CHEMICAL PEACH BLOSSOM THINNING TO REDUCE CROPLOAD AND IMPROVE CROP VALUE

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ABSTRACT

Four field experiments were conducted from 2004 to 2006 in both New York State and one trial in Nueva Casas Grandes, Mexico. We evaluated several chemicals before bloom and at full bloom. Some of the chemical thinning agents we evaluated include 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, .75%). Over the three years of our study ATS was the most consistent thinning agent but in 2006 it clearly over-thinned. Tergitol was also an effective thinner while Soybean oil before bloom, Lime sulfur and Entry were not effective. Our results show that peach chemical blossom thinners can reduce fruit set, improve fruit size, and improve the proportion of larger size fruits. However, in all cases a significant yield penalty or yield reduction was required to achieve large fruit size and this does not always translate to an improvement in crop value. Thinning beyond optimum crop load levels has a strong negative impact on yield and may reduce overall crop value. Our data indicate there is a optimum crop load each year to maximize crop value. The optimum is often different than growers assume when they hand thin. Our results suggest that chemical blossom thinning in peach could reduce the need for hand thinning significantly 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 for a commercial crop. Thus, to implement chemical blossom thinning in New York will require a method to determine the proper rate and/or timing to reduce the risk of over-thinning.

BIOGRAPHICAL SKETCH

Jason Lee Osborne was born and raised in Brunswick Maine. He attended the University of Maine at Orono and earned his Bachelor's degree in Sustainable Agriculture. During his tenure at the University of Maine, he worked at the Maine Soil Testing and Analytical Laboratory. During summers he worked for Cooperative Extension at the Maine Agricultural Experiment Station at Highmoor Farm where he was an Integrated Pest Management scout for sweet corn, strawberry, and apple. He traveled around the state of Maine for four summers as a satellite employee and visited fruit growers on a weekly basis to monitor pests and diseases on their farms. After graduation he returned to Highmoor Farm to gain some practical farming experience. In the spring of 2000, he accepted a technician position at Cornell University's Hudson Valley Laboratory with Dr. Jim Schupp. After two years in Dr. Schupp's program, Jay moved to Cornell's New York State Agricultural Experiment Station in Geneva as a Research Support Specialist with Dr. Terence Robinson, where he also pursued a Master's degree in Pomology from Cornell University. During these five years in Geneva, Jay enjoyed spending time on his antique wooden Penn Yann boat, "the MonaRay" (a family heirloom) in Seneca Lake, or in the garden when he wasn't working at the Experiment station or attending classes.

To my grandfather,

Rodolphe N. deLorimier

‘Pop’, my love of horticulture started with you, in the garden, at 13 Morse Court in Brunswick, Maine.

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CHAPTER 1

GENERAL INTRODUCTION—LITERATURE REVIEW

Introduction

Many fruit tree species, including peach (*Prunus persica* (L.) Batsch.) annually produce an abundance of flowers that set a surplus of fruitlets which the tree is unable to support to achieve adequate commercial fruit size. Thinning is necessary to adjust the number of fruits (i.e. peaches) on a tree so that the remaining fruits will adequately size for commercial acceptance (Reighard, 2006).

Early competition for carbohydrates due to heavy flowering can compromise fruit size even when the crop load is later adjusted to recommended levels (Stover, 2001). Therefore, the earlier thinning is accomplished the greater the resources available for the remaining fruits. The optimum time to thin is Stage I (Day and DeJong, 1999), which is the period from bloom to pit hardening. Thinning during this period results in greater cell division and expansion of the remaining fruits and leads to good fruit size (Tukey and Einset, 1939). However, the reduction in fruit set and yield is undesirable if increased fruit size does not translate into increased crop dollar value (Reighard, 2006). Since early thinning (stage 1) covers a wide range of days in a fruit's early development period, from flowering to the onset of pit hardening, potential fruit size is lost if thinning is delayed until late in Stage 1 when the source-limited period begins (Grossman and DeJong, 1995).

Crop Load Management

Most modern high-density fruit production systems rely upon intensive crop load management strategies to produce high yields of quality fruit (Whiting et al., 2006). For example apple (*Malus* x *domestica* Borkh.) fruit number per tree is monitored often and adjusted several times throughout a growing season and crop load management strategies are usually multi-tiered. These may include both chemical blossom and post bloom thinners (Byers and Carbaugh, 1990; Dennis, 2000; Westwood, 1993) and hand thinning. In contrast, crop load of many stone fruit species (*Prunus* L.) is managed primarily by hand thinning, although research has shown potential for chemical thinning, especially for peach (Byers and Lyons 1984; Southwick et al. 1996).

Flower and fruit thinning of *Prunus* are commercially practiced in an effort to maximize crop value by optimizing fruit size, color, shape, and quality, to promote return bloom, and to maintain tree growth and structure (Farley 1923; Havis 1962; Byers and Lyons 1984; Webster and Andrews 1986; Byers 1989). Even when properly pruned, fruit trees often set many more fruit than they can adequately size (Byers et al., 1990). Removing excess fruits 50 days after bloom is a standard commercial practice to produce large fruits that bring premium prices. Although hand thinning peach trees is expensive and labor intensive, it is cost effective (Marini, 2002). Chemical sprays to reduce flowers or fruitlets have been well researched and documented in pome fruit for almost 80 years. Bagenal et al. (1925) recognized that chemical sprays applied to control pests increased the drop of immature fruit from a healthy tree. They observed that lime-sulfur induced excessive drop of young apples. According to Williams (1979), the first conscious attempts at chemical elimination of flowers with apples didn't occur until 1934. Some of the spray materials used in that era included copper sulfate, oil emulsion, and zinc sulfate.

Bloom thinning of peach with chemicals is less expensive than hand thinning, but results have been inconsistent (Byers and Marini, 1985). Chemical thinning always carries some risk, as the practice must be completed very early in the season, before the grower can accurately judge crop size or market conditions and before the danger of frost has passed. In addition, some thinning agents may sometimes damage the tree or the surviving fruit. Thinning may also influence various fruit quality factors that affect market grade and value, favorably or unfavorably (e.g., Curry and Greene, 1993; Greene, 1995; Stover et al., 2001).

Crop load is defined as a measure of fruiting density typically expressed as number of fruit per trunk or branch cross-section area, or per tree canopy volume (Stover, 2004). Reducing the crop load before or during bloom maximizes fruit size, while hand thinning becomes less effective for each day after bloom thinning is delayed (Havis, 1962). Typically, the longer unwanted fruits remain on the tree, the greater the negative effect they have on fruit size, tree growth, flower bud differentiation, flower bud hardiness, the next season's crop potential, and tree survival (Shoemaker 1933; Byers and Lyons 1985; Byers et al. 1985; Myers 1986; Byers and Marini 1994).

There is a substantial incentive for growers to reduce cropload to increase fruit size. Large fruit is almost always more valuable than small fruit in the current fresh market. Cline (2006) states there are two major factors in how chemical thinners might influence fruit weight: One is their ability to reduce crop load, which indirectly affects fruit weight by reducing interfruit competition. The second factor is their direct effect on fruit growth (Greene et al., 1990; Wismer et al., 1995). In this case, when chemical thinning is done during the cell division period, it may increase cell division and thereby enhance fruit size.

In most studies, flower or fruit thinning is also reported to increase mean fruit size or to shift the fruit size distribution to the larger size categories. Reducing crop load is also likely to reduce 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 (Stover, 2004).

Fruit size is negatively correlated to the number of fruit per tree (Johnson and Handley, 1989) and positively correlated to leaf area per fruit (Overholser and Claypool, 1931; Weinberger and Cullinan, 1932). Researchers routinely report that a significant crop load reduction is accompanied by an increase in fruit size. In a heavy crop year small fruits are produced which are typically less valuable than larger fruit. Frequently this results in a reduced cumulative value of fruit on unthinned trees (Stover, 2004). Crop regulation in apple can moderate alternate bearing, resulting in more consistent production and improve fruit size as well as increase fruit quality. These factors have made thinning a routine practice in apples, pears, and peaches with growers of these fruits widely recognizing that thinning often increases crop value.

