North Carolina Crop Profile
Apples

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PRODUCTION FACTS

- North Carolina ranks seventh in the United States in the production of apples.
- North Carolina produces approximately 2 percent of the total domestic crop.
- In 1996 North Carolina produced 200 million pounds with a farm gate value of more than $24 million.
- There are approximately 13,000 acres of apples in North Carolina; 10,605 of them are bearing acres.
- Annual production costs can range widely; the average cost for a well-maintained orchard is approximately $1,784 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, with the remainder being 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 60 to 70 percent of the crop is produced. The second largest production region is in the Cleveland/Lincoln County area, the lowest elevation of the apple production regions, followed by the Wilkes/Alexander County area. The Haywood County area has the highest elevation, the shortest growing season, and the coolest temperatures.

PRODUCTION PRACTICES

Apples are grown primarily in well-drained soils. The ideal sites have a lesser 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 "specific apple replant disorder" (SARD). Orchard rotation is strongly encouraged, as is conducting a soil bioassay to minimize the potential for SARD.

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 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 abscise. 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 and spread.

Cultural control.

Shredding of leaves after leaf fall with a flail mower will help reduce the inoculum, but will 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 sterol-inhibiting fungicides (fenarimol, Rubigan; myclobutanil, Nova; triflumizole, Procure) for apple scab control. Approximately five 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 (45 to 48 percent of growers) is more widely used than fenarimol (44.7 to 26.5 percent of growers). Triflumizole was just registered on apples in 1998 and has not been used to a great extent. Cyprodinil (Vangard) was registered in May 1998 and was used some in 1999. It has good scab activity, but is weak on powdery mildew. It will likely replace some dodine and sterol-inhibitor use. Kresoxim-methyl (Sovran) is a strobilurin fungicide that was registered for the 1999 growing season. It should replace some sterol-inhibitor use. Resistance is a concern with this product; consequently, it will likely be used in rotation with the sterol inhibitors.

Powdery mildew *(Podosphaera leucotricha)*

Powdery mildew is a problem on the most susceptible cultivars (e.g., Ginger Gold, Jonagold, 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, is used on approximately 6 percent of the acreage at 0.0625 pound active ingredient per acre. Approximately 4.25 applications are made yearly. Sulfur is used 2.8 to 3.75 times a season on 14.5 to 19.6 percent of the acreage. Approximately 16 pounds active ingredient are used per acre with each application. 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 25 percent of the growers use various formulations at about 5 pounds active ingredient per acre. Streptomycin sulfate (Agri-mycin 17) is used approximately four times yearly on 25.3 to 40.8 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 leafspot 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. 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 five to six times in cover sprays on 80 to 85 percent of the acreage at 3 to 4 pounds 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. Thiophanate methyl (Topsin M) and benomyl (Benlate) are used on 39.7 to 52 percent and 55.9 to 57.7 percent of the acreage, respectively. Approximately four to five applications of each fungicide are made. Benomyl is used at 0.25 to 0.5 pound active ingredient per acre, thiophanate methyl at 0.35 to 0.70 pound active ingredient per acre.

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

Bitter rot is the most important rot disease in North Carolina, especially in the piedmont. 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. Control of the disease has been more difficult since restrictions were placed on the use of EBDC fungicides. There is little difference in cultivar susceptibility.

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 this disease. As currently labeled, the EBDC fungicides provide little help in controlling bitter rot. Captan (Captan) is used at 3 to 4 pounds active ingredient per acre as described for back rot and white rot. Ziram (Ziram) is used an average of 4.6 times on 63.3 percent of the acreage at approximately 5 pounds active ingredient per acre. It is usually combined with captan and/or one of the benzimidazole fungicides. When combined with captan, both ziram and captan are used at one-half of the rates reported above.

