomerans* strain *E325*. The bacterium acts by colonizing susceptible blossom tissues and preempting available nutrients to prevent colonization of fire-blight bacteria. In theory, this competitive inhibition will suppress the buildup of fire-blight bacterial numbers and prevent blossom infections. In trials conducted in commercial NY orchards, Bloomtime Biological™ has provided inadequate control of fire blight. Bloomtime Biological™ should be applied as a preventive control and should not be applied after fruit set.

HYDROGEN DIOXIDE (StorOx®, OxiDate®)
This material works like hydrogen peroxide to kill susceptible fungi and bacteria by direct contact with the organism. OxiDate® is labeled for control of diseases in the field, whereas StorOx® is labeled for post-harvest use as a surface disinfectant and as an antimicrobial for hydro-coolers and water flumes in packing houses. Hydrogen dioxide does not have residual activity, nor will it control fungi or bacteria that have already penetrated host tissue. Thus, it must be applied after pathogens have been deposited on plant surfaces but before they can initiate infections. Field applications to apples are not recommended because OxiDate® can cause severe fruit russeting under certain conditions. Controlled inoculation trials indicate no significant efficacy of OxiDate® for preventing fire-blight infection of apple.

BACILLUS SUBTILIS (Serenade®)
This is a biofungicide derived from a common soil bacterium. The *B. subtilis* strain QST713 (Serenade®) was isolated in 1995 by AgraQuest Inc. from soil in a California peach orchard. It is labeled for control of fire blight, apple scab, and powdery mildew, as a wettable powder formulation. The bacterium acts by releasing its cell contents during growth, thereby eliminating or reducing competitor microbes in its immediate environment. Serenade® is relatively ineffective for controlling fungal diseases under the climatic conditions that exist in NY. When used alone, Serenade® provides only partial control of fire blight. In alternation with streptomycin, it sometimes provides control approaching that of a full streptomycin program. Serenade® should be applied 24 hours after each infection event (as determined with predictive models). It can be applied up to and including the day of harvest.

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14. KEY APPLE DISEASES

Pesticides must be currently registered with the New York State Department of Environmental Conservation (DEC) to be used legally in NY. The registration status of pesticides can and does change. Those pesticides meeting requirements in EPA Ruling 40 CFR Part 152.25(b) (also known as 25(b) pesticides) do not require registration. Current NY pesticide registrations can be checked on the Pesticide Product, Ingredient, and Manufacturer System (PIMS) Web site: http://magritte.psur.cornell.edu/pims/. **ALWAYS CHECK WITH YOUR CERTIFIER BEFORE USING A NEW PRODUCT.**

Below we synthesize the available information on organic control strategies, which may work for each pest or type of pest. However, given that only a limited number of replicated experiments have been conducted in organic orchards, and that even fewer studies have attempted to implement multifaceted approaches to pest control, the information provided here should be used only as a guide while developing a control strategy appropriate for your situation.

Additionally, the following information should be used in conjunction with other resources that contain more detailed information about the identification, biology and IPM strategies of these arthropods, such as the NYS IPM Fact Sheets available at http://www.nysipm.cornell.edu/factsheets/treefruit/default.asp, the *Pest Management Guidelines for Commercial Tree-Fruit Production*, and the *Tree Fruit Guide to Insect, Mite, and Disease Pests and Natural Enemies of Eastern North America*.

APPLE SCAB *(Venturia inaequalis)*

IPM strategy: The primary infection period of ascospore release during the early part of the growing season can be estimated from degree-day accumulations. An Ascospore Maturity Degree Day Model is available at the Cornell Tree Fruit and Berry Pathology Web site: http://www.nysaes.cornell.edu/pp/extension/tfabp/ascomatb.shtml. Charts of the model's progress are updated regularly during the spring season using weather data from the NYS IPM NEWA network.

The Revised Mills Table shows the minimum duration of wetting required at various temperatures for initiation of apple scab infections. This is a proven method for documenting when scab infections have occurred. Used in conjunction with accurate weather forecasts, the Mills Table can help growers determine if a protective fungicide application will be needed prior to predicted rains since rains that result in short wetting periods and/or that occur under cool conditions may not result in scab infections. Weather stations that record leaf wetting hours and temperature can be placed in the orchard to document actual wetting events, or growers can access regional data from the NEWA Web site: http://newa.cornell.edu/.

Biological: Plant scab-resistant cultivars. Prune and train trees to allow good air circulation.

***Cultural*:** Removing apple leaves or promoting their decomposition before bud break will help reduce the inoculum dose on overwintering leaves where the scab fungus survives the winter and produces ascospores that initiate new infections of green tissue in the spring. Applying compost or another nitrogen source to the soil under trees after leaves have dropped in late fall or in early spring can help soften leaves and promote microbial and earthworm activity, thus promoting a more rapid breakdown of leaf material. Mechanical cultivators that turn leaves into the soil, and flail mowers and that cut leaves into small pieces can also hasten leaf decomposition. Cultural controls are critically important in orchards that had severe scab the previous year. Sulfur and LLS will rarely provide good scab control if over-wintering inoculum levels are very high.

Pesticidal: Even in orchards of scab-resistant cultivars, several fungicide applications during the primary scab season (late April to mid June in NY) are recommended to reduce the odds of scab fungi overcoming the genetic resistance of these cultivars. Strains of the scab fungus that can infect certain resistant cultivars have been reported in Europe and the midwest and northeastern US. Scab-resistant cultivars should probably receive a sulfur spray at tight cluster, pink, and petal fall, although the latter spray will not be needed where liquid lime sulfur (LLS) is used to adjust crop load.

