GROWTH REGULATORS FOR TREE FRUITS

Introduction

Plant growth regulators can be used to modify growth and development in various ways. Some growth regulators affect primarily vegetative growth; others influence the fruit only; still others may induce modifications in both vegetative and fruiting parts. The responses to a particular growth regulator depend upon factors such as the plant, the chemical, and the environment.

Plant factors include the species, variety, stage of development, and overall plant condition. Among varieties, there are sizable differences in responsiveness, and each variety must be considered separately. Overall plant condition includes stress from excess or inadequate moisture, nutrient deficiencies as well as general vigor. Even for a given variety, growth regulator treatments should be adjusted on the basis of the condition of the plant to both maximize the benefits and minimize the risks.

Chemical considerations relate to the specific compound, the amount applied, and, more specifically, how much is actually absorbed. Absorption can be altered by the chemical formulation, its concentration, and the use of adjuvants as well as coverage. It must be kept in mind that growth regulator effects are very dosage-related; there is often a very small margin of safety. Excessive dosage may cause injury; inadequate levels may give suboptimal response.

Environment may also play a major role in growth regulator treatments. Of major consequence are temperature, rainfall, and relative humidity. Since most growth regulators are most readily absorbed while in solution on the plant, rate of drying of the spray droplets is important. Conditions such as moderate temperatures and high humidity retard drying, so may increase uptake compared to a period of high temperature and low humidity. Rainfall within several hours of a growth regulator application can wash the material off the plant and reduce response. It is, therefore, recommended that applications be made when several hours of rain-free weather are expected to follow. Temperature extremes should be avoided. Optimal growth regulator responses result from applications made at temperatures between 65-85 degrees F. Temperatures below 65 degrees F tend to lead to sub-optimal response; above 85 degrees F, response may be excessive and injury may occur.

A final factor is timing of treatment. Although with some growth regulators there is considerable flexibility, for others there may be only a day or two when response will be ideal.

Always leave some untreated or check plants with which the treated plants can be compared. Without such checks, it is impossible to evaluate the effectiveness of the treatment. It is also important that detailed records, including treatment time, concentration, gallons per acre, etc., be maintained as well as results obtained for future reference.

DETERMINING RATE PER ACRE IN APPLE ORCHARDS - TREE-ROW VOLUME

The use of dosage-dependent chemicals, such as chemical thinners and other growth regulators, in orchard blocks of different tree sizes requires a means of determining effective rate per acre for each tree size situation.

Tree-row-volume calibration is based on application of 1 gallon of spray material uniformly to every 1425 cu ft of tree canopy row. Standard trees, defined as trees 19.5 ft tall and 23.5 ft wide and planted in rows 35-ft apart, require a rate of 400 gallons dilute mix per acre. Many trees in production today are smaller than standard size and these should be sprayed with less than 400 gallons per acre so that chemical deposits are similar in plantings of different tree sizes.

A graph is presented to determine tree-row-volume of blocks in any orchard and the rate per acre necessary for spraying those blocks on a dilute basis (Fig. 4).

To use the graph, the following steps are provided:

A) Draw a line from 0 (bottom left-hand corner) to the number on the right side (midway up) of the chart that corresponds to the specific distance between rows in the block in question. This forms a **base line** for any block which has that same row spacing.

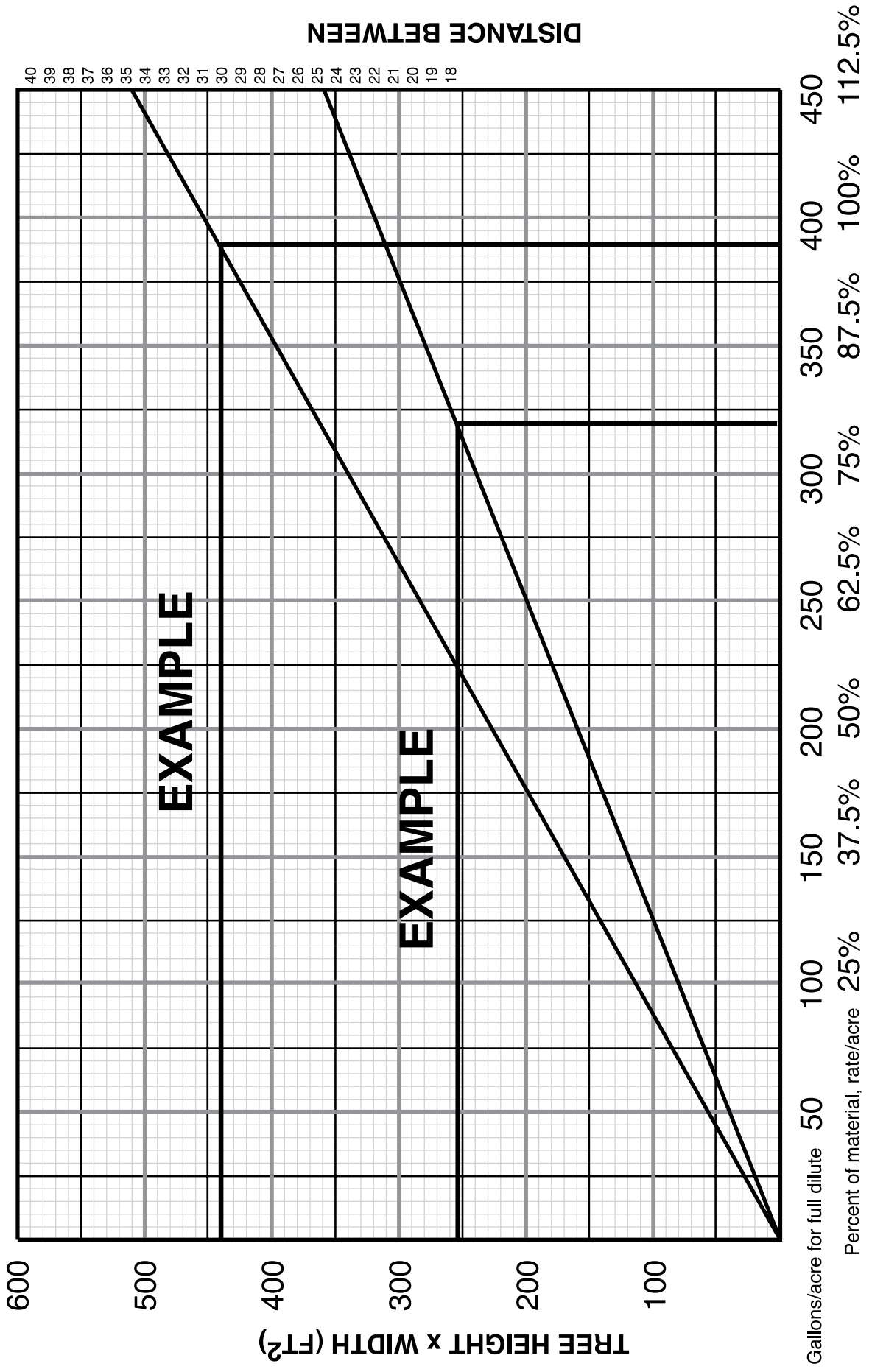
B) Determine tree height and width of trees in block. Multiply height and width to obtain the number for use on left hand side of the graph (tree height x width).

