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Factors affecting chemical thinning of apples

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If the weather during bloom is warm and sunny, most apple varieties will set an excessive crop of fruit. Some varieties will consistently overset even though bloom weather is less than ideal. The components of fruit growth are synthesized by the leaves, and an excessive set of fruit results in an unsatisfactory leaf/fruit relationship. The most obvious effects of such an imbalance are reductions in both fruit size and fruit quality. Crop load is the most important of all the factors that influence fruit size, and removing a part of the crop is the most effective way to improve fruit size. Fruit thinning always reduces total yield because the increase in size of the remaining fruits does not totally compensate for the loss of the fruits removed (Fig. 1). However, the reduction in yield is accomplished through elimination of the smaller sizes, and in today's economic climate, un-dersize apples are definite liabilities. Unless fruit thinning is carried to such extremes that yield is markedly reduced, the increased value due to improved fruit size more than offsets the reduction in yield.

In addition to improving the quality of the current crop, fruit thinning also affects the succeeding crop. The flower buds are initiated almost a year before they bloom. Next year's flower buds are, therefore, being formed early in the development of the current season's crop. These two processes are competitive, and an excessive set of fruit inhibits flower bud formation. The elimination of a part of the current crop encourages flowering the following year (repeat bloom). In strongly biennial varieties, failure to control the size of the crop may virtually eliminate flowering the next year. In other varieties, an excessive crop may result in severe fluctuations in yield with alternating heavy ("on" year) and light ("off" year)crops.When the low yields of the "off" year are applied to present high per-acre production costs, the result is an unrealistic per-bushel cost that can-not be covered by current market prices. The economy can no longer subsidize alternate bearing. In the final analysis of chemical fruit thinning, consistent, annual production is just as important as improvement in fruit size.

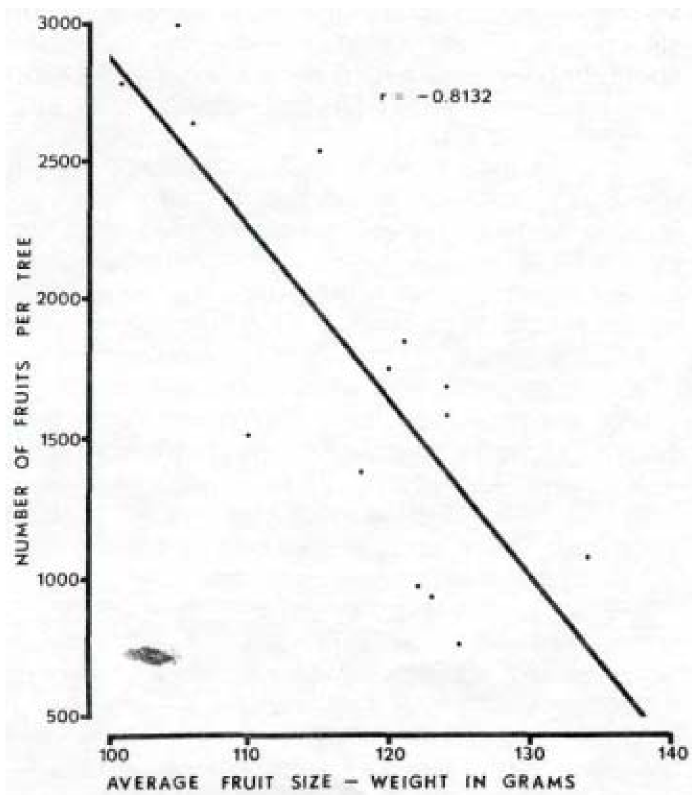

Figure 1.—Relationship between fruit numbers and fruit size. Note that any increase in fruit size is associated with a proportionately greater decrease in fruit numbers. (McIntosh - 1975)

The necessity for fruit thinning is generally accepted. While limited hand thinning is still practiced in some areas, Northeast fruit growers rely almost entirely on chemical thinning. In some years, as much as 85 per cent of the apple acreage in New York State is chemically thinned. This practice is inexpensive and effective, but the results are not always totally satisfactory. Complete failures (little or no thinning or drastic overthinning) are rare, but the variability in results may exceed the limits of expediency. The factors that contribute to this variability can be conveniently divided into six categories as follows: initial fruit set, variety, materials and rates, time of application, physical factors that affect the application of the material and its absorption, and physiological factors that affect the response of the trees.