In orchards of susceptible cultivars in humid regions, some combination of copper, sulfur, and LLS will be needed to control scab infections of both fruit and foliage from bud break until terminal shoots stop growing in late June or early July. Additional sprays during July and August may be needed to protect fruit if scab lesions are visible on foliage by late June. Susceptible cultivars that are not protected from scab during cool humid summers will often drop most of their fruit and many of their leaves by late summer, will be vulnerable to severe cold damage during the following winter, and may fail to produce flowers the following year.

Copper products should be applied to apple orchards prior to the quarter-inch green phenological stage to protect the first green tissue from scab. One to two pre-bloom copper applications are recommended, and copper sprays will generally be more effective against scab than sulfur sprays. Copper applications after petal fall can be made if primary scab infections were not adequately controlled, but applications between petal fall and mid July will likely cause severe discoloration of yellow-skinned cultivars and blackened lenticels on many red-skinned cultivars.

Wettable sulfur can be used at a rate of 5 lb active ingredient per 100 gal of water in early-season sprays in a protective program—meaning that sulfur needs to be on the tree before scab infection takes place. Sulfur sprays should begin once ascospore release has been predicted or observed (usually starting at bud break in NY). Good coverage, and repeated applications (every 7 days, or more frequently after rains) are necessary for effective control during spring and early summer. Sulfur protection will be compromised by an inch of rainfall, and must therefore be applied more frequently in wet seasons. Apple production guides written before 1950 recommended dusting orchards with sulfur during light rains or during breaks in rainy periods because this formulation adheres to wet leaves better than formulations applied with water. Sulfur dusters can also be driven through the orchard more quickly than spray equipment, but the risk for extensive drift, complaints from neighbors, and operator exposure is substantial with dust applications.

Liquid lime sulfur can be used as a post-infection (eradicant) fungicide to suppress sporulation and "burn out" lesions if wettable sulfur applications did not prevent scab infections. This is likely to happen in wet years when sulfur is washed off of the trees and rains prevent timely reapplication of sulfur. A 2% (v/v) LLS application made within 48 to 72 hr from the start of a wetting period, depending upon temperature, will arrest scab infections before they become established in leaves. If scab lesions begin to appear on leaves due to inadequate protection prior to rains, then an LLS application should be made immediately to suppress sporulation and reduce chances for secondary spread. However, applications of LLS made more than 72 hr after and infection period but prior to emergence of scab lesions will have no effect on the infections that are incubating within the leaves.

Some organic farmers have noted that they can achieve better scab control using regular applications of LLS rather than depending on sulfur for protection against scab. However, because LLS suppressed photosynthesis, every application will have some negative impact on fruit size, total productivity, and over-all tree health. Thus, LLS should be used as a scab fungicide only when absolutely necessary.

POWDERY MILDEW *(Podosphaera leucotricha)*

IPM strategy: Plant resistant varieties, prune out and remove mildew infected shoots during late summer and fall, and ensure good coverage with dormant oil sprays.

Biological: There are no known natural controls for powdery mildew, although research is underway involving certain mites that consume the mycelium and spores of this fungus.

Cultural: The fungus over-winters in dormant buds formed at the base of leaves that were infected the previous year. Prune and train trees to remove infected shoots and promote air circulation in the canopy.

Pesticidal: Wettable sulfur can be effective against powdery mildew of apple when three or four applications at 2 to 3 lb active ingredient per 100 gal water are used beginning at tight cluster or pink. Early applications are especially important in orchards where mildew was a problem the previous season. On some cultivars, up to 5 lb per 100 gal may be needed. Lime sulfur can also control powdery mildew. Bicarbonate products may provide some control in low-pressure years. Stylet oil applications at 1 to 2% (v/v) rates during the growing season will reduce sporulation of active powdery mildew infections.

FIRE BLIGHT *(Erwinia amylovora)*

IPM strategy: Use predictive models such as CougarBlight or MaryBlyt©. During the fire-blight season, regional predictions based upon CougarBlight are available at: http://newa.nysaes.cornell.edu/public/apple_home.htm.

Biological: Use resistant cultivars and rootstocks. Note that under high disease pressure, even resistant cultivars may become infected. Cultivars that bloom relatively early in the growing season are generally less likely to become infected because the bacterium reproduces more rapidly in the orchard during warm weather.

Cultural: Remove infected limbs 8 to 12 inches below visible symptoms, disinfecting all pruning tools in denatured alcohol between cuts. This is most effective when done 3 to 5 times per week beginning as soon as any infections appear and continuing until no new infections are appearing or until terminal growth ceases in late June or early July. In severe cases where the rootstock or main trunk is infected, whole trees may need to be removed from the orchard. Susceptibility of trees to fire blight can be reduced by avoiding excessive nitrogen inputs and large pruning cuts that cause vigorous growth of susceptible new shoots. Do not place beehives in orchards with extensive fire-blight lesions, because the foraging bees will spread the bacterial pathogen into other orchards. Cultural controls are especially important in orchards with a history of fire-blight infection.

Pesticidal: Copper should be used as a preventative spray prior to the quarter-inch green phenological stage, and in extreme risk situations fixed copper formulations can be sprayed during bloom-time infection periods if some fruit russeting is acceptable. In orchards that had fire blight during either of the two preceding years or where neighboring orchards have a history of fire blight, streptomycin should be applied when CougarBlight or MaryBlyt© predicts that blossom infections are likely. Accurate timing of streptomycin sprays is critical. A spray applied one day too late may prove totally ineffective. Blossoms that are not yet open when streptomycin is applied will not be adequately protected so repeated applications may be needed if warm rains continue for several days during bloom. MaryBlyt© predictions can assist in determining when repeated streptomycin applications are necessary. The importance of controlling the blossom blight phase of fire blight cannot be over-emphasized. Failure to control blossom blight with streptomycin during one blossom period that is conducive for fire blight can result in the need for repeated applications of streptomycin in future years, high labor costs for cutting out blight during summer, and perhaps loss of the entire orchard. Immature trees (less than 6 to 8 years old) are most susceptible to fire blight and warrant special attention.