C) Draw horizontal line from the calculated height x width value across graph to point where line intersects diagonal base line already present.

D) Draw line from the intersect point down to bottom line on graph (rate per acre). This point is the required gallons per acre for dilute spraying of the block of trees in question.

Two examples are shown on the graph. Example 1 illustrates 35 ft row spacings with trees that are 19 ft high and 23 ft wide. Draw a base line from 0 to 35, multiply 19 x 23 to get 437. Follow a horizontal line from 437 to the base line. Vertically below this, a base gallonage of 390 gpa dilute can be found. Example 2 shows a need of 313 gpa dilute for 25-ft rows and trees that are 16 ft high and 16 ft wide.

Figure 4. Tree-Row-Volume Determination in Apple Orchards



Example 1: Trees space 35' x 35'; 19' high, 23' wide; 390 gpa dilute or 98% of rate/acre.
Example 2: Trees space 16' x 25'; 16' high; 313 gpa dilute or 78% of rate/acre.

The lower row of numbers on the horizontal axis has been added to allow those using concentrate sprayers to compute the needed rate per acre. The base figure to use in this case is the rate of material per acre given on a product label. Whether spraying concentrate or dilute, the basis is that smaller, easier-to-spray trees need less material per acre than standard sized trees. This second row of numbers is used to compute the percentage of the full dilute rate per acre needed.

As with any other production procedure, grower judgment should be used. Where tree size is quite variable, calibration should be done for the average of the largest trees. Two-thirds of the spray is directed to the top of the trees. A well pruned orchard may require only 85% of the base rate early in the season, while a full-foliaged processing orchard may need the full rate. Base-calculated rates may be increased or decreased by 10-20% when grower judgment dictates additional adjustments related to leaf density, pest pressure, or desired results from thinners and growth regulators. Most growth regulators should be applied dilute for maximum effectiveness.

A tree-row volume spraying rate calculator has been developed for apples. A supply of these slide rule calculators is now available at the Virginia Agricultural Experiment Station - Winchester (595 Laurel Grove Rd., Winchester VA 22602) at a cost of $3.00 each.

Failure to apply the proper rates per acre can lead to disastrous results when dealing with thinners, growth regulators, and other rate-sensitive materials. It is also important to note that tree-row-volume or any other concept for determining rate per acre will not make up for poor application techniques or improper timing. This method should allow growers to more precisely calibrate their equipment for the various blocks they must spray and thereby reduce problems that arise from too little or too much material per acre. But, it will only be effective if the necessary adjustments of equipment are made before spraying blocks of different sized trees.

Although many plant growth regulators are registered on the basis of the amount of active ingredient per acre, results may be related to concentration of active ingredient (amount of active ingredient per 100 gallons of spray solution). Therefore, when tree row volume calculations call for low volumes of spray solution per acre, be sure to add enough chemical to the tank to maintain an appropriate concentration of active ingredient. For some products it may not be possible to spray 300 gallons per acre at the effective concentration without applying more material per acre than is allowed on the label.

PROGRAMS FOR APPLES

IMPROVING FRUIT SHAPE OF APPLE

Since typiness is a desirable market characteristic for Red Delicious, crop value may be increased if fruit length is increased in relation to diameter. A bloom application of Promalin has increased typiness in Delicious in some years. Responses may be best with strains that are naturally more typey and under seasonally cool conditions that are naturally better for development of typiness.

Promalin - Apply from early full-King-bloom to first petal drop of King bloom. Response is improved under maximum absorption conditions - warm temperatures or high humidity with slow drying. A rain-free period of several hours is desired after application. Do not apply when windy, after a rain when plant parts are wet, or when air temperatures are below 40 degrees or above 90 degrees F.

Use 1-2 pt of Promalin per acre in 50-200 gal of spray. Dilute applications are not recommended. Using a clean spray tank, add Promalin to half the water to be used in the spray tank, then agitate while adding the rest of the water needed. Do not combine other spray materials with Promalin, although a nonionic wetting agent such as Regulaid may be added at 4 to 8 oz per 100 gal.

In some tests, Promalin has caused thinning of Delicious. An increase in fruit size would be expected if thinning occurs. Thinning may or may not be desirable, depending on fruit set, which cannot be determined at the time of Promalin application.

CONTROLLING WATERSPROUTS AND ROOTSUCKERS ON APPLE

Rootsuckers can interfere with orchard operations and contribute to aphid problems. Watersprouts also reduce spray penetration, and light exposure. Watersprouts and rootsuckers are usually removed by pruning; however, they usually regrow by the next year. An ethyl ester form of NAA (Tre-Hold Sprout Inhibitor A-112) can be used to control rootsuckers and watersprouts by reducing regrowth.

ROOTSUCKER CONTROL

Use Tre-Hold at 10 oz per gal (10,000 ppm). For best results, prune off the existing rootsuckers at ground level during the dormant season and treat when new rootsucker growth is 4 to 12 inches tall. A second application may be necessary the following year if rootsuckers are vigorous and regrowth occurs.