INITIAL FRUIT SET

Soon after bloom, fruit set must be accurately assessed in order to determine the need for thinning. Unrecognized differences in initial fruit set account for much of the apparent variability in thinning. Fruit set is a product of the interaction of a number of factors that include the amount of bloom, frost injury, tree vigor, the weather during bloom, and the weather in the immediate post-bloom period. The amount of bloom is seldom a limiting factor, but strongly biennial varieties, or other varieties inadequately thinned the previous year, may sometimes lack sufficient flowers to set a full crop. Usually, if as many as one-third of the spurs flower, the potential for a full or excessive crop exists. Frost injury that damages or kills flowers can sharply reduce the potential for fruit set.

In some varieties, such as Delicious and Stayman Winesap, the capacity to set fruit may be significantly reduced even though there is no visible evidence of frost injury to the flowers. Trees in low vigor will not set as heavily as similar trees in moderate to high vigor. The weather during bloom is usually the most important factor. Warm, sunny weather is conducive to rapid flower development and good bee activity. Under these conditions, the bloom period is short and many varieties are in bloom at the same time. This maximizes the opportunity for cross pollination, and a heavy fruit set invariably results.

With some varieties, bloom overlap can be critical. In some years, Delicious has a very short period of receptivity that can occur at any time during the bloom period (Fig. 2). Heavy crops of this variety are ensured only when pollen of other varieties is available throughout the entire bloom period. Some varieties present special problems in thinning in that they are sufficiently self-fruitful to set an excessive crop on their own pollen. However, when this happens, they are easily over-thinned. Fortunately, this is limited to a few varieties such as Baldwin, Golden Delicious, and Rome Beauty. When bloom of these varieties does not overlap with that of other varieties, chemical fruit thinning should be approached with caution.

Post-bloom weather is also a major factor in determining

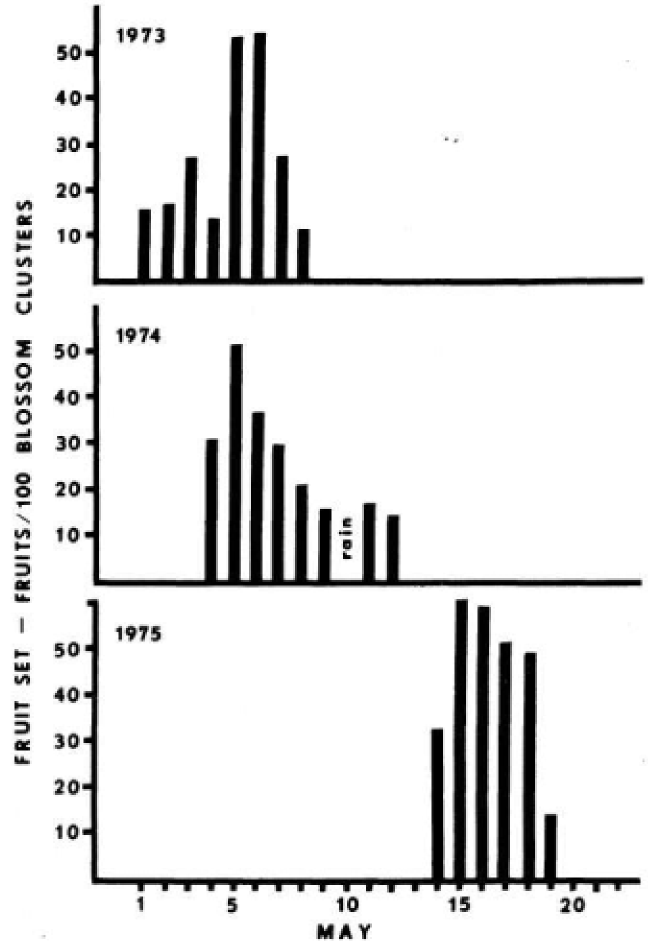

Figure 2.—Effects of hand pollination on successive days on fruit set of Delicious apples. Note the distinct periods of greater receptivity late in the bloom period in 1973 and early in the bloom period in 1974. Warm, sunny weather in 1975 resulted in a shorter bloom period with good receptivity throughout.