FLYSPECK *(Schizothyrium pomi)*

See sooty blotch below. The two disease complexes usually appear together and are often controlled by the same measures.

RUST DISEASES, INCLUDING:

CEDAR-APPLE RUST *(Gymnosporangium juniperi-virginianae)*
QUINCE RUST *(Gymnosporangium clavipes)*
AMERICAN HAWTHORN RUST *(Gymnosporangium globosum)*

IPM strategy: Grow resistant varieties and reduce disease inoculum by eliminating alternate hosts near the orchard. If susceptible cultivars are grown, plant them as far as possible from orchard perimeters where trees are most likely to intercept rust spores being blown into the orchard.

Biological: Some red apple cultivars are resistant or tolerant of the cedar apple rust, but very few cultivars are resistant to quince rust. Note that scab-resistant cultivars vary in their resistance to rust diseases (see Rootstock and Cultivar Selection section).

Cultural: Prune and train trees to promote good air circulation. If possible, remove red cedar trees (*Juniperus virginiana*) and other juniper species (the alternate hosts for the cedar-apple rust fungus) within 300 feet of the orchard. However, infective spores can travel for several miles on air currents, and other practices should be integrated into the control program.

Pesticidal: Sulfur at 5 lb per 100 gal will suppress rust diseases, but it will not control these diseases on susceptible cultivars planted close to inoculum sources. Fruit are susceptible to rust infections from tight cluster through petal fall, so preventive sprays are especially critical during that time period. Cedar apple rust and hawthorn rust will continue to infect leaves for 3 to 4 weeks after petal fall, but trees can tolerate a moderate level of leaf infections that occur after petal fall.

SOOTY BLOTCH COMPLEX, INCLUDING:
(Peltaster fructicola)
(Leptodontium elatius)
(Geastrumia polystigmatis)

Sooty blotch and flyspeck (SBFS) are often found together on the same fruit. They affect only the epidermal layer of the fruit, causing superficial but unsightly cosmetic defects. Vigorous rubbing with a cloth, or additional brushing in packing lines can remove some SBFS blemishes without harming the apples, but well established darker forms of sooty blotch can be almost impossible to remove. Severity of SBFS varies with geographic region and orchard locations within regions. In southeastern New York, SBFS can make organic fruit unmarketable whereas the disease is much less severe in more northerly production regions.

IPM strategy: Sulfur and LLS sprays applied at petal fall and first cover to control scab and adjust crop load will protect trees from the primary SBFS infections that can occur during the several weeks after petal fall. Disease development models have shown that secondary infections by spores blown into the orchard from hedgerows and woodlots begin to occur after 270 leaf-wetting hours have accumulated since petal fall. This is usually sometime in early July, but will depend upon the amount of rainfall received during the season. Leaf wetness sensors are available for most weather stations. Leaf wetness data from regional weather stations can be viewed on the NEWA Web site: http://newa.nysaes.cornell.edu/public/apple_home.htm.

Biological: There are no known biological controls for SBFS.

Cultural: Prune and train trees to allow good air circulation. Dense canopies should be thinned out with summer pruning. Keep ground cover and row middles mowed to lower humidity in the orchard. Thin apples to prevent high-humidity microclimates around the fruit and allow better spray coverage of individual fruit. Brambles (especially wild blackberry) are probably the worst alternate host reservoirs for sooty blotch fungus, but since there are more than 100 wild hosts removing these plants from the area surrounding the orchard will have to be weighed against labor costs and other ecosystem effects.

The SBFS blemishes are much less visible on dark red cultivars than on late ripening yellow or green apples. Early-ripening cultivars often escape severe infection because fruit are harvested before incubating infections can produce visible symptoms. Where orchards must be planted adjacent to woodlots or hedgerows, early-maturing cultivars should be planted near orchard perimeters so that late maturing cultivars will be further away from inoculum sources.

Pesticidal: Research in the Hudson River Valley has shown that liquid lime sulfur at 1 quart per 100 gal of dilute spray was effective for SBFS control when applied on a 10-day schedule during July and August in a year with average rainfall, whereas 2 quarts per 100 gal were required for good control on a 20-day schedule. The lower rates have been shown to be ineffective during a wet growing season. In regions where conditions favor development of SBFS, sprays with lime sulfur must be continued into late September to prevent disease on late-maturing cultivars. It is not known if these low-rate summer sprays of LLS have significant negative impacts on fruit size and yield.

Bicarbonate products, Serenade, and Oxidate failed to control or even suppress SBFS in NY research trials.

SUMMER ROTS, INCLUDING:

BLACK ROT, BLOSSOM END ROT, FROGEYE LEAF SPOT *(Botryosphaeria obtusa)*
BITTER ROT *(Colletotrichum acutatum)(Colletotrichum gloeosporiodes)*
WHITE ROT *(Botryosphaeria dothidea)*

IPM strategy: Some cultivars are resistant or tolerant to these diseases, while cultivars that retain undeveloped fruitlets or infected fruit for many months or over-winter are often susceptible. Fruit that are sunburned may be more susceptible to fruit decays, so summer pruning that suddenly exposes shaded fruit to high-intensity sunlight should be avoided, especially if temperatures greater than 90° F are predicted within the next week.

Biological: There are no known biological controls for these diseases

Cultural: Remove dead wood and fruit mummies (dried remnants of apples and fruitlets that failed to abscise after fruit thinning) from the orchard when pruning at mid summer or the dormant season.

