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# Fruit thinning: Purpose, methods & role of plant growth regulators

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**Abstract**
Fruit thinning and Plant Growth Regulators (PGRs) in Fruit Thinning can be used with some precision to control bloom thinning fruits, regulate growth, and adjust harvest season. Fruit thinning is done at early stage of fruit development to improve the quality of fruits as well as yield of the trees as whole. Depending upon cultivars & characteristics of fruits different methods *viz*. hand, mechanical & chemical things are carried out. Use of PGR like NAA, GA3, etc. has been found to be an effective & economic tool of fruit thinning as well as delaying pre-harvest fruit drop. The current review is based on purpose, method and mechanism of fruit thinning**.** An overabundance of fruits per tree can result in small fruits, poor quality and several more issues. For fruit growers, hand thinning is the most common and important method since the time farming started, followed by mechanical thinning and chemical thinning. A lack of photosynthates and improper Abscisic Acid (ABA) content may have caused excessive abscission of mangosteen flower and fruit, this is due to the lower sugar content. Therefore, in this review paper we have briefly discussed the objective, purpose, method, function of fruit thinning and role of Plant Growth Regulators (PGRs) in Fruit Thinning.

**Keywords:** fruit thinning, PGR, hand thinning, mechanical, chemical

## 1. Introduction
The practice of fruit thinning has been practiced for thousands of years as it can help prevent a variety of problems, including small fruit sizes, poor quality, broken limbs, and reduced cold hardiness. It is also possible that heavy fruiting will partially or completely inhibit flower bud initiation in some species/cultivars. When fruits are thinned at an early stage of their development, they are larger, good in colour, and have more flower buds in the following year, which reduces biennial bearing. To better distribute the crop load, it is often necessary to thin fruit clusters. Thinned fruits within clusters increases fruit size the most, suggesting that fruit distribution, as well as the total number of fruits, is crucial in determining fruit size. Tree fruits such as apples, pears, plums, peaches, cherries, grapes and nectarine may need to be thinned.

## 2. Purpose of thinning
- The goal of thinning is to improve the size and quality of the fruits.
- In trees with heavy crops, the fruits are usually small and of poor quality.
- Through thinning, sunlight and air penetrate the branches more evenly, improving the ripening process.
- In over cropped trees, branches can break.
- The tree can then make a good growth and develop fruit buds for the coming year, preventing the risk of biennial bearing.
- In addition to reducing pests and diseases, fruit thinning may improve quality.

## 3. Factors affecting tree response to thinning

Factors affecting tree response to thinning

| S. N. | Factors | Types |
|---|---|---|
| 1 | Cultivar | Biennial vs. annual spur-type vs. non spur-type fruits set in clusters vs. singles or doubles extent of "June" drop |
| 2 | Fruit haracteristics | Stage of development, position in cluster |
| 3 | Tree condition | Tree and leaf age, vigor, previous crop, bloom and crop density, stress (disease, nutrient, etc.), root system |
| 4 | Weather conditions | Temperature, solar radiation, relative humidity, frost, Rainfall |

## 4. Methods of thinning

### 4.1 Hand thinning

Despite the advances made over the past 75 years, hand thinning remains an important tool for the fruit grower. Einerson *et al.* (1976) [12] reported that hand thinning of flower clusters in grapes get uniform fruit size while, Walker (1903) [40] observed the considerable increase in the value of the crop from thinning peaches. Powell (1900) [27] reported that, although thinning 'Burbank' plums reduced the percentage of diseased fruits, it reduced yield and had little effect on fruit size. Dennis (2000) [8] recommended thinning at early stage because this would improve fruit size more than would later thinning, and also avoid removal of fruits that fall of their own accord. Kosina J. (2008) [20] studied the response of two apple cultivars to fruit thinning and observed that hand thinning get highest yield (73 kg/tree).Another study on fruit thinning in three cultivars of apple (Boskoop, Cox and Golden Delicious) was conducted by Link H. (2000) [18] and reported that hand thinning increased fruit weight as well as another chemical parameters. Messaoudi *et al.* (2009) [26] studied the effect of pollination, fruit thinning and gibberellic acid application on Japanese persimmon and observed that the fruits from thinned trees seem to achieve larger fruit diameter.