Most research on thinning appears to proceed on the assumption that greater mean fruit size and/or greater crop load reduction are the ultimate goals of fruit thinning (Stover, 2004). In a recent review of economics of fruit thinning, Stover

(2004) reports modern fruit thinning studies focus on the relationships between the thinning agents or combination of agents, thinning parameters such as the rate and timing of the application, and the effects on crop load (a measure of fruit density typically expressed as number of fruit per trunk or branch cross-section area, or per canopy volume), fruit size (expressed by mean weight or diameter), fruit quality, and return bloom. However, in Stover's review he identifies several authors that have taken a more comprehensive approach and he attempts to identify underlying patterns in the economics of thinning by examining the general relationships between fruit size, cropload, yield and crop value.

Forshey and Elfving (1977) collected data from three 'McIntosh' apple orchards: one that was thinned by hand, one thinned with NAA, and one left unthinned. They found that yield was so closely related to crop load and that a single regression line accurately described the relationship for all three orchards. They also reported a negative correlation of fruit size with yield and with crop load, but these relationships were significantly different for each orchard. In the two thinned orchards, fruit size distribution, was significantly altered by moderate thinning with mean fruit weight increased by 9 % to 19 %. However, since the increase in fruit size did not compensate for reductions in fruit numbers, thinning was associated with significant reductions in yield. They concluded that thinning beyond a moderate level was counter-productive and thinning should be limited to the minimum that ensures acceptable fruit size and adequate return bloom. They also noted that reports of an increased percentage of fruit in the larger categories, or a shift in the distribution of fruit size, are misleading and that actual yield in each size category is critical.

Dennis et al. (1983) examined the relationship between fruit size and crop load in 'Starkrimson Delicious' apples. They plotted mean fruit size against crop load in seven orchards and observed a close negative relationship in six of the seven. They noted that in the remaining orchard fruit size was much larger than would be expected from crop load but offered no explanation. The fruit size distribution in relation to crop load in three of these orchards was also plotted and the authors noted that in one of the orchards the crop load was heavy and many fruit were too small for commercial use, in another the crop load was light and increased fruit size did not compensate for low fruit numbers. The third orchard was characterized as ideal in yield and fruit size—however, this was the anomalous orchard noted above in which fruit size was larger than expected. Economic data were not shown for any of the three orchards.

Bergh (1990) developed a regression equation for fruit value/ton as a function of several growth parameters, including mean fruit size and crop load for four apple cultivars, using prevailing price by size for each cultivar. The results were inconsistent. For 'Starking' and 'Granny Smith' apple, mean fruit size was positively correlated with fruit value/ton but there was no significant correlation for 'Golden Delicious' or 'Starkrimson'. Similarly, there was a significant positive correlation between crop load and crop value for 'Starking' but there was a negative correlation with both 'Golden Delicious' and 'Starkrimson'. Graphing the relationship between mean fruit size, crop value, and yield showed that crop value/land area increased to a maximum as yield increased and fruit size decreased; crop value then decreased as yield continued to increase and mean fruit size continued to decrease. That is, there was an optimum crop load and associated fruit size. Crop loads that produced either smaller or larger mean fruit size would therefore result in reduced crop value compared to the optimum crop load. Both 'Golden Delicious' and 'Starkrimson' apple production exhibited this pattern, but an optimum level of production to maximize crop value could not be identified for the other two cultivars, ‘Granny Smith’ and ‘Starking’. The author indicated that it would be difficult to maintain production of these cultivars at higher crop loads than those observed, so the optimum was not likely to be achieved. The actual crop load and fruit size corresponding to maximum crop value depend on the prevailing price for each fruit size category for the cultivar. The effect of thinning on return bloom and consequently the value of the following year’s crop was not included in the analysis.

These three economic studies summarized by Stover (2004) illustrate that the economic effects of fruit thinning can vary widely and successful thinning, resulting in reduced crop load and increased fruit size, and sometimes reduces returns to the grower. Moreover, those studies that have examined the relationship between crop load and crop value suggest that thinning beyond that required to regulate biennial bearing may be excessive and counter-productive, even though fruit size may be substantially increased. Researchers routinely report significant crop load reduction accompanied by an increase in fruit size; the effect on total yield varies, but is generally negative in the year of thinning. 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.

Mechanical Peach Thinning

Historically, crop load of peach trees has been regulated by hand-thinning. In the mid 1900’s mechanical means of thinning were developed. Dennis (2000) reported that “club thinning” is a popular method to thin both peaches and apricots.

Typically, a section of rubber hose is attached to a wooden handle and fruit are knocked from the tree during the pit-hardening stage just prior to final fruit swell. Also, high-pressure water spray guns have been used to knock fruit from the tree. Another mechanical thinning method growers' use is to drag heavy ropes over the trees at the blossom stage, thus removing flowers from the tree. The ropes hang from a frame that is mounted to a tractor and the ropes rotate as they are dragged over the trees. Mechanical trunk or limb shakers have also been used to reduce crop load in stone fruit. Finally, a canopy shaker developed by (Glenn, et al., 1994) which used fiber glass rods (fingers) oscillating in the canopy has shown good potential to remove fruitlets during pit hardening.

Hand Thinning

While hand thinning continues to be the most common commercial method to thin fruit in peach orchards, the high labor cost is also one of the greatest expenses incurred in stone fruit production. Southwick (2000) suggests that even though hand thinning is one of the most expensive aspects of stone fruit production, it is frequently justified by poor returns from small fruit size on trees that are not thinned. In 1995, Southwick and Fritts, reported that hand thinning costs as much as $864.00/ ha in early maturing cling and freestone peaches. Hand thinning is necessary for most commercial peach cultivars.

Moran and Southwick (2000) reported that effective chemical fruit thinning for peaches, as used in apples, would reduce production costs but attempts to develop such methods have had limited success. Furthermore, chemical or mechanical blossom thinning offers the possibility for reducing hand-thinning costs, with potential for greater fruit size or total yield through reducing early competition. Bloom thinning peach trees can result in a 7 to 30 % increase in fruit size and yield when compared to hand thinning fruit 40-50 days after full bloom (Byers, 2002). The major physiological effect of bloom thinning is related to influence on current season's leaf surface and crop load as the fruits compete for photosynthates early in the season. Trees with genotypes that mature earlier in the season produce and set a higher percentage of flowers per tree, or produce smaller fruit usually derive a greater economic benefit from bloom thinning than late maturing benefits (Byers, 2002). Furthermore, Byers (1989) reports that the cost of bloom thinning coupled with hand thinning may result in annual costs similar to hand thinning alone 40-50 days AFB. Nevertheless, bloom thinning which partially reduces crop load before traditional hand thinning may increase crop value one to three times and profits several times over hand thinning alone because of increased fruit size, yield, and price.

Blossom Thinning With Fertilizers

Caustic bloom thinners that damage blossoms and/or pollen offer the advantage of early reallocation of limited photosynthates to fewer fruits (Southwick et al., 1996). Early fruit thinning (from bloom up to 2 weeks before pit hardening) has been demonstrated to reduce the number of small peach fruits at harvest (Farley, 1923) to increase total marketable yield (Havis, 1962), and reduce inter fruit competition for scarce or limited resources (Jackson, 1989). The importance of blossom thinning to maximize fruit size at harvest has been recognized for many years (Havis, 1962). While thinning can be done if thinners are applied anywhere from pink bud stage to full bloom, the greatest response is when applications are made near bloom (Byers and Lyons, 1984).

