Plant growth regulator use in apples

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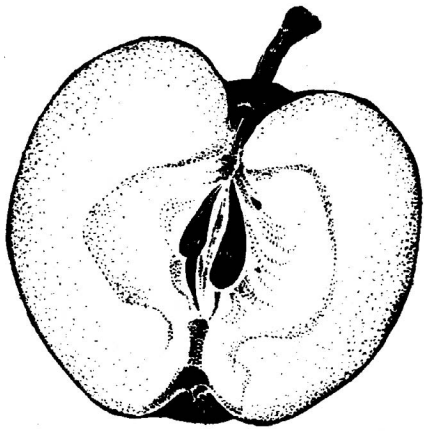


Plant growth regulators (PGRs) can be used with some precision for thinning fruit, regulating growth and adjusting harvest periods for apples. These products are absorbed by plant cells, primarily through the leaves and fruit, where they interact with the biochemical "machinery" of the plant. They work by mimicking naturally occurring plant hormones or by blocking the production of natural plant hormones.

This publication provides information on which plant growth regulators to use for a specific effect and gives instructions on how, when, where, and in what quantities to apply them. Because plant response can vary greatly due to a range of factors, it's important to keep detailed records of use and plant response to help you fine-tune applications for your orchard.

Factors affecting plant response

The effectiveness of a PGR application is determined in part by how well the chemical is absorbed by the plant. Factors such as environmental conditions, tree vigor and age, dosage, timing, and the cultivar all interact to cause variation from year to year in the plant's response. By understanding the role of each variable, you will be better equipped to adjust PGR applications, within product label allowances, to compensate for year-to-year and block-to-block differences.

Environmental conditions. Weather conditions before, during, and after applications can affect plant response to PGRs. High temperatures, slow drying conditions, and healthy foliage will enhance absorption and increase plant response. Cool temperatures, fast drying conditions, and damaged trees or foliage will decrease plant response. If the weather is cool and humid, morning applications are best; if it's been hot and dry, an evening application will be most effective.

Tree vigor and age. Weak trees and young trees are extremely responsive to PGRs. Stresses caused by lack of water, low nitrogen, or plant or leaf injury increase response to PGRs. Doses should be decreased or application eliminated for trees that are stressed. Although damaged foliage can reduce absorption, weak trees can still be oversensitive to PGR application.

Dosage. PGRs are applied in very precise and low concentrations. Extreme care must be taken to mix and apply these chemicals accurately. The crop may be injured if too much chemical is used. Alternatively, the response may not be adequate if too little was applied. PGRs should be sprayed in as much water as possible to ensure adequate coverage. An application of 200–300 gallons per acre is best. Growers with only low-volume equipment should use the highest volume possible. Do not tank-mix PGRs with pesticides.

Evaluation checklist

Treatment block:_____

Keep annual records for each treatment block

Date:_____

Environmental conditions

Time applied: ☐ predawn ☐ morning ☐ midday ☐ afternoon ☐ evening

Air temperature at application: _____

Relative humidity: _____

Wind speed and direction: _____

Did it rain within 8–12 hours after application? ☐ yes ☐ no

Weather conditions for the 2 days following application:

Day 1: ☐ sunny ☐ cloudy | daily temperatures: high _____ low _____

Day 2: ☐ sunny ☐ cloudy | daily temperatures: high _____ low _____

Tree vigor

Fruitlet size (mm): _____

Age of trees: _____

Cultivar(s): _____

General vigor of the block: ☐ high ☐ medium ☐ low

Previous season production: ☐ high ☐ medium ☐ low

Dosage details

What chemical or mix of chemicals was applied? _____

_____

How much formulated material was added to the spray tank? _____

_____

How many gallons of water were applied per acre? _____

When was the sprayer last calibrated? _____

Tree response

What was the plant response? How well did the treatment work? _____

_____

_____

Timing. PGRs can cause different effects if applied at different times during the season. For a predictable response to occur, PGRs must be applied in a narrow time period, usually within a few days.

Cultivar. Different apple cultivars display varying degrees of responsiveness to PGR application. This is especially true for chemical thinning.

Evaluating and monitoring tree response

To evaluate the effectiveness of PGR treatments, leave some trees untreated. Keeping accurate detailed records of application rates, weather, and plant response will help you make adjustments in future years so to achieve the optimal response.

Using the evaluation checklist at left will help you keep track of relevant data for each treatment. Use the information to adjust PGR applications.

