Crop Profile for Apples in North Carolina

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General Production Information

Production Facts:

- North Carolina consistently ranks in the top apple producing states, usually 7th to 9th.
- North Carolina produces 1 to 2 percent of the total domestic crop.
- North Carolina typically produces 115 to 170 million pounds with a farm gate value of more than $18.5 million.
- There are approximately 10,000 acres of apples in North Carolina.
- Annual production costs range widely; the average cost for a well-maintained orchard is approximately $1,800 per acre.
- The majority (60 to 70 percent) of North Carolina apples over the past 10 to 20 years have been sold through processing and juice markets; the remainder is sold through fresh markets. However, with increasing retail markets for tourism in North Carolina and diminishing prices and markets for processing apples, growers are striving to sell more apples through fresh-market channels.

Production Regions:

North Carolina has four primary apple production regions, all in the western part of the state and each with a different geography and climate. The major production region is in Henderson County where 70 to 80 percent of the crop is produced (Figure 1). The second largest production region is in the Wilkes/ Alexander County area followed by the Cleveland/Lincoln County area, which includes the lowest elevation orchards in North Carolina. Orchards in the Haywood County area have the highest elevation, the shortest growing season, and the coolest temperatures.

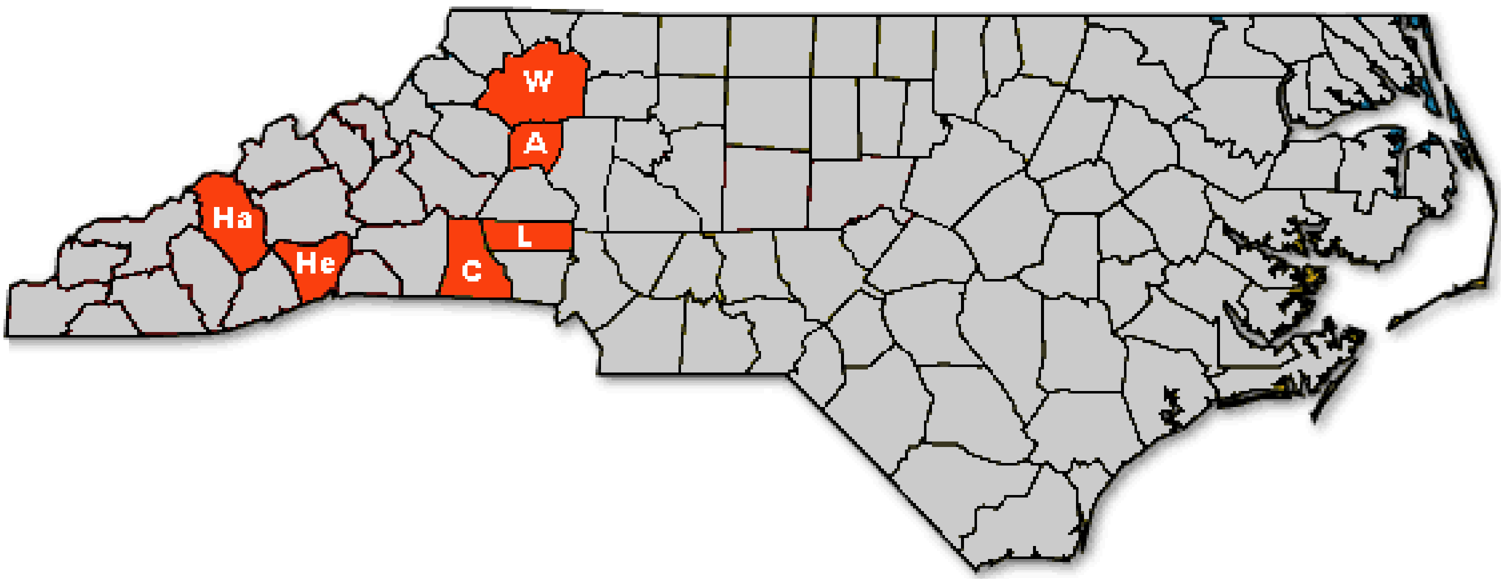

Figure 1. Primary apple-growing counties in North Carolina, including Alexander (A), Cleveland (C), Haywood (Ha), Henderson (He), Lincoln (L), and Wilkes (W) counties. Henderson County produces 70 to 80 percent of the state's apple crop.

Production Practices:

Apples are grown primarily in well-drained soils for both moisture and air drainage. The ideal sites have a lower probability of crop loss from spring frost/freeze conditions. The North Carolina apple industry, as well as that in other U.S. apple production regions, is in the midst of a dramatic changeover to newer cultivars on size-controlling rootstocks. With the newer cultivars and rootstocks, orchard management techniques must also be modified, resulting in a retraining of orchard managers and field workers. However, since apples are a perennial, long-term crop, this change in orchard systems will be very gradual as experience and educational training proceed. North Carolina is in one of the most southern apple production regions in the U.S., so controlling tree vigor and optimizing fruit color and shape under higher temperatures and a longer growing season are a challenge.

One of the potential problems with apple production lies in replanting sites after orchard removal. Frequently, orchards replanted in previous orchard sites fail to thrive, never reaching a profitable level. This problem is referred to as apple replant disease. Rotation with a non-orchard crop such as wheat for several seasons is strongly encouraged.

Worker Activities

The following section deals with the amount of worker activity taking place in a commercial orchard in North Carolina. The activities are listed in order of decreasing amount of direct worker contact with the tree's foliage and wood structure.

Harvesting

In most cases the greatest worker exposure to the foliage and fruit occurs during harvest. With newer cultivars there may be up to three harvests of the tree over a period of several weeks allowing the fruit on the tree to mature, size and color before harvest. Timing is critical for effective harvesting and the optimal harvest window is often a matter of days, especially for fruit destined for long-term storage. Harvest occurs after the preharvest intervals (PHIs) have been reached or exceeded. In many cases no pesticides are applied within at least 4 weeks of harvest. By following the required PHIs growers reduce the risk of pesticide exposure to their workers. In some cases growers provide gloves to workers to minimize the potential for fruit contamination by the harvesting crew.

Pruning

Growers use pruning to remove dead and damaged wood, develop and maintain tree structure and to maintain a balance between vegetative growth and fruit production. A goal of pruning is to open up the canopy to allow adequate penetration of sunlight for fruit initiation and development, to maximize air flow to reduce insect and disease pressure and to allow optimal spray penetration and distribution within the canopy.

Most orchards are pruned once during each winter dormant season and may be also pruned during the growing season. Dormant pruning usually does not begin until several months after the previous season's final pesticide application. Summer pruning on producing trees, undertaken in late June and July, is less extensive and focuses primarily on removing current seasons' growth, which is shading the developing fruit.

Summer pruning can involve extensive contact with foliage. Wearing protective clothing can be problematic in summer heat, and heat stroke risk poses more immediate and severe health concerns than pesticide exposure. However, using long-handled pruners may minimize the amount of worker contact with foliage. While there is usually some flexibility for timing summer pesticide sprays, prolonged reentry intervals (REIs) such as the 4-day REI for captan create scheduling problems for summer pruning which must be done within a limited time frame.

Thinning

Thinning removes excess fruit so that biennial bearing, which is a cycle of fruiting alternating between heavy and light crop years, is minimized. Thinning also provides the optimum crop load for production of large, high quality more profitable apples.

Timing is critical for effective thinning and the effective window is often a matter of days. Chemical thinning agents applied with the air blast sprayer often require follow-up hand thinning and visual crop inspection requiring worker access to the orchard and extensive contact with foliage. Unfortunately, thinning is concurrent with the timing for important pesticide applications for apple scab, plum curculio, leafminers and other key pests. Long REIs on thinning agents, insecticides, or fungicides needed at this time create a major obstacle to effective and profitable crop management and raises the pesticide exposure risk factor. Carbaryl (Sevin) is one of the primary thinners used in apple orchards in North Carolina.

Tree Training

The goal of tree training is to select and develop the central leader of the tree and to position lateral branches to optimize tree structure and maximize the production of high quality fruit. It is done early in the season on new plantings and mature trees.

Tree training involves little contact with bark and foliage and new plantings receive very few pesticide sprays, so there are no major pesticide REI issues. Mature tree training is done at a time of year when trees typically have little or no pesticide residue.

Mowing

Mowing is a standard orchard practice that in many instances is more for aesthetic value than direct benefit to the orchard. However, mowing may allow greater air movement reducing humidity in the orchard, which may discourage fungal diseases. One of the greatest benefits is to aid summer pruning and harvest operation efficiency, and discouraging insect borers, voles and other pests. Mowing is done four to six times per growing season depending on need. Mowing involves very little contact with treated bark and foliage as mowing equipment operators are riding on tractors, which may have enclosed cabs. There is potential for operators in an open cab to brush against overhanging foliage. Pesticide exposure is minimal.

Fertilization

Fertilizer applications consist of ground applications of dry granular fertilizer for nutrients and lime. Foliar spray applications of micronutrients such as boron and magnesium may be used to provide apple trees with not nutrients provided adequately in soil applications. Most soil applications are typically made late in the dormant season and foliar applications may continue throughout the growing season depending on the element and results of foliar and soil assay analysis. Distribution of ground-applied materials involves very little contact with treated bark and foliage as equipment operators are riding on tractors and pesticide exposure is minimal. Foliar applications are typically made in combination with pesticide sprays where proper worker protection measures should be in place to limit pesticide exposure. Calcium is usually used in most cover sprays on several cultivars to minimize calcium-related disorders such as bitter pit.