Chemical blossom thinning may reduce the risk of foliar damage by caustic materials in varieties where leaves emerge after flowers and uneven absorption can contribute to erratic results (Lilleland, 1965). Thinning of blossoms rather than developing fruit maximizes the ability to adjust the fruit-to-leaf ratio, a method particularly desirable in early ripening peach cultivars with a short developmental period and fruit sizing problems (Byers and Lyons, 1984). However, there are disadvantages with blossom thinning. The blossom thinning agents may be phytotoxic at high concentrations and even at concentrations that are not phytotoxic, caustic materials may cause fruit defects such as fruit russeting or dimpling (Williams, 1994). Another disadvantage with blossom thinning is selecting the proper timing of the application. The stage of bloom often varies among trees within an orchard, and even within trees. Timing is critical if successful thinning is to be obtained. Thus, blossom thinning may have a very short window for chemical application which makes application difficult on large acreages while post bloom thinners or fruit thinners can be used successfully over a period of several days or even weeks.

For many decades, horticulturists all over the world have been trying to identify effective peach chemical thinners. In India, Chanana et al. (2002), applied urea, dormex, and the fertilizer ammonium thio-sulfate (ATS) on three low chill peach cultivars to determine efficacy as chemical peach thinners. Dormex or hydrogen cyanamide is not registered for stone fruit blossom thinning but is used to break dormancy where it is usually applied during the dormant period after the chilling requirement is met. At that time it may stimulate flower bud abscission or inhibit flower opening (Byers, 2000). Maximum thinning of 44% was induced by the highest concentration of Dormex (0.05%) in 'Shan-I-Punjab' cultivar and by urea (8%) and ATS (4%) in 'Partap' when applied at full bloom. Maximum increase in fruit weight

(35%) was observed with Dormex 0.50% followed by urea (12%) and ATS (6%). In addition to increased thinning, Chanana et al. (2002) also reported advanced maturity and improvement in fruit weight and fruit quality by the use of urea and ATS. The authors suggest that this may be due to the fact that pedicel attachment of the flowers gets desiccated by the chemicals, and if applied at full bloom they inhibit the fertilization of ovules, resulting in decreased number of fruits and increased leaf/fruit ratio, thereby making more photosynthates available to remaining fruits.

In Massachusetts, Greene et al. (2001) conducted a blossom thinning trial evaluating ATS, Wilthin, and Endothal on ‘Red Haven’ and ‘Garnet Beauty’ peach for three consecutive years. In 1997, they reported Endothal and ATS increased fruit weight and diameter at harvest, whereas Wilthin increased fruit diameter only at the highest rate. In 1998, they found that all treatments generally reduced initial set and reduced subsequent hand thinning required to reduce crop load to a commercially acceptable level. However, when analyzed separately, Wilthin was without effect while ATS and Endothal showed modest reductions in initial set and hand thinning requirements. In their 1999 experiment, blossom-thinning treatments significantly reduced initial fruit set and the subsequent number of fruit that were removed by hand thinning. The response was highly significant for all treatments as well as linear and highly significant for Wilthin and ATS. Only ATS reduced final fruit set. However, all blossom thinners increased fruit weight and fruit diameter at harvest. ATS increased fruit weight and diameter most dramatically, Endothal was intermediate, while Wilthin had the smallest effect, which was significant only at the highest rate used. Their results suggest that application timing may influence the thinner response. The best thinning results were obtained in 1999 when treatments were applied when blossoms were 65% to 80% open rather than near 95% in 1997 and 1998. They suggest that if flowers open over a several day period there may be ample opportunity for pollination and significant pollen tube growth of many flowers, before thinner applications are made at or near bloom. Byers (1999) found effective timing for ATS was when 70-90% of the flowers had opened.

In addition to a reduction in fruit set and maximizing fruit size at harvest, Greene et al. (2001), observed a reduction in subsequent hand thinning between 50% to 80%. This reduction in hand thinning following a successful blossom-thinning spray can be a significant savings in cost of labor. In general, it took investigators about one hour to hand thin a control tree which they calculated would cost $1982/ha ($802/acre) with a labor cost of $7.50/h and a tree density of 264 trees/ha which is an average density for the region. A 50% to 80% reduction in hand thinning would result in savings to the grower of $991 - $1585/ ha ($401 to $642/ acre).

Sanderson (1998) compared ammonium thio-sulfate (ATS), Wilthin, and Endothal on stone fruits and reported that ATS was the best blossom thinner under Washington conditions. However, ATS applications resulted in production of some small fruit that remained on the tree and did not abscise.

Blossom Thinning with Fish Oil Lime Sulfur

Lime sulfur (LS) is frequently used as a bloom-thinning agent in organic apple production in countries where its use is permitted, and is increasingly being used in non-organic production systems for the same purpose (McArtney 2006). Coneva and Cline (2006) reported that lime sulfur is also efficacious in reducing the set of peaches and apples. Currently the mode of action of LS as a thinning agent is not known.

Sulfur sprays have been reported to reduce pollen grain germination (MacDaniels and Furr, 1930) and pollen tube growth (He and Wetzstein, 1994). Sulfur may also reduce or suppress photosynthesis in apple leaves (Hoffman, 1935; Hyre 1939), and it has been proposed by Noordijk and Schupp (2003) that post bloom LS applications thin apple fruit by inhibiting Pn and decreasing assimilate supply to developing fruit. Palmer et al. (2003) have recently shown that LS (3%) or sulfur fungicide over the whole season can reduce Pn of 'Braeburn' apple by almost 50% in mid-summer.

One critical consideration when evaluating blossom thinners is the potential phytotoxic effects on foliage and fruits. For example, Cline (2004) reported severe leaf injury within 1 week of treatment application to 'Harrow Diamond' peach. The phytotoxic response was for ATS was greater than for LS, especially at the rate of 30 $ml \cdot L^{-1}$. LS applications of 40 $ml \cdot L^{-1}$ were not phytotoxic. Guak et al. (2004) observed that a 4% LS application to apple had less leaf burn in comparison with 1.6% ATS on 'Fuji' and 'Gala' apple. Cline (2003) explained that the significant leaf phytotoxicity observed in 'Harrow Diamond' peach might be most likely a result of over spraying from the handgun application. Cline (2003) reports that this result is consistent with Byers (2003) observation that hand spray gun applications of 1170 L/ha almost defruited trees, whereas air-blast sprayer applications at the same water volume resulted in the desired crop load. Some researchers (Dennis and Hull, 2003; Lilleland, 1965) maintain that some species such as *Prunus* in which leaf development occurs after flower opening, are less affected by foliar damage incited by caustic bloom thinners in comparison with species such as apple, in which leaf development occurs before flowering. Cline (2003) explained, another reason for the greater leaf phytotoxicity to 'Harrow Diamond' peach trees in his experiment in 2003 was due to bloom occurring about 30 days later than average. At that time shoot length had expanded to about 6 cm, providing sufficient leaf area for leaves to become exposed to the spray compound, whereas typically the blossom period for peaches coincides with little or no leaf development. Cline (2003) concluded, that the phenological state of the leaves and flowers can greatly influence their response to chemical blossom thinners.

Fallahi et al. (2006) reported that emulsified fish oil (FO) has recently been researched as a thinner on peaches, apples, and sweet cherry (Fallahi, 2006; Robinson et al., unpublished; Whiting et al., 2006) and when combined with LS provides greater thinning efficacy (J. McFerson, personal communication). Fallahi (2006) has investigated the effects of Fish Oil on the efficacy of thinning several peach cultivars and observed that 30 $ml \cdot L^{-1}$ FO reduced peach fruit set in 'Elberta' but not in 'August Lady'. However, fruit size was unaffected by FO in either cultivar. In addition, they also reported that a double application of FO and lime sulfur did not significantly affect fruit set, yield, or fruit quality in 'July Red' nectarine. Most recently, Whiting et al. (2006) reported that fish oil-lime sulfur (FOLS) combination has been the most consistent material in sweet cherry blossom thinning in the last four years of testing. Whiting et al. (2006) theorize that the FOLS combination acts predominantly on the leaves because of the material being adsorbed by the leaf tissue and interferes with photosynthesis.

