Chemical Peach Thinning: Understanding the relationship between crop load and crop value.

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Peach flower and fruit thinning are essential commercial practices to optimize fruit size, maximize crop value, improve fruit color, shape, and quality, promote return bloom, and to maintain tree growth and structure. Hand thinning fruitlets at 45-50 days after bloom is the standard commercial practice in most peach producing areas. Hand thinning of peaches is the single most expensive management practice of growing peaches and can approach $500.00/acre. However, there is a substantial incentive for growers to reduce crop load to increase fruit size since large fruit is almost always more valuable than small fruit in the current fresh market.

> **"Our trials with chemical bloom thinners over three years in New York State have shown that blossom thinners have significant potential to reduce hand thinning costs. Bloom chemical thinning can reduce fruit set, improve fruit size, and increase the proportion of fruit in larger size categories; however, this is accompanied by a significant yield reduction and does not always improve crop value. The crop load where crop value is maximized is often different than growers perceive. Thinning beyond the optimum crop load levels has a negative impact on overall crop value."**

Chemical thinning of peach would be much less expensive than hand thinning, but it is not common in commercial orchards since it is considered risky due to inconsistent results. The greatest risk with chemical thinning is over thinning. This is particularly true with bloom thinning which must be done very early in the season, before the grower can accurately judge crop size or market conditions and before the danger of frost has passed. Nevertheless we feel the cost savings of chemical thinning may justify the effort if the risk of over-thinning can be minimized.

To provide NY growers with low risk options for chemical thinning of peach, we began a series of experiments in 2004-2006 to evaluate several chemical thinners and develop thinning strategies which would have low risk of over-thinning. Most of our chemical treatments were applied during bloom since post-bloom thinning treatments have not been as effective as bloom treatments.

To evaluate the effectiveness of our thinning treatments we not only measured crop load reductions and fruit size improvements but we also calculated the resulting total crop value. It is well known that reducing crop load through thinning also reduces yield per tree. Historically, it has been assumed or implied that a significant increase in fruit size of the remaining fruits will result in fruits of greater value which will compensate for the loss of yield that typically results from thinning. Most research on thinning appears to proceed on the assumption that greater mean fruit size always results in improved returns for the grower. Researchers routinely report that a significant crop load reduction is accompanied by an increase in fruit size but few calculate the impact of thinning on total crop value. It is possible that some thinning treatments over-thin resulting in reduced total crop value. Without calculating the impact on thinning treatments on crop value it is difficult for fruit growers to judge how much thinning is enough to maximize total crop value.

Materials and Methods

Three peach blossom thinning field experiments were conducted from 2004 to 2006 in New York State. We evaluated several chemicals before bloom and at full bloom. Treatments were applied by air-blast sprayers at a spray volume of 100 gallons per acre except soybean and horticultural oil, which were applied at 200 gallons per acre. Some of the chemical thinning agents we evaluated included soybean oil (8%) 15-35 days before bloom, ammonium thio-sulfate (ATS) (1-5%) at bloom, Lime sulfur (1-4%) plus Fish oil (2%) at bloom, Tergitol TMN-6, (0.5, 0.75%) at bloom, Entry (1-3%) at bloom, and Wilthin (0.5, 0.75%).

Fruit set was evaluated on two limbs per tree on which flowers were counted before bloom and then persisting fruit were counted 45 days after bloom. Fruit set was expressed as percentage of flowers, which developed into fruits. Fruits were harvested in two harvests when mature. At each harvest, fruits were counted and weighed. A sample of fifty fruits were collected from both harvests and evaluated for size and red color. Fruits were sorted into four size categories: 100 box size or a 2.75 inch peach, 120 box size or a 2.5 inch peach, 140 box size or a 2.25 inch peach, and a 160 box size for all fruits that were smaller than 2.25 inches. A sub sample of ten fruit was randomly selected from the 50 fruit sample for evaluation of fruit firmness and soluble solids.

A predicted pack-out was calculated assuming a normal distribution of fruit sizes on a tree and using the average fruit size of each tree and a standard deviation of 20 g within a tree (Stover, et al., 2001). Crop value was calculated based on farm gate fruit prices for a bushel (20 kg) of different fruit sizes. Prices used were

Table 1. Effect of chemical thinning agents on percent fruit set, fruit size, crop load, and yield of 'Rising Star' peach.

