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# CHEMICAL FRUIT THINNING OF APPLES

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Chemical fruit thinning is an established practice in all apple producing areas of the world. The immediate objective of thinning is an increase in fruit size because an excessive crop always results in a high percentage of small fruits. An excessive crop may also adversely affect fruit color, sugars and other flavor components, and fruit condition and storage life. These negative effects of an excessive crop are due to an unsatisfactory leaf/fruit ratio. The leaves, through the process of photosynthesis, produce all the carbohydrates that are used in fruit growth and that contribute to fruit quality. Optimum fruit size and quality require about 30 leaves/-fruit. Fruit thinning improves the leaf/fruit ratio by increasing the leaf area available to each of the persisting fruits. Obviously, the number of leaves cannot be increased; therefore, adjustments in the leaf/fruit ratio are possible only by reducing the number of fruits. Effective fruit thinning is usually rewarded handsomely. This point is well illustrated by data collected in a 1984 study. In McIntosh, the smaller apples that are normally packed in 12/3 poly bags often make up as much as one-third of the total crop. At prices prevailing at harvest in 1984, this resulted in an average selling price/box of $7.42 (Table 1). Upgrading one-half of the bag-size apples to larger sizes increased the average selling price/box by $0.51. At the yield recorded in this study (660 boxes/acre). This represents an increase in net return/acre of $302.94, or 48.7 percent (assuming growing costs or $1,318/acre, harvesting costs of $1.58/box, packing costs of $2.16/box, and a 10 percent sales commission).

The reduction in fruit size is not the only adverse effect of an excessive crop. Trees that produce a very heavy crop usually have a light bloom and a light crop the following year. This often initiates a continuing cycle of alternating light and heavy crops that is known as biennial or alternate bearing. The heavy crop years are called "on" years and the light crop years are called "off" years. With very light crops, the fruits are often oversize with significant condition problems. The oversize fruits of the "off" year may be as objectionable as the small fruits of the "on" year. The reduced flowering following a heavy crop is due to the fact that the individual spurs alternate; that is, a given spur may produce a fruit, or a flower bud for the following year, but usually not both. A small percentage of the spurs may produce both or neither, but the majority of the spurs will alternate strictly. To ensure uniform, annual production, a significant percentage of the spurs must be non-fruiting each year because it is the non-fruiting spurs that form the flower buds for the succeeding crop. In the past, biennial bearing was considered to be due to low carbohydrates. With a heavy crop, nearly all the products of the leaves were used in fruit growth and little was left for flower bud initiation for the following crop. However, it has now been established that this is controlled by growth regulators rather than by carbohydrate metabolism. It is the seeds in the developing fruit that inhibit flower bud initiation, not a lack of carbohydrates. The specific factor has been identified as gibberellins produced by the developing seeds early in the growing season. Just as small fruit has

**Table 1. Increase In value of McIntosh apples associated with an increase in fruit size (1984).**

| Size and grade | Price/ box | Average packout | | Upgrading 50% of 12/3's | |
|---|---|---|---|---|---|
| | | Percent | Value | Percent | Value |
| Extra-fancy | | | | | |
| 100 | $11.50 | 3.68 | $0.42 | 5.53 | $0.64 |
| 120 | 10.00 | 16.67 | 1.67 | 25.07 | 2.51 |
| 140 | 9.50 | 12.71 | 1.21 | 19.12 | 1.82 |
| 12/3 poly bags | 7.00 | 33.33 | 2.33 | 16.67 | 1.17 |
| Utility | 6.00 | 27.81 | 1.67 | 27.81 | 1.67 |
| Cider | 2.00 | 5.80 | 0.12 | 5.80 | 0.12 |
| Average selling price per box | | | $7.42 | | $7.93 |

serious economic repercussions, alternate bearing is equally costly. Many of the production costs are per acre costs and are independent of yield, and the low yields of the "off" year do not cover basic growing costs. Total production suffers because the heavy crops of the "on" year do not compensate for the light crops of the "off" year. Marketing is a problem because there is never a normal range of fruit sizes; it is either small apples or large apples. And management of higher density plantings is more difficult because regular, consistent cropping is the first step in controlling vegetative growth.