Blossom Thinning with Surfactants

Several surfactants have been found to have thinning effects when sprayed during bloom. Wilthin (monocarbamide dihydrogen sulfate or sulfcarbamide) has been used for blossom thinning in stone fruit, including peaches (Fallahi, 1997;

Greene et al., 2001; Sanderson, 1998) and plums (Fallahi, 1998). Southwick (1998) reported that Wilthin and other surfactants have produced inconsistent thinning effects. For example, Wilthin treatments were less effective in 1996, in comparison with 1997. In 1996, fruit set, fruit diameter, number of fruits thinned, and salable yield were unaffected by Wilthin treatments at either the 14 L or 21 L /ha rate. However, in 1997, Wilthin over thinned at both rates. Southwick et al. (1998) reported that at treatment time in 1996, many buds had just begun growth and flowers were unopened, with bloom development highly variable from tree-to-tree and within the canopy, reducing the potential efficiency of a bloom thinner applied at a single time. Southwick (1998) reported, that in order for blossom thinners to be effective, flower buds must have opened and flowers must be at an advanced stage of anthesis, with the greatest effectiveness achieved when a maximum number of flowers are at the same bloom stage. In cases of protracted bloom, Southwick suggests a split application of bloom thinners may be preferable in order to affect sufficient flowers at sensitive bloom stages. Further study of which bloom stages are most susceptible to an individual chemical thinner is needed.

Most recently a surfactant named Tergitol-TMN-6 (2,6,8-trimethyl-4-nonyloxypolyethyleneoxyethanol) has been reported to be an effective blossom thinner of peach, nectarine, and plum (Fallahi, 2006). Wilkins et al. (2004) reported that Tergitol effectively reduced fruit set in 'Fireprince' peach. In that report, there was no difference in thinning response at full bloom or petal fall, suggesting a wide window of efficacy for this chemical. However, Fallahi et al. (2006) reported that applications of Tergitol at bloom were more effective than application after bloom. Fallahi (2006) suggests that the optimum stage for spraying Tergitol is when about 75% to 80% of blooms are open, and when reasonably good pollination and fertilization conditions exist before application. They also reported that a double application of Tergitol-TMN-6 at 35% and 80% to 85% open bloom was also effective in thinning and seemed to be slightly better than a single application. In addition, it also seems that higher concentrations of Tergtitol-TMN-6 are needed when the percentage of open blooms is high (i.e. 85%-100%). Fallahi (2006) concluded that the effective rates for Tergitol-TMN-6 for stone fruit blossom thinning are between 5 $mL \cdot L^{-1}$ and 12.5 $mL \cdot L^{-1}$.

Dormant Flower Bud Thinning with Oil

In the past 10 years, soybean oil has received considerable attention as a potential peach flower bud thinner. In 1935, Farrar and Kelley reported that applications of 8% petroleum oil resulted in a retardation of apple bloom and bud break. Call and Seeley (1989) reported that petroleum oil applied at the end of endodormancy delayed flower bud development, increased cold hardiness, and delayed peach bloom by 5 days. Deyton et al. (1992) reported that application of 6 to 12% petroleum oil delayed peach bloom but caused bud death at higher concentrations.

In addition to delaying bloom, soybean oil (SO) applied pre-bloom to dormant trees has caused thinning of peach flower buds (Deyton et al., 1992; Meyers et al., 1996; Moran et al., 2000, Reighard et al., 2006). Meyers et al. (1996) tested the effect of applying soybean oil to dormant peach buds to determine if oil affects shoot respiration, internal concentrations of CO_2 and O_2, flower bud development, time of anthesis, or flower bud death. Three-year-old ‘Redhaven’ trees were sprayed 62 days before bloom with a single application of 0%, 2.5%, 5%, 10%, 15%, or 20%

degummed soybean oil with 0.6% Latron AG 44M emulsifier. Repeated applications of 2.5 % or 5% degummed soybean oil were also applied to trees 48 days before bloom. They found that the internal CO_2 concentration of shoots from trees treated with 2.5 % crude soybean oil was at least 33% higher than that of untreated shoots on the first and third day after treatment. The CO_2 concentrations of shoots treated with 5% to 20% crude soybean oil were more than double the untreated shoots on the third day after treatment. However, they detected no consistent effect of crude soybean oil on 0_2 concentrations within shoots. Thus, the enclosure of shoots with soybean oil appears to affect CO_2 levels more than O_2 levels, implying that the oil may act as a film to restrict diffusion of CO_2 but with micro pores that allow more diffusion of O_2 than CO_2 (Robertson, 1993). The interference with diffusion of CO_2 out of shoots probably results in the elevated internal concentrations. The principal effect of increased CO_2 in plant tissue is inhibition of the reversible decarboxylation reactions of the respiratory systems (Isenberg, 1979).

Meyers et al. (1996) also reported that soybean oil caused damage to flower buds. They observed browning of anthers and pistils two weeks after treatment. Moreover, viable flower bud density decreased with increased soybean oil concentration. Finally, dormant sprays of soybean oil modified internal CO_2 concentration of peach shoots and reduced respiration. This could result in a controlled atmosphere (CA) like condition within the oil-enveloped shoots. Flower bud development was delayed and bloom was delayed by 6 days.

Moran et al. (2000) evaluated soybean oil as a dormant bud thinning agent in Arkansas. In 1997, soybean oil was applied at a rate of 6 %, 8 %, 10 %, and 12 % to 6-year-old ‘Redhaven’ peach trees on Lovell rootstock. Soybean oil thinned fruit buds in all experiments in all years. However, Moran (2000) explained that year-to-year variability occurred in the amount of bud thinning and was partially due to factors other than soybean oil, such as cold injury. In 1992, bud death on untreated trees was negligible so soybean oil resulted in bud loss ≥ 53%. However, in 1993, bud death was 42% on untreated trees, and bud loss with soybean oil thinning was as high as 92%. Flower bud death due to the soybean oil alone was concentration dependent.

In 1997, Moran et al. reported that when a mild freeze (-4° C) occurred during the blossom period, untreated control trees were at petal fall but soybean oil treated trees sprayed at a concentration of 10-12% still had ≈ 80 % to 90 % of the flowers open. Although soybean oil had killed ≈ 50 % of the flower buds before bloom, the remaining buds were hardier than those from control trees. The survival of remaining buds increased significantly with increasing soybean oil, and more than 95% of the remaining flowers survived the freeze. In contrast, only about 65% of flowers from untreated trees survived.

Moran, et al. (2000) also found that dormant oil applications reduced the need for follow-up hand thinning. The time required for hand thinning was reduced 40 to 80% by applications of 8 to 12% oil. Soybean oil at 10 to 12% required little or no follow up hand thinning. This reduction was similar to that obtained with other thinning agents, such as rope thinning (Baugher et al., 1991), gibberellin applications (Southwick et al., 1995), or caustic bloom thinners (Zilkah et al., 1988). The advantages of soybean oil are similar to those of gibberellin (Southwick et al., 1995), which include a wide window of timing, bloom delay, minimal toxicity to mammals, no fruit phytotoxicity or fruit blemishes, low cost, and earlier fruit maturity. Bloom thinners, have a narrow window in which they can be used, unlike soybean oil, which can be applied during a period of several weeks (Moran et al., 2000). However, when a significant number of flower buds have been damaged by a previous freeze, spraying 10% or 12 % oil may overthin the fruit.

Moran, et al. (2000) also reported that thinning with soybean oil was fairly consistent from year-to-year (34%-51%) when 10% of soybean oil was applied, but was less consistent (6%-40%) when 5% oil was applied. Fruit clustering was observed to be greatest in untreated trees and decreased with the degree of thinning. Clustered fruit are undesirable since they can have reduced fruit size and increased incidence of disease (Southwick et al., 1995), such as *Sclerotinia* (brown rot).