Pesticidal: Low rates of copper fungicides or LLS applied during late July and August may help control summer rots. However, there is also some evidence that high rates of LLS applied during summer may increase susceptibility to summer rots, presumably by damaging fruit surfaces and making them more suitable for pathogen invasion. Thus, avoid applying LLS during or just ahead of hot weather that is likely to exacerbate phytotoxicity of LLS sprays.

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15. WILDLIFE DAMAGE MANAGEMENT

Strategies for reducing wildlife damage should be integrated into the site selection and overall orchard design (see Site Selection and Orchard Design section). While some damage is probably inevitable and should be expected, growers can mitigate problems with habitat modification, exclusion, repellents, scare devices, population reductions, trapping, and/or altering harvest timing.

Habitat modifications, in particular, fit in with organic management requirements to reduce damage levels by making areas less suitable for problematic wildlife species. Removal of brush, stone piles, and non-mowable wet areas in and near orchards will reduce the populations of rodents and rabbits. Regular mowing in established plantings reduces preferred foods of rodents, remove protective cover, enhances predation, and exposes pest animals to severe weather conditions. Sites adjacent to orchards should also be managed to reduce pest numbers, as nuisance wildlife may reinvade orchards from these habitats. For example, owls, hawks and snakes will provide more useful control of meadow voles and rabbits where there are perches and nesting sites for these predators, and local coyote or fox burrows should be protected to provide suitable homes for these useful predators.

DEER AND RABBITS

White-tailed deer (*Odocoileus virginianus*) are usually the most serious wildlife problem in Northeastern orchards, and fencing is the most common and effective exclusion technique used to prevent white-tailed deer damage. Permanent 8-foot tall woven wire fences are the most effective method for year-round protection, and such a fence will also discourage wayward humans from entering your orchard. Long-term damage abatement and low maintenance requirements usually justify the high installation costs for woven wire fences. Electric high-tensile fences can also protect orchards, provided that the system is kept operational through regular inspection and maintenance. Weeds contacting an electric fence can short the current and disable the fence. Weed control is therefore essential beneath the fence, and some hand weeding may be necessary in organic plantings. Another disadvantage of electric fencing is the potential for pets, customers, or farm workers to accidentally get shocked. Although the current in electric fences is very low amperage and intermittent, so it will not inflict serious harm, it is an unpleasant and frightful experience that would not be acceptable in U-Pick orchards or densely populated areas. The costs per acre for perimeter fencing decrease substantially as the fenced area increases, and fencing is considerably more difficult and expensive in uneven terrain where there are ditches, streams, or ravines that need to be fenced. For small plantings, fencing can individually surround trees but any branches that extend beyond the fence are likely to be nipped by wildlife.

Some growers have trained dogs to patrol and protect orchards. The dogs are kept within the orchard area through the use of an "invisible" perimeter fence (a buried wire that sends out a radio signal). When the dog approaches the invisible fence it gets a small shock through a receiver collar. After preliminary training the shock can be replaced by a warning sound. Field-testing of this approach has shown that resident dogs in orchards can keep deer browsing to a minimum. However, intensive dog training is needed and the dogs must be docile and friendly to customers and workers on the farm, and physically capable of living outdoors in harsh winter conditions.

Organically approved repellents to reduce deer or cottontail rabbit (*Sylvilagus* sp.) browsing in orchards include ammonium soaps, hot pepper sprays, and various predator urines (e.g., coyote). The effectiveness of these products is extremely variable and is affected by factors such as deer or rabbit numbers, feeding habits, and environmental conditions. Repellents will be most effective when light to moderate damage is evident, small acreages are damaged, and dry weather ensures that few applications will be needed for adequate control. With the use of repellents some damage must be tolerated, even if browsing pressure is low. None of the existing repellents provides reliable protection for more than five weeks when deer or rabbit densities are high, even during dry weather.

Wildlife population reductions may be necessary to reduce damage to tolerable levels. For plantings of 50 acres or more where deer damage can be documented, a "nuisance permit" can be obtained from the NYS DEC for lethal control of wildlife species outside of regular hunting seasons. The NYS DEC also offers Deer Management Assistance Program (DMAP) permits to farmers, permitting the hunting of antlerless deer on agricultural and forested lands. However, wildlife population reduction by lethal methods usually fails to provide long-term relief from damage. Where habitat conditions are suitable, and exclusion is not attempted, most pests will repopulate the site soon after lethal control efforts have ceased. Habitat modification and exclusion methods (fencing) require more initial effort and expense, but these techniques will provide long-term damage prevention, especially when a few problem animals can inflict substantial losses.

If trapping rabbits or rodents, care and experience are necessary to reduce captures of non-target species. Live-traps should be substituted for body-gripping traps in areas where pets or endangered wildlife may inadvertently be captured. Animals captured live cannot be transported off of your property without NYS DEC permits, so they must be humanely euthanized, or released alive elsewhere on your land. When practical, reductions in populations of game species (i.e., deer, rabbits, etc.) should occur during open hunting seasons.

MEADOW AND PINE VOLES

Two species of voles cause frequent damage in NY orchards. Meadow voles (*Microtus pennsylvanicus*) are found throughout the state and probably inhabit every orchard, while pine voles (*Microtus pinetorum*) are primarily a problem in Hudson River Valley and Long Island orchards on well-drained soils. The different required habitats of meadow and pine voles have important implications for their detection and control. Meadow voles live primarily above-ground in dense sod or vegetation, and cause damage by gnawing the bark from lower trunks of fruit trees. Pine voles live primarily below ground and damage the root systems of trees. Because of their underground habits, pine voles are more difficult to control.