### FACTORS AFFECTING FRUIT SIZE

The immediate objective of fruit thinning is an increase in fruit size. There is a strong inverse relationship between the number of fruits on an apple tree and the size of those fruits (Fig. 1), and an increase in fruit size can reasonably be expected from a significant reduction in fruit numbers. However, fruit size at harvest is the result of the interaction of many factors. Crop load, or the number of apples on the tree, is only one of a number of contributing factors, and the effects of crop load can be modified by other factors. Events of the previous season, such as an excessive crop, prolonged soil moisture stress, or severe foliage injury from insects or diseases, can adversely affect fruit size

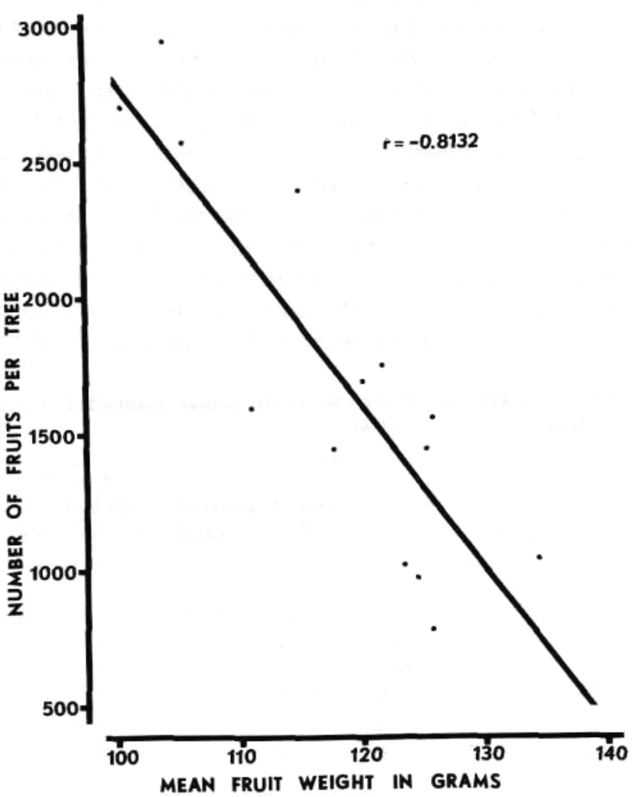


*Fig. 1. Relationship between fruit numbers and fruit size. (McIntosh - 1975).*

of the succeeding crop. Low temperature injury to the conducting tissues, particularly the spurs, can impose definite limitations on fruit size potential. Spring frost may kill some buds outright, leaving others injured but surviving, and fruits developing from these damaged buds will not size properly. Frost often kills the king blossoms while most of the lateral blossoms survive. The king blossom is the strongest blossom in the cluster and the one that will develop into the largest fruit, but it is also the earliest to develop and that makes it the most susceptible to frost injury. When the majority of the king blossoms are killed, the crop develops from lateral blossoms and these inherently produce smaller fruits. Frost may also severely damage the spur leaves and this injury reduces early fruit growth and, ultimately, fruit size at harvest.

Bloom weather that severely limits cross-pollination can adversely affect fruit size because one of the basic requirements for large fruits is a high seed count. The immediate post-bloom weather is important because all of the cell division in the developing fruit occurs in the 3-4 weeks after bloom. Warm, sunny weather favors rapid growth, but if the weather is cool and cloudy, growth will proceed slowly and the total number of cells, and the potential fruit size, will be reduced accordingly.

Nutrition is a very obvious factor affecting fruit size with deficiencies of nitrogen and potassium often associated with high percentages of small fruits. Prolonged periods of soil moisture deficits, whether due to inadequate or poorly distributed rainfall, will significantly reduce fruit size. Under these conditions, optimum fruit size may be attainable only through supplemental irrigation.

Low vigor can easily become the limiting factor in fruit size. There are actually 2 vigor situations to consider: the vigor of the total tree, and the vigor of different areas within the tree. Low vigor of the total tree is often due to nutritional imbalance or to inherent soil physical problems. Low vigor of lower branches or of the interior of the tree is usually associated with shading due to inadequate or improper pruning. In some varieties, and spur-types are the worst offenders, a low vigor situation known as "spur-bound" sometimes develops. Affected trees produce high percentages of undersize apples in spite of good thinning, fertilization, and irrigation.

Alar is widely used, particularly on McIntosh, for a number of reasons. Under some conditions, Alar carryover can dramatically reduce fruit size. The term carryover refers to effects from the previous year's application. Significant carryover effects are usually associated with high rates, late application, or low vigor.