Do not apply from bloom to 4 weeks after petal fall because fruit thinning may result. Experience in Virginia and West Virginia indicates that rootsuckers often reach the 4- to 12-inch stage before 4 weeks after petal fall. In this case, rootsuckers can be burned down by paraquat treatment usually made during this time of the year. Tre-Hold can then be applied to regrowth when it reaches the optimum stage.

Apply with a handgun or back-pack sprayer as a low-pressure, directed spray to avoid spray drift.

WATERSPROUT CONTROL AROUND PRUNING CUTS

Use Tre-Hold at 10 oz per gal (10,000 ppm). Apply with a brush, roller, or small low-pressure pump-up sprayer to pruning cut and several inches around the cut after time of pruning but before growth starts in the spring.

Do not apply with a pressurized handgun. Do not spray into the trees, permit contact with fruit buds, or apply when green growth is present because serious damage can occur.

White exterior latex paint can be mixed at the rate of 1-4 pt per gal of water to mark where treatments are made.

(Do not use oil based or latex paints that contain oil)

DEFRUITING YOUNG APPLE TREES

Apple trees, particularly spur-types and trees on dwarfing rootstocks, will often set more fruit than desirable before the tree is large enough to support the crop. Fruit compete with shoot growth when maximum tree growth is desired to fill the allotted bearing space. Allowing fruit to develop on the central leader can cause the leader to bend out of position and ruin attempts to develop a good tree structure. In addition, fruit on young trees are usually large, irregular in shape, and of poor keeping quality.

The fruit can be removed by hand shortly after bloom; however, this is a slow and labor-demanding process. Chemical sprays can be used to remove most of the fruit.

CARBARYL (SEVIN) + NAA + TWEEN-20 OR SUPERIOR OIL

This combination removes a large portion of the fruit on some varieties. Use 1.0 lb of Sevin 50W or 1 qt of Sevin XLR PLUS combined with 5-8 ppm NAA along with l/2 pt of Tween-20 or 1 qt of Superior oil per 100 gal of water. Apply the spray 7 to 14 days after bloom, preferably a dilute application with a high-pressure handgun before fruit reaches an average of 8 mm in diameter. Select a calm day when temperatures are expected to reach 70 degrees F. Although this treatment usually will not remove all fruit, it will reduce the amount that must be removed by hand. It is critical to follow-up chemical spray with hand removal because only a couple of fruit too many can damage the central leader. Observe young trees periodically for mite development that may occur following the use of carbaryl. Treat with a recommended miticide if necessary to maintain tree vigor.

CARBARYL (SEVEN) + ETHEPHON (ETHREL) + SURFACTANT OR SUPERIOR OIL

This combination will remove most fruit but will cause tree growth reduction and increase flowering the following year. Use 1 lb of Sevin 50W combined with 1.0-1.5 pt of Ethrel along with 1/2 pt of a surfactant or 1 qt of Superior oil. Apply when fruit are between 10-15 mm in diameter as a dilute, high-pressure, handgun treatment. Select a day when daytime high temperatures are expected to be between 70-90^{0}F.

DEVELOPMENT OF LATERAL BRANCHING IN APPLE

Some varieties, such as spur-types of Delicious, tend to produce long, vigorous, unbranched scaffolds, particularly in the early years. This characteristic results in the slow and often inadequate development of fruiting spurs and lateral shoots.

PROMALIN

Promalin treatment can be used to promote the development of spurs and lateral branching on young trees.

Branching is primarily limited to stimulation of growth on 1-year-old wood. Thus, the spray can be directed to these areas of scaffold limbs. Directed sprays can also be used to induce branches for a second or third whorl of scaffolds on the central leader. Treatment of low-vigor trees or trees under drought or low fertility conditions will likely be ineffective, and may injure trees. High vigor is necessary for optimum response.

For small trees, applications with a small hand sprayer or handgun are most practical for directing the spray. Thoroughly wet bark and foliage surface of areas where response is desired.

Apply foliar applications of Promalin at 0.5 to 1.0 pt per 5 gal water (250 to 500 ppm) when new terminal shoots are 1 to 3 inches long (about 1 to 2 weeks after full bloom). Adjuvants or wetting agents may improve the response but have also resulted in phytotoxicity in some cases. Use wetting agents at the rate of 1.0 oz per 5 gal water. The wetting agent should be added to the spray tank before the Promalin. The final spray mixture should not be alkaline. If the spray mixture tests alkaline, add an acidifying agent such as vinegar or a buffered surfactant.

Promalin at these rates (250 to 500 ppm) can cause fruit set and can also prevent flower bud formation for the next year. Thus, whole tree treatments should be limited to young non-bearing trees.

PROMOTING FLOWER INITIATION AND CONTROLLING VIGOR IN APPLE

Various orchard practices can be employed to initiate flowering and fruiting and control vegetative growth. These include limb spreading, proper pruning, proper nitrogen fertilization, scoring, and growth regulator treatments. Ethephon can be used to control shoot growth and induce flowering and fruiting of nonbearing trees in the following year.

NON-BEARING TREES

Young, vigorously growing apple trees can be slow to come into bearing, especially varieties such as Delicious and trees on vigorous rootstocks. Along with other cultural practices, growth regulators (Ethephon) can help to bring such trees into bearing. Such growth regulator programs should only be used on young, non-bearing trees that have developed an adequate structure to support a crop. Stunting may occur if applied to weak or very young trees, particularly spur types. Ethephon will likely slow shoot growth.

ETHEPHON (ETHREL)

Ethrel at 1.0 pt per 100 gal applied to non-bearing trees 2 weeks after full bloom will promote flower bud initiation for the following year. This treatment may cause fruit thinning. Do not apply Ethrel to trees that are stressed or trees that are low in vigor.