Voles reproduce prolifically and their populations increase rapidly during the summer months in orchards that provide favorable cover. During the winter months when alternate food sources are scarce and groundcover vegetation, mulches, or snow cover provide a protective cover for them to forage, the voles feed extensively on the bark of lower tree trunks. Young trees with thin bark (trees ranging in age from 1 to 10 years) are most susceptible to vole damage. Also, young trees interplanted in older orchards are especially vulnerable and must be protected with plastic or wire mesh trunk guards.

Consistent mowing and weed control will lower rodent numbers considerably during the growing season, because voles require green, growing vegetation for survival and breeding. The meadow vole is especially vulnerable to close mowing of orchard drive-rows. Rotary mowers have proven to be more effective than sickle-bar types for removing orchard ground cover and thatch. Maintaining a weed-free strip beneath the trees and along the tree rows will also help reduce meadow vole populations. Wood-chip mulches are usually less favorable vole habitat than other (fabric, hay or straw) mulches or groundcovers.

Clean cultural practices, including removing windfall apples, winter prunings, and vegetation near the base of trees, will aid in reducing vole population buildup and damage to trees. Wire or polyethelene mesh guards are a must for protecting younger trees from voles as well as rabbits. Mixing sand with latex paint and coating the lower 2 feet of trunks has shown some effectiveness in reducing rodent chewing. Owl boxes and hawk perches can be installed in the orchards to attract natural predators of rodents and other small animals. Resident dogs with the invisible fence system will also help suppress vole populations. Where woven wire deer fences are used to protect orchards, creating small holes in the wire near the ground at intervals along the fence can allow improved access by foxes and coyotes that feed on voles but may also allow access to problem animals.

WOODCHUCKS

Woodchucks (*Marmota monax*), also known as groundhogs, are found in agricultural lands throughout much of eastern North America. Woodchucks cause damage by digging burrows and building associated dirt mounds, which can be a hazard to farm workers or customers, and damage farm machinery or tree root systems. Woodchucks also shred the bark on tree trunks during scent-marking territorial activities.

Electric, high-tensile deer fences may be modified to exclude woodchucks by adding an additional strand of electrified wire above the soil surface. Removing or killing woodchucks is only marginally successful, as other woodchucks quickly reoccupy established burrow systems. Many farm dogs, and coyotes, are also effective woodchuck predators.

BEAVERS

Beavers (*Castor canadensis*) will occasionally chew bark on fruit trees situated within 300 feet of a permanent water source, such as a stream or pond. Removal of a problem beaver or family group may reduce tree damage for several years. However, if damage persists, other management options may be needed to reduce economic losses. Beavers seldom stray far from water, and installing a 2-strand electric fence between the pond or stream and the orchard may eliminate beaver access and damage. Also, wire-mesh trunk guards for voles will provide protection from beavers if the guard extends to 30 inches height. Growers will need to integrate exclusion techniques along with occasional beaver removal to reduce tree damage in orchards. In NY, removal of problem beavers or destruction of their dam or lodge requires a permit issued by the NYS DEC. Likewise, shooting or trapping beavers causing damage to agricultural crops must be authorized by NYS DEC.

BIRDS

Numerous bird species can cause damage to fruit crops, including blue jays (*Cyanocitta cristata*), crows (*Corvus brachyrhynchos*), sparrows (*Passer* sp.), finches (*Carpodacus purpureus* and *C. mexicanus*), robins (*Turdus migratorius*), and European starlings (*Sturnus vulgaris*). As fruit ripen, sugars and red coloration make them more attractive to birds. Birds lack the chemoreceptors necessary for many organically approved repellent products (i.e., garlic oil and hot pepper sprays). Furthermore, these products may leave residual smell or taste on harvested fruit. Bird-scare devices such as propane powered canons and bird distress calls broadcast through loud speakers can be an effective method to keep birds away. However, nearby residents and customers in U-Pick operations may be annoyed or unnerved by these sound alarms. Visual scare tactics that mimic flames (e.g., flash tape or dangling CDs), or predators (e.g., yellow, black, and red bird-eye balloons or scarecrows) will only briefly repel birds from the orchard; they learn quickly that there is no real threat from these objects. Bird netting that covers the trees is the only reliably effective option for bird control, although it can be difficult to install without a support structure, especially with larger trees, and is cost prohibitive in large orchard operations. Smaller orchards and those located near dense hedgerows, large perch trees, electric power lines, and other favorable aggregation sites will be more prone to damage from fruit-eating birds.

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Further information, including Cooperative Extension publications, can be found at the Northeast Wildlife Damage Management Cooperative Web site: http://wildlifecontrol.info.

16. HARVEST AND POSTHARVEST HANDLING

Harvest considerations for organic fruit follows the same principles used for non-organic fruit. The ideal harvest date will depend upon site, climatic, and horticultural factors, as well as the intended market destination. Most studies have shown minimal differences in harvest timing and fruit maturation among organic, conventional, and integrated fruit production systems. Fruit that will be refrigerated for an extended period of time is generally harvested earlier than fruit that will be sold soon after harvest.

The DRC list elsewhere in this guide provides approximate harvest timing and information about the storage potential of these cultivars, and harvest time information for disease susceptible mainstream cultivars is readily available from many other sources. The use of qualitative (e.g., color and varietal flavor development) and quantitative (e.g., firmness, starch hydrolysis index, soluble solids content, and acidity) harvest indices will also help determine proper harvest timing. Fruit can be inexpensively field tested for background blush color, starch-iodine indices, flesh firmness, and soluble solids concentration. With unfamiliar cultivars it might take a few years of evaluations to determine the proper harvest dates for any given site.

Selectively culling fruit during harvest provides growers the opportunity to remove and recycle unmarketable fruit in the orchard, though this will slow picking operations and increase costs considerably. Fruit should be harvested and packed carefully to prevent bruising that will detract from sales and dramatically decrease postharvest storage life.