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. Captan is used at 3 to 4 pounds active ingredient per acre, ziram at 5 pounds active ingredient per acre, benomyl at 0.25 to 0.5 pound active ingredient per acre, and thiophanate methyl at 0.35 to 0.7 pound 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 active ingredient per acre, usually in combination with captan (2-3 lb active ingredient/acre), improve control on late season cultivars where EBDC fungicides can be used through late June and still comply with the 77-day phi.

Alternaria blotch *(Alternaria mali)*

Alternaria blotch has become a serious problem on the cultivar Delicious over the past 10 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. Fosetyl Al (Aliette) is registered for control of the disease but provides only partial control. The 17 percent reduction in the acreage of Delicious in North Carolina over the past few years has been attributed to growers' inability to control the disease. 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.

None

Chemical control.

Fosetyl Al is applied to about 30 percent of the acreage of Delicious in two to three applications of 2.4 pounds active ingredient per acre.

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, and Gala are susceptible.

Cultural control.

None

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 lb active ingredient/acre) are used in combination with captan (Captan) at 2 pounds active ingredient per acre. Benzimidazole fungicides (Benlate, 0.25 lb active ingredient/acre or Topsin M, 0.35 lb active ingredient/acre) are used in combination with captan (Captan, 3-4 lb active ingredient/acre). 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.

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 active ingredient per acre when combined with captan (Captan) at 2 pounds active ingredient per acre. Benzimidazole fungicides (Benlate, 1/4 lb active ingredient/acre or Topsin M 0.35 lb active ingredient/acre) are used in combination with captan (Captan) at 3 to 4 pounds active ingredient per acre.

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 lb active ingredient/ acre) is usually used in combination with captan (2 lb active ingredient/acre). Thiram (Thiram) is also effective, but its use has gone down (20.4 percent vs. 1.7 percent from 1990 to 1996). It is used at about 4 pounds active ingredient per acre in an average of two applications. It is often used in combination with captan and/or benzimidazole fungicides at one-half the rate per acre reported above.

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.

Preplant-methyl-bromide fumigation at 900 pounds active ingredient per treated acre helps control these diseases. Individual replant sites are treated at the rate of 1 pound active ingredient per site. Less than 1 percent of the acreage is treated yearly for these diseases.

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 one to three 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 significant 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 active ingredient per acre on 2 percent of the acreage. Metalaxyl (when the disease is severe) is used as a collar drench twice a year. The rate varies according to tree size, but approximately 0.25 to 0.5 pound active ingredient per treated acre is used on approximately 3 percent of the acreage. Mefenoxan, an isomer of metalaxyl, has now replaced metalaxyl for most uses.

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. Many growers who plant high-density orchards on replant sites fumigate with methyl bromide as a preventative measure.

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 two years, and planting cover crops of sorghum and/or canola.

Chemical control.

Methyl bromide at 900 pounds active ingredient per treated acre is used by growers establishing high-density orchards. Approximately 50 acres are treated yearly. Chloropicrin is also effective but is not used.

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. Nine of these arthropods are direct pests, and damage tolerance 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. On average, eight insecticide applications are made annually to commercial apples. The use and availability of 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 organophosphate insecticides. Hence, 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 20 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

Codling moth (*Cydia pomonella)*

The codling moth completes three generations per year and is considered to be the most important insect pest of apples in North Carolina. Larvae of the codling moth tunnel into fruit and render it unmarketable as fresh fruit. In addition, the processing industry will not accept loads with any live worms. Critical periods for control vary, depending on location in the state, but damaging populations can occur anytime from the first cover spray through harvest.

Biological control.

Naturally occurring predators and parasites can be found in commercial orchards, but to a limited extent. Natural enemy populations are low, and their potential as a control tool is limited because of the low tolerance for damage.