Thinning fruit

Apple trees typically produce more flowers and fruit than are needed to produce a full crop of marketable fruit. Many of these excess fruit will drop shortly after petal fall or later, during the June drop period. In a good crop year the remaining fruit load will still be too large for the fruit to develop adequate size. Thinning the crop will maximize fruit size and quality.

Fruit size is determined by the total cell number per fruit. In apples, cell division ceases by about 30 days after full bloom. Therefore, final fruit size is determined within a month after full bloom. For trees to develop large fruit, excess fruit must be removed before cell division stops. This allows remaining fruit to develop more cells and thus become larger fruit. Allowing too much fruit to develop not only produces poor fruit size in the current year, it can also lead to poor bloom the following year. Such trees will continue to bear heavy loads of small fruit every other year. Unlike hand thinning, chemical thinning preferentially removes small, weak fruit.

Determining crop load

The following questions will help you evaluate whether your crop needs to be thinned. Remember, it's best to be conservative when applying thinning materials so you don't remove more fruit than you'd intended.

- **How many seeds are present?** When fruitlets are 3–5 mm, cut open a few and count the seeds. Fruit with fewer than five seeds are more likely to drop naturally and will be easier to thin than fruit with more seeds.
- **What color are the seeds?** Tan or brownish seeds indicate frost injury and will drop early. Frost damage won't necessarily make thinning unnecessary, but it does call for more careful evaluation and conservative thinning.
- **Are there too many apples on the tree?** If fruit clusters are within 6–8 inches of each other and if there are more than two fruits per cluster, there are too many apples on the tree.
- **What was the crop load like last year?** Following a heavy crop trees will thin more easily.
- **What was bee activity like in the orchard?** Were pollination conditions satisfactory?

Available products

Four materials can be used for fruit thinning in Wisconsin: carbaryl (Sevin), benzyladenine (Maxcel), naphthalene acetic acid (NAA), and naphthalene acetamide (NAD). The best material to use will depend on the cultivar, the condition of the trees, and time of application.

Carbaryl (Sevin) is a very effective thinning agent for apples. Trees thinned with carbaryl will have larger fruit than those thinned with NAD or NAA. However, carbaryl is an insecticide that is highly toxic to bees, mite predators, and other beneficial insects. To minimize danger to these essential beneficial insects, use the lowest effective rates and spray after petal fall when bees are not active in the orchard.

Caution: Do not apply carbaryl at petal fall unless bees have been removed from the orchard.

Carbaryl should be applied within 28 days after petal fall, after the crop load has been determined. If the weather has been cool, delay application until the largest fruit are 10–15 mm in diameter.

Apply ¼ to ½ lb of carbaryl per 100 gallons of water. For increased thinning action, add NAA or NAD to the mix. Surfactants will not increase the thinning action of carbaryl.

Benzyladenine (Maxcel) is a relatively new thinning material that increases fruit size beyond that expected by reducing fruit number. Benzyladenine is a synthetic cytokinin. It should be applied when first, or king, fruitlets are 5–10 mm in diameter. They typically reach this size within 7–21 days after full bloom, depending on the cultivar and weather.

Using a calibrated sprayer, apply 48–128 fl oz (75–200 ppm) of Maxcel per acre in as much water as possible. For best results, apply in early morning or late afternoon to prolong the drying period. High temperatures within 8 hours before or after application may increase the thinning response. Maxcel is most effective when air temperatures are between 70°F and 75°F. Do not apply when temperatures are below 60°F or above 80°F.

Maxcel can be tank-mixed with carbaryl to improve the thinning action. Usually ¼ lb of carbaryl is sufficient. (See carbaryl discussion for cautions.) Do not tank-mix Maxcel with other pesticides.

Naphthalene acetic acid (NAA) is a synthetic auxin growth regulator and is recommended for cultivars that mature after September 1. Fruit thinned with NAA do not show as strong of a size response as they do with carbaryl or benzyladenine.

NAA should be used when the king fruit are 8–12 mm in diameter and side fruit are 8–10 mm. Since fruit tends to shrink during the day and swell at night, measure at the same time each day starting at petal fall. Measure cultivars separately and keep a record of the results. If temperatures fall below 50°F after bloom, NAA application may be delayed up to 21 days after petal fall. Apply NAA at the rate of 10–15 ppm for most fall to winter cultivars.