Some organic certifying agents and buyers require specific details about the location, timing, and even the employee who harvested each lot of fruit. This information is used to enable traceability, whereby questions about quality, pesticide residues, or pathogens can be answered quickly and accurately. Traceability is particularly important for export markets that require Good Agricultural Practices (GAP) certifications, such as GLOBALGAP (formerly known as EUREPGAP). Maintaining complete records for traceability can also protect growers from undue liability if problems or contamination occur during the storage or retail chain after the fruit leaves their farm.

All fruit storage areas must follow NOP regulation §205.271 on facility pest management practices. This section specifies that pest prevention and control practices must be undertaken before an approved organic product may be applied. If none of the listed strategies work, then a synthetic substance not on the National List may be applied. When this occurs, the handler and certifying agent must agree on the substance, method of application, and measures taken to prevent contact of the organically produced products or ingredients with the substance used.

Recommendations for growing and handling practices that will prevent phytosanitary problems are available in printed and CD form from the Cornell GAP Program online at: (http://www.gaps.cornell.edu/). For organic growers the use of manure fertilizer sources is of special concern, and the rules for minimum days to harvest after livestock grazing or manure applications, and minimum time and temperature of hot composting must be strictly followed to avoid potential hazards of fruit contamination (see Soil Fertility and Crop Nutrient Management section). Rodent populations within packing houses and cold storage facilities can also be a problem, and there are no NOP permitted organic fumigants for rodent control. Most rodents enter storage facilities in bins of fruit brought in from the field, so rapid transport of full bins into cold storage during harvest will not only increase fruit packouts and storage life, but also prevent rodents from hitch-hiking into the packing house within bins. Rodent traps baited with peanut butter or other attractants will also help control these pests, which can do considerable damage to stored fruit.

Section §205.272 of the NOP describes methods for preventing the commingling of organic and non-organic products or materials at harvest, and in packing lines and storage facilities. Certifying agents may require organic apple growers to exclusively use plastic harvest bins because of the possibility of non-compliant materials contaminating wooden bins. Plastic bins are more easily steam-cleaned to remove microbial contaminants or pesticide residues. Packing lines may be shared between organic and non-organic fruit, provided that the entire line is thoroughly cleaned before grading and packing organic fruit. In mixed operations, a set of line brushes used exclusively for organic fruit are usually required. Organic apples may be kept in refrigerated and controlled atmosphere (low oxygen environment) storage rooms with non-organic fruit, provided that efforts are made to designate organic and non-organic bins and/or boxes.

However, some prohibited materials may volatilize from conventional fruit to organic fruit in storage. In particular, diphenylamine (DPA), an antioxidant used to protect apples from scald, has been detected on organic fruit stored in close proximity to treated conventional fruit. As a synthetically derived compound, DPA is not allowable under the NOP. Certifying agents will likely want prior approval and documentation of plans for commingled storage facilities. Regions with a large number of organic operations (mainly Washington and California) have dedicated certified organic packing facilities, which significantly decrease the possibility of commingling problems.

There are also NOP regulations on processing food (§205.270), which must be followed when making value-added products, such as cider, applesauce, sliced apples, and baked goods.

Although not commonly used on organic apples, carnauba waxes are permissible under the NOP. Carnauba wax is derived from the leaves of carnauba palms (*Copernicia prunifera*) grown in Brazil. These waxes are primarily used for improving fruit appearance, but they also aid in extending shelf life by reducing water loss and respiration rates. Waxing fruit is usually done by larger fruit packinghouses with specialized equipment.

Postharvest diseases and rots are best managed through careful fruit handling and storage. Many storage infections enter fruit through bruises or punctures that occur during harvest, packing, or transportation. Several yeasts and bacterium have postharvest biocontrol efficacy against blue mold (*Penicillium expansum*) and gray mold (*Botrytis cinerea*) infections on stored apples. Blue mold can cause extensive losses if wounded fruit are exposed to inoculum. Most inoculum comes from harvest containers or storage rooms that contained rotted fruit the previous year, so contaminated storage room floors and harvest containers should be washed with detergent before they are reused. Bio-Save® 10 LP, made by Jet Harvest Solutions (Longwood, FL), is one commercial formulation currently approved for organic production. In research trials, postharvest biocontrols have produced variable results, especially when compared with synthetic fungicides; however, these products might be useful with organic operations that have few other options. Ideally, no postharvest fungicide should be needed if fruit are handled properly, harvest containers and storage rooms are sanitized, and fruit are not exposed to recycling water flumes that might accumulate spores of decay fungi.

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Wojciech, J.J. and L. Korsten. 2002. Biological control of postharvest diseases of fruit. Annual Review of Phytopathology 40:411-441.

17. COSTS OF PRODUCTION AND MARKETING

The profitability of any farming enterprise depends upon the cost of production and the gross returns received. Land-values can also vary widely depending upon the location, as can the costs associated with preparing, planting, and bringing an orchard into bearing. These costs will be fairly similar between organic and convention orchards. However, the direct costs—especially the greater labor needs and higher costs for fertilizers and pest control products—make organic apples generally more expensive to grow than conventional or integrated apples, especially under the intense and complex pest pressures typical of Northeastern orchards. Organic pest control materials also tend to be sprayed frequently (sometimes two or three times per week), further increasing labor, fuel, and machinery costs.