Ethephon (Ethrel) for Return Bloom Ethephon will have a direct effect on flower bud formation when applied from petal fall to about 6 to 8 weeks after full bloom. The greatest effect is from sprays timed during the 0 to 4 weeks after bloom. Since ethephon will cause substantial fruit thinning, multiple weekly applications at rates 1/2 that of the thinning rate will usually not cause thinning. These sprays should not begin until 7 days or more after the last thinning spray has been completed. Sensitivity to Ethrel is very different between cultivars, thus it is important to choose a rate specific to each variety. Do not exceed 8 pts/ acre per year. If trees are over cropped ethephon may not effectively give adequate return bloom the following season. Higher soluble solids and lower starch levels at harvest may be expected with some cultivars, and this will depend on the amount and lateness of the applications. No loss of firmness has been detected with 'Red Delicious' at the optimum harvest date.

These sprays will reduce tree growth (and is dependent on timing and amounts used) and thus may not be desirable for young non-bearing trees if maximum tree growth is desirable.

Apogee For Control Of Apple Tree Growth

AS AN AID FOR REDUCED PRUNING

The primary objectives of pruning are to: control tree size, reduce shading within the tree canopy, increase spur vigor, promote spray penetration, maintain tree structure, and promote good fruit color, size, and quality. Many apple cultivars are grown on vigorous rootstocks and require much pruning, especially in tops of older trees. Ideally, growers should prune annually; but in order to cut costs and/or to reduce labor requirements, a grower may choose to prune every second or third year. Dense canopies caused by current season shoot growth and/or by not pruning in some years, may be detrimental to pest control, fruit quality, color, spray application costs, and yields in subsequent seasons. The advantage of Apogee sprays compared to pruning is that growth inhibition occurs early and continuously throughout the season, which *cannot be accomplished by dormant pruning*.

Prohexadione calcium (Apogee 27.5DF) applied soon after bloom (1 to 3 inches shoot growth) and at intervals of approximately 3 weeks to apple trees will reduce the current season's shoot growth (shoot length and weight), reduce the number of pruning cuts, pruning time, and pruning weight per tree, and increase the number of nodes on the lower 40 cm of long shoots. Flower bud formation, fruit diameter, soluble solids, starch, individual fruit weight, fruit drop, and fruit cracking (Stayman), typically will not be affected, but fruit set per tree may be slightly increased. Apogee applications did not interfere with thinner activity if applied as a tank mix or before or after the spray. Fruit color and firmness were slightly increased in only one experiment. The amount of growth suppression will be related to tree vigor. Thus, growth will be suppressed more by Apogee when trees are cropped heavily or stressed by drought, and when trees are grown on dwarfing rootstocks. Registered rates for Apogee are 6-12 oz/ 100 gal dilute or 24-48 oz/acre. Calcium in hard water or Calcium chloride added to the spray solution will reduce or inactivate Apogee. To reduce interference from calcium in the spray water, ammonium sulfate should be added to the tank before Apogee, at the same rate per 100 gal of spray mix as for Apogee. Based on research at Winchester, the combination of 6 oz of Apogee plus 6 oz of ammonium sulfate per 100 gal is suggested for moderately vigorous trees. An adjuvant such as Regulaid should be included to improve systemic uptake of Apogee. Vigorous trees might be more responsive to the 12 oz Apogee rate than to the 6 oz rate. Multiple applications are typically needed to obtain season-long growth suppression. Tree vigor, soil moisture, crop, load, rootstock, etc. will influence the need for additional applications. For maximum effectiveness it is critical that the first application be made in the late bloom (1 to 3 inches of shoot growth), the second application should be made before growth begins again at the most vigorous tips (approximately 3 weeks). Since maximum growth suppression is obtained before growth resumes, the vigorous trees in the block should be observed so that any additional applications are well timed. If vigorous trees have no crop and adequate soil moisture, more than 4 applications may be required to obtain adequate shoot growth suppression. Do not apply more than 99 oz/acre per year or 48 oz/acre in any 21-day period. Do not apply to Empire as fruit cracking may occur.

USE OF APOGEE FOR FIRE BLIGHT SHOOT BLIGHT SUPPRESSION

Apogee (prohexadione-calcium) is registered for suppression of fire blight shoot blight. Shoot blight suppression results from hardening off of vegetative shoot growth starting about 10 days after the initial Apogee application, which should be made at late bloom when active shoot growth is 1-3 inches long. Studies at Winchester indicate that Apogee may be tank-mixed with Agri-Mycin, allowing Apogee to take effect while there is residual protection from streptomycin. Registered rates for Apogee are 6-12 oz/100 gal dilute or 24-48 oz/acre. An adjuvant such as Regulaid or LI-700 should be included to increase systemic uptake of Apogee. To reduce interference from naturally occurring calcium in the water used for spraying, ammonium sulfate should be added to the tank **before** Apogee, at the same rate per 100 gal of spray mix as for Apogee. Based on research at Winchester, the combination of 6 oz of Apogee plus 6 oz of ammonium sulfate per 100 gal is suggested for moderately vigorous trees. Vigorous trees might be more responsive to the 12 oz Apogee rate than to the 6 oz rate.

Shoot blight suppression is related to early hardening off of shoot tip growth within 10-14 days after bloom. Vigorous trees might benefit from further protection with additional Apogee applications in mid-season if shoot growth is resumed. Studies in WV showed that Apogee reduced shoot blight infections that occurred with hail injury in June. Do not apply more than 48 oz/A within a 21-day period. Practical usefulness of Apogee for shoot blight suppression in a given year might be estimated by the potential severity of fire blight based on the number of infection days that occurred during the bloom period, as well as tree vigor, cultivar susceptibility, and disease history. Apogee is not to be considered a replacement for streptomycin sprays for blossom blight control. Apogee treatment for shoot blight suppression is strongly suggested for vigorous young trees that have nearly filled their tree space.

Apple Fruit Thinning

Fruit thinning promotes annual bearing, reduces limb breakage, and improves fruit size and color, thereby increasing value of the crop. With a heavy set, it may be necessary to remove 70 to 80% of the fruit. Fortunately, overthinning seldom occurs. Failures usually are on the underthinning side.