### 4.2 Mechanical thinning

- Club thinning can be used to thin peaches and apricots; a section of rubber hose is attached to a wooden handle and fruit are knocked from the tree during the pit hardening state, prior to the final swell.
- High pressure spray guns can also be used to knock fruit from the tree
- Mechanical trunk or limb shakers are sometimes used with stone fruit.
- Such methods are not recommended for apple because they are easily bruised, and the damage is visible on the mature fruit
- Menzies (1980) [25] evaluated the effects of thinning in Royal Delicious cv of apples with a tree shaker at intervals from 4 to 12 weeks after full bloom, increased fruit size
- Bertschinger, *et al.* (1997) [4] reported that rope thinners can be used for blossom thinning of peaches.

Mechanical thinning is eco friendly, use of thinning chemicals are more severe, especially in "bio-orchards" devoted to the production of organically-grown fruit.

### 4.3 Chemical thinning

#### 4.3.1 Use of plant bio-regulators

Numerous research dealing with chemical thinning of fruit crops early decades of the 20th century. Gardner *et al.* (1939) [14] had reported that NAA @10 ppm delayed pre-harvest drop.Burkholder and McCown (1941) reported that NAA 7.5 mg/L applied at full bloom reduced fruit set of apple. Tukey (1965) [38] observed that NAA was most effective on apple cv 'Rome Beauty' when fruit diameter was 10–11 mm.Edgerton and Greenhalgh (1969) [11] appear to have been the first to evaluate the thinning activity of ethephon. Stembridge and Morrell (1972) reported a significant reduction in fruit set of 'Delicious' when applied Promalin (BA+GA4) @25mg/l, at full bloom stage. Unrath (1974) [39] reported that Benzyladenine(BA) @100mg/l, stimulate cell division in young apple flowers and fruits, with early applications (full bloom to petal fall)being most effective. Greene (1995) [15] observed that both thidiazuron and CPPU thinned both 'Mclntosh' and 'Empire' when applied at either full bloom or at 22 days after full bloom.

Some recent experiments conducted by several researchers on use of PBRs in thinning of fruit crops. Sterna R. A. (2007) studied the effect of synthetic auxins on fruit development of 'Bing' cherry (*Prunus avium* L.) and he observed that the application of 2,4-D 25 mg/ l + NAA at 30 mg/ l, (as 0.3% Amigo TM) increase the fruit diameter.

Robinson T. and Iungerman K (2010) [29] studied the chemical thinning for consistent return cropping of 'Honeycrisp' Apples. They recommend a multi-spray thinning for better return bloom.

- A bloom thinning spray of 20 ml·L-1 Ammonium thiosulfate (ATS)
- A petal fall thinning spray of 10 mg·L-1 NAA + 600 mg·L-1 carbaryl
- A 12 mm fruit size thinning spray of 7.5 mg·L-1 NAA + 600 mg·L-1 carbaryl
- series of 4 summer sprays of 7.5 mg·L-1 NAA beginning 5-6 weeks after full bloom applied every 10 days

Messaoudi *et al.* (2009) [26] also studied the effect of pollination, fruit thinning and gibberellic acid application on Japanese persimmon. Application of GA3 at the beginning of flowering affected positively current year vegetative growth and induced two vegetative growth flushes in comparison to unsprayed or GA3 sprayed trees at mid or end flowering.

**Table 1:** Effect of $GA_3$ application on fruit diameter and fruit size profile on kaki 'Fuyu' solaxe trained in the sais plateau

| Treatments | Fruit diameter (mm) | Fruit percent per size class (%) (cm) | | |
|---|---|---|---|---|
| | | 5,5-6,5 | 6,5-7,5 | 7,5-8,5 |
| $T_0$ | 55,1 b (*) | 45,45 | 45,45 | 9,09 |
| 25DF | 63,2 a | 50,00 | 41,67 | 8,33 |
| 25PF | 61,1 a | 53,85 | 46,15 | 0,00 |
| 25FF | 59,6 a | 53,85 | 38,46 | 7,69 |

Marini R. P. (2004) [24] studied the combinations of ethephon and Accel (6-BA + gibberellins 4+7) for thinning 'Delicious' apple trees. Effective thinning was obtained with ethephon at concentrations 100 mg/L and with Accel at concentrations of 500 mg/L.