These studies suggest that the use of high rates of soybean oil may be a viable commercial method to thin peach flower buds. Soybean oil is inexpensive is exempted from normal Environmental Protection Agency (EPA) registration because it is a relatively non-toxic, is a common food constituent, is not persistent in the environment, and has no significant adverse effects on the environment (U.S. Congress, 1996).

Reducing Flower Initiation With Gibberellic Acid

Gibberillic acid (GA) is thought to inhibit flower bud development during the flower inductive period (late May through July in stone fruit) (Southwick, 2000). GA3 has been researched the most. However, Southwick (2000) compared several other GA's. GA3, GA4, and GA7 were applied at 30 and 60 mg · L^{-1} on three dates from 8 May to 8 June, to determine the relative efficacy in reducing flowering of the apricot variety ‘Royal Blenheim’. They found that only GA_4 at 60 mg · L^{-1} applied on

20 May significantly reduced flowering the following year. On one date, both concentrations of GA_7 increased flowering and on two dates the low rate of GA_3 increased flowering.

The timing of GA application has also been investigated. Painter and Stembridge (1972) found GA significantly reduced flowering when applied at two timings: 1) peach flower initiation and 2) just before leaf fall. This work suggests that GA may affect other processes other than flower initiation. Stembridge (1969) earlier reported that October applications of GA resulted in delayed bloom the following season and proposed that this may be due to a delay in the development of flower buds. Clanet and Salles (1976) observed GA effects after flower induction, during the differentiation period, which included delayed floral differentiation and bloom without affecting flower number. Southwick (1995) applied GA on ‘Patterson’ apricot and observed flower reductions when sprays were applied in late May through early July (about two weeks after harvest). Sprays applied in August did not reduce subsequent flower number, however, the early August sprays did delay full bloom date. The spray timings of late May through early June were most effective in reducing subsequent flower numbers on apricot but late June sprays were not effective.

In 1995, Southwick evaluated effects of GA concentrations for reducing flower numbers on both peach and apricot. Treatments ranged from 10 to 1000 $mg \cdot L^{-1}$ on ‘Patterson’ apricot and 50 to 120 $mg \cdot L^{-1}$ on ‘Loadel’ cling peach. The most effective concentrations for consistent flower reduction without over-thinning were 50 to 100 $mg \cdot L^{-1}$ and risk of over-thinning was reduced not exceeding 75 $mg \cdot L^{-1}$. The concentrations of 50 to 75 $mg \cdot L^{-1}$, never gave overthinning and fruit set was never increased, therefore the need for hand thinning was reduced in more than 70% of applications within the sensitive time period. Only when very high GA concentrations have been sprayed and where flower numbers were reduced drastically has fruit set been increased or sometimes reduced. Finally, lower GA concentrations appear to be more effective when applied during a period of greater sensitivity to GA application (Southwick et al., 1995).

To properly time GA sprays, the period of flower induction and differentiation must be known or determined for each species or cultivar. There are several factors that can modify shoot growth at the time of flower differentiation in perennial fruit species, including light (Grant and Ryugo, 1984), climate, irrigation regime, (Bustamante-Garcia, 1979), nutrient status, (Weinbaum et al., 1980), rootstock, and pruning, (Rom and Feree, 1984). Southwick (2000) suggests that finding an appropriate GA concentration and spray timing for adequate flower reduction may be difficult from season to season and among cultivars.

Southwick compared GA concentration (dose) and spray timing effects on freestone and cling peach varieties of different maturity dates. The three cultivars included: 'Loadel', an early maturing processing peach, 'Andross' a mid-season peach, and 'Ross' a late season cultivar. The rate of GA applied was 75 and 100 mg · L^{-1} on 15 July and 29 July 1998. The second application was applied immediately after 'Loadel' harvest, with 'Andross' and 'Ross' harvested 2 and 3 weeks later, respectively. GA reduced flowering on all tested cultivars, but flower reduction in 'Ross' was much greater following the later application and showed greater rate responsiveness. The results were consistent with later floral induction and initiation in the late-maturing 'Ross', than earlier cultivars such as 'Loadel' and 'Andross'. This is consistent with the theory that GA sensitivity is somewhat time and cultivar specific, depending on timing of meristematic activity or sensitivity in floral buds (Southwick et al., 1999).

Southwick (1995) found that the flower reduction induced by GA sprays generally led to larger fruit at thinning time, a reduction in the need to hand thin, and in some cases, no hand thinning was required. Often fruit size on GA treated trees was as great as on hand-thinned trees with equivalent yields per tree. In some cases, GA treated trees had greater yield than hand thinned trees with similar size.

GA has also been proven to be a consistent and reliable thinner. In experiments with 'Patterson' apricot over three consecutive seasons, Southwick (1997) reported that flowering was consistently reduced in the first 2 years by sprays of GA at 50 mg $\cdot$ L^{-1} applied in early June. However, in the third season, insufficient chilling occurred and low numbers of viable flowers resulted. However, the 50 mg $\cdot$ L^{-1} GA spray applied in early June did not reduce flowering more than the untreated control. This is contrary to the fear of some stone fruit growers that sprays of GA will reduce flower number below that on untreated trees which lack chilling and thus have reduced flower bud numbers.

Conclusion

A number of concerns impede the widespread commercial use of stone fruit blossom thinners mentioned in this literature review. Many growers and researchers 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 early 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.

The advantages to blossom thinning are well documented in the literature, caustic bloom thinners that cause damage to blossoms and pollen offer the advantage of early reallocation of limited photosynthates to fewer sinks (Southwick et al., 1996). Early fruit thinning (from bloom up to 2 weeks before pit hardening) has been demonstrated to reduce the number of small peach fruits at harvest (Farley, 1923), to increase total yield (Havis, 1962), and to reduce inter-fruit competition for limited resources (Jackson, 1989). While thinning can be done if thinners are applied anywhere from pink to full bloom, the greatest response is when applications are made near bloom (Byers and Lyons, 1984). Finally, bloom thinning can maximize the tree's capacity to allocate sufficient resources to developing fruit when the leaf-to-fruit ratio is increased early in the growing season (Southwick, 1996).

The ability of blossom thinners to reduce hand labor costs is also noteworthy. In 1998, Greene et al. reported that all bloom thinning treatments generally reduced initial set and hand thinning required to reduce crop load to a commercially acceptable level. They reported a reduction in hand thinning between 50% and 80%. Moran and Southwick, (2000) also reported that dormant oil applications (8 to 12% soybean oil) also reduced the time required for hand thinning from 40% to 80%.

Urea and ammonium thio-sulfate (ATS) liquid fertilizer formulations have been found to be effective blossom thinners in peach. The use of ATS as a blossom thinner in stone and pome fruit has been commercially practiced without registration in peach and apple orchards in the United States. ATS is one of the most effective thinners and easiest to use because it formulated as a liquid (Byers, 2003). Soybean oil also has great potential as a stone fruit thinner. Although currently not registered, registration would probably be quick because soybean oil is exempted from EPA registration 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).

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CHAPTER 2

CHEMICAL BLOSSOM THINNING INCREASES FRUIT SIZE AND CROP VALUE OF 'RISING STAR' PEACH

Abstract

In 2004, we conducted a chemical thinning field study at Appleton NY on five-year-old 'Rising Star' peach trees (*Prunus persica* L. Batsch) on Lovell rootstock. Treatments included Soybean oil (SO) or horticultural/petroleum oil applied (PO) at (8%) approximately 30 days before bud break. Ammonium thio-sulfate (ATS) (3.5%, 5.0%), Lime sulfur (LS) (1%, 3%) plus Crocker's fish oil (FO) (2%), and Wilthin (0.3%) were applied at full bloom and the grower standard hand thinning treatment at 45 DAFB. Trees treated with thinning agents were not given supplemental hand thinning.