NAA is a very active, potent material and should be used with caution. Consider the following factors before applying NAA for fruit thinning:

- Weak trees and young trees are more responsive to NAA. Shaded limbs tend to overthin.
- For best results, apply on a calm day when temperatures are between 70° and 75°F.
- Light rain or mist within an hour before or after NAA application will increase uptake and thinning action.
- Trees thinned annually have a more predictable response to NAA thinning sprays.
- For some hard-to-thin cultivars, adding carbaryl or a surfactant to the mix may be needed to increase the effectiveness of NAA. (Carbaryl is more effective than a surfactant at increasing thinning.) Be sure to decrease the NAA concentration by half when adding either product to the spray. Follow label guidelines closely.

Naphthalene acetamide (NAD) is another synthetic auxin growth regulator. It is best for summer apples that mature before September 1. It is less active than NAA and less likely to overthin. Apply NAD between late bloom and petal fall (4–8 days after full bloom). Application after petal fall can result in poor thinning.

NAD is applied at a rate of 35–50 ppm for most summer cultivars. Using a surfactant with NAD will increase the thinning action. Reduce the NAD concentration by 50% when a surfactant is added.

Caution: Do not use NAD on Delicious as it can result in many small seedless pygmy fruit that persist on the tree.

Controlling tree vigor

There are many reasons for controlling an apple tree's vegetative vigor. Trees that grow overly vigorously take longer to prune and have more internal shading that may reduce apple coloring. Dense canopies require more spray and are harder to cover adequately with pesticides. Trees that are planted too close together on overly vigorous rootstocks may also be a problem. Also, trees that produce much succulent shoot growth are more susceptible to fire blight infection.

Apogee is a growth regulator that interferes with the production of gibberellins by plants. Gibberellins cause shoots to elongate. When fewer gibberellins are produced, shoot growth is reduced. The effect of a single application of Apogee lasts only a couple of weeks depending on the inherent vigor of the trees and when it's applied during the season. In Wisconsin, usually three to five applications per season are needed for adequate growth control. Growers in the southern part of the state will need more applications and growers in the north will need fewer.

A beneficial side effect of Apogee is that trees have a lower incidence of fire blight due to the reduced amount of succulent growth. Apogee has no direct effect on the bacteria that cause fire blight.

The first application of Apogee should be made when trees have 1–3 inches of new growth. Apply 18–36 oz of product per acre in the initial application. Subsequent applications should be made every 2–4 weeks depending on the vigor of the tree. Reduce the rate to 9–24 oz per acre, and do not exceed application of 48 oz per acre in any

21-day period. Apply no more than 99 oz of Apogee per acre per season. Adjust the amount of product and water according to the tree row volume calculated for each block of trees. (To calculate tree row volume, consult Extension publication, *Commercial Tree Fruit Spray Guide,* A3314.)

Preventing russet

Fruit russet, rough tan to brown patches or streaks on the skin of apples, is a common problem throughout the East and Midwest. In Wisconsin, Golden Delicious and Haralson are particularly prone to russet. It's typically caused by the presence of water on the fruit surface during the first 45 days of fruit development. High relative humidity, dew or rain, light frosts, and reaction to some pesticides may all cause russetting.

Multiple applications of gibberellic acid (GA_{4+7}) during the 45 days after bloom have been shown to reduce fruit russetting. Beginning at late bloom or petal fall, apply GA_{4+7} (ProVide) in four consecutive sprays every 7–10 days. Apply 10–13 oz (15–20 ppm) per 100 gallons of finished spray per acre. Do not exceed 40 oz/a of ProVide in a single season. Excessive water volumes can contribute to fruit russet. ProVide can be tank-mixed with pesticides, but should not be mixed with sticker-spreaders or nutrient sprays. Do not apply ProVide through an irrigation system.

Managing fruit maturity

Controlling when fruits mature allows more efficient use of labor and other resources, and it prolongs the harvest season. Using PGRs, it's possible, for example, to advance fruit maturity in one portion of a block and to delay maturity and improve storability in another portion of the same block.

Hastening fruit maturity

Ethephon application will advance apple maturity by 3–5 days under favorable weather conditions. This product will also shorten the storage life of treated fruit, so avoid using it on any apples intended for long-term storage.