fruit set. The weather after bloom should be conducive to rapid growth of the developing fruitlets. This requires warm, sunny days, and when this type of weather prevails after bloom, growth of developing fruitlets should be readily apparent 4-5 days after petal-fall. Favorable weather both during and after bloom is invariably followed by a generally heavy crop that requires extensive thinning. On the other hand, unfavorable weather after bloom may nullify an excellent bloom period. Cool, wet, cloudy weather is not conducive to rapid development of the fruitlets, and prolonged periods of such weather will result in the drop of many properly pollinated and fertilized flowers. This type of post-bloom weather is associated with a heavy "June drop." Continuous growth of the developing fruitlets is necessary for their survival, and only those that are visibly growing will persist to harvest.

The developing fruitlets are not equal in vigor. That some are more favorably situated than others is clearly indicated by the diversity in fruit size at harvest. The vigor of the individual fruitlets varies with such factors as position within the flower cluster ("king" or lateral), pollination, number of seeds, spur vigor, position within the tree, and the number of fruits developing in the immediate vicinity. The fruits compete with each other for the products of the leaves, and the weaker ones are eliminated under stress conditions. Chemical thinning intensifies this competition among fruits. The response to thinning is directly proportional to the initial fruit set (Fig. 3) with the most fruits removed where the original competition among fruits was greatest. A given treatment will remove more fruits from a tree with a heavy fruit set than from a similar tree with a moderate set. This is not always readily apparent because the tree with the heaviest initial set may still retain too many fruits. On trees with a light set, relatively few fruits are removed because there is less initial competition among fruits. This is an important consideration when fruit set is variable or "spotty." Many growers hesitate to thin in this case because they are afraid of defruiting the lighter trees. However, the thinning effect on trees with a light fruit set is minimal, and the best policy is to thin the entire block uniformly to insure a good bloom the next year.

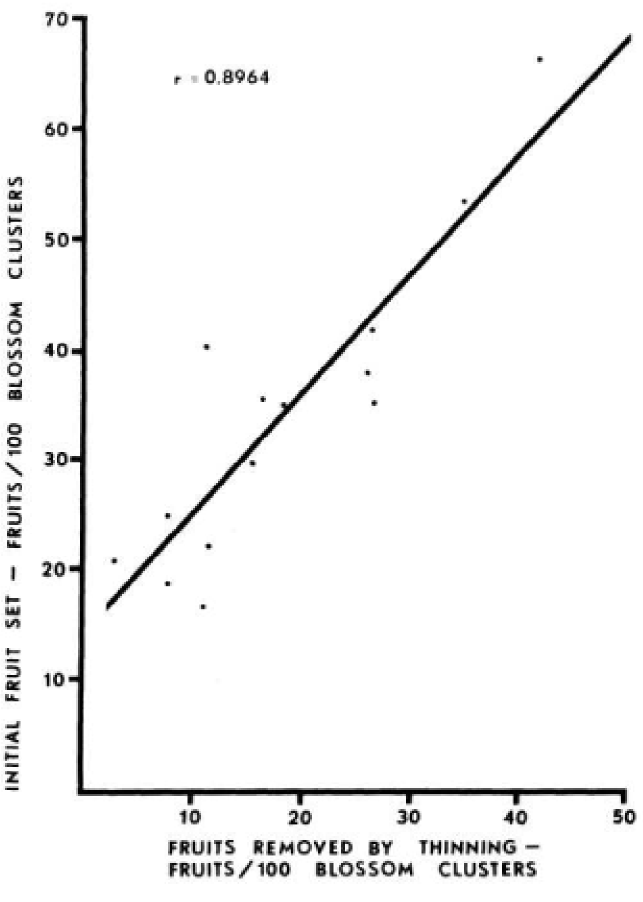

Figure 3.—Relationship between initial fruit set and the number of fruits removed by chemical thinning. More fruits are removed from the trees with the heaviest initial set with the result that differences between trees are much less after thinning than before. (Golden Delicious - 1969).