The high rate of ATS, (5.0%) and Wilthin (0.3%) had the greatest thinning effect and reduced fruit set by 55% and 61%, respectively, compared to the untreated control. The high rate of ATS (5%) also increased fruit size 25% but reduced yield by 45%. Soybean and petroleum oil treatments did not significantly reduce fruit set. Lime sulfur plus fish oil (LS+FO) treatments 1% and 3% also did not significantly reduce fruit set. Although the high rate of ATS and Wilthin treatments resulted in a greater proportion of the crop sorting into 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.

Introduction

In New York State, peaches are a minor crop, however, they are a high value crop for New York tree fruit growers and provide diversity in their production systems. Hand thinning at 45 DAFB is the main practice that is used to adjust crop load. Partial crop thinning by chemical blossom thinners has tremendous potential to minimize high hand labor costs, increase fruit size, and improve overall crop value. The objective of this study was to evaluate several blossom thinning chemicals for efficacy in New York State.

Material and Methods

Plant material

Five-year- old 'Rising Star' peach trees on 'Lovell' seedling (*P. persica*) rootstock were selected from a commercial peach orchard in Niagara County, in western New York State. Trees were planted at a spacing of 3.1 x 5.5 m or 10 x 18 ft. with a tree density of 598 trees per hectare or 242 trees per acre. Trees were trained to an open vase shape and were moderately pruned at the pink bud stage. Trees were mature bearing trees and were approximately 2.5 meters tall by 3.5 meters wide and were generally healthy trees with adequate vigor.

Experimental design

A randomized complete block design with 9 treatments and 6 replications was used in the study for a total of 54 test trees. Each plot consisted of 3 trees with the center tree used for data collection.

Treatments

Treatments were applied by an air-blast sprayer at a spray volume of 935 L/ ha or 100 gallons per acre except soybean and horticultural oil which were applied at 1870 L/ha or 200 gallons per acre. The 9 treatments were: 1) untreated control, 2) hand-thin at 45 days after full bloom, 3) Soybean oil (SO) (8%) plus an emulsifier Latron B 1956 (0.8%) applied at 25 days before full bloom, 4) Horticultural oil (HO) (8%) applied 25 days before bloom, 5) Lime sulfur (LS) (1%) plus Crocker's Fish Oil (FO) (2%) applied at 90% bloom, 6) Lime sulfur (3%) plus Crocker's Fish Oil (2%) 90% bloom, 7) ATS (3.5%) applied at 90% bloom, 8) ATS (5 %) applied at 90% bloom, 9) Wilthin (0.3%) + Regulaid (0.05%) applied at 90% bloom.

Measurements

Trunk circumference measurements were taken at 30 cm above the soil and used to calculate trunk cross sectional area (TCA). Two limbs per tree were selected at pink bud stage and the flowers were counted. Persisting fruit were counted 45 days after bloom. Fruit set was expressed as percentage of flowers, which developed into persisting fruits. A phytotoxicity rating scale was developed to quantify foliar injury which was assessed one week after blossom thinners were applied. A four point scale was used; 1) no leaf burn injury observed; 2) slight or marginal leaf burn; 3) moderate leaf burn; 4) severe leaf burn. Fruits were harvested in 2 harvests when mature. At each harvest, fruits were counted and weighed. Total yield was calculated by summing harvested weight of each data tree over two harvests. A sample of fifty fruits were collected from both harvests and evaluated for size and red color using a commercial MAF RODA Pomone fruit grader. Four size categories were used to sort the fruit. The size category that were used are as follows; 120 box size or a 2.75 inch peach, 140 box size or a 2.5 inch peach, 160 box size or a 2.25 inch peach, and a cull category in which all fruits that are not equal to or larger than 2.25 inches fall into this category. 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 $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.

Statistical Analysis

Data were analyzed by ANOVA using SAS Proc GLM (SAS Institute, Cary, NC). Significant differences among means were determined by LSD, ($P \leq 0.05$). The effect of treatment on fruit size independent of crop load was determined by adjusting fruit size for crop load (Stover et al., 2001). Rate responses of ATS or LS+FO were determined by regression analysis.

Results

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 2.1). 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%).

Regression analyses of both ATS and LS+FO rate responses indicated that there were no significant differences in fruit set.

Table 2.1 Effect of chemical thinning agents on percent fruit set, crop load, and fruit number of 'Rising Star' peach.

Treatment	Fruit Set (%)	Crop Load (fruit/cm^2 LCA)	Fruit Number / Tree
Untreated control	18.1 ab	10.3 a	695 a
Hand thin 45 DAFB	18.0 ab	6.1 cd	415 cd
Soybean oil (8%)	22.2 a	8.8 ab	596 ab
Petroleum oil (8%)	17.6 ab	6.6 bc	449 bc
LS (1%) + FO (2%)	17.5 ab	7.3 bc	493 bc
LS (3%) + FO (2%)	17.5 ab	6.8 bc	459 bc
ATS (3.5%)	17.6 ab	6.5 bc	444 bc
ATS (5.0%)	13.5 bc	3.9 d	267 d
Wilthin 2.8 L	11.4 c	5.3 cd	361 cd
Regression analyses			
ATS rate response	NS	L	L
LS+FO rate response	NS	L	L

[y] Means followed by the same letter are not significantly different using LSD. $P \leq 0.05$, n=6.

Treatment effects of blossom thinners on crop load were highly significant and ranged from a low of 3.9 (ATS 5%) to 10.3 (control) fruits per cm^2 limb cross-sectional area (Table 2.1). Petroleum oil, both rates of LS+FO (1, 3%), and the low rate of ATS (3.5%) had statistically similar crop loads ranging between 6.5 and 7.3

fruits per cm^2. The hand thin treatment at 45 DAFB treatment had a crop load similar to Wilthin (0.3%) (6.1 and 5.3 fruits cm^2 respectively). Soybean oil treated trees carried a moderately heavy crop load of 8.8 fruits per cm^2.

Regression analyses of both ATS and LS+FO rate responses indicated that there was a significant negative linear relationship between rate of blossom thinner and crop load.

ATS (5%) caused the greatest reduction in total fruit number to an average of 267 fruits/tree (Table 2.2). The unthinned control trees had an average fruit number of 695. Soybean oil (8%) treatment was not different than the unthinned control with an average fruit number of 596 fruits per tree. Petroleum oil, LS+FO (1, 3%), and ATS (3.5%) treatments had lower fruit numbers and were statistically similar ranging from 443 to 493 fruits per tree. The hand thinned treatment and Wilthin (0.3%) were statistically comparable at 415 and 361 fruits per tree. Total fruit number plotted against yield (Figure 2.1) illustrates a positive linear relationship; yield increases as total fruit number increases.

Regression analyses of both ATS and LS+FO rate responses indicated that there was a significant linear relationship between rate of blossom thinner and fruit number.