Treatment	Fruit Set (%)	Fruit Size (g)	Crop Load (fruits per cm²/ TCA)	Yield (bu. / acre)
Untreated control	18.1 abz	90.9 c	10.3 a	754 a
Hand thin 45 DAFB	18.0 ab	106.7 ab	6.1 cd	524 cd
Soybean oil (8%)	22.2 a	100.0 bc	8.8 ab	686 ab
Petroleum oil (8%)	17.6 ab	107.6 ab	6.6 bc	583 bc
LS (1%) + FO (2%)	17.5 ab	100.8 bc	7.3 bc	597 bc
LS (3%) + FO (2%)	17.5 ab	100.4 bc	6.8 bc	543 bc
ATS (3.5%)	17.6 ab	106.4 ab	6.5 bc	570 bc
ATS (5.0%)	13.5 bc	119.4 a	3.9 d	376 d
Wilthin 2.8 L	11.4 c	112.1 ab	3.3 cd	469 cd

z Means followed by the same letter are not significantly different using LSD. P≤0.05, n=6.

Table 2. Effect of chemical thinning agents on percent fruit set, fruit size, and yield of 'Redhaven' peach.

Treatment	Fruit Set (%)	Fruit Size (g)	Crop Load (fruits per cm²/ TCA)	Yield (bu. / acre)
Untreated control	25.3 abcz	117 h	5.2 a	767 a
Hand thin flowers FB	18.6 bcdef	188 ab	0.87 f	210 e
Hand thin fruit 45 DAFB	10.0 efg	170 bcdef	1.7 efd	364 cde
SO 25 DBFB	23.6 abcd	148 fg	3.75 bc	657 ab
SO 18 DBFB	31.0 a	151 efg	4.01 ab	750 a
LS (2%) + SO (2%)	17.6 bcdef	174 abcde	1.70 efd	369 cde
LS (4%) + SO (2%)	10.6 efg	182 abcd	1.18 ef	262 de
ATS 3.5%	8.8 fg	194 a	0.86 f	212 e
ATS 5.0%	4.2 g	185 abc	0.75 f	181 e
Wilthin 0.5%	20.2 abcde	141 g	3.91 ab	654 ab
Wilthin 0.75%	27.2 ab	150 fg	3.48 bc	650 ab
Entry 1.5 %	19.8 abcdef	154 efg	3.08 bcd	573 abc
Entry 3.0%	13.2 defg	159 defg	3.55 bc	662 ab
Tergitol 0.75%	15.0 cdefg	144 g	3.88 ab	672 ab
Tergitol 1.5%	11.2 efg	163 cdefg	2.34 cde	475 bcd

z Means followed by the same letter are not significantly different using LSD. P≤0.05, n=5.

$7 per bushel of 160 count, $10 per bushel of 140 count, $13 per bushel of 120 count and $15 per bushel of 100 count. The crop value of each treatment was calculated with the assumption of no differences in fruit color between treatments.

Results

In 2004, Wilthin (0.3%) and the high rate of ATS (5%) were the two treatments that had the greatest thinning response and significantly reduced fruit set (Table 1). Wilthin (0.3%) and ATS (5%) reduced fruit set to 11.4% and 13.5%, respectively, compared to the untreated control (18.1%). Petroleum oil, both rates of LS+FO (1, 3%), ATS (3.5%), and the hand thin treatment at 45 DAFB did not reduce fruit set and were statistically similar to the untreated control. Soybean oil (8%) did not reduce fruit set and showed a trend toward increased fruit set (22.2% compared to the untreated control at 18.1%). Wilthin (0.3%) and ATS (5%) thinned aggressively but ATS (5%) was the treatment that produced the largest peaches with an average fruit size of 119 grams. Untreated control trees had an average fruit size of 91 grams. The hand thinning treatment at 45 DAFB, petroleum oil, ATS (3.5%), and Wilthin (0.3%) produced statistically similar sized fruits ranging between 106 and 112 grams. Soybean oil and both rates of LS+FO (1, 3%) produced smaller sized fruits (100 g).