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 organophosphate insecticides for control of codling moth. Although the number of applications per season varies from one to eight, depending on population densities in individual orchards, the average among all orchards is five. 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 @ 1 lb active ingredient/acre), phosmet (Imidan 70WP @ 1.75 lb active ingredient/acre), chlorpyrifos (Lorsban 50W @ 1 lb active ingredient/acre), and methyl-parathion (Penncap-M 2F @ 1 lb active ingredient/acre). Azinphosmethyl, phosmet, and methyl-parathion all provide excellent control, with azinphosmethyl and methyl-parathion being slightly more effective than phosmet. Chlorpyrifos is less effective than the other materials. The use of methyl-parathion has declined dramatically since 1995 because it is a hazard to honey bees foraging on orchard floors.

Carbaryl applied for thinning in May (Sevin XLR @ 2 lb active ingredient/acre) coincides with timing of the first spray for codling moth. Hence, on those varieties and in those years when carbaryl is used for thinning, one less organophosphate application is made. Also, in recent years a few growers (less than 2 percent) have begun to use esfenvalerate (Asana XL @ 5 oz/acre) for codling moth. However, this approach is strongly discouraged because of esfenvalerate's 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.

Tebufenozide (Confirm 2F @ 0.28 lb active ingredient/acre) was used in North Carolina under an EPA Section 18 exemption in 1998, and full registration was granted in 1999. This insect growth regulator was used by approximately 40 percent of growers in 1998 and provided excellent codling moth control. Its use is expected to increase considerably soon. Spinosad (Spintor 2SC @ 0.12 lb active ingredient/acre) was registered in 1998, but its use has been minimal because of lack of full knowledge about its efficacy against codling moth.

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 hardly used. Phytotoxicity resulting from the incompatibility of oil with sulfur-containing fungicides (e.g., captan) will inhibit the use of oils in North Carolina.

Tufted apple bud moth (*Platynota idaeusalis*)

Tufted apple bud moth (TABM) completes two generations per year in North Carolina and is considered the second most important direct pest of apples. It is of greatest importance in Henderson County (which accounts for almost 75 percent of the state's acreage) where populations have developed resistance to certain organophosphate insecticides. 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. Research to evaluate the effectiveness of augmentative releases of *Trichogramma exiguum* is in progress in North Carolina. Applications of *Bacillus thuringiensis* var. *kurstaki* (Dipel @ 1 lb/acre, Biobit @ 1 lb/acre and Javelin @ 1 lb/acre) and/or *aizawai* (Xentari @ 1 lb/acre), and engineered *Bts* (CryMax II @ 1 lb/acre) have provided good control and are a viable option for organophosphate-resistant populations.

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 three insecticide applications per season; two applications are made against the first generation in June, and one or two (depending on harvest date) are made against the second generation. Before 1998, chlorpyrifos (Lorsban 50W @ 2.5 lb active ingredient/acre) or methyl-parathion (Penncap-M 2F @ 1 lb active ingredient/acre) were the principal insecticides used for TABM control because populations had developed resistance to other organophosphates. Most applications in June consist of chlorpyrifos, and those in August/September are methyl-parathion. Tebufenozide (Confirm 2F @ 0.28 lb active ingredient/acre) was used on a large percentage of the acreage in 1998 under a Section 18 exemption. Because of the long residual activity of tebufenozide on apple foliage, only one application per TABM generation is necessary. Tebufenozide is expected to replace chlorpyrifos and methyl-parathion for TABM control, and the potential for resistance to tebufenozide is a concern. Spinosad (Spintor 2SC @ 0.12 lb active ingredient/acre) was registered in 1998, is effective against TABM, and hence is a potential tool for rotation with tebufenozide; but its use is currently limited because of insufficient data on proper use patterns.

Esfenvalerate (Asana XL @ 5 oz/acre) is extremely effective against TABM larvae; however, foliar applications are strongly discouraged because of the abovementioned effects on European red mite populations. Applications of esfenvalerate to the ground cover at petal fall help to reduce overwintering populations of TABM larvae, but they do not prevent the need for supplemental control during the season.