Data collected from a recent four-year trial was used to develop the following table, which summarizes some of the direct production-related costs associated with producing Liberty apples from a mature high-density orchard in NY. Because Liberty is a disease-resistant cultivar, disease-control costs were relatively low. Fungicides were used to control fire-blight and summer diseases, but not scab, rusts, or powdery mildew. Pruning, irrigation, mowing, pest scouting, and certification fees are not included in this table. Additionally, a Wonder Weeder cultivator was purchased specifically for use in this orchard. The standard model of this cultivator was purchased for $5,795 (plus tax, shipping, and handling). Most organic apple growers will likely find the need to purchase a similarly priced mechanical cultivator. Chicken manure compost was applied once during the trial, but it is assumed that compost applications will be needed once every three years. Therefore, the costs associated with applying chicken manure compost were divided by three to show the projected annual costs in the table below.

TABLE 17.1. Some direct production related costs for managing a 'Liberty' apple orchard.

Costs	$/acre/yr
Machinery Operation	
Tractor + Airblast sprayer	93
Tractor + Wonder Weeder (three cultivations per year)	13
Applying chicken manure compost (once every three years)	24
Total machinery costs	130
Materials	
Dormant spray (copper and Stylet oil)	47
Insecticides	233
Kaolin clay	143
Pheromone mating disruption ties (for codling moth and oriental fruit moth)	181
Fungicides	17
Adjuvants	11
Thinning chemicals (liquid lime sulfur and Crocker's fish oil)	150
Foliar fertilizers	75
K-Mag (Sul-Po-Mag)	94
Chicken manure compost (applied once every three years)	16
Total material costs	967
Labor	
Tractor airblast spraying	102
Chicken manure application (applied once every three years)	22
Cultivation	17
Hand hoeing	72
Hanging pheromone ties	24
Hand thinning	347
Harvesting	1,222
Total labor costs	1,806
Grand Total	**2,903**

Many organic fruit growers in the Northeast market their produce through direct to consumer channels such as farmers' markets and community supported agriculture (CSA) programs, or directly to retail stores or restaurants. Because there are only a few large Northeastern apple plantings that are certified organic, wholesale marketing channels have only been minimally explored. However, with rising fuel costs, and increasing consumer interest in locally grown foods there is ample opportunity for expanding the volume of organic apples in both the direct and wholesale markets. Additionally, several food-processing companies have been actively seeking organic apples from the Northeast to use in existing plants used for conventional fruit in the region.

As mentioned throughout this guide, growing organic apples in the Northeast will be more expensive than growing organic apples in arid regions of the Northwest, or than growing conventional or integrated apples in the Northeast. Growers should assess the need to compete with these other apples in the marketplace, and to generate enough revenue to compensate for the greater costs of organic production.

Furthermore, there is a greater likelihood that organic apples will be blemished with diseases such as scab, sooty blotch, and flyspeck, and have some superficial insect damage. In wholesale markets, many of these apples will not pass USDA grading standards. In local direct markets, growers have the opportunity to educate consumers about their practices and why there may be blemishes on organic apples. Several studies have shown that some consumers are willing to pay more for organic apples when they are identical in appearance and size to conventional apples, but that the majority of consumers are unwilling to pay the organic premium for undersized or blemished fruit. Of course, there will be some consumers who are strongly motivated to buy organic fruit regardless of price or fruit quality. Buyers for processing companies may not be as concerned with cosmetic blemishes.

With so few apples being grown organically in the Northeast it is difficult to ascertain how much the organic label is worth to consumers. Additionally, organic premiums are based upon factors such as the volume of apples available in the marketplace, the cultivar in question, and the market destination. This makes organic price premiums somewhat of a moving target. In 2007, USDA-ERS data on organic and conventional apples sold through the Boston Produce Terminal Price indicated a 62% price premium for certified organic apples. This was based on average organic and conventional sales data for eight apple cultivars without regard to origin, color grade, size, or month of sale. Interestingly, the lowest organic premium (18%) was for Golden Delicious sold in May, and the highest premium (127%) was for Golden Delicious sold in February. Conventional apple prices were nearly the same on both dates. In recent years, growers from Washington State have found that at certain times of the year for some cultivars, particularly Red Delicious and Gala, that organic prices may actually be lower than conventional prices. In these cases, the organic fruit could be sold as conventional if it met grading standards.

Wholesaling organic apples in the Northeast may be limited by the lack of nearby facilities equipped to handle organic fruit. The regulations concerning these facilities have been discussed previously in the postharvest handling section of this guide. Fruit are often sold through cooperatively owned and managed packinghouses and marketing programs, and in the future, there may be enough organic apple producers in the Northeast to create a regional organic fruit cooperative.

Additional resources for direct marketing are available through:

- county cooperative extension offices (http://www.cce.cornell.edu/),
- The Small Farms Program at Cornell (http://www.smallfarms.cornell.edu/),
- NYS Department of Agriculture and Markets (http://www.agmkt.state.ny.us/),
- NYS Farmers' Direct Marketing Association (http://www.nysfdma.com/),
- and the Farmers' Market Federation of New York (http://www.nyfarmersmarket.com/).

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APPENDIX ONE: SUPPLIERS OF ORGANIC PRODUCTS AND MATERIALS

Crop Production Services (formerly United Agri Products – UAP)
Several locations in New York
http://www.cropproductionservices.com

Fedco Co-op Garden Supplies
PO Box 520
Waterville, ME 04903
(207) 873-7333
www.fedcoseeds.com

Great Lakes IPM, Inc.
10220 Church Rd NE
Vestaburg MI 48891
(989) 268-5693
(989) 268-5911
(800) 235-0285
http://www.greatlakesipm.com/

Harmony Farm Supply & Nursery
3244 HWY. 116 North
Sebastopol, CA 95472
(707) 823-9125
http://www.harmonyfarm.com

Pacific Biocontrol Corporation
14615 NE 13th Court, Suite A
Vancouver, WA 98685
(800) 999-8805
http://www.pacificbiocontrol.com

Peaceful Valley Farm & Garden Supply
P.O. Box 2209
125 Clydesdale Court
Grass Valley, CA 95945
(530) 272-4769
(888) 784-1722
http://www.groworganic.com

APPENDIX TWO: ADDITIONAL RESOURCES

BOOKS AND GUIDES ON ORGANIC OR SUSTAINABLE FRUIT PRODUCTION

Braun, G. and B. Craig. 2008 (eds.). Organic Apple Production Guide for Atlantic Canada 3rd Ed. Agriculture and Agri-Food Canada, NS, Canada.