**Table 2:** The effect of combining Accel and ethephon on fruit weight (g) in 2000. Analysis of covariance was used to estimate least squares means at three levels of crop load (fruit/tree)

| Ethephon ($mg \cdot L^{-1}$) | Accel ($mg \cdot L^{-1}$) | Fruit/tree | | |
|---|---|---|---|---|
| | | 250 | 400 | 550 |
| 0 | 0 | 184 ab[z] | 175 a | 167 a |
| 0 | 500 | 174 a | 175 a | 175 a |
| 100 | 0 | 192 ab | 184 a | 176 a |
| 100 | 500 | 217 b | 188 a | 158 a |

[z]Separation of least squares means within columns by the probability of the difference, 5% level.

#### 4.3.2 Use of caustic sprays

Drain (1924) [9] reported that iron sulfate sprays thinned at concentrations as low as 2 gL−1. The sprays tended to under-thin apples, while over-thinning inJapanese plums (*Prunus salicina*L.). MacDaniels and Hildebrand (1940) [21] reported the effects of dinitroo-cresylate (DNOC, or ElgetolR) in preventing pollen germination when applied to the stigmata of apple flowers. Williams MW (1994) [41] reported that

Concentration of most of these chemicals is crucial, as all can be phytotoxic at higher concentrations. fruit defects such as russeting and "dimpling" can be a problem. Other natural products, including soap, waterglass (sodium silicate), mineral oils, and rapeseed oil, have been tested for blossom thinning in Europe (Strimmer 1997) [36].

#### 4.3.3 Use of insecticidal carbamates

Greene DW (1994) [16] reported that carbaryl is considered to be a mild thinning agent, and is best used with another compound, such as NAA or BA, for difficultto-thin cultivars such as 'Golden Delicious' and spur type cvs. of apple. Marini (1996) [22] reported that in 'Delicious' cvs of apple carbaryl (@500 mg/L) is preferred for combinations with BA (@50mg/L). Marini (1997) [23] also reported that some other insecticidal carbamates, such as oxamyl are also effective in thinning of apples.

#### 4.3.4 Use of inhibitors of photosynthesis

Byers (1991) [6] reported that chemicals that inhibit photosynthesis, including the herbicide terbacil can also thin apples and peaches. Stopar *et al.* (1997) [35] reported that NAA (@2–5 mg/L) application inhibited carbon assimilation by as much as 25% for up to 48 h in apple cvs. 'Delicious' and 'Empire' leaves, and inhibition continued for as long as 2 weeks.

## 5. Mechanisms to explain the fruit thinning action of chemicals

1. Abortion or inhibition of growth of embryo
2. Delay of abscission, increasing competition among fruits for nutrients
3. Inhibition of phloem transport to fruit
4. Inhibition of auxin synthesis by seed
5. Inhibition of auxin transport from seed
6. Stimulation of ethylene biosynthesis
7. Inhibition of photosynthesis/stimulation of dark respiration

## 6. The mechanisms by which growth regulators have been investigated.

### 6.1 Naphthaleneacetic acid (NAA)

NAA treatment delayed fruitlet abscission, this delay increased competition for nutrients, thereby increasing the final number of fruits that abscised. However, several facts make this hypothesis untenable. The fruit that eventually drop usually cease growth soon after treatment, and therefore should not attract nutrients from persisting fruits. Furthermore, NAA does not always delay abscission. The seed abortion was common in fruitlets sprayed with NAA, this response reduced the ability of some fruits to compete for nutrients, leading to abscission. The embryos were smaller in NAA-treated fruits of 'Wealthy'. If NAA induces abscission by causing seed abortion, application directly to the seeds should be effective. Although NAA-induced seed abortion is common in some cultivars, e.g., 'Delicious' 'Mclntosh', 'Golden Delicious', 'Jonathan', and 'Winesap' fruits can be thinned without affecting seed number. Even in 'Delicious', there is little relationship between the degree of seed abortion and thinning response. Thinning chemicals may interfere with translocation of nutrients from leaf to fruit, or of endogenous auxins down the pedicel. The amount of auxin recovered from small fruits was lower than that from large fruits. The reduced auxin transport was the major factor responsible for the thinning action of all three compounds. In many plant tissues production of ethylene stimulates due to auxin application, and abscission could induce due to the increase in ethylene concentration. Ethephon, as noted above, can be used for thinning. The NAA uncouples oxidative phosphorylation, leading to a sequence of events, including reduced hormone content of the endosperm, reduced fruit growth, reduced embryo growth, an increase in ethylene production, and finally, fruitlet abscission.