Insects and Mites

More than 20 arthropods can potentially damage the North Carolina apple crop in a given year. Among this group, 10 to 12 occur in almost every orchard every year, and the ability to effectively manage these pests is critical for successful production. The tolerance for direct damage to fruit is very low so that the crop can meet strict cosmetic standards. Management programs for direct pests have relied extensively on synthetic chemical insecticides, because they have provided the most cost-effective method of control. Depending on pest pressure, six to ten insecticide applications are made annually to commercial apples. Organophosphate insecticides have been an important component of the integrated pest management (IPM) program for apples for more than 25 years, because many biological control agents of secondary pests are tolerant to these insecticides. A diversity of new insecticides classified as "reduced-risk" have been registered on apples in recent years, and these products have helped to fill gaps created by the loss of certain organophosphates through regulatory actions and/or resistant pest populations. The availability of selective pest control tools is essential for maintaining biological control programs in apples.

Similar to the pathogen complex in apples, certain of the major insect pests occur concurrently in orchards. Hence, some insecticide applications are targeted to more than one pest species and, in certain situations; mixtures of two insecticides are applied to manage the insect pest complex. However, the most important arthropod pests are discussed separately. These pests are listed in order of relative importance as either direct or indirect pests.

DIRECT INSECT PESTS

Internal-Feeding Lepidopterans

This group of insects consists of the codling moth, oriental fruit moth, and to a lesser extent the lesser appleworm. While the codling moth has long been a potentially serious pest of North Carolina apples, the oriental fruit moth has only recently emerged as a key pest of apples. Beginning in 1998, this pest complex has developed into the most threatening insect pests of apples in North Carolina, with worm-infested fruit a common occurrence in many orchards. Although the reason for the greater importance of these insects is not entirely understood, the increased use of narrow-spectrum insecticides, increased number of abandoned orchards, and in some instances the development of populations resistant to organophosphate insecticides are contributing factors. Fruit infested with larvae of these insects are not acceptable for the fresh market. Threshold levels for processing fruit vary with market demand, although infestation levels with greater than 2 percent damage or the presence of any live worms is at risk of being rejected.

Codling moth (*Cydia pomonella*)

The codling moth completes three generations per year and damage is the result of larvae tunneling into fruit. Critical periods for control vary, depending on location in the state, but damaging populations can occur anytime from the first cover spray (May) through harvest. Moths lay eggs on leaves and fruit, and larvae enter fruit shortly after emergence from eggs. A degree-day model that predicts egg laying of each generation is used to help time insecticide applications.

Biological control

Naturally occurring predators and parasites can be found in commercial orchards, but to a limited extent. Due to low enemy populations and the extremely low tolerance for damage, the potential of natural enemies as a control tool is limited.

Cultural control

Removing abandoned orchards, which serve as a nursery and point of dispersal for codling moths to nearby orchards, is an important management practice. However, the fate of abandoned orchards is often beyond the control of the owners of nearby orchards. Also, empty apple bins are an ideal overwintering site for codling moth larvae, and infestations within 100 to 200 yards of bin storage areas are a common occurrence. Storing empty boxes away from orchards will minimize this problem, but neither of these practices will eliminate the need for other management programs.

Chemical control

Virtually all commercial apple orchards are sprayed with insecticides for control of codling moth. The number of applications per season targeted for this insect varies from two to six, depending on population densities in individual orchards. In general, two applications are made in May, and one each in June, July, and August. The most common materials used for codling moth control, in order of percentage of acreage treated, are azinphosmethyl (Guthion 50WP at 1 pound of active ingredient per acre), phosmet (Imidan 70WP at 1.75 pounds of active ingredient per acre), methoxyfenozide (Intrepid at 0.19 pound of active ingredient per acre), fenpropathrin (Danitol 2.4EC at 0.3 pound of active ingredient per acre), and esfenvalerate (Asana XL at 3 pounds of active ingredient per acre). Azinphosmethyl is preferred over phosmet among most growers, because it is slightly more effective and has longer residual activity. Azinphosmethyl is the most effective insecticide for control of high codling moth populations (e.g., near bin storage areas). Populations resistant to organophosphate have developed in a few orchards. Methoxyfenozide is an insect growth regulator that is active against codling moth eggs and larvae. Its use has increased in recent years among those growers seeking alternatives to organophosphates, and also in situations where both codling moth and tufted apple bud moth require control. Among the pyrethroids, fenpropathrin is used on more acreage than esfenvalerate, because it also controls European red mite populations, whereas esfenvalerate causes mite flare-ups. The use of pyrethroids in general, is discouraged because of its high toxicity to many natural enemies and resultant flare-ups of European red mite, woolly apple aphid, and, potentially, San Jose scale and Comstock mealy bugs. Indoxacarb (Avaunt 30WDG at 0.11 pound of active ingredient per acre) and to a lesser extent spinosad (SpinTor 2SC at 0.09 pound of active ingredient per acre) are used by some growers for control of second generation codling moth when populations are low and when the need for applications coincides with apple maggot emergence. Pyriproxyfen (Esteem 35WP at 0.1 pound of active ingredient per acre) controls low to moderate densities of codling moth, but cost has limited its use. The neonicotinoid acetamiprid (Assail 70WP at 0.14 pound of active ingredient per acre), which was registered on apple in 2003, has looked promising in small plot trials, but the fit if this product in apple IPM programs has not yet been determined.

Alternatives

Pheromone-mediated mating disruption is used on a low percentage of acreage (less than 1 percent). Factors that limit the more widespread use include cost, need for chemical control of other pests that coincide with codling moth insecticide sprays, and poor efficacy under moderately high to high codling moth populations. Highly refined, narrow-range petroleum oil sprays, which provide ovicidal control of codling moth, are rarely used. Phytotoxicity, resulting from the incompatibility of oil with sulfur-containing fungicides (e.g., captan), inhibit the use of oils in North Carolina.

Oriental fruit moth (*Grapholita molesta*)

A minimum of four generations is completed per season, and damage can occur from May through harvest. In general, populations on apple increase as the season progresses, with late season damage (August and September) most common. Damage is similar to that of codling moth, in which larvae tunnel into fruit. The appearance of oriental fruit moth and codling moth larvae are very similar, and are distinguished by the presence of an anal comb on the last abdominal segment. Insecticides applied for other insects usually control first and second-generation populations.

Biological Control and Cultural Control

Comments under codling moth are also pertinent to oriental fruit moth.

Chemical Control

The organophosphates azinphosmethyl and phosmet are commonly used for oriental fruit moth control, although populations resistant to these insecticides are suspected in some orchards. Some growers use late-season applications of pyrethroids (fenpropathrin or esfenvalerate). Methoxyfenozide is also effective against oriental fruit moth, although this insecticide is slightly less effective against oriental fruit moth compared with codling moth.

Alternatives

Pheromone-mediated mating disruption is very effective against oriental fruit moth and is used by an increasing number of growers. Mating disruption is particularly effective on later maturing varieties that are harvested in late September or October, because the last insecticide applications are made in late August or early September, which will not protect fruit after mid September. Both hand applied pheromone dispensers (Isomate M-100 and Isomate Rosso) and sprayable pheromone (3M Canada and Suterra) are used.

Apple maggot (*Rhagoletis pomenella*)

Historically this fruit fly was a sporadic pest of apples in North Carolina until 2000, when severe infestations occurred in many orchards. This increasing problem is attributed to an increased number of abandoned orchards that serve as nurseries for sources of infestations, and to the increased use of narrower spectrum insecticides such as methoxyfenozide. This insect overwinters in the pupal stage in the soil, and adults begin to emerge in mid to late June. Adults can be found in orchards through August, with peak activity occurring in mid July to early August. Females oviposit directly into apples, where eggs are protected from insecticides and natural enemies. Larvae hatch and tunnel throughout the apple. Infested fruit is unmarketable as either fresh or processing products.

Biological Control

Although there are a few parasites of apple maggot, their low densities in commercial orchards combined with the low tolerance for damage makes natural control of limited utility. Apple maggots overwinter as pupae in the soil, and parasites and soil-dwelling predators can help to reduce populations.

Cultural Control

Commercial apple orchards located adjacent to abandoned orchards, or near infrequently sprayed homeowner trees, are at greatest risk of infestation. Hence, removal of these nursery sites is an important cultural control tool.

Chemical Control

The organophosphates azinphosmethyl and phosmet are the most effective and commonly used insecticides for apple maggot control. The neonicotinoids imidacloprid (Provado 1.6F at 0.075 pound of active ingredient per acre) and acetamiprid also provide good control of apple maggot, although the shorter residual activity of these latter compounds dictates more frequent applications compared with organophosphates. Although indoxacarb and spinosad will kill adults when they ingest these products, they will not control gravid females immigrating into orchards.

Alternatives

The use of multiple point sources of baited red sticky spheres as a trap-out control method is a viable option only in small plantings of apples.

Plum curculio (*Conotrachelus nenuphar*)

Plum curculio adults invade apple orchards from overwintering sites surrounding orchards during a 1- to 3-week period beginning at petal fall. Adult feeding and oviposition scars on fruit are unacceptable for fresh-market fruit, but do not reduce the value of processing fruit. Damage is usually restricted to areas of orchards bordered by woods, but under certain circumstances, damage can occur throughout orchards. In orchards not sprayed with broad-spectrum insecticides, second generation adults that emerge in July can feed on and damage fruit.

Chemical control

Insecticides are the only reliable method of controlling plum curculio in commercial apples. In North Carolina, a single insecticide application administered at petal fall has generally provided good control. However, in years with cool springs when adult emergence is extended, first cover insecticide sprays are also useful. Insecticides commonly applied include azinphosmethyl and phosmet. Carbaryl (Sevin 50WP at 1 pound of active ingredient per acre) applications made for fruit thinning at petal fall also provides control of plum curculio. Permethrin (Ambush 2EC at 0.2 pound of active ingredient per acre) and esfenvalerate are used by some growers at petal fall and will control plum curculio, but this is strongly discouraged because they disrupt integrated mite management programs. The neonicotinoids indoxacarb and thiamethoxam also provide good control of plum curculio, and their use is increasing among many growers because when applied at petal fall they also both control first generation oriental fruit moth, and thiamethoxam controls rosy apple aphid.