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 limited availability of 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. While the optimum timing of applications is at pink, insecticides with long residual control (i.e., pyrethroids) work well when applied at green tip. Virtually all orchards must be treated with a prebloom insecticide for control of RAA. Insecticides commonly used before bloom are endosulfan (Thiodan/Phaser 3EC or 50WP @ 2 lb active ingredient/acre), permethrin (Ambush 2EC @ 0.03 lb active ingredient/acre), esfenvalerate (Asana XL @ 0.03 lb active ingredient/acre), and diazinon (Diazinon 50WP or 600AG @ 2 lb active ingredient/acre). Oxamyl (Vydate 2L @ 1 lb active ingredient/acre) is also effective, but infrequently used. In situations where insecticides were not applied before bloom, or where effective control was not achieved with prebloom insecticides, diazinon or imidacloprid (Provado 1.6F @ 0.05 lb active ingredient/acre) are the only options for rescue treatments.

There is widespread resistance to chlorpyrifos and localized resistance to endosulfan, esfenvalerate, and permethrin. If resistance to these latter two materials spreads, which is expected, this will leave only diazinon available for reliable prebloom control. The unavailability of other products will create a shortage for rotation in a resistance management program. Zeneca is seeking registration of primicarb (Pirimor 50DF @ 0.25 lb active ingredient/acre) for RAA control on apples, which would be an important resistance-management tool for this pest.

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.

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 provided control. However, in years with cool springs when adult emergence is extended, first cover insecticide sprays are also useful. Insecticides commonly applied include azinphosmethyl (Guthion 50WP @ 1 lb active ingredient/acre), phosmet (Imidan 70WP @ 1.75 lb active ingredient/acre), and chlorpyrifos (Lorsban 50W @ 1 lb active ingredient/acre). Endosulfan (Thiodan/Phaser 3EC or 50WP @ 2 lb active ingredient/acre) is also effective against plum curculio, but it is used on a relatively small percentage of the acreage (about 15 percent), primarily where plant bugs are a concern. Formetenate (Carzol 92SP @ 1 lb active ingredient/acre) is an excellent plum curculio material that will also suppress European red mite populations when applied at petal fall, but it is used infrequently because of cost. In addition, carbaryl (Sevin XLR @ 2 lb active ingredient/acre) also controls plum curculio, but applications administered for thinning are usually too late to produce effective results. Finally, permethrin (Ambush 2EC @ 0.03 lb active ingredient/acre) and esfenvalerate (Asana XL @ 0.03 lb active ingredient/acre) are excellent materials for fighting plum curculio, but their use is strongly discouraged because they would disrupt an integrated mite management program.

Apple maggot (*Rhagoletis pomonella*)

The apple maggot is a sporadic pest of apples in North Carolina, most common in orchards above 3,000 feet elevation. However, it is also common in lower-elevation orchards (2,000 to 3,000 feet) adjacent to abandoned orchards. This insect overwinters in the pupal stage, and adults begin to emerge in mid to late June. Adults can be found in orchards until mid-August, with peak activity occurring in mid- to late July. 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.

Cultural control.

Removing abandoned orchards, which are a point of dispersal for gravid females, is an extremely effective control strategy for apple maggot.

Chemical control.

Organophosphate insecticides provide the most effective control, and one or two applications in July and/or early August are made as necessary. Materials most frequently used include azinphosmethyl (Guthion 50WP @ 1 lb active ingredient/acre), phosmet (Imidan 70WP @ 1.75 lb active ingredient/acre), and methyl-parathion (Penncap-M 2F @ 1 lb active ingredient/acre). Carbaryl (Sevin XLR @ 2 lb active ingredient/acre) and esfenvalerate (Asana XL @ 0.03 lb active ingredient/acre) control apple maggots, but their disruption of integrated mite management programs makes them a poor control option.

Although less than 5 percent of orchards were sprayed for apple maggots in 1996, there is concern that this insect will become a more serious problem with the expected increase in the use of narrow-spectrum control tools. In fact, the appearance of apple maggots in commercial orchards using mating disruption and/or tebufenozide in 1997 was the first occurrence of this pest in these 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.