VARIETY

Varietal differences are the basis for adjustments in many cultural practices, and it is not surprising that there are important differences between varieties in the response to thinning sprays. Susceptibility of commercially important apple varieties ranges from Early McIntosh, which is almost impossible to adequately thin chemically, to varieties such as Northern Spy, which can sometimes be satisfactorily thinned with a concentration of naphthaleneacetic acid as low as 2 ppm. Not only is it necessary to adjust the rate for variety, but this may also be the criterion for choice of material. Some varieties can be successfully thinned with any of the currently recommended materials while only a single material may be appropriate for others. In some cases, there are specific undesirable effects associated with certain variety/material combinations. Naphthalacetamide is not used on Delicious because it induces numerous stunted, "pygmy" fruits that persist to harvest. There are also important differences between strains of a given variety. Spur-type Delicious are more difficult to thin than conventional Delicious.

MATERIALS AND RATES

The chemicals most commonly used to thin apples are naphthaleneacetic acid (NAA), naphthalacetamide (NAD), and 1-naphthyl N-methyl carbamate (Sevin). NAD and Sevin are less effective than NAA and are preferred for those varieties that are less difficult to thin. With both NAA and NAD, thinning is directly proportional to concentration. Thinning with Sevin also increases with concentration up to 0.75 pound/100 gallons, but there may be little additional thinning with higher concentrations. This is an advantage in that the hazard of over-thinning through error in concentration is eliminated, but it can also be a disadvantage in situations requiring heavier thinning. Rates of less than 0.75 pound/100 gallons are rarely adequate under Northeast conditions.

Uniform thinning over a wide range in concentration is due to the relative insolubility of Sevin. This material forms a saturated solution at about 0.75 pound/100 gallons, and absorption is limited to the material in solution. However, a residue of Sevin may presist on the foliage for some time, and re-wetting, from dew or light rain, may result in additional absorption. Extended periods of frequent light rains of insufficient intensity to wash the residue from the leaves may result in over-thinning of sensitive varieties. Later absorption from re-wetting does not occur with NAA or NAD because both of these materials are rapidly inactivated in sunlight.

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. To be effective as an insecticide, Sevin must be applied at tne rate of 2 pounds/100 gallons.

With several varieties, it is advantageous to use combinations of Sevin with NAD or with reduced rates of NAA. Such combinations are more effective than maximum rates of any of these materials alone. In addition, this avoids the foliage injury that often develops when high rates of NAA are applied to sensitive, but difficult to thin varieties such as Early Mclntosh. With varieties that are normally thinned at petal fall, the bees may still be attracted to the trees when it is time to apply the thinning spray, and their presence precludes the use of Sevin. To avoid this problem, combinations of NAD with NAA are sometimes used, but they are not as effective as combinations containing Sevin. It is generally better to delay the application a day or two until the bees have been removed. Some growers are reluctant to use Sevin because of possible adverse effects on fruit finish.

Specific recommendations for commercially important varieties are presented in Table 1. For each variety, a range in concentration of NAA or NAD, rather than one specific concentration is suggested. When conditions for absorption are good or the trees are particularly susceptible, the lower rate is recommended. In less favorable circumstances, the higher concentration should be used.

TIME OF APPLICATION

Summer apples may be damaged by applications later than petal-fall. To avoid the possibility of stunting the fruit or of inducing premature and uneven ripening, chemical thinning of these varieties should be completed within 7 days of full bloom. Obviously, it is impossible to assess fruit set at this early stage of development, but most of the varieties that require petal-fall thinning are notorious for oversetting even under adverse conditions. Those varieties that require treatment at this stage are indicated in Table 1. Later-maturing varieties can be satisfactorily thinned with NAA, NAD, or Sevin at any time from full bloom to 3-4 weeks after bloom. Macoun is a notable exception that should be thinned at petal-fall. In general, thinning is most effective at petal-fall with fairly uniform response for an extended period thereafter.

It has been suggested that thinning sprays should be applied when the fruits reach a specific size, but neither experimental nor commercial experience in the Northeast has established a distinct advantage to this approach. Timing the application by fruit size would unnecessarily complicate fruit thinning. The rate of fruit growth is so rapid that the fruits would be at the suggested optimum size for only 1

Table 1.—Appropriate concentrations for thinning certain apple varieties.