Factors important to the success of a chemical thinning program are keeping accurate records, observing conditions in the orchard, and understanding the factors affecting chemical thinning response. Such information can then be put together to select the best material, rate, and timing for the chemical thinning operation (Table 18).

MATERIALS AND TIMING

Naphthylacetamide (NAD), Amid-Thin, is usually applied 4 to 8 days after full bloom (generally at petal fall) for summer cultivars. The same timing has been effective on fall and winter cultivars. Fall and winter cultivars have also been satisfactorily thinned when NAD has been applied from petal fall to 2-1/2 weeks after full bloom. Because pygmy fruit may be induced this material should not be used on Delicious, or other pygmy-prone cultivars, after petal fall.

Carbaryl (Sevin) is usually applied from petal fall to 2l days after full bloom (5-14 mm average fruit diameter). Sevin is particularly toxic to bees. Sevin can also result in increased mite populations because it is toxic to natural mite predators. Sevin XLR-Plus is less toxic to bees and mite predators than the 50W formulation. The addition of 1 qt/100 gal of a 70 sec superior oil sometimes promotes additional thinning. Dilute applications by handgun or removal of swirl plates in airblast sprayers will also increase thinning. Addition of oil may cause russetting on cultivars that are prone to russet.

Naphthaleneacetic acid (NAA) is usually applied 14 to 18 days after full bloom (7-12 mm average fruit diameter). This material has often induced pygmy fruit on spur strains of Delicious and other pygmy-prone cultivars. Cool weather following NAA application may cause pygmy fruit development on all cultivars. Do not combine Accel with NAA because additional pygmy fruit may develop. Application of NAA when fruit are smaller than 10 mm will cause more thinning and will induce fewer pygmy fruit.

Accel is a mixture of Gibberellins and N-(phenyl)-1H-purine 6-amine. Accel may increase fruit size of some cultivars in some parts of the country, but increased fruit size has not been observed in Virginia. Accel should be applied at the maximum rate of 30 grams of active ingredient (53.4 fluid ounces of Accel) per acre. One fluid ounce contains 0.56 grams of active ingredient. Application is recommended when king fruitlets are approximately 10 mm in diameter or when combined with carbaryl or Vydate. Relatively poor thinning has been observed in Virginia when Accel was applied at the recommended rates and time. Improved thinning may be achieved when Accel is applied at petal fall.

Do not combine Accel with NAA because excessive numbers of pygmy fruit may develop. Combinations of Accel and carbaryl, especially at petal fall, may provide better thinning than when either material is used alone.

MaxCel contains 1.9% (w/w) 6-benzyladenine (6BA). The difference between MaxCel and Accel is that Accel contains gibberellins but MaxCel does not. MaxCel is usually applied at the rate of 48 to 64 fl oz per 100 gal of spray solution (75 to 100 ppm) when the average diameter of king fruitlets is about 10 mm. Fruit-thinning effect increases with increasing temperature. It has no effect on bees and mite predators.

Oxamyl (Vydate L) applied at the rate of 2 to 4 pints per acre at petal fall to 14 mm fruit diameter has thinned comparable to carbaryl. Do not apply Superior Oil with Vydate because fruits may develop a dark dull red color at harvest.

Carbaryl (Sevin) + Naphthaleneacetic acid (NAA) + surfactant combinations may be used when inadequate thinning is obtained with single chemicals. Use carbaryl at 1-2 pounds and reduce NAA to 1/4-3/4 of full rate for the cultivar depending on thinning desired. Several years of experience are desirable if combinations are to be used successfully. This combination may also induce pigmy fruit on spur strains of Delicious. NAA used alone or combined with Sevin or Vydate usually does not improve thinning on spur Delicious trees

Carbaryl (Sevin) and Accel combinations cause substantially more thinning than either material used alone. The addition of superior oil may cause even greater thinning.

Ethephon (Ethrel) for thinning is most effective when applied for late thinning when fruit size is 14 to 28 mm in diameter. Applications as early as petal fall to 10 mm are somewhat effective. Ethephon is usually combined with carbaryl or Vydate on difficult to thin cultivars and where return bloom has been a severe problem. Where water is alkaline, buffering the spray solution to a pH of 3 to 5 will increase chemical stability and effectiveness.

Over thinning and a higher degree of variability related to temperature, humidity, and water volumes is more likely with this material than with other thinners. For this reason it has been primarily used where first applications have not been successful or on very difficult to thin cultivars and where return bloom has been a severe problem. Thinning results with Ethephon vary greatly with cultivar. Ethephon is not very effective on Gala, but it is very effective on Golden Delicious and Rome.

Do not use before a light rain or dew or when temperatures above 90˚F are expected soon after the application since additional thinning will likely occur.

TIMING BY FRUIT SIZE

Response of fruit to thinners, particularly NAA, depends partly on the stage of fruit development at time of application. Weather conditions following bloom can influence the rate of fruit development — cool weather slows fruit growth while warm weather accelerates fruit growth. Different varieties, as well as blocks in different locations may grow at different rates. Consequently, days-after-full-bloom may not be the best method to determine application time.

Fruit diameter can be used to determine the stage of fruit development (Fig. 5).

Figure 5. Selected Diameters (mm) For Timing Chemical Thinners

A. Fruit with diameters greater than 14.0 mm will usually not respond to recommended rates of NAA, oxamyl, Accel, and carbaryl. Fruit with diameters of 10.0 to 12.0 mm exhibit optimal thinning for these materials. Ethephon is a mild thinner if applied when average fruit size is less than 10.0 mm. Optimum thinning with Ethephon occurs when fruit are 14.0 to 24.0 mm, but combinations of Ethephon plus carbaryl or oxamyl may be very effective on fruit diameters of up to 28 mm.

B. The smaller fruit on a tree on the day of treatment are most susceptible to most thinning materials except Ethephon. So the larger fruit will be preferentially retained. However, all fruit on the tree, regardless of size, are equally susceptible to Ethephon. So Ethephon usually removes large and small fruit on the tree to a similar extent.

C. If the crop is light due to frost or light bloom, a larger number of fruit may be retained on trees by waiting until the desired number of large fruit are 13.5 mm and larger.