Plant bugs (*Lygus lineolaris*)

Tarnished plant bugs pierce young fruit with their sucking mouth parts 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. Endosulfan (Thiodan/Phaser 3EC or 50WP @ 2 lb active ingredient/acre), permethrin (Ambush 2EC @ 0.03 lb active ingredient/acre), esfenvalerate (Asana XL @ 0.03 lb active ingredient/acre), diazinon (Diazinon 50WP or 600AG @ 2 lb active ingredient/acre), and oxamyl (Vydate 2L @ 1 lb active ingredient/acre) all provide effective control when applied at the pink stage of bud development. Ambush, Asana, and Thiodan/Phaser are the most common materials used. 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.

Oriental fruit moth (*Grapholita molesta*)

Oriental fruit moth (OFM) is a sporadic pest of apples in North Carolina. The biology of this pest is similar to codling moth, but OFM prefers peaches over apples, and infestations in apples usually occur in areas where peaches are also grown. This insect completes three generations per season, but when damage occurs on apple it is often caused by the first generation, which begins oviposition near petal fall. Damage is caused when larvae tunnel into fruit, which is not acceptable for fresh market or processing.

Chemical control.

Insecticides applied at petal fall and first cover for other pests usually control OFM. Materials most commonly applied, and which also control OFM, include azinphosmethyl (Guthion 50WP @ 1 lb active ingredient/acre), phosmet (Imidan 70WP @ 1.75 lb active ingredient/acre), and chlorpyrifos (Lorsban 50W @ 1 lb active ingredient/acre). Also effective are diazinon (Diazinon 50WP and 600AG @ 2 lb active ingredient/acre) and carbaryl (Sevin XLR @ 2 lb active ingredient/acre). Esfenvalerate (Asana XL @ 0.03 lb active ingredient/acre) is effective against OFM, but again its use is discouraged.

Alternatives.

Pheromone-mediated mating disruption is registered and is an effective option, but it is not used because of high cost and the sporadic nature of this pest.

Redbanded leafroller (*Argyrotaenia velutinana*)

The redbanded leafroller is a minor pest of apples primarily because it has been maintained in 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 the organophosphates azinphosmethyl (Guthion 50WP @ 1 lb active ingredient/acre), phosmet (Imidan 70WP @ 1.75 lb active ingredient/acre), chlorpyrifos (Lorsban 50W @ 1 lb active ingredient/acre), and methyl-parathion (Penncap-M 2F @ 1 lb active ingredient/acre), as well as lepidopterous-specific products such as tebufenozide (Confirm 2F @ 0.28 lb active ingredient/acre) and *Bacillus thuringiensis* materials (Dipel @ 1 lb/acre, Biobit @ 1 lb/acre, Javelin @ 1 lb/acre, Xentari @ 1 lb/acre, and CryMax II @ 1 lb/acre).

San Jose scale (*Quadraspidiotus perniciosus*)

Scales are seldom a problem in well-managed orchards, but when populations increase to the point that scales are present on fruit, they can be difficult to control. 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 first appear near first cover. This insect may complete up to four generations per year.

Biological control.

At least nine hymenopterous 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 @ 1 lb active ingredient/acre) or methidathion (Supracide 2E @ 1 lb active ingredient/acre); or 2) a first-cover application of azinphosmethyl (Guthion 50WP @ 1.0 lb active ingredient/acre), phosmet (Imidan 70WP @ 1.75 lb active ingredient/acre), chlorpyrifos (Lorsban 50W @ 1 lb active ingredient/acre), or diazinon (Diazinon 50WP or 600AG @ 2 lb active ingredient/acre). Almost 50 percent of growers make green-tip applications of chlorpyrifos for SJS.

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. Current research focuses on the development of soybean oil as a replacement for petroleum oils.