Variety	NAD ppm[1]	NAA ppm[1]	Servin lbs/100 gal.[2]	Combinations
Lodi[3]	-----	-----	-----	NAD 25-50 + Sevin 1-2 or NAA 5-10 + Sevin 1-2
Transparent[3]	-----	-----	-----	NAD 25-50 + Sevin 1-2 or NAA 5-10 + Sevin 1-2
Quinte[3]	-----	-----	-----	NAD 25-50 + Sevin 1-2 or NAA 5-10 + Sevin 1-2
Dutchess[3]	-----	-----	-----	NAD 25-50 + Sevin 1-2 or NAA 5-10 + Sevin 1-2
Early McIntosh[3]	-----	-----	-----	NAD 25-50 + Sevin 1-2 or NAA 5-10 + Sevin 1-2
Tydeman	-----	5-10	1-2	-----
Milton	35-50	5-10	-----	NAA 2.5-5 + Sevin 1-2
Wealthy	-----	15-20	-----	NAA 5-10 + Sevin 1-2
Paulared	-----	5-10	1-2	-----
Opalescent	-----	5-10	-----	-----
Jonamac	-----	5-10	1-2	-----
Jonathan	35-50	5-10	1-2	-----
McIntosh	35-50	5-10	1-2	-----
Spartan	-----	10-15	-----	NAA 5-7.5 + Sevin 1-2
Cortland	35-50	5-10	-----	NAA 2.5-5 + Sevin 1-2
R.I. Greening	35-50	10-15	1-2	NAA 5-7.5 + Sevin 1-2
Macoun[3]	-----	5-10	-----	-----
Empire	-----	5-10	1-2	-----
N.W. Greening	35-50	-----	-----	-----
Delicious	-----	5-10	1-2	-----
Baldwin	-----	15-20	-----	-----
Northern Spy	35-50	-----	1-2	-----
Idared	-----	-----	1-2	-----
Golden Delicious	-----	15-20	-----	NAA 5-10 + Sevin 1-2
Yellow Newtown	-----	15-20	-----	-----
Stayman Winesap	-----	5-10	-----	-----
Rome Beauty	-----	10-15	1-2	NAA 5-7.5 + Sevin 1-2
Ben Davis	35-50	10-15	-----	-----

[1] Lower concentrations suggested for conditions favorable for thinning.
[2] When applied solely for thinning, use the 1-pound rate. If insecticidal activity is also deisred, use the 2-pound rate.
[3] Petal-fall applications only.

or 2 days. This would seriously limit the period over which thinning could be done, and the coverage of large acreages would become impossible. The weather might be unfavorable for application when the fruit reached optimum size, and the opportunity to thin would be lost. In addition, fruit size varies from tree to tree within an orchard with such factors as vigor and crop load, and strict adherence to size timing would require spraying some trees on one day and traveling through the same orchard to spray other trees on succeeding days.

Most varieties are now thinned 14-21 days after full bloom. Satisfactory thinning could be accomplished earlier, but there are several advantages to this delay. With a given level of thinning, applications made 2 weeks after bloom have consistently produced more repeat bloom than petal-fall applications. This delay also allows more time to appraise fruit set and to select a favorable day for treatment. In addition, the possibility of frost after thinning is lessened considerably. However, the application should be made as soon after this 2-week period as is practical.

At about the time cell division ceases in the developing fruit, these materials become ineffective in reducing fruit set. Unfortunately, this loss of effectiveness is associated with complex internal changes in the fruit and the embryo, and there is no visible external evidence of these changes. They are physiological rather than chronological, and there is no guarantee that the receptive period will extend a full 4 weeks after bloom in all years.

Under unusually good growing conditions, susceptibility to thinning may cease several days earlier than normal. In this case, applications made more than 3 weeks after bloom could fail to thin adequately, and with high cncen-trations of NAA, fruit size might be adversely affected instead of improved. Fruit set can be accurately evaluated 12-14 days after bloom. The best policy is to make a decision then and to apply the material on the first favorable day thereafter. All thinning should be completed 21 days after full bloom.

PHYSICAL FACTORS

The recommended rates of application are expressed in terms of concentration, but the concentration of the material in the spray tank may be less important than the way it is applied. The results will depend on the absolute amount of thinning chemical deposited on the foliage of the tree, and this is affected by volume as well as by concentration. Where 10 ppm of NAA is recommended, the objective is to apply 0.4 gram of chemical to a mature, standard-sized tree. To accomplish this, sufficient volume must be applied to wet all the foliage to the point of drip. If the volume applied is significantly less than this, the effect will be reduced proportionately. Some growers consistently use concentrations above the recommended rates. While this might suggest that their trees are more difficult to thin, it is more likely that they are compensating for inadequate volume with increased concentration.