Tufted apple bud moth (*Platynota idaeusalis*)

During the 1990’s, tufted apple bud moth (TABM) was the most important direct insect pest of apple in North Carolina, because it was resistant to organophosphate insecticides. It completes two generations per year in North Carolina, and larvae feed on leaves and the surface of fruit. Although leaf feeding is not significant, damaged fruit is unsuitable for the fresh market. Damage to apples destined for processing leads to increased weight loss and fruit decay during storage. Also, the price received for processing apples with excessive damage (more than 5 percent damage) is reduced, particularly in years with a large crop on a regional and/or national basis. Egg hatch occurs during June (first generation) and from mid-August to mid-September (second generation).

Biological control

Although two *Trichogramma* species and more than 40 larval parasitoids of TABM occur in the mid-

Atlantic region, the combined action of these parasites and generalist predators does not provide economically acceptable control. Applications of *Bacillus thuringiensis* have provided good control and are a viable option, the need for multiple applications is not cost effective.

Cultural control

TABM larvae overwinter on the orchard floor and feed on broadleaf weeds and apple suckers in the spring. Hence, maintaining a ground cover free of broadleaf weeds helps to reduce overwintering populations, but does not eliminate the need for supplemental control during the season. Thinning is an important practice that helps to reduce damage because clusters of three or more apples are an ideal microhabitat for larvae. Finally, planting of early-maturing apples (e.g., Gala, Jonagold, Ginger Gold, etc.) can be used to escape damage by second-generation larvae because they are harvested before second-generation egg hatch begins. However, market demands limit the acreage planted to these cultivars.

Chemical control

Almost 70 percent of the North Carolina crop is sprayed with an average of 1.5 insecticide applications per season for tufted apple bud moth; one application each against the first generation in June and the second generation in August. Early maturing cultivars harvested before September do not require second generation control. Methoxyfenozide is the most commonly used insecticide for tufted apple bud moth control. Larvae of all ages are highly susceptible to this insecticide, so there is a relatively wide window during which applications may be made. Spinosad and fenpropathrin are also effective against tufted apple bud moth larvae, but are used less frequently than methoxyfenozide.

Alternatives

Pheromone-mediated mating disruption has worked well against low to moderate populations of TABM, but it does not provide control of high populations. Unreliable results, high cost, and absence of a commercial product have limited its use to an experimental basis only.

Rosy apple aphid (*Dysaphis plantaginea*)

Rosy apple aphid (RAA) is the most important aphid pest of apple in North Carolina, and management of this insect on an annual basis is essential for successful production. This insect is both a direct and indirect pest because it attacks the fruit and leaves. RAA overwinters in the egg stage on apple twigs, and nymphs begin to emerge at the green-tip stage. Egg hatch is complete by pink, when aphids begin to feed on new leaves. Several generations are completed on apples before aphids disperse to alternate hosts, such as plantain, by mid June. Aphids return to apples in the fall where they lay overwintering eggs. Injured leaves become curled and twisted, and aphids reside within these injured leaves. Aphid feeding on fruit results in stunted and malformed fruit. Controlling aphids after petal fall is very difficult because aphids are protected within curled leaves.

Cultural control

Plantain is an alternate host of RAA, and control of this weed can help reduce, but not control, populations.

Chemical control

Insecticides provide the only reliable method of RAA control. Control is most successful when applied at the pink or petal fall stage, although insecticides with long residual control work well when applied at green tip. Insecticides commonly used the pyrethroids permethrin, esfenvalerate, and fenpropathrin, and the organophosphates diazinon and dimethoate. Due to instances of resistance to one or all of the above insecticides, use of the neonicotinoid insecticides imidacloprid, thiamethoxam and acetamiprid is increasing. Because of concerns about toxicity of neonicotinoids to honey bees, these materials are most frequently used after bloom.

Plant bugs (*Lygus lineolaris*)

Tarnished plant bugs pierce young fruit with their sucking mouthparts early in the season and cause large dimpling effects on fruit. Although plant bugs are an annual pest in most orchards, rarely do they damage more than 2 percent of fruit.

Cultural control

Plant bugs are attracted to apple orchards by flowering broadleaf weeds before bloom and move into trees during bloom. Maintaining a clean orchard floor free of broadleaf weeds, particularly before and during bloom, is the most effective control strategy for plant bugs.

Chemical control

Insecticides applied for rosy apple aphid control at pink also provide good plant bug control. Fenpropathrin, permethrin, esfenvalerate, diazinon, and thiamethoxam all provide effective control when applied at the pink stage of bud development. The cost effectiveness of insecticides applied solely for plant bug control is questionable, but the timing of this application (pink) coincides with optimum timing for control of rosy apple aphid, which is essential in most orchards.

San Jose scale (*Quadraspidiotus perniciosus*)

Scales are seldom a problem in well-managed orchards, but when insecticides effective against this insect are not applied for more than two consecutive years, fruit infestations do occur. Populations left unchecked can eventually kill a tree, but rarely does this occur in managed orchards. San Jose scale (SJS) overwinters as immature black caps on twigs and branches, reaching the adult stage near bloom. Mated females produce live crawlers, which appear near first cover. When crawlers settle on fruit and begin to feed, a reddish area develops around the feeding site. This insect may complete up to four generations per year.

Biological control

At least nine hymenopteran parasitoids of SJS occur in North Carolina. Unfortunately, little is known about the impact of these natural enemies on populations in commercial orchards, other than the fact that they are highly susceptible to pyrethroid insecticides.

Cultural control

Pruning is important. It will help to ensure an open canopy for spray penetration and will remove heavily infested wood.

Chemical control

Effective insecticidal control can be achieved with a wide range of organophosphate insecticides. Control may be achieved with one of two application timings: 1) a green-tip application of either chlorpyrifos (Lorsban 4E at 1 pound of active ingredient per acre) or methidathion (Supracide 2E at 1 pound of active ingredient per acre); or 2) a first-cover application of azinphosmethyl (Guthion 50WP at 1.0 pound of active ingredient per acre). The insect growth regulator pyriproxyfen provides excellent control of SJS, but its relatively high cost has limited its use. Approximately 50 percent of growers apply an insecticide specifically for this insect.

Alternatives

Petroleum oils (2 percent solution) applied at green-tip kill many of the overwintering black cap scales, and this is a standard practiced by nearly 80 percent of growers. Also, highly refined, lightweight petroleum oils applied at first and second cover help control crawlers.

Redbanded leafroller (*Argyrotaenia velutinana*)

The redbanded leafroller is a minor pest of apples primarily because it has been maintained at relatively low densities by insecticides applied for other insect pests (i.e., codling moth and tufted apple bud moth). This insect overwinters in the pupal stage in leaf litter, emerges in the early spring (March), and completes three generations per season. Egg hatch of the first, second, and third generations occurs at petal fall, June, and late August/early September, respectively. Larvae feed on leaves and fruit; fruit damage consists of surface feeding similar to that of the tufted apple bud moth.

Biological control

Trichogramma egg parasites, larval parasites, and lacewing larvae can help to suppress redbanded leafrollers.

Chemical control

Insecticidal control, when necessary, is directed against early instar larvae, which are present shortly after peak flight periods of each generation. Seldom are insecticides applied specifically for this pest; but excellent control can be achieved with a variety of materials, including azinphosmethyl, phosmet, methoxyfenozide, spinosad, fenpropathrin and Bacillus thuringiensis materials (i.e., Dipel 2X at 1 pound of per acre).

Comstock mealy bug (*Pseudococcus comstocki*)

This insect is a sporadic pest of apples that appears to be increasing in importance in North Carolina. The biology of this insect in relation to apples in North Carolina is not well understood. Both adults and immatures can be found on apples from July though September, with adults first observed in June. Mealy bugs infest the calyx end of fruit, and their honeydew secretions serve as a substrate for growth of sooty molds, which results in downgrading of fruit. Infestations appear to be favored in orchards treated with post bloom applications of pyrethroids (i.e., Asana XL).

Biological control

An encrytid parasite of Comstock mealybug has been observed in high numbers in some orchards. Currently there is little information on the impact of this parasite on apple infestations.

Chemical control

Organophosphates that have shown good activity against this insect include diazinon and dimethoate. Recent laboratory bioassays have shown that the neonicotinoids imidacloprid (Provado), acetamidprid (Assail) and thiamethoxam (Actara) and also highly toxic to adults and immatures. Insecticides are usually applied in mid June when adults are first observed in orchards.

Lesser appleworm (*Grapholita prunivora*)

Lesser appleworm (LAW) is a sporadic pest in North Carolina. The life cycle and time of occurrence are similar to the codling moth's, but larvae form mines under the skin and do not enter the core of the apple.

Third-generation larvae, which occur in August and September and are most problematic in North Carolina, feed within the calyx area of fruit.

Chemical control

Insecticides that are used for codling moth also control LAW, including azinphosmethyl (Guthion 50WP at 1 pound of active ingredient per acre), phosmet (Imidan 70WP at 1.75 pounds of active ingredient per acre), methoxyfenozide (Intrepid 2F) and fenpropathrin (Danitol 2.4EC). Although tebufenozide is expected to work well against LAW, there are no data to support this claim due to the sporadic nature of this pest and, hence, the difficulty in obtaining data.

Green fruitworms (*Orthosia* spp.)

Green fruitworms of several species are rare pests of apples. Eggs are laid early in the season and hatch near green tip. Larvae feed on young apples just after petal fall, chewing large holes in the side of fruit. At harvest, the misshapen fruit are covered with sunken, corky tissue.

Chemical control

Insecticides applied before bloom and at petal fall for other pests usually control green fruitworm larvae. Most insecticides used at pink and petal fall provide good control.