D. If the crop load is heavy and maximum thinning is required, average fruit size should be approximately 10.0 mm in diameter and the largest fruit about 12.0 mm for NAA, carbaryl, and oxamyl.

E. Fruit set is reduced when conditions are poor for pollination and fertilization. Thinners remove a similar percentage of fruit regardless of pollination. To avoid over thinning in years with poor pollination, mild thinners should be applied or thinners should be applied when average fruit diameter is larger than normal.

F. Earlier timing (8.0 to 10.0 mm) on spur strains of Delicious and most other apple cultivars will improve thinning when NAA is used. NAA, when used alone or in combination with other materials, is often ineffective on spur Delicious.

G. Often a single thinner application will not provide adequate thinning. In such situations a second thinning application, usually Ethephon, may be required.

Results from chemical thinners can vary depending on the average fruit size at the time of thinning. Measuring many individual fruits is time consuming and expensive. Fruit diameter for conical-shaped varieties, such as Delicious and Golden

Delicious, and round varieties, such as York, Rome, and Empire, can be estimated accurately by collecting 100 fruits with stems attached per block and weighing them. Collect 4 spurs from each of 10 trees per block. Remove all the fruits with stems from a spur that appear as if they are still growing. Place the fruits in a bag and record the weight in ounces or grams. To convert from ounces to grams multiply ounces by 28.35 (10 oz = 283.5 grams). The following table gives the fruit diameter corresponding to the weight of 100 fruits for conical and round varieties.

Weight of 100 fruits with stems		Average fruit Diameter in millimeters	
Weight in ounces	**Weight in grams**	**Red & Golden Delicious**	**Rome & York**
0.88	25	5.1	5.4
1.06	30	5.9	6.4
1.4	40	7.1	7.9
1.8	50	8.0	9.0
2.5	70	9.3	10.5
3.2	90	10.3	11.6
3.9	110	11.1	12.6
4.6	130	11.8	13.2
5.6	160	12.7	14.2
7.0	200	13.7	15.2
8.5	240	14.6	16.2
9.9	280	15.4	16.9
11.6	330	16.4	17.7
13.8	390	17.5	18.5
15.9	450	18.6	19.5
18.4	520	19.7	20.5
20.8	590	20.9	21.7

Example: If 100 'Red Delicious' fruit weigh 4.6 ounces (130 grams), then average fruit diameter is 11.8 mm. If 100 'York' fruit weigh 9.9 ounces (280 grams) then average fruit diameter is 16.9 mm.

FACTORS AFFECTING THINNING RESPONSE

Although still poorly understood, responses to chemical thinners seem to be affected by a number of factors. These factors likely interact with each other, making it difficult to determine the effect of each factor. Depending on the condition of the tree, a factor such as temperature may not be important in any given season. Therefore, some degree of judgment, based on experience, thinning of a given block of trees is necessary when selecting chemicals, rates, and timing.

Absorption of chemical thinner by the leaf is necessary for activity and is affected by the cutin layer on the leaf surface. Dry, sunny conditions for one or more weeks before thinning increases the thickness of the leaf cuticle and reduces absorption. Prolonged cool periods condition leaves for increased absorption. Exposure of blossoms and young leaves to freezing conditions increases absorption.

Drying time. Slow drying time usually causes greater absorption and response. Low humidity, wind, and inadequate spray volume can result in fast drying, low absorption, and poor thinning. Warm temperatures accompanied by high humidity before or soon after the chemical application can favor high absorption. Applications when temperatures are below 60 degrees F are usually ineffective, particularly with NAA. Optimum temperatures are 70-75 degrees F. Above 85 degrees F, the thinning response is increased.

Shade. The combination of 2-3 days of cloudy weather with chemical thinners may greatly increase effect of thinner, particularly when fruit are 10-30 mm in diameter. Low light exposure of fruiting wood reduces vigor. In thick trees, poor thinning occurs in tree tops and excessive thinning occurs in shaded lower areas. Sometimes rain occurs shortly after thinners are applied. Observations in Blacksburg indicate that substantial thinning will occur if the spray dries before a rain event. If rain occurs before the spray dries, some, but not enough, thinning will occur.

Temperature. The effectiveness of chemical thinners appears not to be related to temperature at the time of application. We are just starting to understand the importance of fruit size, light levels and temperature on thinning. Preliminary results indicate that in general temperature and light levels during the 3 or 4 days after treatment are important. Small fruits (less than 8 mm in diameter) seem relatively non-sensitive to temperature and light, and will thin equally well over a wide range of temperatures and light conditions. However, larger fruits (12 to 18 mm in diameter) are very difficult to thin when temperatures are low (day- time high temperatures less than 60 degrees F). Several days of cloudy weather following the application of thinning chemicals, especially when temperatures are high, may result in increased thinning. Cloudy weather

accompanying low temperatures often results in less thinning than is desired. For these reasons growers should apply thinners to hard-to-thin blocks soon after bloom if temperatures are adequate. Preliminary results from experiments at Blacksburg indicate that temperature for the two days before thinning may influence thinning results. Warm temperatures during the two days before thinning, especially if fruit are 12 to 14 mm in diameter, may increase the effectiveness of thinners.

Fruit set should be carefully evaluated prior to chemical thinning. Following bloom, the developing fruits compete for food products in the tree. The number of viable seeds affects fruitlet strength, and, consequently, poor pollination and low temperatures can reduce set. However, evaluating seed number when fruit are 10-12 mm in diameter is difficult because fertilized seeds and nonfertilized seeds may look similar. Cool, overcast weather and low temperature will reduce photosynthesis and can result in weak fruit and poor set. Warm, overcast weather will cause fruit abscission. Chemical thinners act to intensify the fruit-to-fruit and fruit-to-shoot competition. On trees where return bloom is light, chemical thinning removes few fruit because fruit-to-fruit competition is low. If poor set is anticipated, the thinner may be applied slightly later in fruit development.

Tree Vigor. Low tree vigor intensifies fruit-to-fruit competition and results in trees being easier to thin. Stress can be caused by inadequate or excessive moisture, and poor fertilization.