A good fruit size response to thinning assumes that all other factors are at or near optimum. With problems in other of these areas, the response to thinning may be disappointing. Unfortunately, most of these negative effects tend to be additive. The worst combination is probably an excessive crop and drought, but Alar carryover and low vigor, or low temperature injury and drought, can be very damaging. **A good thinning job will not guarantee good fruit size if there are significant problems in other areas that affect fruit size.**

## FRUIT NUMBERS, FRUIT SIZE, AND YIELD RELATIONSHIPS

The crop of an apple tree is the product of 2 factors: the number of apples on the tree and the size of those apples. If the number of fruits per tree is compared with yield, a very strong, positive relationship is obvious. In addition, this is a broad, general relationship because different orchards and different years can be combined without altering the relationship (Fig. 2). However, when fruit size and yield are similarly compared, a different relationship is revealed. First of all, the relationship is negative; as fruit size increases, yield decreases. Second, the relationship is less precise or less predictable. Also the relationship tends to be specific for location (Fig. 3). This is an expression of the influence of factors other than crop load on fruit size. If fruit size is compared with fruit numbers, the relationship is again negative (Fig. 1). This is not surprising because one of the objectives of fruit thinning (reducing the number of fruits) is an increase in fruit size. However, it is significant to note that the increase in fruit size is proportionately less than the reduction in fruit numbers. The increase in size does not compensate for the reduction in numbers. Effective thinning always results in some loss in yield, but the increase in value is greater than the loss in volume as long as the thinning is not carried to extremes. While thinning does increase the leaf area available to the persisting fruits, not all of the increase in carbohydrate supply goes to the fruits. A part of it is always diverted to vegetative growth and this inevitably results in some reduction in yield.

## FRUIT THINNING

Initially, all thinning was done by hand, but this is no longer practical. First of all, present labor costs make this approach prohibitively expensive. In addition, supervision is difficult, and consistent, uniform thinning is almost impossible. But most important, because of time limitations and the difficulty of thinning early in the season when the fruits are small and inconspicuous, it is difficult to complete thinning early enough for maximum effect. This is important in terms of both fruit size and return bloom. Thinning induces a change in fruit growth rate and this increased rate persists throughout the remainder of the season. The earlier in the season this increased rate is initiated, the greater the total effect on final fruit size. With respect to return bloom, it was earlier indicated that the individual spurs alternate and a significant percentage of non-fruiting spurs is required for a sufficient return bloom for the