INDIRECT INSECT AND MITE PESTS

European red mite (*Panonychus ulmi*)

European red mite (ERM) is the most important indirect arthropod pest of apples in North Carolina. Although apple rust mite, *Aculus schlechtendali*, is also common, rarely does it occur at damaging levels. European red mite overwinters as eggs on the tree, which begin to hatch near bloom. Population densities vary considerably from year to year, but supplemental control may be required at any time from mid May through mid July. Mite feeding causes leaves to turn bronze, which reduces photosynthesis and increases respiration. Damage is expressed as smaller fruit, premature drop, and reduced soluble solid content. The interaction of ERM and Alternaria blotch on Delicious apples causes premature defoliation. Maintenance of mites at very low densities is an important management practice for this disease.

Biological control

A number of naturally occurring predators can help to suppress ERM populations in North Carolina, including the phytoseiid mite *Amblyseius fallacis* and the coccinellid *Stethorus punctum*. *A. fallacis* is most effective when it enters the orchard early in the season (May), while *S. punctum* does not appear until ERM has begun to increase. The preservation of these beneficial predators in orchards depends on the use of selective insecticides that are non-toxic to these predators. Carbamates and pyrethroids are extremely toxic to these predators and will eliminate the potential for biological control. Also, certain fungicides such as benomyl and thiophanate methyl are incompatible with *A. fallacis*. A number of other predators can also play an important role in biological control of ERM, including the black hunter thrips, *Leptothrips mali*, and lacewing larvae. However, the abundance of these latter predators is dependent on avoiding insecticide use during periods of mite activity or the use of narrow-spectrum insecticides.

Cultural control

Pruning to ensure an open canopy for spray penetration is important because thorough coverage is a key element of oil and pesticide applications. Ground-cover practices that minimize herbicide use and increase the percentage of ground covered with vegetation can suppress mite populations on apples. The competition between trees and weeds for nutrients can reduce the nutritional content of leaves such that ERM population growth will be suppressed. However, this practice is not recommended because of the negative effects on vole management and tree growth.

Chemical control

Chemical control of ERM can be achieved either with preventative applications of abamectin (AgriMek 0.15EC at 0.01 pound of active ingredient per acre) at petal fall, or clofentezine (Apollo 4SC at 0.125 pound of active ingredient per acre) or hexythiazox (Savey 50WP at 0.09 pound of active ingredient per acre) at first or second cover. Approximately 25 percent of the acreage in North Carolina is treated with one of these products. Curative control of mites based on threshold levels is practiced by most growers, and pyridaben (Pyramite 60WP at 0.165 pound of active ingredient per acre) and bifenazate (Acramite 50WS at 0.375 pound of active ingredient per acre) are most commonly for this purpose. Other miticides that are used on a very small percentage of the crop include hexakis (Vendex 50WP at 1 pound of active ingredient per acre) and dicofol (Kelthane 50WP at 1.5 pounds of active ingredient per acre). Approximately 60 percent of the acreage is annually treated with a miticide.

Alternatives

Petroleum oil (2 percent solution) is used on nearly 90 percent of the acreage for control of overwintering eggs. The use of highly refined, lightweight summer oils (1 percent suspension) at first and/or second cover can suppress building ERM populations and eliminate the need for curative miticides later in the summer. However, the incompatibility of oils with sulfur-containing fungicides (e.g., captan) limits the use of this strategy.

Apple aphid (*Aphis pomi*)

Spirea aphid (*Aphis spiraecola*)

Apple and spirea aphid both infest apples, with populations most abundant during May and June. Aphids feed on new shoot growth and cause little if any damage on mature trees. On new trees or in high-density plantings, control is more important. Although the loss of plant sap can cause indirect damage when populations are excessively high, this type of damage is not common. Of more concern to growers is the occurrence of aphid honeydew on fruit when numbers reach high densities. When summer shoot growth hardens off in July, aphid populations naturally decline.

Biological control

Generalist predators such as lacewing larvae, lady beetles, syrphid larvae, and predatory midges can suppress populations below damaging levels when broad-spectrum insecticide use is minimized.

Cultural control

Summer pruning of water sprouts removes the preferred habitat for aphids and is an effective control strategy.

Chemical control

A single application of an insecticide when populations build to high densities and before honeydew accumulates on fruit provides season-long control. Dimethoate (Dimethoate 4EC at 0.5 pound of active ingredient per acre) has been most commonly used insecticide, but the neonicotinoids imidacloprid (Provado 1.6F at 0.05 pound of active ingredient per acre), acetamiprid (Assail 70WP at 0.1 pound of active ingredient per acre) and thiamethoxam (Actara 25WP at 0.04 pound of active ingredient per acre) are highly effective and their use is increasing. On average, 50 percent of growers make an average of one application per season. Fenpropathrin and esfenvalerate (Asana XL at 0.03 pound of active ingredient per acre) also control aphids.

White apple leafhopper (*Typhlocyba pomaria*)

White apple leafhopper (WALH) is a common pest of apples that completes two generations per season. It overwinters in the egg stage in twigs, and nymphs begin to emerge at petal fall. Peak populations of nymphs occur by first or second cover. Second-generation nymphs occur from late July through August. Feeding injury, which results in white stippling on leaves, is generally of little consequence to the productivity of the tree. Of greatest concern is honeydew accumulation on fruit, which is the result of second-generation adults from late August through September. Second-generation adults are also a nuisance to pickers during harvest.

Chemical control

Insecticidal control is usually only necessary against the first generation of the season because control of the first generation will usually reduce populations so that second-generation populations do not reach damaging levels. Applications of carbaryl made for thinning coincide with the proper timing for control of first-generation nymphs. Other products used for control and which are highly effective include imidacloprid, acetamiprid and thiamethoxam and abamectin. Also, the miticide pyribaden is effective against WALH if applications for mite control are made in mid July or later. The pyrethroids fenpropathrin and esfenvalerate are also effective against leafhoppers.

Alternatives

Insecticidal soap has provided partial control of WALH when applied as a 1 percent solution.

Potato leafhopper (*Empoasca fabae*)

This insect does not overwinter in North Carolina, but migrates from southern locations each year. The timing of infestations varies among years and ranges from mid-May through June. Leafhoppers feed and reproduce on new shoot growth. When feeding, they inject a toxin into the leaf, which causes leaves to curl and turn brown on the edges. Injury is inconsequential on mature trees but can affect the growth of new trees and those in high-density plantings. There is some belief that potato leafhoppers facilitate the transmission of fire blight, but the data are variable.

Cultural control

Summer pruning of water sprouts, the preferred site of colonization, can help to control populations by removing their habitat.

Chemical control

Potato leafhoppers are easily controlled by a wide range of insecticides, including most organophosphates, carbamates, neonicotinoids, and pyrethroids. Pyribaden, when applications for mite control coincide with leafhopper infestations.

Alternatives

Insecticidal soap has provided partial control of potato leafhoppers when applied as a 1 percent solution.

Spotted tentiform leafminer (*Phyllonorycter blancardella*)

Spotted tentiform leafminer (STLM) is a common apple pest in North Carolina, but damaging populations occur only sporadically. It completes four generations per season, but mines of the second (mid-June to early July) and third (August) generations are most damaging if they increase to large numbers. Leafminer mines reduce capacity for photosynthesis, and damage is expressed as premature ripening and fruit drop.

Biological control

Biological control by two naturally occurring larval parasitoids (*Sympiesis marylandensis* and *Pholetis ornigis*) plays an important role in suppressing populations of this insect since they were introduced into North Carolina in the mid 1980s. Both parasites have developed a tolerance to organophosphate insecticides, and parasitization rates of more than 50 percent are common by August.

Chemical control

Abamectin applied at petal fall provides good control of first- and second-generation populations and help to suppress third-generation population mines. When second-generation mines do increase to damaging levels in June or July, spinosad is the most effective and common insecticide used. Other insecticides with leafminer activity that suppress populations include imidacloprid, acetamidaprid, and fenpropathrin.

Japanese beetle (*Popillia japonica*)

Adults feed on leaves, causing foliage to be skeletonized so that leaf tissue between the veins is removed. Control is necessary when populations reach high densities and/or the beetles attack small trees, which have a low leaf:fruit ratio. Beetles begin to emerge in June and are active on apples through July.

Cultural control

While some new varieties have demonstrated resistance to Japanese beetle, these varieties are not well adapted to North Carolina.

Chemical control

Japanese beetles are most effectively controlled with organophosphate insecticides, including azinphosmethyl and phosmet. June/early July applications of either azinphosmethyl or phosmet applied for codling moth coincide with the proper timing of Japanese beetle emergence. Carbaryl (Sevin XLR at 1 pound of active ingredient per acre) is also very effective and sometimes is applied specifically for beetles. Other insecticides with activity against Japanese beetles include indoxacarb, thiamethoxam, acetamiprid, and fenpropathrin.

Dogwood borer (*Synanthedon scitula*)

Dogwood borer is the larva of a small clearwing moth that infests burr knots and the graph union. Feeding in burr knots causes no harm to the tree, but when larvae feed below the bark they may girdle the tree, or create wounds that are invaded by wood rot fungi. Persistent infestations over several years can reduce tree vigor and yields. Infestations are most important on dwarfing rootstocks and certain cultivars that are prone to burr knot production. Adults are active from May through September, with two periods of peak activity based on pheromone trap catches; the first in late May/early June, and the second in late August.

Cultural control

Certain rootstocks are less susceptible to dogwood borer attack, but only MM111 exhibits considerably lower infestation levels. Undiluted white latex paint applied to the graph union and lower trunk before egg laying begins can reduce infestations.