Untreated control trees had the highest yield producing 37.3 tons per hectare or 754 bu. per acre; followed by Soybean oil, yielding 33.9 tons per hectare or 686 bu. per acre (Table 2.2). Hand thinning at 45 DAFB and Wilthin (0.3%) had similar yields (25.9 and 23.2 t/ha or 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 26.9 and 28.8 t/ha or 543 and 597 bu/acre. ATS (5%) severely over thinned and thus produced the

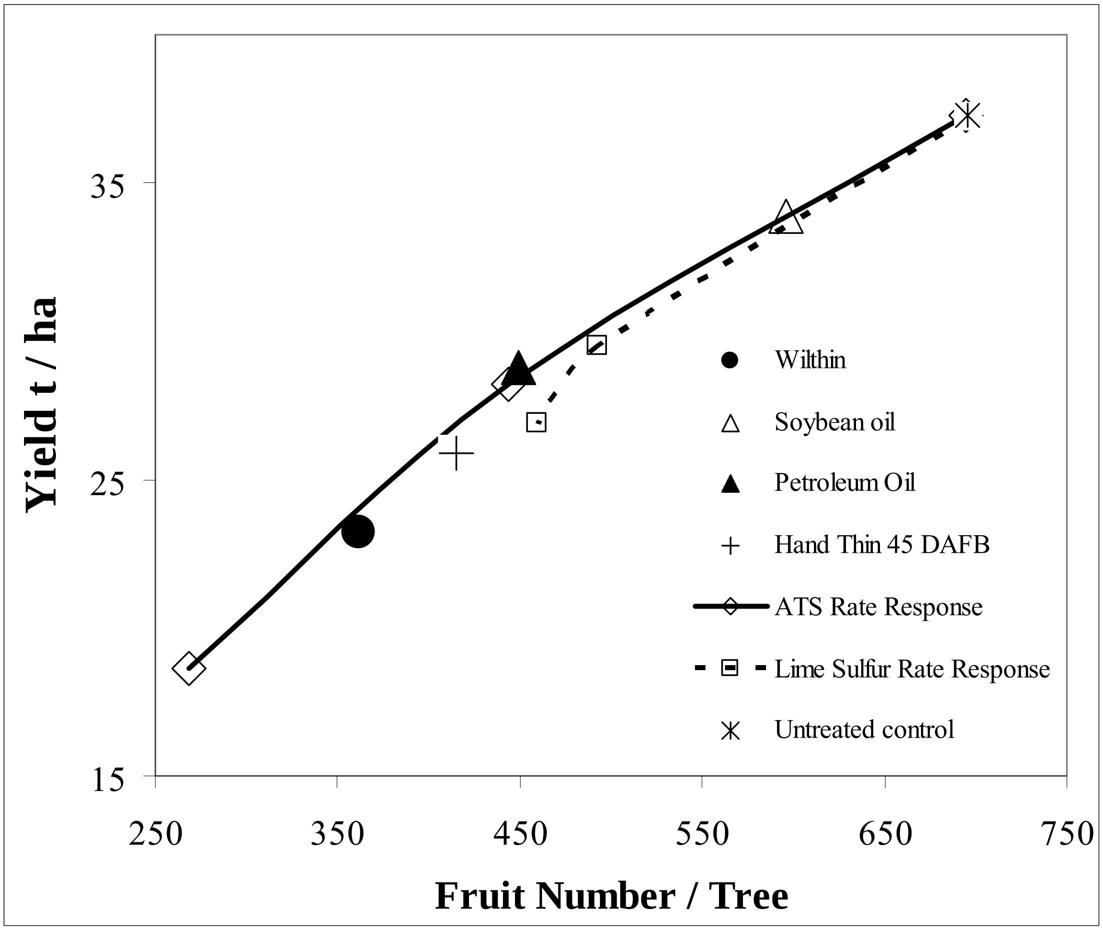

Figure 2.1 Relationship between fruit number per tree and yield /ha of 'Rising Star' peach.

lowest yield of 18.6 t/ha and 376 bu./acre. The Wilthin treatment had significantly higher yield than the high rate of ATS (5%) producing 23.2 tons per hectare or 469 bushels to the acre.

Regression analyses of both ATS and LS+FO rate responses indicated that there was a significant linear relationship between rate of blossom thinner and yield.

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 (Table 2.1). Untreated control trees had an average fruit size was 91 grams. 'Rising Star' peach is an early to mid-season cultivar and is typically small in size (Jim Bitner, personal communication). 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).

Table 2.2 Effect of chemical thinning agents on yield, fruit size, and crop load adjusted fruit size of 'Rising Star' peach.

Treatment	Yield (t/ ha)	Fruit Size (g)	Crop load Adjusted Fruit Size (g)
Untreated control	37.3 a	90.9 c	105.7 ab
Hand thin 45 DAFB	25.9 cd	106.7 ab	102.8 ab
Soybean oil (8%)	33.9 ab	100.0 bc	108.1 a
Petroleum oil (8%)	28.8 bc	107.6 ab	106.0 ab
LS (1%) + FO (2%)	29.5 bc	100.8 bc	102.0 ab
LS (3%) + FO (2%)	26.9 bc	100.4 bc	99.5 b
ATS (3.5%)	28.2 bc	106.4 ab	104.5 ab
ATS (5.0%)	18.6 d	119.4 a	105.7 ab
Wilthin 2.8 L	23.2 cd	112.1 ab	104.6 ab
Regression analyses			
ATS rate response	L	L	NS
LS+FO rate response	L	NS	NS

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

Regression analysis of ATS rate responses indicated that there was a significant linear relationship between rate of blossom thinner and fruit size. Regression analysis of LS+FO rate response was found to be not significant.

There was a negative linear relationship between fruit size and crop load (Figure 2.2). ATS (5%) resulted in the largest fruit size and the lowest crop load while the unthinned control had the smallest fruit size and the greatest crop load. Petroleum oil, ATS (3.5%) and hand thinning at 45 DAFB, had similar fruit sizes, however the blossom thinning treatments carried heavier crop loads. Also, both rates of LS+FO

(1,3%) had smaller fruit size than expected from their crop loads (treatments means lie below the thinner vs. crop load response curve).

The strong relationship between crop load and fruit size required that crop load be used as a covariate to determine the effect of the chemical thinners on fruit size independent of the crop load effect (Figure 2.2)