### 6.2 Benzyladenine (BA)

BA has been used as a thinner for only a short time relative to the use of NAA, and therefore its mechanism of action has not been studied extensively. It is more effective when applied to the leaves alone than to the fruit alone but fruit size was increased only when BA was applied to the fruit and occurred even in the absence of significant thinning. Application of BA stimulated ethylene production in both leaves and fruits, and the rate of evolution increased with the concentration applied. Nevertheless, although the amount of ethylene evolved was greater than that induced by NAA, the thinning response was less. BA might reduce the supply of sugar to the fruit. when BA was applied to the fruit, but not when it was applied to the leaf. Net photosynthesis was inhibited 10–15% by BA application (50 or 100 mgL−1), and leaf carbohydrate levels were also reduced. Application of BA inhibited the growth of single fruits on girdled branches only if leaf number was less than 16, and induced abscission only when less than two.

### 6.3 Carbaryl

Carbaryl is not a hormone by definition, as much higher concentrations are required for activity than is the case with NAA (1000 mgL−1 vs. 5–15 for NAA). Nevertheless, much effort has be devoted to its mechanism of action. The carbaryl retarded fruit growth for a brief period following application, but did not study the mechanism of action. Although carbaryl induced some seed abortion, no relationship was found between abortion and fruit abscission. carbaryl was applied to the pedicel, it moved to the fruit, but when applied to the bourse or spur leaves, it did not. Carbaryl applied to the fruit remained there and did not move to the seeds. The action in the pedicel, i.e., directly on the abscission zone, or seeds was unlikely. The carbaryl might favor sink activity in the bourse shoots, thereby limiting export of essential metabolites to the fruit. However, this does not explain its direct action on the fruit. The carbaryl is more effective when applied to the fruit, but is partially effective on the bourse leaf, as well, especially when branches are shaded. Thinning response was greatest in Starking 'Delicious', intermediate in 'Jonathan', and negligible in 'Ralls'. Ethylene production was stimulated in 'Delicious' fruitlets, but not in those of the other two cultivars. The carbaryl reduced IAA transport, the results were variable, as noted above for the effects of NAA.

### 6.4 Ethephon

Ethephon, once absorbed by the tissues, is hydrolyzed to release ethylene, and this gas can induce abscission of leaves in plants held within containers. Thus, this could be the basis for its thinning effect. In thinning action of other chemical, role of ethylene remain controversial, as noted above.

### 6.5 Economic value of thinning

Cook (1987) [7] estimated that thinning with NAA increased net income by 10 to 20%, whereas hand thinning alone

reduced it by 23 to 29%. Bergh (1990) [3], develop a model for optimizing crop level to maximize return per hectare. He concluded that income could be maximized by thinning Golden Delicious'. Silsby, *et al.* (1991) [31] evaluated that 25 days after full bloom of hand thinning in apple cv 'Empire' gain net income ($2455/ha or approx. `1.47 lakh/ha).

### 6.6 The future of fruit thinning

- Carbaryl can no longer be used in some areas of Europe and will soon be unavailable in the United States.
- Ethephon remains a possibility for post-bloom thinning, and is used commercially, but is considered to be erratic in effect by most investigators.
- Mechanical methods of thinning provide a last resort as an alternative to chemicals.
- Hand thinning is costly, time consuming management practices and the farm labor cost is also high.
- For environmental concern " Eco friendly" chemicals must be used
- These include the use of several chemicals, together or sequentially, surfactants to improve penetration through the cuticle, modeling, spray application technology, etc.

## 7. Conclusion

High ABA content, low IAA and a low supply of photosynthates can cause excessive abscission of mangosteen flower and fruits. Low sugar content of leaves from shoots with abscised flowers and fruit showed the low supply of photosynthates than for those with retained flowers and fruit. Flower and fruit abscission did not get infulence by leaf N, P and K status. Factors related to ethylene could be the potential reason inducing flower drop during production and post harvest period of fruits.

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