Chemical control

Trunk applications of a long residual insecticide, such as chlorpyrifos (Lorsban 50W at 1 pound of active ingredient per acre) applied the last week of May or in early June, are most effective. Endosulfan (Thiodan 50WP or 3EC at 1 pound of active ingredient per acre) and esfenvalerate are less effective than chlorpyrifos, but satisfactory levels of control will be achieved. Insecticidal control is most common on high-density plantings of dwarfing rootstocks.

Woolly apple aphid (*Eriosoma lanigerum*)

Woolly apple aphid (WAA) is a common pest, but the occurrence of large foliar populations is not common. WAA can infest apple trees both above and below ground. Most orchards have root infestations, but they are usually damaging only to trees infested when young. Root feeding causes gall-like formations on roots. Foliar infestations can arise from immigration of aphids from alternate hosts (e.g., elm) or from movement of root aphids to the foliage. Only when populations are extremely high do foliar aphids cause problems by excessive production of honeydew.

Biological control

The aphid parasite *Aphelinus mali* can be an important biological control agent of WAA. However, A. mali is very sensitive to carbamate and pyrethroid insecticides, and destruction of this natural enemy by postbloom use of these materials contributes to increased WAA populations. Generalist predators, such as syrphid fly larvae, lacewing larvae, and lady beetles, can also serve as useful controls of WAA.

Cultural control

The Malling Merton (MM) series of rootstocks was bred for resistance to WAA, and root infestations are lower on these rootstocks.

Chemical control

Few insecticides registered on apples provide good control of WAA; endosulfan and thiamethoxam have demonstrated moderate levels of activity. Insecticides are applied specifically for WAA on less than 5 percent of orchards. There are no insecticides registered on apple that control root infestations.

Trunk and root borers

In addition to the dogwood borer, a number of beetles infest the trunks and roots of apple trees. Larvae of the flatheaded appletree borer, *Chrysobothris femorata*, and roundheaded appletree borer, *Saperda candida*, both infest trunks of trees. In addition, larvae of *Prionus* spp. can be serious pests of roots. These pests are of relatively minor importance in commercial orchards because broad-spectrum insecticides applied for other insects have maintained adult beetle populations at low levels.

Diseases

Thirteen major diseases of fruit and foliage affect apples in North Carolina, as well as seven diseases of the roots and crown. Although each disease is discussed separately in this section, they are managed in groups according to when they occur during the growing season. Consequently, many fungicide applications target more than one pathogen. In other cases, two or more fungicides are combined to make up for weaknesses one or the other has on the particular pathogen complex present.

Apple scab (*Venturia inaequalis*)

Apple scab occurs more sporadically in North Carolina than in many northern growing areas in the U.S.; nevertheless, growers in the Southeast have identified it as their number one disease concern. The disease affects the fruit and foliage. Affected fruit are downgraded, and if the disease is severe, many fruit and leaves fall prematurely. The critical period to control scab is from green-tip through first or second cover. The disease is rarely a problem after second cover in North Carolina because warm temperatures are not conducive to secondary cycles.

Cultural control

Shredding of leaves after leaf fall with a flail mower helps reduce the inoculum, but does not provide adequate control alone. Resistant cultivars are available but are not of sufficient quality to justify planting under conditions in North Carolina.

Chemical control

Approximately 75 percent of the growers use one or more sprays of sterol-inhibiting fungicides (fenarimol, Rubigan; myclobutanil, Nova; triflumizole, Procure) for apple scab control. Approximately 2.5 applications are made, usually in combination with the protectants captan (Captan) at 1.4 pounds active ingredient per acre or an EBDC (ethylene bisdithiocarbamate) fungicide (mancozeb or metiram) at 2.4 pounds active ingredient per acre. Combinations with protectants are used to avoid resistance and improve the spectrum of activity. Myclobutanil (48 percent of acreage treated) is more widely used than fenarimol (28 percent). Triflumizole is not used to a great extent. Cyprodinil (Vangard), registered in 1998 has good scab activity, but is weak on powdery mildew. It has replaced some dodine and sterol-inhibitor use in the first 1 to 2 sprays. The Strobilurin (QoI) fungicides kresoxim-methyl (Sovran) and trifloxystrobin (Flint) have good scab and mildew activity but are used primarily for summer disease control in North Carolina. Approximately 1 spray of strobilurin fungicide per season is targeted for apple scab control. Typically the lower labeled rate (2.0 ounces of active ingredient of kresoxim-methyl and 1.0 ounce of active ingredient of trifloxystrobin per acre) is used for apple scab control.

Powdery mildew (*Podosphaera leucotricha*)

Powdery mildew is a problem on the most susceptible cultivars (e.g., Ginger Gold, Jonagold, Granny Smith, Rome, etc.). It primarily affects the foliage; however, it can cause a net-like russet on the fruit. Yields are reduced when the disease is severe. The most important period for controlling powdery mildew is from the tight cluster/pink phenophase until terminal growth has stopped in the summer.

Cultural control

Pruning out silver-appearing, mildewed terminals in the dormant season helps reduce the inoculum. Cultivars vary widely in their susceptibility.

Chemical control

The sterol-inhibiting fungicides (fenarimol, Rubigan; myclobutanil, Nova; triflumizole, Procure), used as described above for apple scab, satisfactorily control powdery mildew. Triadimefon (Bayleton, also a sterol inhibitor), which does not have scab activity, was used on approximately 6 percent of the acreage at 0.0625 pound of active ingredient per acre in 1998. Approximately 4.25 applications are made yearly. Sulfur is used 1.6 times a season on 20 percent of the acreage. Sulfur is usually applied to processing fruit because it is less expensive and phytotoxicity is not as great a concern as on fresh-market fruit.

Fire blight (*Erwinia amylovora*)

Fire blight is a very destructive disease that can reduce yield (through blossom infections), cause loss of scaffold limbs, and even cause the tree to die. The disease is sporadic in North Carolina, causing significant losses about one year in five, although, with the increased planting of susceptible cultivars on susceptible rootstocks, fire blight is likely to become more important. Initial infection occurs in blossoms during warm (above 18 degrees C), wet periods. Secondary spread can occur through sucking insects and injuries (i.e., hail). Control is achieved primarily by use of copper bactericides/fungicides applied during the dormant season and with streptomycin applied during bloom.

Cultural control

Pruning to remove overwintering cankers helps to reduce the overwintering inoculum. Cultivars vary in their susceptibility to the disease.

Chemical control

Copper fungicides/bactericides are used once just before bud break on susceptible cultivars to reduce the overwintering inoculum. About 30 percent of the growers use various formulations of copper at 0.6 to 1.5 pound of active ingredient per acre. Streptomycin sulfate (Agri-mycin 17) is used approximately 1.6 times yearly on 20 percent of the acreage. Resistance to streptomycin has not been identified in North Carolina but is a problem in some states. Fosetyl Al is also registered for fire blight control but is not used because of its erratic performance. Similarly, BlightBan (a biological control based on a strain of Pseudomonas) is registered but not used.

Black rot (*Botryosphaeria obtusa*)

White (Bot) rot (*B. dothidea*)

Both *B. obtusa* and *B. dothidea* cause a fruit rot. *B. obtusa* causes a firm, brown rot, primarily at the calyx end; *B. dothidea* causes a soft, watery rot. *B. obtusa* also has a leaf spot phase, called frogeye leafspot. Black rot and frogeye leafspot tend to be more severe early in the season, although both B. obtusa and B. dothidea can cause fruit infections throughout the growing season. Infections arise from spores produced in dead wood, mummied apples, etc., in the tree and dispersed by rainfall. There is a canker phase of both diseases, although Bot canker tends to be more important in North Carolina. Cultivars do not vary greatly in their susceptibility to the two diseases.

Cultural control

Pruning to remove cankers and dead wood and removing mummied fruit are essential aids in controlling these two diseases.

Chemical control

Captan (Captan) is the most important fungicide used in the summer season in North Carolina. It is used 4.5 times in cover sprays on 60 percent of the acreage at 3 to 4 pounds of active ingredient per acre to control black rot and white rot, as well as many of the other summer diseases described below. Benzimidazole fungicides (Benlate and Topsin M) are usually used in combination with captan to improve control of black rot, white rot, sooty blotch, and flyspeck. They are used on approximately 75 percent of the acreage. Thiophanate methyl (Topsin M) has replaced benomyl (Benlate) as supplies of Benlate have been used. Five to seven applications of benzimidazole fungicides are applied yearly. Topsin M is used at 0.45 pound of active ingredient per acre. The strobilurin fungicides kresoxim-methyl (Sovran) and trifloxystrobin (Flint) have good activity on both diseases. Typically 1 to 3 applications of the lower labeled rate of each fungicide (2.0 ounces of active ingredient of kresoxim-methyl and 1.0 ounce of active ingredient of trifloxystrobin per acre) is used for control of black rot, bot rot and other summer diseases.

Bitter rot (*Colletotrichum acutatum, C. gloeosporioides, Glomerella cingulata*)

Bitter rot is the most important rot disease in North Carolina. It was identified by growers as the third most important disease problem. Bitter rot is very difficult to stop once infections appear in the orchard because of secondary spread by the copious conidia that are produced on infected fruit. Losses of up to 50 percent have been observed in some orchards. Infections can occur on the fruit throughout the growing season during warm, rainy periods and arise from spores produced in dead wood, cankers, mummied apples, etc., in the tree. Glomerella leafspot first appeared in 2000 in one orchard of cv. Gala and has the potential to become a significant problem. Control of bitter rot has been more difficult since restrictions were placed on the use of EBDC fungicides. There is little difference in the susceptibility of cultivars to bitter rot.

Cultural control

Removing dead wood, mummied apples, etc. is essential to aid in controlling bitter rot.