Untreated control trees had the highest yield producing 754 bu. per acre; followed by Soybean oil, 686 bu. per acre (Table 1). Hand thinning at 45 DAFB and Wilthin (0.3%) had similar yields (524 and 469 bu. per acre, respectively). Yields of the Petroleum oil, both rates of LS+FO (1%, 3%), and the low rate of ATS (3.5%) treatments also had statistically comparable yields ranging between 543 and 597 bu/acre. ATS (5%) severely over thinned and thus produced the lowest yield of 376 bu./acre.

Table 3. Effect of blossom thinning agents on fruit pack out of 'Redhaven' peach in 2005.

Treatment	Yield by box size category (%) 100 Count	120 Count	140 Count	160 Count
Untreated control	3.9 abz	9.0 abcd	17.8 a	8.5 a
Hand thin flowers FB	2.8 ab	3.2 e	2.3 fg	1.2 e
Hand thin fruit 45 DAFB	3.4 ab	7.4 bcde	4.7 efg	2.6 ed
SO 25 DBFB	3.1 ab	10.2 abc	13.0 abc	6.5 ab
SO 18 DBFB	6.2 a	13.1a	13.8 ab	4.6 bcd
LS (2%) + SO (2%)	3.8 ab	6.5 cde	4.2 efg	3.3 cde
LS (4%) + SO (2%)	3.1 ab	4.6 de	2.9 fg	1.8 e
ATS 3.5%	3.6 ab	3.1e	1.2 g	1.1 e
ATS 5.0%	2.4 b	3.1e	1.3 g	1.0 e
Wilthin 0.5%	4.7 ab	9.2 abcd	13.3 abc	5.4 bc
Wilthin 0.75%	4.1 ab	13.0 a	9.9 bcd	5.0 bcd
Entry 1.5 %	3.4 ab	10.6 abc	8.9 cde	6.0 ab
Entry 3.0%	5.0 ab	12.7 a	10.4 bcd	4.9 bcd
Tergitol 0.75%	4.5 ab	11.8 ab	10.6 bcd	6.7 ab
Tergitol 1.5%	2.6 b	8.7 abcd	6.8 def	4.8 bcd

z Means followed by the same letter are not significantly different using LSD. P≤0.05, n=5.

In 2005, the high rate of ATS (5%) caused an 85% reduction in fruit set and resulted in severe over-thinning. The low rate of ATS (3.5%) reduced fruit set by 65% and was followed in order by Lime sulfur 4%, Entry 3.0%, Tergitol 1.5%, Tergitol 0.75% and Lime sulfur 2.0%. Wilthin (0.5%) and Entry (1.5%) reduced fruit set by 25% compared to the untreated control, but the difference was not significant. The dormant oil applications of soybean oil, applied either 18 or 25 DBFB, did not significantly reduce fruit set.

All thinning treatments increased fruit size compared to the untreated control (Table 2). The treatment that most significantly improved fruit size was ATS (3.5%) producing an average fruit size of 195 g. In contrast, the untreated control had the smallest fruit size of 117 g with the greatest crop load of 5.2 fruits per cm² TCA. ATS (5%) and hand thinning of flowers at FB dramatically improved fruit size to 185 and 188 g respectively. LS (4%) plus SO (2%) also considerably increased fruit size to 182 grams. LS (2%) plus SO (2%) and hand thin fruit at 45 days after FB similarly increased average fruit size to 173 and 170 grams. Tergitol (1.5%) and Entry (3%) produced intermediate fruit sizes of 163 and 159 grams. Entry (1.5%) and SO (8%) applied 18 days before FB produced statistically similar fruit sizes of 154 and 151 grams. SO (8%) applied 25 days before FB, Tergitol (0.75%) and Wilthin (0.75%) increased fruit size the least resulting in sizes between 142 and 150 grams (Figure 4.2). The untreated control trees and SO (8%) applied 18 days before FB treatments produced the highest yields, averaging approximately 750 bu /acre (Table 2). ATS (3.5%, 5.0%) reduced yield most dramatically to 182 or 263 bu /acre.