Lesser appleworm (*Grapholita prunivora*)

Lesser appleworm (LAW) is a sporadic pest of apples 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 @ 1 lb active ingredient/acre), phosmet (Imidan 70WP @ 1.75 lb active ingredient/acre), chlorpyrifos (Lorsban 50W @ 1 lb active ingredient/acre), and methyl-parathion (Penncap-M 2F @ 1 lb active ingredient/acre). Although it is expected that tebufenozide works 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.

Comstock mealy bug (*Pseudococcus comstocki*)

This insect is a sporadic pest that is rarely encountered in North Carolina. However, when infestations do occur, they can cause considerable damage to fruit. The biology of this insect in relation to apples in North Carolina is not well understood. However, both adult females and immatures are known to infest apples in mid to late July. 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 postbloom applications of pyrethroids (i.e., Asana XL).

Chemical control.

The only reliable method of controlling this insect is with applications of chlorpyrifos (Lorsban 50W @ 1 lb active ingredient/acre), diazinon (Diazinon 50WP or 600AG @ 2 lb active ingredient/acre), or methyl-parathion (Penncap-M 2F @ 1 lb active ingredient/acre). Applications need to be made when crawlers first appear in July.

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.

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*. Neither appears to overwinter in orchards in significant densities, and they must re-infest orchards annually. *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 organophosphate insecticides and/or narrow-spectrum insecticides such as *B. thuringiensis*, tebufenozide, or spinosad. 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 clofentezine (Apollo 4SC @ 0.125 lb active ingredient/acre) or hexythiazox (Savey 50WP @ 0.09 lb active ingredient/acre) before bloom, or with abamectin (AgriMek 0.15EC @ 0.01 lb active ingredient/acre) at petal fall. Approximately 30 percent of the acreage in North Carolina is treated with one of these products. Summer miticides are applied for curative control on an additional 30 percent of the acreage. Pyridaben (Pyramite 60WP @ 0.165 lb active ingredient/acre) is the most commonly used curative miticide, applied to nearly 90 percent of the acreage treated with summer miticides. Other miticides that are used on a small percentage of the crop include hexakis (Vendex 50WP @ 1 lb active ingredient/acre), dicofol (Kelthane 50WP @ 1.5 lb active ingredient/acre), and formetenate (Carzol 92SP @ 1 lb active ingredient/acre). Hexakis is the most commonly used of these latter materials, because it is safe to predatory mites and reduced rates (0.25-0.5 lb active ingredient/acre) can be used to adjust predator:prey ratios to encourage biological control of ERM. The use of chemical miticides has increased dramatically since 1990, when less than 25 percent of the acreage was treated. The increase in miticide use is due largely to the appearance of Alternaria blotch.

Alternatives.

Petroleum oil (2 percent suspension) 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. Soybean oil is being developed as an alternative to petroleum oils.

Apple aphid *(Aphis pomi)*
Spirea aphid *(Aphis spiraecola)*

Apple and spirea aphid both infest apples, with populations most abundant during May, June, and July. 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 will provide season-long control. Dimethoate (Dimethoate 4EC @ 1 lb active ingredient/acre) and imidacloprid (Provado 1.6F @ 0.05 lb active ingredient/acre) are the most effective and commonly used insecticides for apple/spirea aphid control. On average, 50 percent of growers make an average of one application per season. Chlorpyrifos (Lorsban 50W @ 1 lb active ingredient/acre) when applied against first-generation tufted apple bud moth also controls aphids. Although esfenvalerate (Asana XL @ 0.03 lb active ingredient/acre) provides good aphid control, it is not recommended for postbloom use.

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 (Sevin XLR @ 2 lb active ingredient/acre) made for thinning coincide with the proper timing for control of first-generation nymphs. Sevin XLR (0.5 lb active ingredient/acre) is often used for control of second-generation adults before harvest. Other products used for control and which are highly effective include imidacloprid (Provado 1.6F @ 0.05 lb active ingredient/acre) and abamectin (Agri-Mek 0.15EC @ 0.01 lb active ingredient/acre). Also, the miticide pyribaden (Pyramite 60WP @ 0.165 lb active ingredient/acre) is effective against WALH if applications for mite control are made in mid-July or later. Other effective materials, which are rarely used, include formetenate (Carzol 92SP @ 0.5 lb active ingredient/acre), methomyl (Lannate 90SP @ 0.25 lb active ingredient/acre), and esfenvalerate (Asana XL @ 0.02 lb active ingredient/acre).