Chemical control

Restrictions on the use of the EBDC fungicides through the summer growing season (e.g., the 77-day preharvest interval [PHI]) have seriously hampered the ability to control bitter rot. As currently labeled, the EBDC fungicides provide little help in controlling bitter rot. Captan (Captan) is used at 3 to 4 pounds of active ingredient per acre as described for back rot and white rot. Ziram (Ziram) is used an average of 3.6 times on 39 percent of the acreage at approximately 5 pounds of active ingredient per acre. It is usually combined with captan and/or thiophanate methyl. When combined with captan, both ziram and captan are both used at one-half rate. The strobilurin fungicides kresoxim-methyl (Sovran) and trifloxystrobin (Flint) have good activity on bitter rot . Typically 1 to 3 applications of the higher labeled rate of each fungicide (4.2 ounces of active ingredient of kresoxim-methyl and 2.0 ounces of active ingredient of trifloxystrobin per acre) are used for control bitter rot. This rate will also provide good control of other summer diseases.

Sooty blotch (disease complex caused by *Peltaster fructicola, Leptodontidum elaitus, Geastrumia polystigmatis*, and other fungi)

Flyspeck (*Zygophiala jamaicensis*)

Sooty blotch and flyspeck are the most common diseases of apples in North Carolina and would affect nearly 100 percent of the crop in most years if not controlled. The fungi that cause these diseases grow epiphytically on the cuticle and result in fruit being downgraded from fresh market to processing or juice grades. The fungi that cause the two diseases can survive from season to season on apple twigs, but most inoculum comes from reservoir hosts surrounding the orchard. Infection occurs from mid-May until harvest. Rain is important in spreading the pathogens, but dew is equally important in symptom development. The diseases have been more difficult to control since restrictions have been placed on the use of EBDC fungicides.

Cultural control

Cultural practices, such as proper tree structure, pruning during the dormant as well as summer season, and fruit thinning, are important to reduce the drying time within the canopy and improve fungicide penetration into the canopy. Removing reservoir hosts, especially brambles, aids in reducing the inoculum.

Chemical control

Benzimidazole fungicides (benomyl, Benlate; thiophanate methyl, Topsin M) in combination with captan (Captan) or ziram (Ziram) are widely used to control these diseases. Thiophanate methyl has almost completely replaced Benlate since most supplies are exhausted. Captan is used at 3 to 4 pounds of active ingredient per acre, ziram at 5 pounds of active ingredient per acre, benomyl at 0.25 to 0.5 pound of active ingredient per acre, and thiophanate methyl at 0.35 to 0.7 pound of active ingredient per acre. When combined, captan and ziram are used at one-half the rates indicated above in five to six applications. EBDC fungicides applied at 2.4 pounds of active ingredient per acre, usually in combination with captan (2 to 3 pounds of active ingredient per acre), improve control on late season cultivars where EBDC fungicides can be used through late June and still comply with the 77-day PHI. The strobilurin fungicides kresoxim-methyl (Sovran) and trifloxystrobin (Flint) have good activity on these diseases. Typically 1 to 3 applications of the lower rate of each fungicide (2.0 ounces of active ingredient of kresoxim-methyl and 1.0 ounce of active ingredient of trifloxystrobin per acre) are used for control of sooty blotch, flyspeck and other summer diseases.

Alternaria blotch (*Alternaria mali*)

Alternaria blotch has become a serious problem on the cultivar Delicious over the past 15 years, causing significant losses to many growers. The disease primarily affects the leaves, causing a leaf spot. In severe cases, defoliation has exceeded 75 percent, and yield losses have been greater than 50 percent. European red mites act synergistically with Alternaria blotch to increase defoliation. Strains of Delicious and cultivars with Delicious parentage (i.e., Empire) are most severely affected. First infections are usually noticed in early June, and the disease increases in severity during warm, wet periods throughout the summer.

Cultural control

Leaf shredding may help reduce the overwintering inoculum.

Chemical control

The strobilurin fungicides kresoxim-methyl (Sovran) and trifloxystrobin (Flint) have good activity on this disease. Typically 3 applications of the lower labeled rate of each fungicide (2.0 ounces of active ingredient of kresoxim-methyl and 1.0 ounce of active ingredient of trifloxystrobin per acre) are applied from mid June through late July to control the disease. Fungicide control needs to be coupled with good mite control to effectively manage the disease. Resistance to the strobilurin fungicides in several orchards in 2003 threatens our ability to control the disease.

Brooks fruit spot (*Mycosphaerella pomi*)

This disease is characterized by small, slightly sunken, green spots primarily located at the calyx end of the fruit. Infection is by ascospores produced in leaves during the period from first through third cover and discharged during rainy periods. Cultivars vary in their susceptibility: Delicious is relatively resistant; Golden Delicious, Rome, Stayman, Cameo, Ida Red and Gala are susceptible.

Cultural control

Leaf shredding may help reduce the overwintering inoculum.

Chemical control

EBDC fungicides (metiram, Polyram; mancozeb, Dithane, Manzate, Penncozeb) and benzimidazole fungicides (benomyl, Benlate; thiophante methyl, Topsin M), in combination with captan, provide good control when applied in three to four applications from petal fall through third cover. EBDC fungicides (about 2.4 pounds of active ingredient per acre) are used in combination with captan (Captan) at 2 pounds of active ingredient per acre. Benzimidazole fungicides (Benlate, 0.25 pound of active ingredient per acre or Topsin M, 0.35 pound of active ingredient per acre) are used in combination with captan (Captan, 3 to 4 pounds of active ingredient per acre). Topsin M has almost completely replaced Benlate since supplies are almost exhausted. Sterol-inhibiting fungicides have very little activity on *M. pomi*. Growers who use them without a mixing partner (captan or mancozeb) often have severe Brooks spot infection. The strobilurin fungicides kresoxim-methyl (Sovran) and trifloxystrobin (Flint) have good activity on Brooks spot, but are typically not used during the time that the pathogen is most active.

Black pox (*Helminthosporium papulosum*)

This disease is characterized by circular lesions (approximately 2 to 5 millimeters in diameter) on the fruit. *H. papulosum* overwinters in twig lesions on the tree, and conidia produced in these lesions are washed or are blown to fruit and initiate infections during warm, wet periods of the summer. Black pox is most severe on Golden Delicious but can be found on other cultivars.

Cultural control

Pruning out water sprouts to remove overwintering cankers aids in control.

Chemical control

EBDC fungicides (metiram, Polyram; mancozeb, Dithane, Manzate, Penncozeb), in combination with captan, used through second or third cover (depending on the anticipated harvest date of the cultivar) or benzimidazole fungicides (benomyl, Benlate; thiophanate methyl, Topsin M) used in combination with captan, provide good control. EBDC fungicides are used at approximately 2.4 pounds of active ingredient per acre when combined with captan (Captan) at 2 pounds of active ingredient per acre. Benzimidazole fungicides (Benlate, 1/4 pound of active ingredient per acre or Topsin M 0.35 pound of active ingredient per acre) are used in combination with captan (Captan) at 3 to 4 pounds of active ingredient per acre. Topsin M will replace Benlate as supplies of Benlate are used. The stroblurin fungicides do not have much activity on this disease.

Blister spot (*Pseudomonas syringae pv. papulans*)

Symptoms of this bacterial disease are characterized by purplish-black lesions, 4 to 5 millimeters in diameter, associated with the lenticels. Fruit are most susceptible to infection for a period of about 6 weeks, beginning 2 weeks after petal fall. The disease has been observed in only a few orchards in North Carolina. It is most common on the variety Mutsu.

Cultural control

None

Chemical control

In orchards where the disease is a problem three sprays of streptomycin (Agri-Mycin 17) at 0.5 pound per 100 gallons (1 to 1.5 pounds per acre) are applied in 3 sequential applications beginning approximately 2 weeks after petal fall.

Necrotic leaf blotch of Golden Delicious

This physiological disorder affects only strains of Golden Delicious. The disorder is initiated by cool, rainy periods during the growing season and occurs in distinct periods or waves during the growing season. Affected leaves often turn yellow and abscise. Up to 75 percent defoliation can occur in years favorable for development of the disorder.

Cultural control

None

Chemical control

Ziram (Ziram), used in the third- through sixth-cover sprays, will give about 80 percent suppression of necrotic leaf blotch. Ziram (2.5 pounds of active ingredient per acre) is usually used in combination with captan (2 pounds of active ingredient per acre). Thiram (Thiram) is also effective, but is not widely used. It is used at about 4 pounds of active ingredient per acre in an average of two applications. It is often used in combination with captan and/or benzimidazole fungicides. Zinc oxide (Ele-Max Super Zinc Fl) applied at 1 pint per acre in 3 to 5 sprays beginning in mid June is also effective in suppressing the disorder and is becoming more widely used.

Black root rot (*Xylaria* spp.)
Clitocybe root rot (*Clitocybe tabescens*)
Armillaria root rot (*Armillaria* spp.)
White root rot (*Scytinostroma galactinum*)

These root rot diseases cause general tree decline and death and are scattered in orchards throughout the apple-growing region of North Carolina. Losses in most orchards are less than 0.5 percent per year, but some orchards sustain tree losses of 25 percent or more over the life of the orchard.

Cultural control

Removing old roots that harbor the fungi when orchards or sites within orchards are replanted aids in control of the diseases, but it seldom completely eliminates the pathogens from the site.

Chemical control

None

Southern stem blight (*Sclerotium rolfsii*)

This disease occurs primarily in orchards in the Piedmont that have been planted on sites previously planted to a susceptible host such as soybeans. Trees are affected during the first 1 to 3 years after planting. Bark on affected trees appears shredded at the soil line, and sclerotia of the fungus often can be found on or near affected stems. Losses of about 5 percent of the trees have been observed in severely affected plantings. The disease is also a problem in nurseries.

Cultural control

Clean cultivation around newly set trees removes dead plant material that may act as a food bridge for *S. rolfsii*.

Chemical control

None

Phytophthora crown, collar, and root rot (*Phytophthora* spp.)