Soybean Oil (8%) applied 18 DAFB generated the highest crop value, $14,949.00. Entry (3.0%) and Wilthin (0.75%) treatments generated crop values of $12,866.00 and $12,552.00 respectively (Figure 2). SO (8%) applied 25 DBFB, the untreated control, Wilthin (0.5%) and Tergitol (0.75%) had statistically similar val-

Table 4. Effect of chemical thinning agents on fruit set, fruit size, crop load and yield of 'Babygold 5' peach.

Treatment	Fruit Set (%)	Fruit Size (g)	Crop Load (fruits per cm²/ TCA)	Yield (bu. / acre)
Untreated control	33 abcz	219 cd	1.43 a	360 a
Hand thin flower 1 frt/ TCA @ FB	17 cde	228 cd	0.51 cd	146 defg
Hand thin flower 2 frt/ TCA @ FB	24 bcde	237 abcd	0.54 cd	168 cdefg
Hand thin fruit 1 frt/TCA @ 45 DAFB	36 ab	241 abcd	0.59 bcd	184 bcdef
Hand thin fruit 2 frt/TCA @ 45 DAFB	29 abcd	211 d	1.16 ab	318 ab
Tergitol 0.75% @ 35+85% FB	16 cde	241 abcd	0.22 d	66 efg
Tergitol 1.5% @ 35+85% FB	10 e	273 a	0.11 d	42 g
Tergitol 0.75% @ 85% FB	21 bcde	244 abcd	0.36 cd	108 efg
Tergitol 1.5% @ 85% FB	16 cde	233 bcd	0.23 d	71 efg
ATS 2% @ 35+85% FB	23 bcde	240 abcd	0.19 d	61 fg
ATS 4% @ 35+85% FB	12 de	252 abc	0.25 d	81 efg
ATS 2% @ 85% FB	25 bcde	235 bcd	0.52 cd	153 cdefg
ATS 4% @ 85% FB	22 bcde	265 ab	0.61 bcd	208 bcde
Wilthin .075% @ 35+85% FB	22 bcde	245 abcd	0.93 bcd	291 abc
Wilthin .075% @ 85% FB	44 a	248 abcd	0.93 bcd	286 abcd

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ues and varied between $11,191.00 and $11,902.00. Entry (1.5%) had a moderate crop value of $9,864.00. Tergitol (1.5%) had an intermediate crop value of $8,581.00. Hand thinning of fruit at 45 DAFB and LS (2%) plus SO (2%) had statistically similar crop values at $6,711.00 and $7,371.00. ATS (3.5%) and LS (4%) plus SO (2%) also had statistically comparable crop values of $5,250.00 and $5,515.00 respectively. Finally, ATS (5%) and hand thinning of flowers at FB had the lowest crop values, $4,356.00 and $4,193.00.

In 2006, the most effective treatments to reduce fruit set were the high rates of ATS (4%) and Tergitol (1.5%) applied twice at 35% and 85% bloom (Table 4). The low rate of Tergitol (0.75%) applied twice at 35% and 85% bloom and Tergitol 1.5% applied once at 85% bloom were also quite effective and reduced fruit set to 16 percent. Tergitol (0.75%) applied once at 85% bloom, ATS (2%) applied twice at 35 and 85% bloom, ATS (2 or 4 %) applied once at 85% bloom, and Wilthin (0.75%) applied at 35% and 85% bloom reduced fruit set moderately between 21 and 25 percent. Untreated control fruit set was 33 percent. Wilthin (0.75%) was without effect at 44% fruit set.

Fruit size for all the treatments was very large due to the low crop loads. Fruit size was smallest with the untreated control and the hand thinning of fruits @ 45 DAFB (2 fruits per cm² TCA) treatments which had fruit sizes of 219 and 211 grams respectively (Table 4). Tergitol (1.5%) applied at both 35% and 85% bloom and ATS (4%) applied at 85% bloom yielded the largest fruit sizes at 273 and 265 grams respectively. Hand thinning flowers @ FB (1 fruit per cm² TCSA) produced a fruit size of 228 grams. Tergitol (1.5%) applied at 85 % bloom and ATS (2%) applied at 85% bloom yielded similar fruit sizes, of 233 and 235g, respectively. The remainder of the treatments had an average fruit size between 237 and 248 grams.