Young trees. It is easy to over-thin young trees in good vigor.

Cultivar. Differences in response to various chemicals may be substantial. For example, 'Golden Delicious' is difficult to thin with carbaryl, but may be overthinned with Ethephon.

Table 18. Chemical Concentrations for Thinning Apples

Variety	NAA (plus 1/2 pt Tween 20 per 100 gal water) (ppm)	Amid-Thin (ppm)	Accel (g/acre)	Carbaryl XLR (Sevin) (pt per 100 gal)	Oxamyl (Vydate) (pt/acre)	Ethrel (pt/100 gal)
Lodi	-	50	-	-	-	-
Transparent	-	40	-	-	-	-
Grimes	5	50	-	-	-	-
Jonathan	5	50	-	-	-	-
Delicious (Std)	5	-	-	1	-	-
Delicious (Spur)	-	-	30	1-2[1]	2-4	1.5
Fuji	-	-	30	1-2	-	-
Gala	-	-	30	1-2	-	-
Golden Delicious	8-10	-	-	-	-	0.75
Stayman	5	50	-	1-2	2-4	-
York	5	50	-	1-2	2-4	1.5
Rome	5	50	-	1-2	2	0.5
Winesap	-	-	-	2	2-4	-

[1] Addition of 70 sec superior oil (1qt/100gal) will increase thinning. Caution: If a fungicide is to be used within 7 days of a thinning spray, check for compatability with Superior oil.

PROVIDE 10SG FOR IMPROVING FRUIT FINISH

Fruit russetting is a common disorder that reduces the market value of Golden Delicious in most years. ProVide 10SG is a combination of gibberellins and may reduce the severity of russet on Golden Delicious when applied during the first 50 days after bloom.

Apply ProVide 10SG in 2-4 consecutive sprays, beginning at late bloom to petal fall, and continuing at 7-10 day intervals for remaining sprays. Apply 2.1-3.5 oz (60-100 grams) of ProVide 10SG in 100 gallons of spray solution per acre. Do not apply more than 8 oz in a single season. Do not use spreader stickers or other spray adjuvants in combination with ProVide 10SG because they may aggravate russet development. ProVide 10SG can be used to suppress russet of varieties other than Golden Delicious.

PROVIDE 10SG FOR REDUCING STAYMAN CRACKING

ProVide 10SG is a mixture of gibberellins that can reduce 'Stayman' cracking if applied before cracking begins. Apply ProVide 10SG 6 times at 14- to 21-day intervals, starting 2 to 3 weeks before cracking begins (mid-June to early July). Apply ProVide 10SG at the rate of 3.6-7.0 oz (100-200 grams) per acre per application and enough water should be used to wet the fruit (100 to 200 gallons per acre). If ProVide 10SG is used to suppress russet on Stayman, it cannot be used to suppress cracking.

Table 19. Growth Regulator Fruit Responses

Growth regulator(s)	Stayman cracking	Red color	Fruit firmness	Watercore	Preharvest drop	Ripening	Storage life
ProVide 10SG	-	—	—	—	—	—	—
Ethephon		++	-	+	++	++	—
NAA			-		-	+	-
Retain		?	+	–	–	–	+

(-) decrease

(+) increase

ETHEPHON FOR STIMULATION OF COLORING AND RIPENING OF APPLE

Ethephon (Ethrel) provides several fruit modifying effects (Tables 19 and 20). Used properly, it can spread out picking time for selected parts of orchards by permitting earlier harvesting of better colored fruit.

Ethephon response is greatest under good fruit-coloring conditions and cannot substitute for conditions associated with poor color development, such as hot weather and poorly-pruned trees. Hot, dry conditions may stimulate ripening, softening, and watercore with inadequate red color, particularly on fruit treated with ethephon. Ethephon is not advised under conditions of severe water stress and high temperature.

Ethephon applied alone can cause early and severe fruit drop. Combination of NAA with ethephon will provide adequate drop control. Two sprays of NAA at 20 ppm may be needed. NAA will only prevent fruit drop for 7-10 days. Therefore, 7 days after the initial ethephon-NAA application, an additional NAA application should be used if treated fruit will not be harvested by 8-9 days after initial application. Since only two NAA applications are permitted for fruit drop control, ALL treated fruit MUST be harvested by 8-10 days after the second NAA application.

For stimulating red color on fruit to be marketed early, use a dilute spray combination of ethephon at 3/4 to 1 pt per 100 gal plus 4 oz of a surfactant plus NAA as shown in Table 20.

Use ethephon 1 to 2 weeks before normal picking time. Do not spray ethephon earlier than 3 weeks before normal harvest date because response may be limited.

Check fruit development closely, and harvest when treated fruit are ready. Do not spray more fruit than can be harvested in a 2-3 day period. Watch fruit condition because ethephon reduces starch levels, increases soluble solids, and stimulates ripening and softening of apples on the tree and after harvest. It may be possible to begin harvest earlier in some seasons, or to pick more or most fruit with better color at normal picking time.

Ethephon absorption is decreased at low temperatures. Apply when air temperature is 60°F to 85°F. Reduced response may be expected if application is followed by rain or excessive heat.

Table 20. Ethephon Timing and Stop-drop Concentration

Variety	Timing (weeks before normal picking)	Concentration (ppm) NAA[1]
Jonathan	1-2	10
Delicious	1-2	10
Golden Delicious	1	10
Rome	1	10-20
Stayman	1	10-20
Winesap	1	10
York	1	10

[1] An additional application should be made if fruit are not harvested by 8-9 days after initial application.

PREHARVEST DROP CONTROL OF APPLES

Naphthaleneacetic acid (NAA) provides preharvest drop control (Table 19, 20, and 21).

Proper timing and rate are important for effectiveness (Table 21). Anticipating the expected time of drop is affected by weather conditions; however, the period is usually around the normal harvest period for a given variety. Heavy, late season rains or wind, particularly following drought conditions, have been associated with heavy preharvest drop.