Phytophthora crown rot primarily affects trees propagated on size-controlling rootstocks and trees planted in heavy, poorly drained soils. The disease is characterized by brick red, necrotic lesions on the roots, collar, and crown tissues, which eventually girdle the tree and cause its death. Tree death is usually greatest during the third to fifth growing seasons. The disease does not cause significant losses in most orchards, but some growers have lost 5 to 10 percent of their trees by the fifth growing season.

Cultural control

Planting on well-drained sites and on beds (berms) reduces the likelihood of infection. The most susceptible rootstocks should be avoided, especially in sites not well drained.

Chemical control

Fosetyl Al (Aliette) is registered as both a preplant dip for nursery stock and as a foliar spray for established plantings. In established plantings it is used two to three times a year at 2.4 to 4 pounds of active ingredient per acre on 2 percent of the acreage. Where the disease is severe, mefenoxan (Ridomil Gold) is used as a collar drench twice a year on approximately 3 percent of the acreage. The rate varies according to tree size.

Replant disease (various biotic and abiotic causes)

The replant disease is part of the replant problem, which is characterized by poor tree growth on replant sites. In other areas of the world it is associated with various nutritional problems, nematodes, and several pathogenic fungi and bacteria; however, its cause in North Carolina has not been determined. Sites vary in the degree of the problem.

Cultural control

Good site preparation is essential to minimizing the replant problem. Practices to reduce the severity of the disease include fertilizing and liming, fallowing for at least 2 years, and rotating to nonorchard crops for at least 2 years. The performance of new rootstocks is being evaluated in replant sites.

Chemical control

Chloropicrin and metam sodium are moderately effective but are not used.

Weeds

There is a direct relationship between apple tree growth and the level of weed control. Competition from weeds for water and nutrients has reduced crop weight by 16 to 49 percent and has led to financial losses of from 25 to 55 percent. When weeds are not controlled, reductions in total yield and the number of fruit have been as high as 27 percent and 57 percent, respectively. Weeds also create a desirable environment for voles. Within three years of implementing an aggressive weed management program in one test orchard, vole populations have been eliminated. Therefore, weed control is part of an integrated approach to managing voles.

In addition to competing with apple trees for water and nutrients and creating a desirable vole habitat, weeds inhibit worker efficiency. Apples are very labor intensive (pruning, training, hand harvesting), and weeds can limit the mobility of workers. Laborers dislike working in orchards infested with weeds like brambles and poison oak or poison ivy.

Mechanical control

Physical removal, by mechanical means, is used to control weeds in some production regions. However, this can have undesirable effects on the trees. Since apple production is moving toward high-density orchards, cultivation becomes less feasible because it is extremely difficult to move equipment through the orchard. Cultivation is also usually practiced in regions where the land is relatively flat. In North Carolina, apples are grown in areas that are very susceptible to erosion. Therefore, the sod-herbicide strip has proven to be the most efficient means of managing weeds while minimizing erosion.

Biological control

Few biological options have proven to effectively manage weeds. Some organic growers have used mulches to suppress weed emergence. However, mulches can be very expensive. Additionally, mulches contribute to the development of Phytophthora root and crown rot and provide a favorable habitat for voles.

Sod-herbicide strip

The most commonly used approach to managing weeds is the sod-herbicide strip. The area in the tree row, beneath the trees, is maintained weed free with herbicides while a grass sod is established in the row middles. This management approach minimizes both weed competition and soil erosion.

Common orchard weeds

Weeds can be divided into two distinct categories: annual and perennial. Some of the most common annual weeds in North Carolina orchards are Carolina geranium, chickweed, crabgrass, fall panicum, foxtail, goosegrass, horseweed, lambsquarter, morningglory, nightshade, ragweed, and wild mustard. Some of the most common perennial weeds are Bermudagrass, blackberry, dallisgrass, dandelion, honeysuckle, horsenettle, Johnsongrass, mugwort, plantain, poison ivy, poison oak, Virginia creeper, and white clover.

Control options

Growers make a minimum of two herbicide applications each year. This consists of at least one preemergence herbicide application in combination with a postemergence non-selective herbicide, followed by additional applications as needed. In addition to broadcast herbicide applications, spot-spraying perennial weeds with glyphosate is recommended on an as-needed basis. Currently, the number of herbicides registered for use in orchards is limited. There are weed species that could be managed more effectively with additional herbicide registrations. The loss of any herbicide would have a negative effect on the industry.

Preemergence herbicides

The preemergence herbicide simazine is very widely used by apple growers for preemergence weed control. It is one of two herbicides that provide economical, effective preemergence broadleaf weed control. In 1990, simazine was applied to 34 percent of the acreage. In 1996, its use had increased to 44 percent of the acreage. In 2003 it is estimated that the percentage is still the same.

Diuron is the other preemergence herbicide that provides economical, effective broadleaf weed control. In addition to its performance as a preemergence herbicide, Diuron is important in terms of its role in resistance management. It has been well documented that the continued use of triazine herbicides (like simazine) have led to the development of triazine-resistant weeds. In 1990 and 1996, the acreage treated with Diuron was 22 percent and 10 percent, respectively. In 2003 it is estimated that approximately 30 percent of the acreage is treated.

Although less widely used, both terbacil (Sinbar) and norflurazon (Solicam) were been used on approximately 10 to 15 percent of the acreage in 2003.

Postemergence herbicides

Glyphosate is the broadest-spectrum herbicide growers can use for post-emergence weed control. It is a nonselective, postemergence herbicide that effectively controls annual and perennial weeds. A 1990 survey of North Carolina growers found that only 30 percent of the acreage was treated with Roundup. A 1996 survey of apple growers in the Southeast indicated that Roundup was applied to 48 percent of the acreage. Today, the acreage treated with Roundup is probably 75 percent or higher. Without Roundup there would be no herbicide registered on apples for effective perennial weed control.

Paraquat is another nonselective herbicide. It is used to control annual broadleaf and grass weeds. Paraquat also suppresses perennial weeds. The 1990 survey indicated that 80 percent of the acreage was treated with Paraquat but by 1996 it declined to 60 percent where it has remained relatively constant. The decline was probably related to the increased use of glyphosate. Paraquat is used on young trees and in the late summer when apple trees are more sensitive to glyphosate.

2,4-D provides inexpensive, effective control of broadleaf weeds. It is sometimes applied in combination with glyphosate to improve dandelion, dock, morningglory, and plantain control. It may be tank-mixed with sethoxydim (Poast) for broadleaf weed control in situations where bermudagrass may be a problem. 2,4-D can be applied in the sod strips to eliminate or suppress blooming weeds like dandelion and white clover. Blooming weeds on the orchard floor compete with apple bloom for pollination. There is also concern for bee exposure to pesticides while working flowering weeds on the orchard floor. In 1990, 2,4-D was applied to 24 percent of the acreage, but by 1996 that had increased to 36 percent. The growth in 2,4-D use can be explained by increased grower awareness of bee-kill potential if blooming weeds were present on the orchard floor. In 2003 it is estimated that approximately 25 percent of the acreage currently receives an application of 2,4-D. The reduction in its use could be attributed to reduced cost of glyphosate since it is no longer a patented herbicide and is being marketed by a number of manufacturers. Currently, no other herbicide registered for use in apple orchards could replace 2,4-D in its capacity to eliminate or suppress blooming weeds on the orchard floor.

Vertebrate Pests

There are five vertebrates that damage apple trees in North Carolina. Two species, pine voles and meadow voles, cause the most damage and can be controlled with rodenticides. Voles account for 50 percent of apple tree losses in North Carolina. Exclusion, hunting, repellents, and trapping are recommended for the other pests - rabbits, beavers, and deer.

Pine voles (*Microtus pinetorum*)

Pine voles occur throughout North Carolina and are considered edge animals whose habitat consists of sparsely spaced trees with grass and succulent plants. Apple orchards are such a habitat. Pine voles are burrowing rodents that will girdle the cambium underground, making the damage difficult to see until the tree is dying or dead.

Cultural control

Frequent mowing and clean culture practices help reduce vole habitat but will not reduce existing populations if they are high. Clean culture will reduce habitat and populations in a new planting. Research in Henderson County has indicated that creeping red fescue as a ground cover reduces meadow vole and pine vole populations. This result is based on studies from 1995 to 2003 vole populations using creeping red fescue as a ground cover.

Chemical control

A majority of the acreage is treated with a rodenticide for voles. The rodenticides used are zinc phosphide (ZP Rodent Bait-Ag, Ridall-Z, Roban II, and Zinc Phosphide Pellets), diphacinone (Ramik Brown and Ramik Green), and chlorophacinone (Razol "Paraffinized Pellets", and Razol Ground Spray). These products are rotated from year to year and within the same year due to product label restrictions (limits of the number of applications), bait refusal and potential resistance. The method of application depends on the grower and type of ground cover. Often apple growers use the *apple sign test* to determine the locations of vole populations in the plantings and control measures are restricted to those locations. To minimize off-target exposure, growers use bait stations containing the rodenticides. North Carolina Cooperative Extension Service Publication AG-472-1, *Voles in Commercial Orchards and Ornamental Nurseries* (http://www.ces.ncsu.edu/nreos/wild/wildlife/wdc/voles.html), provides information on vole management in North Carolina.

Meadow Voles (*Microtus pennsylvanicus*)

These voles are present in most of the orchard areas of North Carolina and live on the surface, feeding on succulents, grasses, and broadleaves. They will girdle the cambium of trees above the soil line, thus killing the tree. They frequently use the same habitat and area as pine voles.

Cultural control

Because meadow voles live on the surface, a clean-culture management program will reduce the habitat to the point that meadow voles leave or die.

Chemical control

The use of rodenticides for managing meadow voles is the same as for pine voles.