Ethephon improves the color of red-skinned apples. Fruit requires cool nighttime temperatures and direct exposure to light to change color, even when ethephon has been applied. Proper training and pruning is critical to allow good light distribution within the canopy. Cultivars and strains that color poorly may not respond adequately to ethephon application. Do not use ethephon on yellow or green skinned cultivars to advance fruit maturity.

Temperatures will influence the effectiveness of ethephon. Ideally, nighttime temperatures should be between 55°–65°F and daytime tem-

Determining how much formulation to apply

Calculating the how exactly how much plant growth regulators to apply based on ppm can be difficult. Parts per million is not an amount, but a concentration of PGR in the spray water. Therefore, to determine the correct application rate, you need to know how much water per acre you will be applying and the desired ppm. The correct rate can be calculated using this formula.

$$\text{lb of material needed} = \frac{(\text{desired ppm})}{1{,}000{,}000} \times \frac{(\text{gallons of water}) \times 8.345}{(\%\ \text{active ingredient})}$$

To convert pounds to ounces, multiply the result by 16.

Example: A commercial formulation of NAA contains 3.5% active ingredient. How much formulation per 100 gallons is needed to make a solution of 10 ppm for thinning 'Golden Delicious'?

$$\frac{10\ \text{ppm}}{1{,}000{,}000} \times \frac{100\ \text{gal} \times 8.345}{0.035\ \text{a.i.}} = 0.24\ \text{lb}$$

To convert the rate to ounces: 0.24 lb x 16 oz/lb = 3.85 oz

A primer on plant hormones and growth regulators

A plant hormone is commonly defined as an organic substance that is produced in one part of a plant and translocated to another part where, at very low concentrations, it stimulates a physiological response. Plant hormones may promote or inhibit growth depending on the specific hormone involved, the concentration, the time, and the plant part it is acting on. Plant hormones occur naturally; when they're synthesized chemically they're known as plant growth regulators. More recently, compounds that block the creation of plant hormones have become available (Apogee and ReTain).

Plant hormones can be grouped into five classes of compounds: auxins, gibberellins, cytokinins, abscisic acid, and ethylene. Detailed descriptions of these plant hormones, their discovery and history of their use is beyond the scope of this publication, but are available to those who have a greater interest.

Auxins. These are primarily growth-promoting substances that contribute to the elongation of shoots, but at high concentrations they can inhibit growth of lateral buds. Auxins are generally produced in apical buds, young leaves, and developing seeds. In addition to being used as plant growth regulators, auxins can also be herbicides (2,4-D and other phenoxy herbicides). In apple production, NAA and NAD are synthetic auxins that can be used to thin fruit, to inhibit water sprout and sucker growth, and to prevent fruit drop shortly before harvest. Carbaryl, while not strictly an auxin, has a similar chemical structure.

Gibberellins. Gibberellins also promote growth. They are produced in very young leaves, developing seeds, fruit, and roots. Gibberellins cause cell elongation, including shoot growth, and are involved in regulation of dormancy. Commercially, gibberellins have been used to improve fruit size and to prevent russetting. The plant growth regulator Apogee limits biosynthesis of gibberellins and thus inhibits shoot growth.

Cytokinins. Cytokinins promote cell division. They are thought to be produced in the roots and by young fruit. Cytokinins are involved in apical dominance, branching, and stimulating bud initiation. Commercially they are used as fruit thinners (Accel and Maxcel).

Abscisic acid. Abscisic acid (ABA) is a growth inhibitor. It controls the dormancy of buds and seeds and inhibits shoot growth. Exactly how ABA works is not well understood. It may act directly by blocking synthesis of enzymes, or it may operate indirectly by blocking RNA synthesis thus blocking the formation of enzymes that in turn form the growth promoters. ABA is produced in mature leaves along with many other plant tissues; it has not been chemically synthesized for commercial use.

Ethylene. This is the only known gaseous plant hormone. Many plant organs synthesize ethylene and it moves readily in the air surrounding the tree. Usually ethylene has an inhibitory effect on plants. It promotes abscission of leaves and fruits, inhibits shoot elongation and favors caliper development, and, along with auxin, inhibits lateral bud development. On the other hand, it can break dormancy in buds and seeds and causes rapid ripening of apples. In apples, ethylene is involved in the transition of fruit from being physiologically mature to ripe. Once exposed to ethylene their storage life is shortened. Ethephon is a synthetic compound that releases ethylene upon application. ReTain interferes with ethylene biosynthesis. It allows fruit to hang on trees longer and lengthens storage life.