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, and pyrethroids. Imidacloprid (Provado 1.6F @ 0.05 lb active ingredient/acre) is also effective, as is pyribaden (Pyramite 60WP @ 0.165 lb active ingredient/acre) 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.

Prebloom sprays of endosulfan (Thiodan/Phaser 3EC or 50WP @ 2 lb active ingredient/acre), permethrin (Ambush 2EC @ 0.03 lb active ingredient/acre), esfenvalerate (Asana XL @ 0.03 lb active ingredient/acre), or oxamyl when applied for rosy apple aphid help to lower second-generation STLM mines in June and July. Abamectin (Agri-Mek 0.15EC @ 0.01 lb active ingredient/acre) and imidacloprid (Provado 1.6F @ 0.05 lb active ingredient/acre) applied at petal fall provide 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, oxamyl (Vydate 2L @ 1 lb active ingredient/acre) or methomyl (Lannate 90SP @ 1 lb active ingredient/acre) are the only options for curative control.

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 large 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 (Guthion 50WP @ 1 lb active ingredient/acre), phosmet (Imidan 70WP @ 1.75 lb active ingredient/acre), chlorpyrifos (Lorsban 50W @ 1 lb active ingredient/acre), methyl-parathion (Penncap-M 2F @ 1 lb active ingredient/acre), and diazinon (Diazinon 50WP or 600AG @ 2 lb active ingredient/acre). June/early July applications of either azinphosmethyl or phosmet applied for codling moth or chlorpyrifos applied for tufted apple bud moth coincide with the proper timing of Japanese beetle emergence. Carbaryl (Sevin XLR @ 1 lb active ingredient/acre) is also very effective and sometimes is applied specifically for beetles.

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. Persistent infestations over several years can reduce tree vigor and yields. Infestations in graph unions on dwarfing rootstocks have increased in recent years. Adults emerge during a 1- to 2-month period beginning in late May, and egg laying begins within days of emergence. Peak adult emergence occurs in early June in North Carolina.

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, as can the use of tree guards.

Chemical control.

Trunk applications of a long, residual insecticide, such as chlorpyrifos (Lorsban 50W @ 1 lb active ingredient/acre) applied the last week of May or in early June, are most effective. Endosulfan (Thiodan/Phaser 50WP or 3EC @ 1 lb active ingredient/acre) is slightly 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 killer 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 on 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; encapsulated methyl-parathion (Penncap-M 2F @ 1.5 lb active ingredient/acre) and chlorpyrifos (Lorsban 50W @ 1.5 lb active ingredient/acre) are the most effective. Application of these insecticides for other insects has helped to suppress WAA, but foliar infestations have increased in recent years in orchards where these products are no longer used. Insecticides are applied specifically for WAA on less than 5 percent of orchards. There are no insecticides registered on apple that control root infestations. Triazamate (Aphistar 50WP @ 0.25 lb active ingredient/acre) does control root infestations, but is not registered on apples.

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.

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 rots 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, 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 Roundup Ultra 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.

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.

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

Postemergence herbicides.

Roundup Ultra is the broadest-spectrum herbicide growers can use. 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 near 75 percent. Without Roundup there would be no herbicide registered on apples for effective perennial weed control.

Gramoxone Extra is another nonselective herbicide. It is used to control annual broadleaf and grass weeds. Gramoxone also suppresses perennial weeds. The 1990 survey indicated that 80 percent of the acreage was treated with Gramoxone. But by 1996 Gramoxone was used on 60 percent of the acreage. The decline was probably related to the increased use of Roundup. Gramoxone is used on young trees and in the late summer when apple trees are more sensitive to Roundup.