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LISTSERVS, DISCUSSION GROUPS, AND WEB SITES

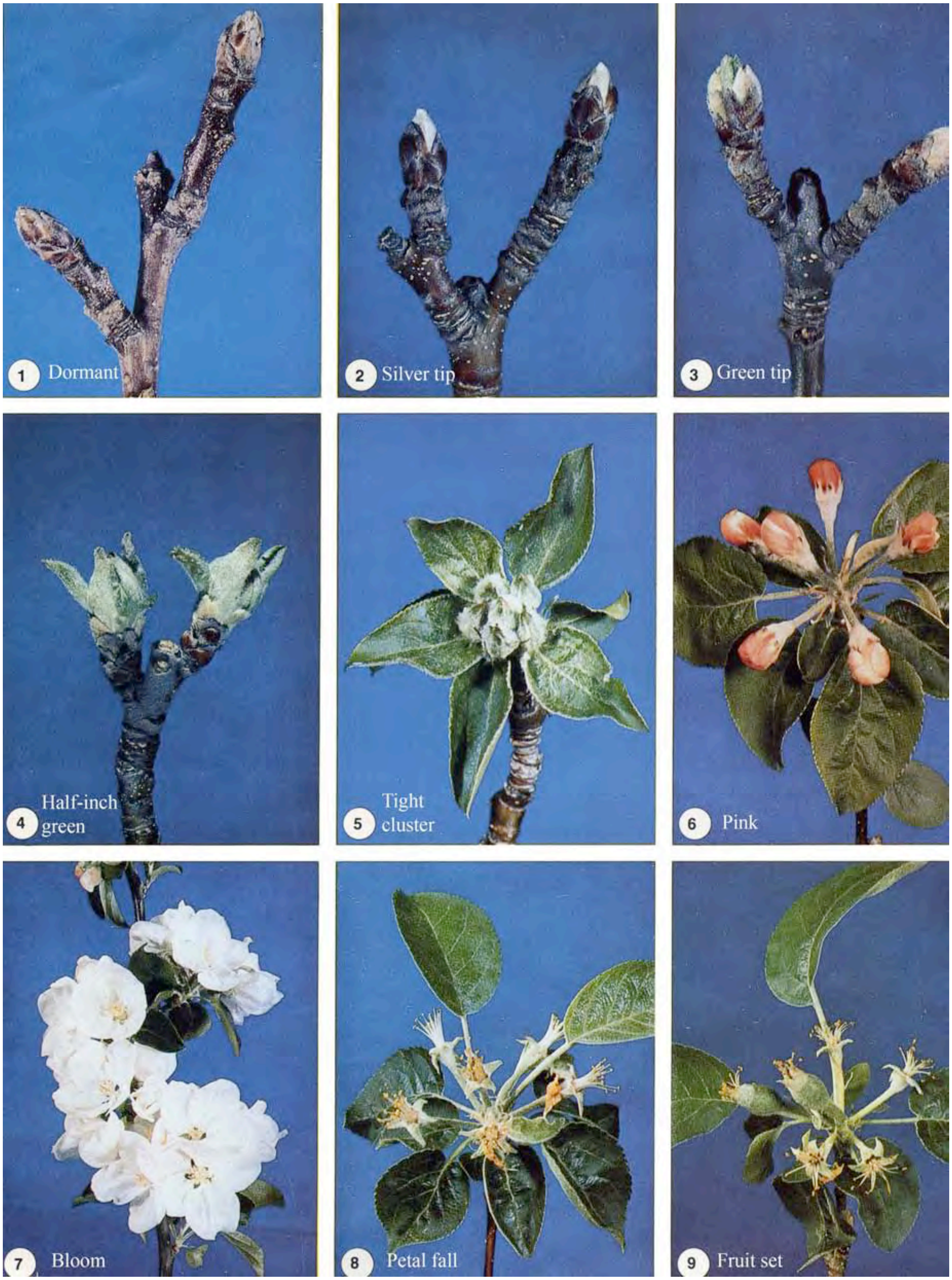
Apple-Crop. "Provide[s] a forum which will foster the exchange of information between University researchers, Extension agents and specialists, students, commercial apple growers, wholesalers/brokers, retailers and direct marketers of apples." http://www.virtualorchard.net/applecrop.html

Grow Organic Apples. "Our Holistic Orchard Network focuses on sharing sustainable fruit growing techniques that emphasize orchard soil health which in turn makes for healthy trees and thus healthy apples and -- blessed be! -- healthy people." http://grou.ps/groworganicapples/home

OrganicA – A Resource for Organic Apple Production. "The pages of this site are intended to provide information to New England apple growers who are interested in organic apple production and who want to examine the opportunities of organic production given the shift in cultivars and the new research-generated information that is available." Sponsored by the University of Vermont. http://www.uvm.edu/~organica/.

Upper Midwest Organic Tree Fruit Growers Network. "Share[s] information and encourage research to improve the organic production and marketing of tree fruit in the Midwest, and to represent the interests of growers engaged in such." http://www.mosesorganic.org/treefruit/intro.htm.

APPENDIX THREE: APPLE GROWTH STAGES



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