Yields were extremely low for all treatments including control trees (Table 4). Untreated control trees had the highest yields at 360 bushels to the acre. Hand thinning of fruits @ 45 DAFB (2 fruit per cm² TCA) yielded 318 bushels per acre. Wilthin (0.75%) applied at 35 and 85% bloom and Wilthin (0.75%) applied at 85%

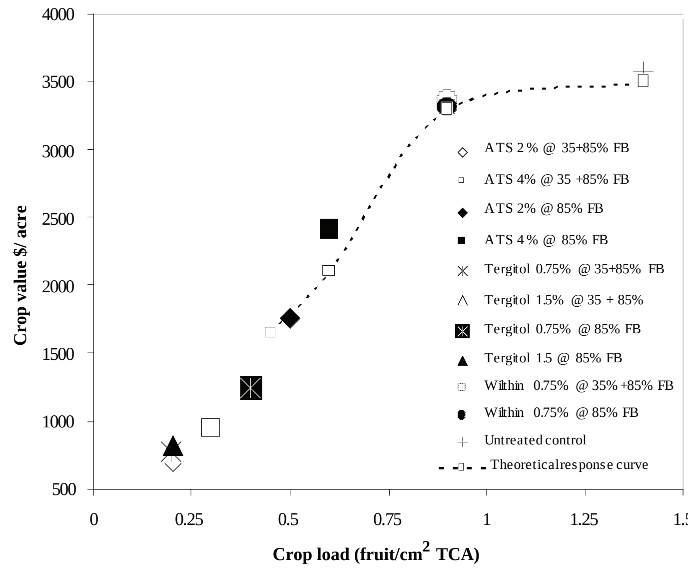

Figure 1. Effect of crop load on crop value of 'Rising Star' peach in 2004.

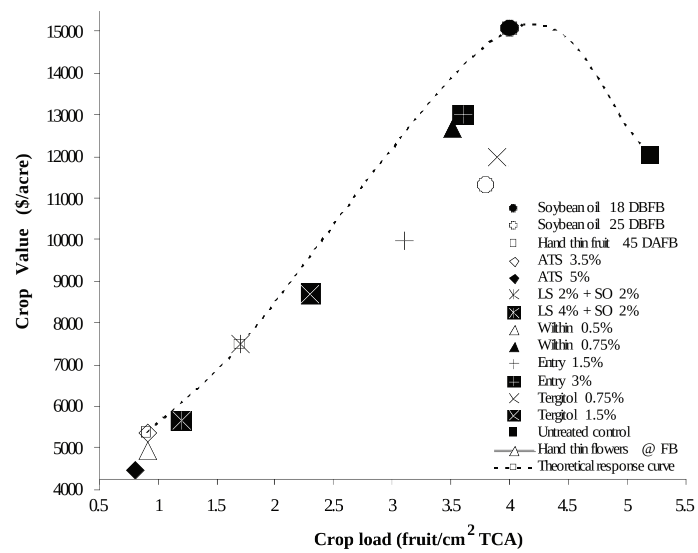

Figure 2. Effect of crop load on crop value of 'Redhaven peach' in 2005.

bloom produced 291 and 286 bushels per acre, respectively. Hand thinning of flowers @ FB (2 fruit per cm² TCA) and ATS (2%) applied at 85% bloom were statistically comparable at 168 and 153 bu/acre. The remainder of the treatments produced yields between 42 and 108 bu/acre.

Crop values were calculated using current processing market fruit prices (Figure 3). The treatments that generated the highest crop value were both treatments of Wilthin, followed by hand thinning of fruits @ 45 DAFB (2 fruit per cm² TCA) and the untreated control which had values between $7,111.00 and $7,613.00 (Table 5). Treatments with intermediate crop values were the high rate of ATS (4%), hand thinning of fruits @ 45 DAFB (1 per cm² TCA), hand thinning of flowers @ FB (1 per cm² TCA) which had values between $4,358.00 and $5,438.00/ha. Treatments with lower crop values were Tergitol (0.75%) and ATS (2%) applied at 85% bloom, which had crop values between $2,730.00 and $3,600.00/ha. Treatments with the lowest crop values were Tergitol 1.5% applied at 85% bloom and ATS (4%) applied at both timings (35 and 85% bloom), Tergitol (0.75 and 1.5%) applied two times and ATS (2%) applied two times which