Fruit should be harvested as near to the optimum harvest date as possible, even with the use of NAA. NAA reduces the drop of fruit, but fruit ripening continues at normal or even faster rates, especially for Rome and Golden Delicious. If allowed to remain on the tree too long, NAA treated fruit will be of poor quality and have decreased storage life.

NAA may not be effective when applied at low-volume concentrations. Use dilute or not higher than 3x, based on tree-row-volume calibration. Thorough coverage is necessary. Healthy leaves are necessary for maximum stop-drop spray effectiveness; severe mite injury on leaves can reduce response.

Recent research results indicate that NAA may be most effective when applied before fruit loosen on the tree. We suggest an application at least 2 weeks before the first fruits drop (about 3 to 4 weeks before optimum harvest, based on flesh firmness, not color). NAA becomes effective 2-3 days after application. It may be necessary to apply a second spray of NAA if fruit start to loosen. Do not make more than two applications because additional applications may not be effective. Do not use within two days of harvest.

Aminovinylglycine (AVG, ReTain) + a silicone surfactant provide preharvest drop control and delays fruit maturation. ReTain delays the loss of fruit firmness and starch after the optimum harvest date for most cultivars. The delay is less for 'Red Delicious' and 'York' than for 'Rome' or 'Golden Delicious'. The delay in maturity may allow a cultivar to be harvested several days after the optimum harvest date since fruit quality is maintained better than with NAA. A delay in harvest will allow for an increase in fruit diameter and yields that may amount to 0.5% to 1% per day.

For single-pick harvest, ReTain must be applied 4 weeks prior to the anticipated harvest in sufficient gallonage to ensure thorough coverage. A silicone surfactant will improve ReTain effectiveness. For multiple-pick harvest, ReTain can be applied 1-2 weeks prior to the anticipated beginning of the normal harvest period of untreated fruit. It will not delay the start of the harvest (first pick), but will help control the maturation rate of later picks. Mixing ReTain in a tank mix with pesticides is not recommended.

Table 21. Rates of NAA and Retain for preharvest drop control.

Variety	NAA (ppm)	Retain (AVG) & Silicone Surfacant (g/acre)
Grimes	5	333
Jonathan	10	333
Delicious	10	333
Golden Delicious	10	333
Rome	10-20	333
Stayman	10-20	333
York	10-20	333
Winesap	10-20	333
Other late varieties	10-20	333

The combination of NAA and AVG more effectively reduces preharvest fruit drop than either alone. The combination of NAA and AVG also slows the loss of fruit firmness enhanced by NAA. The fruit treated by the combination of NAA and AVG will ripen at the same time as untreated control fruit but they are firmer than untreated control fruit. AVG and NAA are applied 4 and 2 weeks prior to the anticipated harvest, respectively. NAA at 10-20 ppm and AVG at 333 g/acre are usually used.

CALCULATING PARTS PER MILLION (PPM)

In this guide, the amounts of material to be added to 100 gal of water are given along with ppm. In the event a grower needs to calculate ppm (if a different formulation is used, etc.), the following are presented.

Labels on some materials present active ingredient (AI) as a salt (NAA-sodium salt) and as an acid equivalent. Here we assume that ai refers to the percentage of equivalent ai.

1) For wettable powders:

$$\frac{[(\text{lbs of material} \times (\%\ \text{ai})]}{(\text{gal water} \times 8.345)} \times 10{,}000 = \text{ppm}$$

Eamples:

a) What is the concentration of a solution made by puting .072 lbs of a material that contains 3.5% ai, in 300 gal of water?

$$\frac{(0.72 \times 3.5)}{(300 \times 8.345)} \times 10{,}000 = 10 \text{ ppm}$$

b) How much of the same material must be added to the 300 gallon tank to obtain the 10 ppm concentration?

$$\frac{\text{ppm}}{10{,}000} \times \frac{(\text{gal water} \times 8.345)}{\%\ \text{ai}} = \frac{10}{10{,}000} \times \frac{(300 \times 8.345)}{3.5} = 0.715 \text{ lb material}$$

2) For liquid formulation:

$$\frac{(\text{oz of material}) \times (\%\ \text{ai})}{(\text{gal water} \times 128)} \times 10{,}000 = \text{ppm}$$

Examples:

a. What is the concentration of a spray solution resulting from putting 11 oz of a material containing 7% ai, into 300 gallon of water?

$$\frac{(11 \times 7)}{(300 \times 128)} \times 10{,}000 = 20.05 \text{ ppm}$$

b. How much of the same material must be added to 300 gallons of water to obtain a 20 ppm solution?

$$\frac{\text{ppm}}{10{,}000} \times \frac{(\text{gal water} \times 128)}{\%\ \text{ai}} = \frac{20}{10{,}000} \times \frac{(300 \times 128)}{7} = 10.97 \text{ oz material}$$

Peach Flower Thinning

Flower thinning promotes increased fruit size and yields, increased tree growth and flower bud numbers the next season compared to hand thinning 35 to 50 days after full bloom. Under cool conditions only 30% of the flowers may set fruit while under ideal conditions some cultivars may set 85% of the flowers. At the time of bloom it is desirable to have twice as many flowers set fruit as would be required for a full crop. This is to allow enough fruit for subsequent freezes and/or poor fruit set.

CHEMICALS AND TIMING

WILTHIN (+ Regulaid 1 pt/100 gal) is one of several chemicals being researched for flower thinning of peach. This material is registered in Virginia for applications from 3 to 6 quarts/acre. Our data indicate that 5 to 6 quarts will likely be required to obtain thinning. Even this rate may be too low under Virginia conditions. Applications should be made with an airblast sprayer dilute. This requires 100 to 250 gallons of water per acre. Do not combine WILTHIN with other materials. Do not apply when foliage is wet or if rain is expected within two hours. Subsequent hand thinning 35 to 45 days after full bloom may be required. For maximum effectiveness, application should be made when about 90% of the flowers have opened with approximately 10% of the buds in the pink stage of development. Fruit that have not set from this application may remain on the trees for a period of 35 to 45 days, but at hand thinning time they will likely be smaller fruit with small ovules. Growers are encouraged to apply this material to only a few trees to gain experience before wide scale use.