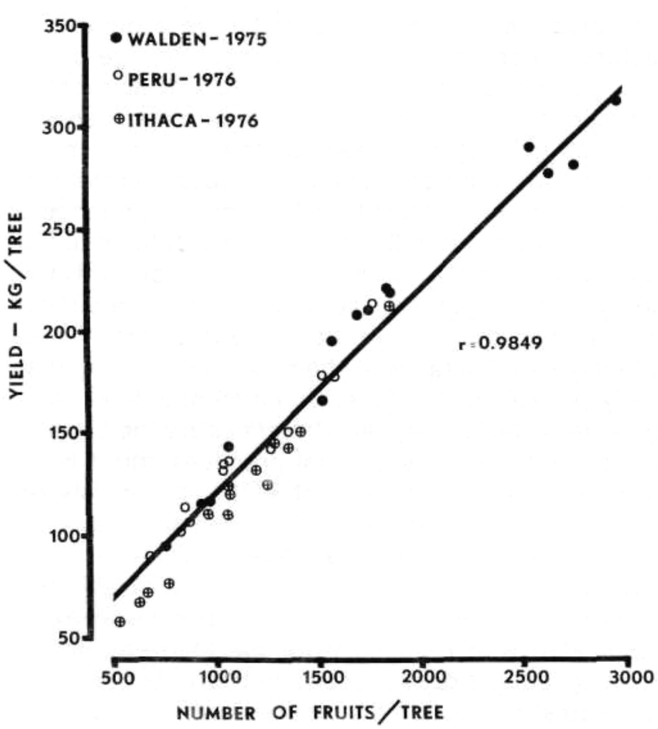


*Fig. 2. Relationship between fruit numbers and yield. (McIntosh - 1975-76).*

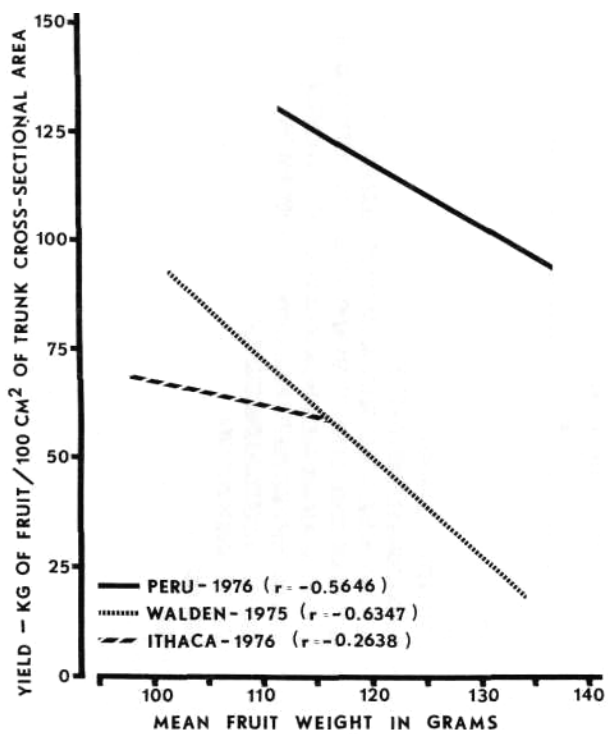


*Fig. 3. Relationship between fruit size and yield. (McIntosh - 1975-76).*

succeeding crop. The flower buds are initiated during the first 3-4 weeks after bloom. This is the period when gibberellins from the developing seeds of the fruits inhibit floral initiation. The presence of developing fruits during this period prevents flowering the following year while the removal of fruits before this period is completed encourages flowering. The removal of fruits after this period is complete (later in the summer) has no effect on flowering. Hand thinning is normally limited to minor adjustments following chemical thinning.

The first attempts at chemical fruit thinning involved caustic materials such as DN, which caused thinning by damaging the blossoms. Because of numerous problems with such materials, most chemical thinning in the Northeast is now done with growth regulators. The exact mechanism of thinning is still somewhat vague, but with all growth regulators, thinning is associated with seed abortion and this is one of the most obvious effects. An important consideration in the use of thinning chemicals is the fact that the developing fruitlets vary considerably in vigor. This point is well illustrated by fruit size distribution at harvest (Fig. 4). The differences in final fruit size are indicative of differences in vigor of individual fruits during the growing season. A number of factors contribute to this variation in vigor. The vigor of the individual spur is a major factor and differences are apparent in spur age, diameter, bud size and the number and size of the spur leaves. The position of the fruit in the cluster is also a factor with the king blossom, because of better vascular connections, stronger than the lateral blossoms. Seed count is important with the larger fruits consistently having more seeds. Injury from low winter temperatures or from spring frost may reduce vigor. The injury can be to the flower or developing fruitlet, to associated conducting tissue, or to the adjacent spur leaves. The developing fruitlets compete with one another for the products of the leaves and, because they vary in vigor, some compete more successfully than others. There is a distinct pecking order from the strongest to the weakest and, in times of stress, the weakest abscise. This is the basis of the selectivity in chemical fruit thinning. The chemical thinners intensify the natural competition among fruitlets. The strongest are unaffected by thinners, but the weakest succumb. The strongest fruitlets, that is the ones with the greatest size potential, persist, and the weakest fruitlets, those with the least size potential, are eliminated. The heavier the fruit set, the greater the thinning. In this case, there is already intense competition and thinning chemicals have their maximum effect. With a light fruit set, the leaf/fruit ratio is high and there is relatively little competition among fruits. In this case the effectiveness of chemical thinners is reduced. Where there is a spotty, uneven bloom, the best practice is to spray all the trees uniformly because there will be little thinning of those with light bloom.