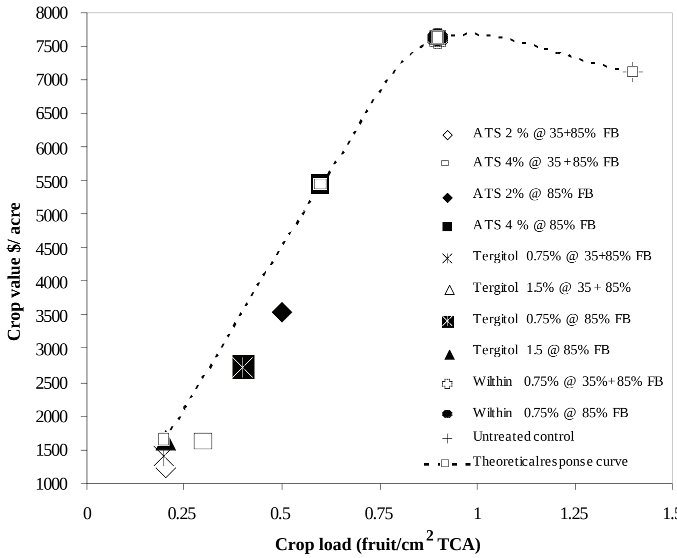

Figure 3. Effect of crop load on crop value per acre of 'Babygold 5' peach in 2006.

had crop values varying between 985.00 and 1650.00. In general, the treatments with the highest yields also had the highest crop values.

Discussion

Our data indicate there is an optimum crop load each year to maximize crop value. The optimum crop load or fruit number is often different than growers assume when they hand thin. Our results suggest that chemical blossom thinning in peach could significantly reduce the need for hand thinning for peach growers. However, it is variable from year to year and while our data concludes that ATS is the most promising bloom thinner for peaches in New York State, this chemical is a potent thinner and can remove too many fruits if the rate is too high. Thus, to implement chemical blossom thinning in New York it will require developing a method to determine the proper rate and/or timing to reduce the risk of over-thinning. In 2004**,** ATS was an effective blossom-thinning agent on 'Rising Star' but high concentrations (5.0%) resulted in severe over thinning. The rate response of thinning with ATS appears to be linear which would allow an optimum rate to be identified with additional experimentation. The variability in this study prevented identifying a significant relationship between crop load and crop value. A study with greater replication and/or more rates of ATS would allow an optimum crop load to be identified. Nevertheless, based on our data in Figure 1 it appears that a curvilinear relationship exists with rate of ATS and crop value. A target crop load that maximizes crop value can be found somewhere between 1 and 4 fruits per cm^2 TCA depending on the year and the orchard. In our study, the low rate of ATS (3.5%) gave a crop load in this range. In contrast the rate response of LS+FO with crop load did not show an optimum rate. ATS has been found by others to be effective blossom thinners in peach (Byers et al., 2003; Byers and Lyons, 1984; Zilkah et al., 1988). The use of ATS as a blossom thinner in pome fruit has been commercially practiced in some areas of the USA.

The application of Soybean oil or petroleum oil before bloom did little thinning in New York State. Soybean oil was slightly less effective in reducing crop load though not significantly than Petroleum oil (8.8 vs. 6.6 fruits per cm^2 TCA). Although crop loads were slightly different, crop values were very similar. Research by Myers et al. (1996) and Reighard (2006) have shown that Soybean Oil (SO) can be an effective fruit thinner in the southeastern USA when applied at the proper dosage and applied before bud break, but after chilling requirement has been met. The lack of thinning response of dormant soybean oil in our trial may have been due to improper timing, low spray volume or environmental conditions. Furthermore, the cool spring conditions in New York State may not be conducive to allow the required reduction in respiration in flower buds during warm periods reported in southern climates for the thinning effect of the oil to be achieved. If Soybean oil could be made to work in NY State, it would probably be quickly registered since Soybean oil is exempted from EPA tolerances because it is a relatively non-toxic, common food constituent, not persistent in the environment, and has no significant adverse effects on the environment (U.S. Congress, 1996).