2,4-D provides inexpensive, effective control of broadleaf weeds. It is sometimes applied in combination with Roundup to improve morningglory control and may be tank-mixed with Poast for broadleaf weed control. The majority of 2,4-D is 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 that bees working on blooming weeds on the orchard floor might be killed by insecticides used on apple trees. 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. 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)*

These pests 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. Work is under way now in Henderson County to test a ground cover (creeping red fescue) that may reduce pine vole populations. This study is based on 1995 data on meadow vole populations using creeping red fescue.

Table 1. Rodenticide use against pine voles

Trade name	*Common name / %*	*% acreage*	*Method of application*
Ramick Brown	diphacinone/.005	1.3	hand bait
Rozol	chlorophacione/.005	15.3	hand bait
Rozol	chlorophacione/.005	8.0	ground spray
Zinc phosphide	zinc phosphide/.02	44.9	hand bait
Zinc phosphide	zinc phosphide/.02	15.5	broadcast

Chemical control.

Approximately 85 percent of the acreage is treated with a rodenticide (see Table 1, page 15).

These products are rotated from year to year and within the same year due to bait refusal and some resistance. The method of application depends on the grower and type of ground cover. See publication AG-472-1, *Voles in Commercial Orchards and Ornamental Nurseries.*

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 broadleafs. 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 meadow voles is the same as for pine voles.

Eastern cottontails *(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. See publication AG-472-4, *Beavers.*

Chemical control.

None, although some of the rabbit repellents have been used.

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

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 volume per acre or as a single application or 1 pint per 100 gallons using two applications. Average estimated use of this product is 5 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

Table 2. Chemical thinning recommendations		
Variety / Strains	*Acreage*	*Chemicals used, depending on crop load and weather*
Red Delicious	3,000	
Non-spur strain		Sevin, Sevin + Surf, Sevin + low rates of NAA
Easy-to-thin spur strain		----- Sevin + NAA, Seven + NAA + low rate Ethrel
Harder-to-thin spur strain		Sevin + (Oil, Surf), Sevin + Ethrel
Rome	3,000	
Green and Red Rome		Sevin, Sevin + Surf, Sevin + NAA
Spur Romes		Sevin + (Oil, Surf), Sevin + Ethrel
Golden Delicious	2,000	NAA, NAA + Sevin
Gala, Jonagold, Ginger Gold	1,000	Sevin + Surf, Sevin + NAA, Accel
Fuji	300	Sevin + Accel, Sevin + Ethrel
Second application of chemical thinner, all varieties	5%	Sevin + Ethrel
To achieve much larger fruit (2 weeks after first application)		or Sevin + Ethrel + NAA

fruit cracking of susceptible varieties. ProVide is used in orchards where top-quality fruit for fresh markets is needed and where growers are concerned about grade and acceptance for processing. ProVide for russet control is applied at a rate of 10 ounces per acre, regardless of water volume, 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 and continuing at three-week intervals until harvest. Average estimated use of this product is 5 percent of the bearing acreage. Main varieties treated are Golden Delicious, Gala, Ginger Gold, 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 salability 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, sometimes including second applications. In still other 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, strain, and specific crop load. The production guide *Integrated Orchard Management Guide for Commercial Apples in the Southeast,* AG-572, has 13 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. Four chemical-thinning compounds—Sevin, NAA (naphthaleneacetic acid), Ethrel, and Accel—used alone, with surfactant, and/or in tank-mix combinations make up current thinning recommendations. These recommendations are summarized in Table 2 (above).

Each of the chemical-thinning compounds listed in Table 2 has a specific use that is irreplaceable by another chemical. Note, too, that Sevin is used in all but 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 the orchard management guide, 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 as required.

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 salable yield as opposed to dropped fruit, which suffers damage and is culled.

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 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 two to four weeks and is also a strong drop-control treatment. It is applied as a single, 50-gram-active-ingredient-per-acre application with a specific surfactant at four 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.

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