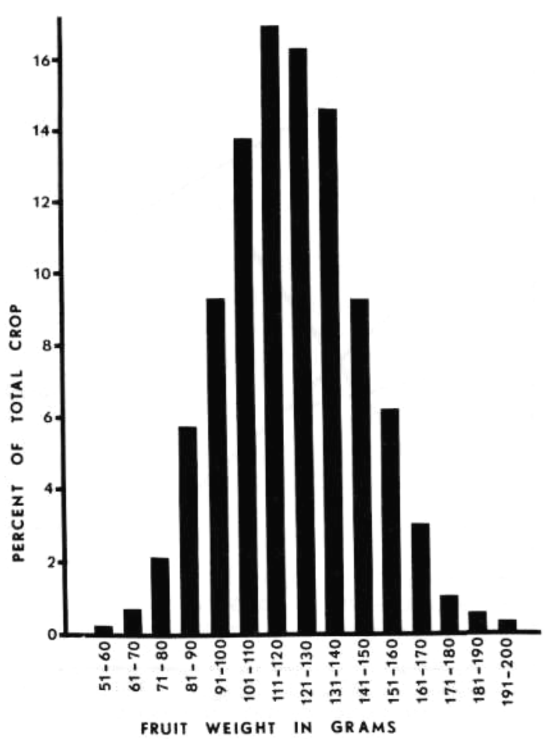


*Fig. 4. Fruit size distribution of McIntosh apples.*

## FACTORS AFFECTING CHEMICAL FRUIT THINNING

In practical fruit thinning, there are a number of factors to consider: variety, tree vigor, foliage condition, pollination, apparent fruit set, and application conditions. There are important differences between varieties in both the need for thinning and in the response to thinning treatments. Mutsu is rarely thinned and both Idared and Northern Spy are easily thinned or overthinned. Golden Delicious is very difficult to thin and Early McIntosh may be impossible to properly thin consistently. In general, spur-types are more difficult to thin than their conventional counterparts. These differences in tolerance to chemical thinners are genetically controlled and represent inherent differences in enzyme systems. Varietal differences are the basis for adjustments in many cultural practices and it is not surprising that there are notable differences between varieties in the response to thinning chemicals.

A number of factors affect tree vigor and some of these go back to the previous season. The most important would be the previous crop with an excessive crop associated with reduced vigor the following spring. Fruiting reduces growth of all plant parts, but the effect is greatest on roots. This reduces both the supply of reserves and some essential growth regulators that are involved in early season growth the following spring. It is a well established fact that in varieties that are biennial in habit, it is easier to thin in the "off" year (following a heavy crop) than in the "on" year (following a light crop). Other stress problems, such as drought and late season foliage injury, may similarly reduce vigor the following spring.

Nutritional status obviously affects vigor, but one of the major problems is shading. In larger, older trees, or in crowded plantings, the lower branches are usually visibly lower in vigor than the well lighted top of the tree. This difference is often compounded by poor spray application, with most of the thinner going to the weaker lower branches, where it is not needed, and relatively little going to the vigorous top, which is the most difficult to thin. The interior of the tree also tends to be measurably less vigorous than the outside. Other factors such as wet feet, low temperature injury, and pine vole damage may also reduce tree vigor. The important point to remember is that **trees in low vigor may be easily thinned, but this does not necessarily ensure optimum fruit size.**

A healthy, functional leaf surface is essential for normal growth and development of the fruitlets, and this becomes a factor in both fruit set and the response to thinning. Warm, sunny weather favors rapid development of the leaf surface, optimum production of carbohydrates, and a thick layer of cutin. This suggests a strong fruit set, reduced absorption of thinning sprays, and difficult thinning. In contrast, cool, cloudy weather is associated with a weaker set and maximum absorption of thinning chemicals. Frost injury to the spur leaves that results in marked distortion and limited growth of the leaves is an indication of a weaker set and easier thinning.

Pollination is important largely because of its influence on seed count. A high seed count makes thinning more difficult while a low count facilitates thinning. The most important points are the bloom overlap of different varieties and bee activity. This is largely controlled by weather. Warm weather stimulates rapid flower development so that the total bloom period is short and many varieties are in bloom at the same time. This maximizes the opportunity for cross pollination. Warm weather is also conducive to bee activity. In general, the higher the temperature during bloom the better, but there are some limitations. At temperatures above 90 F, the viable life of the pollen may be significantly reduced. Wind is also an important consideration. Strong winds not only interfere with bee flight, but may also dessicate the stigmatic surfaces of the blossoms. Rain will hamper bee flight as well as wash the pollen from the flowers. After significant rainfall, at least 24 hours are required for additional pollen to ripen. There are a few varieties (Rome Beauty, Golden Delicious, Paulared) that will set full or excessive crops on their own pollen if not adequately cross pollinated. However, **when this happens, the crop is easily thinned or overthinned.**