The recommended concentrations in Table 1 are based on dilute application. However, on fruit farms today most or all sprays are concentrate applications. While application of all thinning sprays on a dilute basis would undoubtably reduce variability in results, most growers are reluctant to change nozzles and recalibrate the sprayer for this single application. There are two objections, one theoretical and one practical, to concentrate application of thinning sprays, and these become increasingly important as the volume of spray is reduced. The chemical is absorbed by the foliage from solution, and almost all absorption of NAA and NAD is from the original spray solution. There may be significant additional absorption of Sevin from re-wetting. Good absorption of all of these materials is associated with slow drying and poor absorption with rapid drying. At high concentrate levels, with the volume of water greatly reduced, drying is relatively rapid, and the potential for absorption is diminished.

The practical objection to concentrate application of thinning sprays is the increased potential for error. If an error is made in calculating the amount of material required for the desired concentration, this error may be compounded in the conversion from dilute to concentrate.

In spite of the above considerations, extensive practical experience has shown that satisfactory thinning can be accomplished with concentrate applications. The important point to remember is that, unlike most pesticides, there is no wide margin of safety with NAA and NAD, and thinning will be directly proportional to the amount of chemical deposited on the foliage of the trees. For optimum results, the sprayer must be carefully calibrated and adjusted to provide both accurate volume and uniform application throughout the tree. If the volume is inadequate, recommended rates will under-thin. Improper spray distribution results in a distinctive pattern of over-thinning the lower branches and under-thinning the tops of the trees. Obviously, the rather common practice of reducing the volume of water to a certain level of concentration and then adding materials for a lower level of concentration (e.g., calibrating sprayer for 4X and adding materials for 3X) is not applicable to chemical fruit thinning.

A factor of major importance is the weather at the time the spray is applied. Applications when the temperature is less than 65 F are usually ineffective, and increasing the concentration will not compensate for low temperature. The best results are obtained when temperatures are 70-75 F. Above 80 F, the effectiveness increases to the extent that a reduction in rate is usually advisable. At temperatures above 80 F, NAA may cause pronounced flagging of the foliage, but if the concentration is within the recommended range for the variety, recovery is usually rapid, and there is no cause for alarm. Some growers associate conspicuous flagging with good thinning, but there is no consistent relationship between these two factors. Flagging may be a better measure of the succulence of shoot growth than of potential thinning.

Humidity, by its effect on the rate of drying, can influence absorption and the ultimate thinning results. However, this is rarely a limiting factor in the Northeast. In this area, wind is a much more common and more serious problem. A strong breeze not only interferes with good coverage, but also increases the rate of drying and reduces absorption.

The weather prior to application must also be considered. Most important is its effect on cutin development. Practically all absorption occurs directly through the cell wall, and a thick layer of cutin on the leaves inhibits absorption. Dry, sunny weather favors cutin development, and when such weather prevails for a week or more before the thinning spray is applied, absorption is reduced, and maximum rates are required. Cool, cloudy weather during the same period retards cutin development with the result that absorption is enhanced, and lower concentrations will thin adequately.

Exposure to freezing temperatures also increases ab-sorbancy of the foliage. Frost injury to the leaves provides a clear warning that maximum rates will over-thin. Unfortunately, an increase in absorptive capacity is not always indicated by visible frost injury symptoms. This effect is possible without actual freezing of the leaves, and on farms with definite "frost pockets," over-thinning of these areas is a perennial hazard. A maximum-minimum thermometer should be installed in each area known to be frost-susceptible. If temperatures below 32 F are recorded during the pre-bloom or bloom periods, lower rates should be used even though there is no visible frost damage. Sevin at relatively low rates (less than 0.75 lb/100 gal.) may satisfactorily thin trees with frost-injured foliage.