Because plant growth regulators may have several means of causing a desired response, results with use of these products is highly variable. Results are affected by weather, tree vigor, surfactant use, concentration, and timing.

peratures between 75°–85°F. Color development will not be enhanced if nighttime temperatures are above 70°F and daytime highs are above 90°F. However, maturity will still be advanced.

Apply ethephon 15–20 days before normal harvest date in a dilute application of ⅓–⅔ pint ethephon plus 10 ppm NAA per 100 gallons of water. Treat only a small group of trees, no more than can be picked and packed in 3 days. Treating blocks sequentially 2–3 days apart will allow adequate time for harvest and packing.

Caution: Ethephon promotes fruit drop. Always use it with a preharvest stop-drop spray such as NAA (see below).

Preventing premature fruit drop

Some cultivars, particularly early ones, are susceptible to preharvest fruit drop. This condition is apparently caused by a deficiency in natural auxin concentration (a plant hormone). When auxin concentrations are too low, abscission layers begin to form and the fruit drops from the tree. Most susceptible cultivars respond to a dilute application of auxin in the form of NAA. Make the application 7–14 days before the anticipated harvest date at a concentration of 10–20 ppm.

Do not apply NAA within 2 days before harvest nor use more than twice per season as a stop-drop treatment. If making a second application of NAA as a stop-drop treatment, allow at least 7 days after the first application. NAA used on early season cultivars can result in fruit splitting at maturity. Do not exceed 20 ppm concentration and don't apply as a concentrate spray. NAA will shorten the storage life of treated fruit, so do not apply it to any fruit intended for long-term storage.

Delaying fruit maturity

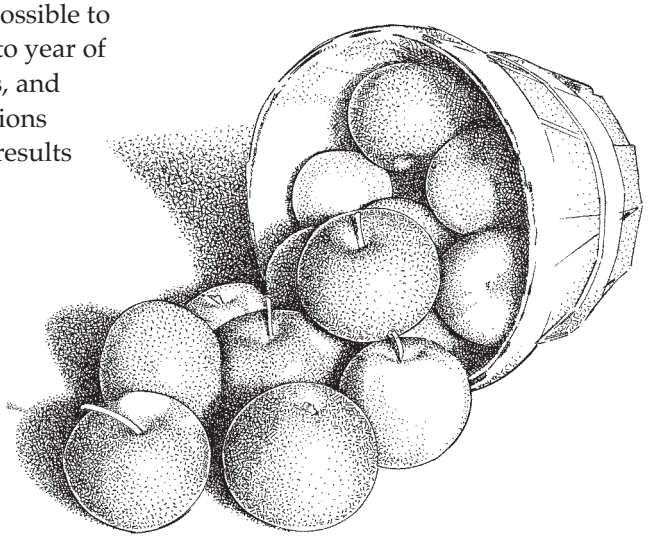
ReTain blocks the formation of ethylene by plants and can be used to delay maturity and to hold fruit on trees. Allowing fruit to hang on trees can also allow color to develop. ReTain has no direct effect on fruit color. Timing is critical when using ReTain. Apply at the label rate 4 weeks before the anticipated normal harvest. Apply in early morning or evening when drying times are long and the fruit is cool. Include a silicone surfactant at the rate of 0.05 to 0.1% in the spray tank. Coverage is critical, spray both sides of the tree—no alternate row spraying. Spraying 100 gallons per acre will provide sufficient coverage.

Fruit treated with ReTain tends to be firmer at harvest and remains firm longer in storage. Treated fruit often can be stored somewhat longer than untreated fruit.

Conclusion

Plant growth regulators can be a substantial aid to apple growers if care is used in timing, mixing, and spraying. Sloppy technique will lead to disappointing results and will waste time and money.

Record-keeping is critical. Without good records, it's impossible to keep track from year to year of which rates, materials, and environmental conditions produced acceptable results on which cultivars.



References to chemical in this publication are for your convenience and are not endorsements of particular products over other similar products. Plant growth regulators are classified as pesticides by the U.S. Environmental Protection Agency. You are responsible for using pesticides according to the manufacturer's current label directions. Follow directions exactly to protect people and the environment from pesticide exposure. Failure to do so violates the law.

This information is provided as an educational tool to inform growers what materials are legal to apply and what is effective. No implication is intended that the University of Wisconsin-Madison or UW-Extension recommends the use of any materials.

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