One of the most obvious factors in determining the need for thinning is the apparent fruit set. This is evaluated on the basis of the growth rate of the developing fruitlets immediately after bloom. Conditions conducive to rapid growth are essential for a strong fruit set. Cool, cloudy weather is associated with slow growth, seed abortion, and easier thinning. The fruitlets must grow to survive—they cannot stand still. Obvious, rapid growth is a healthy sign. There should also be some size differentiation after a week or so. Rapid growth will tend to accentuate the inherent differences in vigor between individual fruitlets. On the other hand, with slow growth this differentiation may not be so obvious. This is another indication of a weaker set and easier thinning. Seven to ten days after petal fall, more than 7-8 visibly growing fruitlets/cm of branch circumference is indicative of an overset and a need to thin. **Apparent set must be very carefully evaluated because many alleged errors in thinning are actualSy errors in estimating initial set.**

Application conditions play a major role in thinning. Temperature is the most important single factor and applications of growth regulator-type thinners will be relatively ineffective at temperatures below 70 F. Increasing the concentration will not compensate for low temperature. The weather should be calm because wind not only interferes with spray coverage, but also accelerates drying. Slow drying conditions encourage absorption and enhance thinning. Warm, sunny weather immediately after application is important because both metabolism and translocation are involved. Good growing weather makes the response more predictable and the results more obvious. Prolonged cool weather after application may slow the response and, since this reduces stress, reduce the effectiveness of the treatment. Continuous cloudy weather after application may enhance thinning.

## THINNING CHEMICALS

The first chemical thinners were caustic materials such as DN's and these are still used in some areas. However, their use in the Northeast is limited. They are effective with some varieties, but they require rather precise timing which is not always possible with the variable Eastern springtime weather. DN applications, while quite safe in dry, sunny weather, may be hazardous in wet weather. If rain falls within 2-3 days of application, overthinning and severe leaf damage are likely to result.

NAA (Naphthaleneacetic acid) is a strong thinner that is strictly rate responsive. It is effective over a range of 2-20 ppm with the effect directly proportional to rate. It is often used in combination with other thinners. Varieties that are easily thinned may be overthinned with NAA and, under some conditions, it may cause serious foliage injury. These conditions include sensitive varieties, high rates, and application at high temperatures (above85 F.) NAD (Naphthaleneacetamide) is a derivative of NAA that is similar in activity, but somewhat milder.

Carbaryls include such insecticides as Vydate and Measurol, but the one most commonly used for thinning is Sevin. Sevin is a relatively mild thinner. Unlike NAA, it is not strictly rate responsive. It produces a saturated solution at about 3/4 lb/100 and only the material in solution is active for thinning. Since the recommended rate is 1 lb/100, increasing the rate has little or no effect on thinning. This is an advantage in that overthinning by error in concentration is unlikely, but a disadvantage in that thinning activity cannot be increased. Sevin has a unique advantage in that it is an insecticide. With varieties that are effectively thinned by Sevin, thinning can sometimes be accomplished by substituting this material for the usual insecticide in the first cover spray. This eliminates the need for a separate thinning application. There are some problems with Sevin in that some growers feel that it increases russeting of sensitive varieties such as Golden Delicious. It may kill some predator mites, although the effects at the time thinning sprays are applied is debatable. Sevin can also be activated by rewetting. This is not a problem with NAA because any unabsorbed residue on the leaf is quickly inactivated by sunlight, but the undissolved residue of Sevin remains fully active. Periods of damp, drizzly weather, with precipitation sufficient to keep the foliage wet but not enough to wash off the residue, may significantly increase thinning. Cortland seems to be particularly susceptible to this effect.

In some cases, combinations of NAA and Sevin, or NAD and Sevin are appropriate. A synergistic effect seems to be involved with the thinning of the combination more effective than the effects of either alone. This is particularly good for some of the hard-to-thin varieties because effective thinning can be accomplished without the use of possibly damaging high rates of NAA alone. For many varieties, these combinations are the best choice. In general, when NAA is combined with Sevin, the rate of NAA is reduced to 1/2 the concentration that would be used if it were applied alone.

## RATES AND TIMING

The different varieties, in combination with different seasonal considerations, provide a wide range in specific recommendations. There are unlimited choices for some varieties such as McIntosh and Rome Beauty. Sevin might be applied alone where light thinning seemed appropriate; NAA for slightly more aggressive thinning; and NAA + Sevin for heavy thinning. In contrast, Sevin alone is all that is ever recommended for such easily thinned varieties as Idared and Northern Spy. NAD is never applied to Red Delicious because it usually induces the formation of pygmies—persisting fruitlets that fail to size. While Sevin will thin Tydeman adequately, NAA is preferred because it usually induces more return bloom. For some of the more difficult varieties to thin, combinations of NAA and Sevin generally work best. For spur-type Red Delicious, Sevin plus NAA 2.5 - 5.0 ppm is recommended; for Spartan and Paulared, Sevin plus NAA5.0 ppm; and for Golden Delicious, Sevin plus NAA 10 ppm. Specific recommendations are presented in Table 2.