Tergitol and Wilthin were also effective thinners while Lime sulfur and Entry were not. In 2004, Wilthin (0.3%) had the greatest thinning effect and reduced fruit set by 61% compared to the untreated control. Lime sulfur plus fish oil (LS+FO) treatments 1% and 3% also did not significantly reduce fruit set. Although Wilthin treatment resulted in a greater proportion of the crop in the larger size categories, there was a significant yield reduction associated with these treatments. This resulted in no improvement in crop value from the blossom thinning treatments.

Our results suggest blossom thinners may be used to reduce hand-thinning costs and early thinning can significantly increase fruit size but the impact on crop value depends on the severity of thinning. Over the three years of our study ATS was the most consistent thinning agent but in 2006 it clearly over-thinned. The excessive reduction in fruit set and yield is undesirable if the increased fruit size does not translate into increased crop value (Reighard, 2006). In a recent summary of economic analyses of many thinning trials, Stover (2004), noted that those studies that have examined the relationship between crop load and crop value suggest that thinning beyond that required to regulate bearing may be excessive and counter-productive, even though fruit size may be substantially increased. Therefore, as Stover (2004) suggests, it is critical to quantify the economic benefit of thinning and identify crop loads that balance the trade-off between yield and fruit size to provide optimal crop value. For example, our study showed that in 2006 only a modest reduction in crop load was needed to maximize crop value and this was achieved with Wilthin which thinned very little while the more potent thinners (ATS and Tergitol) over-thinned and reduced crop value.

Our data suggest that blossom thinning in peach is variable and demonstrates that peach chemical blossom thinning involves risk. Our data indicates that ATS is the most promising bloom thinner for peaches in New York State. However, the results have been variable from year to year. If growers were to adopt the practice of chemical thinning in peaches a method of reducing this variability must be developed. A large part of this variability has been due to different levels of bud viability after sub-zero winter temperatures and severity of pruning. An assessment protocol for growers should be based on the percentage of live buds at bloom, the severity of pruning (number of fruiting twigs left per scaffold) duration of bloom period, and the quality of pollination weather to determine the dose of ATS to apply.

A number of concerns impede the widespread commercial use of stone fruit blossom thinners. Many growers prefer to thin after bloom to avoid the risk of spring frost at bloom. Byers (2003), suggests that the optimum time for thinning peach fruits may be approximately two weeks after bloom. At this time the fruit are not yet a serious drain on the tree's photosynthetic reserves and the chance of a spring freeze is much lower. Although bloom thinners may have a greater risk when there is a spring frosts, this must be weighed against the economic impact of expensive hand thinning. Growers need to consider the probability of a local freeze, the earliness of bloom, the value of the crop in relation to later fruit hand thinning costs, and availability of labor.

Conclusion

Our trials with chemical bloom thinners have shown that blossom thinners can reduce fruit set, improve fruit size, and increase the proportion of fruit in larger size categories but this is accompanied by a significant yield reduction and does not always improve crop value. Thinning beyond optimum crop load levels has a negative impact on yield and reduces overall crop value.

Over the three years of our study ATS was the most consistent thinning agent but in 2006 it clearly over-thinned. ATS sprays during bloom offer a way for NY peach growers to reduce hand-thinning costs significantly if the risk of over-thinning can be minimized.

Our next goal is to develop an assessment protocol for growers to use each spring to determine if chemical blossom thinning is justified and the rate of ATS to use. It will entail an assessment of pruning severity (fruiting branches per scaffold), winter bud survival (% live buds), and pollination conditions. With this protocol a grower would be guided not to apply ATS in years with poor winter bud survival or heavy pruning but in other years with high bud survival and more moderate pruning to apply ATS.

Future research on blossom thinning should identify key variables that ultimately influence ATS thinning and reduce the risk of over thinning, and identify appropriate concentrations of ATS or other promising chemical thinners. More data will help assess which situations are more conducive to blossom thinning and avoid blossom thinning when the risks are too high. A better understanding of the relationship of flower bud density and fruit set should be sought. This should help in developing the proposed thinning assessment protocol. Finally, future research should continue to evaluate the relationship between crop load and crop value rather than thinning efficacy and fruit size response.

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