PHYSIOLOGICAL FACTORS

Absorption of the thinning chemical is requisite to success, but a combination of circumstances favorable to absorption is no guarantee of satisfactory thinning. The physiological condition of the tree may increase or decrease the effectiveness of the treatment. Trees in low vigor are easy to thin (or overthin), but adequate thinning of such trees does not necessarily result in good fruit size or in adequate repeat bloom. Very low vigor is all too obvious, and trees in this condition are not usually thinned. Unfortunately, a decline in vigor that is serious enough to affect the response to thinning chemicals is not always readily apparent at the time the sprays are applied.

Low vigor is often due to inadequate nitrogen fertilizer. This may be the result of an unintentional error in the fertilization program, but in some cases, nitrogen fertilizer is deliberately withheld for several seasons in an effort to improve fruit quality. This approach, though laudable, is sometimes inadvertently pursued to the point of actual deficiency. Serious over-thinning is easily explained in this situation. Deficiencies of other essential elements severe enough to reduce vegetative growth may also result in excessive thinning.

Soil moisture can play a prominent part in the response to chemical thinning. Since moisture status is influenced by soil depth and texture as well as by precipitation, natural soil variability provides a wide range in moisture availability in most orchards. In the Northeast, serious soil moisture deficits in early summer are rare, but when they do develop, trees under stress at the time the thinning sprays are applied are likely to be over-thinned by maximum rates. On the other hand, in years of excessive rainfall, root activity may be restricted by a high water table in imperfectly drained areas, and this, too, is associated with excessive thinning.

Other common factors that may reduce vigor and enhance thinning are low temperature injury and mouse damage. In areas where pine mice (pine voles) are prevalent, tree vigor can be significantly reduced before the problem becomes apparent.

Light exposure also affects thinning responses. Heavily shaded wood, whether on lower branches that have been over-grown by the tops, or in the interior of dense, inadequately pruned trees, is easily over-thinned. Severe shading is often associated with uneven thinning with the well-exposed tops of the trees under-thinned and the shaded lower branches over-thinned. The solution to this problem is pruning, but the restoration of full productive capacity may require several years. Attempts to compensate for this problem by directing most of the spray to the tops of the trees are rarely successful.

In some instances, events that occurred the previous season will exert a measurable influence on thinning results. An excessive crop reduces tree vigor the following season and at the same time increases susceptibility to thinning. Strongly biennial varieties are easier to thin in the "off" year (following a heavy crop) than in the "on" year (following a light crop). Prior to the development of chemical fruit thinning, this response would have been largely academic because alternating varieties rarely produced significant bloom in the "off" year. However, with regular chemical thinning, it is not unusual for a heavy crop to be followed by a heavy bloom. Where the crop was excessive the previous year and the current set is heavy enough to require thinning, moderate rates are usually adequate.

Prolonged soil moisture deficits can also affect tree vigor, fruit set, and the response to thinning the following year. Moisture stress of sufficient severity to induce wilting for 2-3 weeks will be reflected in increased effectiveness of thinning sprays. This effect will vary inversely with soil depth and may be responsible for a wide range in response throughout the orchard. Applications to trees that suffered moisture stress the previous year should be restricted to the lower rate in the recommended range.

In the same manner, any factor that seriously impairs leaf function or results in the destruction of a significant portion of the leaf area would be sufficient reason for reducing rates of thinning chemicals the following year. Such damage might be the result of symptoms of deficiencies of essential elements or of injury from insects or diseases.

Alar is a growth retardant noted for several desirable physiological responses, and it is routinely applied to many apple trees. In some cases, there may be carryover effects of Alar from one season to the next. These are usually associated with excessive rates of application or with low vigor. When such carryover occurs, fruit set may be increased and fruit size markedly reduced. It has been reported that such trees are difficult or impossible to thin. Satisfactory thinning can be accomplished, but only if maximum rates are used. However, adequate thinning may not completely overcome the adverse effects of Alar carryover on fruit size.

CONCLUSIONS

Factors that influence the effectiveness of chemical fruit thinning sprays are numerous, complex, and interrelated. The net effect of these many opposing and complementary factors must be estimated and appropriate adjustments made if predictable results are to be obtained. Careful observations of weather, bloom, bee activity, tree vigor, and fruitlet development will enable growers to make fruit thinning decisions with confidence. With accurate sprayer calibration and adjustment, these decisions can be translated into effective thinning that guarantees fruit of marketable size and abundant bloom for a full crop the next year.