**Table 2. Appropriate concentrations of thinning chemicals for selected apple varieties.**

| Variety | NAD (ppm[z]) | NAA (ppm[z]) | Sevin (lb/100 gal[y]) | Combinations |
|---|---|---|---|---|
| Jerseymac | - | 5-I0 | - | - - - - - - - - - - - - |
| Tydeman | - | 5-10 | 1-2 | - - - - - - - - - - - - |
| Paulared | - | 5-10 | - | NAA 2.5-5.0 + Sevin 1-2 |
| Jonamac | - | 5-10 | 1-2 | - - - - - - - - - - |
| McIntosh (conventional) | 35-50 | 5-10 | 1-2 | - - - - - - - - - - |
| McIntosh (spur-type) | - | 5-10 | - | NAA 2.5-5.0 + Sevin 1-2 |
| Spartan | - | 10-15 | - | NAA 5.0-7.5 + Sevin 1-2 |
| Cortland | 35-50 | 5-10 | - | NAA 2.5-5.0 + Sevin 1-2 |
| R.I. Greening | 35-50 | 10-15 | 1-2 | NAA 5.0-7.5 + Sevin 1-2 |
| Macoun[x] | - | 10-15 | - | NAA 5.0-7.5 + Sevin 1-2 |
| Empire | - | 5-10 | 1-2 | - - - - - - - - - - - - |
| Delicious (conventional) | - | 5-10 | 1-2 | - - - - - - - - - - - - |
| Delicious (spur-type) | - | 5-10 | - | NAA 2.5-5.0 + Sevin 1-2 |
| Golden Delicious | - | 15-20 | - | NAA 5.0-10.0 + Sevin 1-2 |
| Stayman Winesap | - | 5-10 | - | - - - - - - - - - - - - |
| Rome Beauty | - | 10-15 | 1-2 | NAA 5.0-7.5 + Sevin 1-2 |

[z] Lower concentrations suggested for conditions favorable for thinning.

[y] When applied solely for thinning, use the 1-lb. rate. If insecticidal activity is also desired, use the 2-lb. rate.

[x] Petal fall application only.

Thinning sprays of NAA or Sevin are effective over a relatively long period. The effectiveness is generally greatest at petal fall with a gradual decrease until 3-4 weeks after bloom when it may cease rather abruptly. A few varieties, such as Macoun, are normally thinned at petal fall. Most varieties, however, are thinned 2-3 weeks after full bloom. There are a number of advantages to this delay. First, it allows more time to properly assess fruit set and the need for thinning. In addition, this provides the opportunity to select a good day for application. In this respect, it is always better to delay the application 2 or 3 days than to apply the thinning spray under unfavorable conditions. In considering timing, it is important to remember that the time frame is physiological rather than chronological. The end of the responsive period is associated with changes in the developing seeds and the effectiveness may cease abruptly. A thinning spray applied too late may not only fail to thin, but may actually stunt the persisting fruits. The growth changes involved are largely temperature-dependent which means that they occur more rapidly in warm than in cool weather. Thinning must be completed early if post-bloom weather is warm, but can be delayed if post-bloom weather is cool.

## CONCLUSIONS

Most varieties will overset if bloom is heavy and bloom weather is good. Some varieties will consistently overset even if the weather is less than optimum. As a result, most varieties will need some thinning in most years in order to produce fruit of marketable size on a regular, annual basis. Effective thinning is largely based on 2 factors: observation and analysis. Strict attention to the previous season, the winter, the pre-bloom weather (mostly frost), bloom weather (bloom overlap and bee activity) and the immediate post-bloom weather (growth rate, size differentiation) are absolutely essential. As the time for thinning approaches, fruit set must be assessed, observations must be evaluated, and an attempt must be made to integrate the various positive and negative factors. Some facilitate thinning, others make it more difficult. The net effect of the trade-offs should be an opinion that thinning is about normal, more difficult than normal, or less difficult than normal. Once this determination is made, then the appropriate treatment must be applied without hesitation. Only when all steps are followed will the end product be totally satisfactory.