Eastern cottontail rabbits (*Sylvilagus floridanus*)

Rabbits feed on a wide variety of green vegetation. During winter, they shift to twigs, buds, and bark of woody plants, including young apple trees.

Cultural control

None

Mechanical control

Exclusion is best done with guards around young trees. The best guard is made from 1/4-inch mesh hardware cloth. A 3-foot-high fence made of chicken wire will keep rabbits out. Trapping and shooting are other options.

Chemical control

Repellents only, such as Hinder, Thiram, and Rabbit and Dog Chaser, may discourage rabbit feeding. No toxic chemical can be used.

Beavers (*Castor canadensis*)

Beavers are present in all water drainages in North Carolina. When orchards are adjacent to streams, beavers will cut down apple trees to eat and to construct dams. They may destroy the entire tree and in some cases a half dozen or more in one night.

Cultural control

None

Mechanical control

Fencing and trapping are the most effective methods of control. North Carolina Cooperative Extension Service Publication AG-472-4, *Beavers* (http://www.ces.ncsu.edu/nreos/wild/wildlife/wdc/beavers.html) provides information on the management of beavers in North Carolina.

Chemical control

There are no chemical controls, although some of the rabbit repellents have been used to manage beavers.

Whitetail deer (*Odocoileus virginianus*)

Whitetails occur throughout North Carolina and can cause damage to orchards by horning and eating young buds in winter and early spring.

Cultural control

None

Mechanical control

Fencing is foolproof for small areas. It is expensive but effective. Frightening devices can be somewhat effective, but only for a short time. Sport hunting is the most effective way to reduce a population. Special permits may be obtained from wildlife agencies if needed during a nonhunting season.

Chemical control

No toxicants are registered for deer control. Six repellents are registered for deer, but these materials are generally for small areas and are for short-term use.

Growth Regulators

Apogee

Apogee (prohexidione calcium) applications will suppress terminal shoot growth which when used season long will reduce total tree growth. Reduction in tree growth will reduce dormant pruning as well as increase light and spray penetration into the tree canopy resulting in optimal fruit quality. Another reported benefit that may be realized from reduced vegetative growth is a reduction in the number of shoot fire blight strikes. Apogee applications must begin at 1 to 3 inches of terminal growth and be maintained at 2 week or monthly intervals for as long as the potential for vegetative growth remains or within 45 days of harvest. When applied at two week intervals the rate is 3 ounces per 100 gallons + 1 pint of surfactant and when application interval is one month a rate of six ounces per 100 gallons + 1 pint of surfactant and both rates are calculated based upon tree-row-volume (TRV). Applications can be made dilute but must be applied in at least 50 gallons of water per acre.

Promalin

Fruit size and shape are important quality parameters of grade and consumer acceptance and are a factor in total yield. Promalin (GA 4+7 + BA) is the only compound that enhances shape and total fruit mass by increasing fruit length and thus length-to-diameter ratio of apples. Promalin is used in orchards where top-quality fruit for fresh marketing is needed. Promalin is applied at 1 to 2 pints per 100 gallons at 50 percent of the tree-row-volume (TRV) water rate per acre as a single application or 1 pint per 100 gallons using two applications. Estimated use of this product is 5 to 10 percent of the bearing acreage. Main varieties treated are Red and Golden Delicious, Gala, Ginger Gold, and Gold Rush.

ProVide

Fruit finish is an important quality parameter in fruit grade, consumer acceptance and processed fruit quality. ProVide (GA 4+7) is the only compound that enhances fruit finish by reducing fruit russetting and fruit cracking of susceptible varieties. ProVide is used in orchards where top-quality fruit for fresh markets is needed. ProVide for russet control is applied at a rate of 10 ounces per acre in 100 gallons of water, per application and requires four consecutive applications at 10-day intervals beginning at petal fall.

For fruit cracking, ProVide is used at the rate of 1 to 2 pints per 100 gallons beginning in early June or when cracking first begins and continuing at three-week intervals until harvest. Approximately 5 percent of the bearing acreage is treated with ProVide. Main varieties treated are Golden Delicious, and Gold Rush.

Chemical thinners

The use of chemical fruit thinners is imperative to reduce crop load in order to produce acceptable fruit size for grade standards and marketability and to ensure adequate return bloom for next year's crop. Chemical-thinner use varies widely over years. In some years, poor pollination and/or frost-freeze occurrences reduce crop load to a point where little or no chemical thinning is needed. In other years, full fruit set and no frost-freeze losses require rigorous chemical thinning, usually requiring multiple applications. In some years, the timing of frost-freeze events drastically reduces one variety while another has an abundant to excessive crop load.

Specific chemical use and use of combinations depend on variety, fruit size, and specific crop load. North Carolina Cooperative Extension Service Publication AG-572, *Integrated Orchard Management Guide for Commercial Apples in the Southeast* (http://ipm.ncsu.edu/apple/orchardguide/contents.html), has 12 different chemical thinning scenarios covering this region's main apple varieties and strains. A chemical thinner that works well on one variety can cause adverse side effects on another (such as pygmy or nubbin fruit), particularly as concentration increases. Three chemical-thinning compounds-Sevin, NAA (naphthaleneacetic acid) and Ethrel, and spray oil and Accel used alone, with surfactants and/or in tank-mix combinations make up current thinning recommendations. Each of the chemical-thinning compounds used in North Carolina has a specific use that is irreplaceable by another chemical. Note, too, that Sevin is used in a majority of the two scenarios. Sevin is the foundation of the chemical-thinning programs. Its use for chemical thinning of apples is essential and is not replaceable by any alternative.

It is estimated that, on the average, 75 percent of state apple acreage is chemically thinned annually, but this can vary from 20 to 95 percent or more, depending on the year. Chemical use rates are listed in *Integrated Orchard Management Guide for Apples in the Southeast*, but of particular interest are the Sevin rates (since it is an organocarbamate), which are 1 to 2 pints per 100 gallons of the XLR formulation in the first thinning application and always 2 pints per 100 gallons in any second application if needed.

Fruit maturity and drop control

Being able to control or delay the onset of fruit drop is important for an orderly and complete harvest before a significant amount of fruit loosens and falls off. This maximizes marketable yield as opposed to dropped fruit, which have no market.

NAA

Treatment using this compound delays fruit loosening by halting abscission zone formation. NAA is used either as a 10- to 20-parts-per-million treatment with one to two applications after fruit loosening is observed or as multiple, low-rate applications of 5 parts per million at weekly intervals during the month before the start of harvesting. This strategy pre-loads the NAA for fruit-drop delay before harvesting commences. The use of NAA for stop-drop will vary greatly with climatic condition and drop pressure from year to year, but overall, an average of 5 to15 percent of the North Carolina apple acreage is treated.

ReTain

In addition to the benefits of drop control mentioned above, the ability to delay fruit maturity in some orchards further promotes orderly harvesting and allows certain trees and/or varieties to grow longer for improved fruit size and packout grade. Additionally, delaying maturity slows the onset of maturity-related disorders such as water core and fruit cracking. ReTain delays fruit maturity for 2 to 4 weeks and is also a strong drop-control treatment. One packet (50 grams active ingredient) is applied per acre with a specific surfactant at 4 weeks before anticipated normal start of harvest for each variety.

This product is very expensive and is used on 2 to 3 percent of the acreage where better size and high-quality packout grade are desired.

SmartFresh

Apples treated with SmartFresh (1-MCP) will maintain flesh firmness and acidity for a longer period of time and fruit will not develop superficial scald or greasiness during storage. There are significant varietal differences in response to SmartFresh as well as to how quickly the treatment must be initiated after harvest and company recommendations should be read and followed. In general, for optimal response fruit must be treated within 3 to 10 days of harvest. SmartFresh comes as a powder and is mixed with water to release the active ingredient of 1-MCP at a concentration of one part per million. The treatment of the fruit must take place in a fairly airtight treatment facility with the apples for 24 hours. The amount of material to be used is dependent upon the volume of the facility in which the fruit are treated and is sold for a specific volume of the facility. In North Carolina, refrigerated truck trailers have been used successfully when leak tested before use with carbon dioxide. After treatment, fruit can be stored in a standard cold storage facility. SmartFresh will be sold through distributors that will help in evaluating the adequateness of the treatment facility and for determining the amount of material that will be used to ensure adequate treatment of fruit.

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On-line Resources

Disease Information Notes - Fruits/Nuts, Department of Plant Pathology, North Carolina State University (http://www.ces.ncsu.edu/depts/pp/notes/Fruit/fruit_contents.html)

Horticultural Information Leaflets - Commercial Tree Fruits, Department of Horticultural Science, North Carolina State University (http://www.ces.ncsu.edu/depts/hort/hil/trfruit-index.html)

Insect Notes - Fruit Pest Problems, Department of Entomology, North Carolina State University (http://www.ces.ncsu.edu/depts/ent/notes/Fruits/fruit_contents.html)

Integrated Orchard Management Guide for Commercial Apples in the Southeast, North Carolina Cooperative Extension Service Publication AG-572 (http://ipm.ncsu.edu/apple/orchardguide/contents.

html)

North Carolina Agricultural Chemicals Manual, College of Agriculture and Life Sciences, North Carolina State University:

- Apple Spray Program (http://ipm.ncsu.edu/agchem/chptr7/701.pdf)
- Chemical Weed Control in Fruit Crops - Tree Fruits (http://ipm.ncsu.edu/agchem/chptr8/814.pdf)
- Growth-Regulating Chemicals for Apples (http://ipm.ncsu.edu/agchem/chptr9/903.pdf)
- Fertilizer Suggestions for Tree Fruit (http://ipm.ncsu.edu/agchem/chptr10/1002.pdf)

North Carolina Agricultural Statistics - Fruit and Nuts, North Carolina Department of Agriculture and Consumer Services (http://www.agr.state.nc.us/stats/fruit/fruit.htm)

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