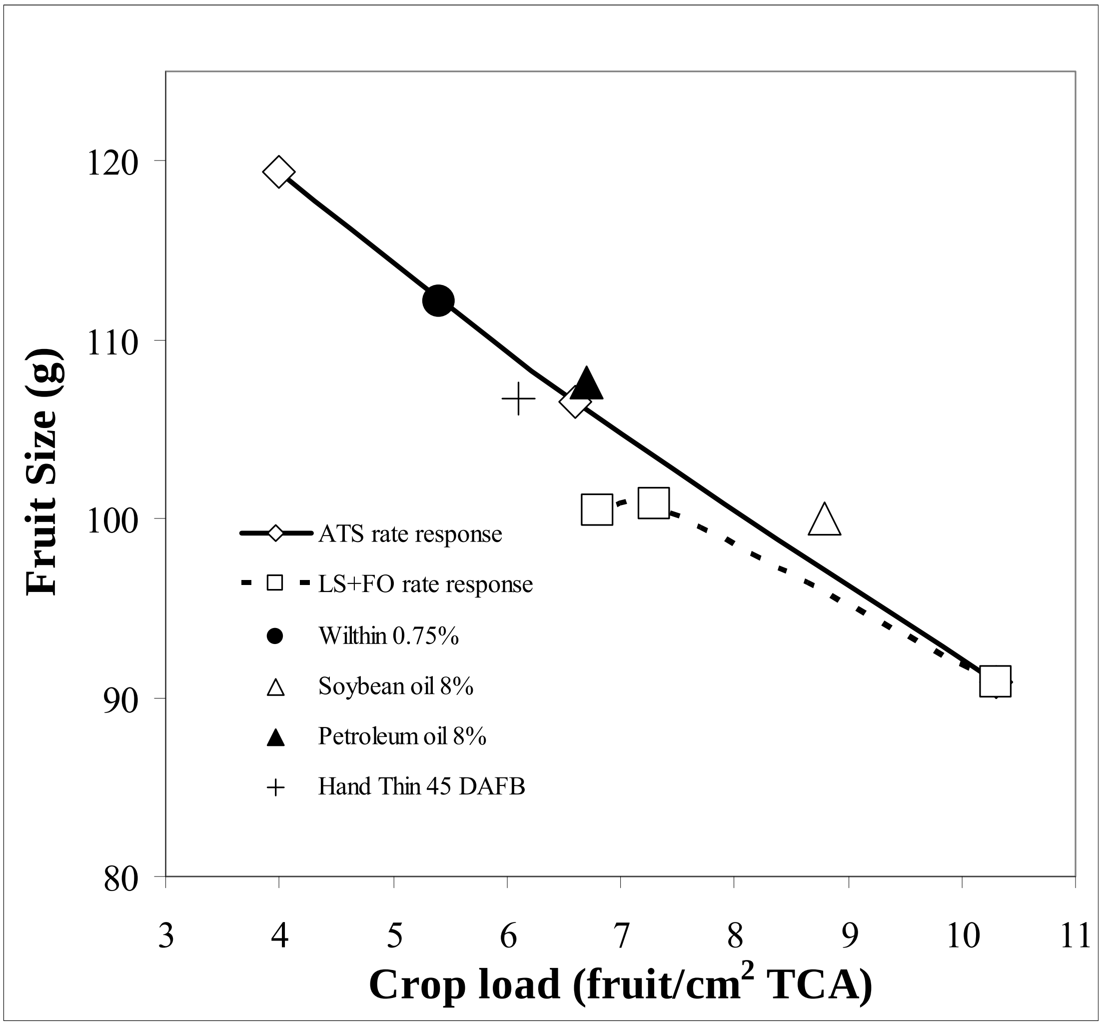

Figure 2.2 Effect of crop load and chemical thinning agents on fruit size of 'Rising Star' peach.

After covariate analysis, the high rate of LS (3%)+FO significantly reduced crop load adjusted fruit size (99.5 g), whereas Soybean oil significantly improved crop load adjusted fruit size (108 g) (Table 2.2). The remainder of the treatments had similar crop load adjusted fruit size which varied between 102 and 106 grams.

Crop load adjusted fruit size plotted against crop load also illustrates that LS+FO treatments have a significant negative effect of fruit size since the means fell below the response curve of adjusted fruit size and crop load (Figure 2.3). The hand thin 45 DAFB treatment mean also fell under the response curve. While this treatment was effective at reducing crop load, it suggests that the earlier thinning by the blossom thinners were slightly more effective at increasing fruit size independent of crop load.

Regression analyses of both ATS and LS+FO rate responses indicated that there was a no significant difference in fruit size adjusted for crop load (Table 2.3).

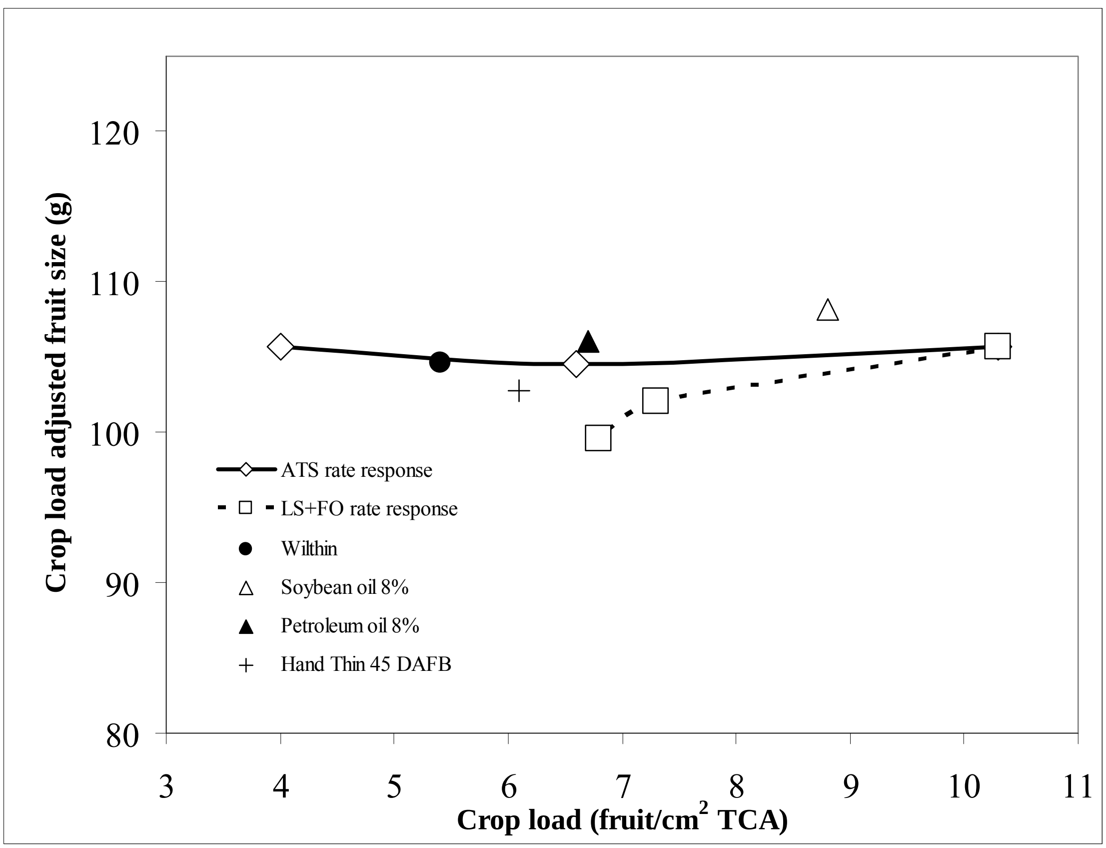

Figure 2.3 Effect of crop load and chemical thinning agents on fruit size adjusted for crop load on 'Rising Star' peach.

Fruit size when evaluated by box size category showed that in the largest fruit size category (120 box size) there were no significant difference among the treatments; however, Soybean oil, ATS (5%) and Wilthin produced l.1, 0.9, and 0.8 t/ha in this fruit size category (Table 2.3). The remainder of the treatments produced less than 0.6 t/ha in this box size.

Petroleum oil produced the greatest yield of the next largest box size category (140's) with 6.9 tons per hectare (Table 2.3). Untreated control, Soybean oil, LS+FO (1%), ATS (3.5%), and Wilthin produced between 4.4 and 6.4 tons per hectare in the 140 box size category.

The two treatments with the greatest number of fruit in the 160 box size category were LS+FO (3%) and ATS (3.5 %) producing 16.6 and 16.3 tons per hectare (Table 2.3). Untreated control, hand thin at 45 DAFB, Soybean oil, Petroleum oil, and LS+FO (1%) yielded between 14.3 and 15.9 tons per hectare in this category. Wilthin 0.3% produced 11.2 tons in the 160 count category while; ATS (5 %) had the lowest yield in this size category with 7.8 tons per hectare.

Untreated control yielded the greatest number of fruit, 14.8 tons hectare in the smallest fruit size or cull category (Table 2.3). Soybean oil and LS+FO (1%) had statistically similar yields of the cull size category at 9.9 and 8.5 tons per hectare respectively. Hand thin at 45 DAFB, Petroleum oil, LS+FO (3%), ATS (3.5%), and Wilthin were statistically comparable and ranged between 3.7 and 6.3 tons per hectare in the cull category. ATS (5 %) had the fewest number of fruit in this category (1.0 ton per hectare).

Crop values for each treatment varied numerically between \$5008.00 and \$8,211.00 per hectare and were found to be significantly different at the P >0.05 level (Table 2.3). Plotting crop load against crop value and drawing a theoretical response curve showed that the optimum crop load to achieve maximum crop value is somewhere between 7 and 8 fruits per cm^2 trunk cross-sectional area (Figure 2.4). ATS (3.5%), Petroleum oil, and LS+FO treatments gave crop loads in this range with high crop values. Wilthin had a lower crop load but similar crop value. Soybean oil had a considerably higher crop load (8.8 fruits per cm^2 TCA) than petroleum oil but similar crop value. ATS (5%) had a very low crop value due to the excessive thinning caused by this treatment. Hand thinning at 45 DAFB resulted in a lower crop value although crop load was in the optimum range.

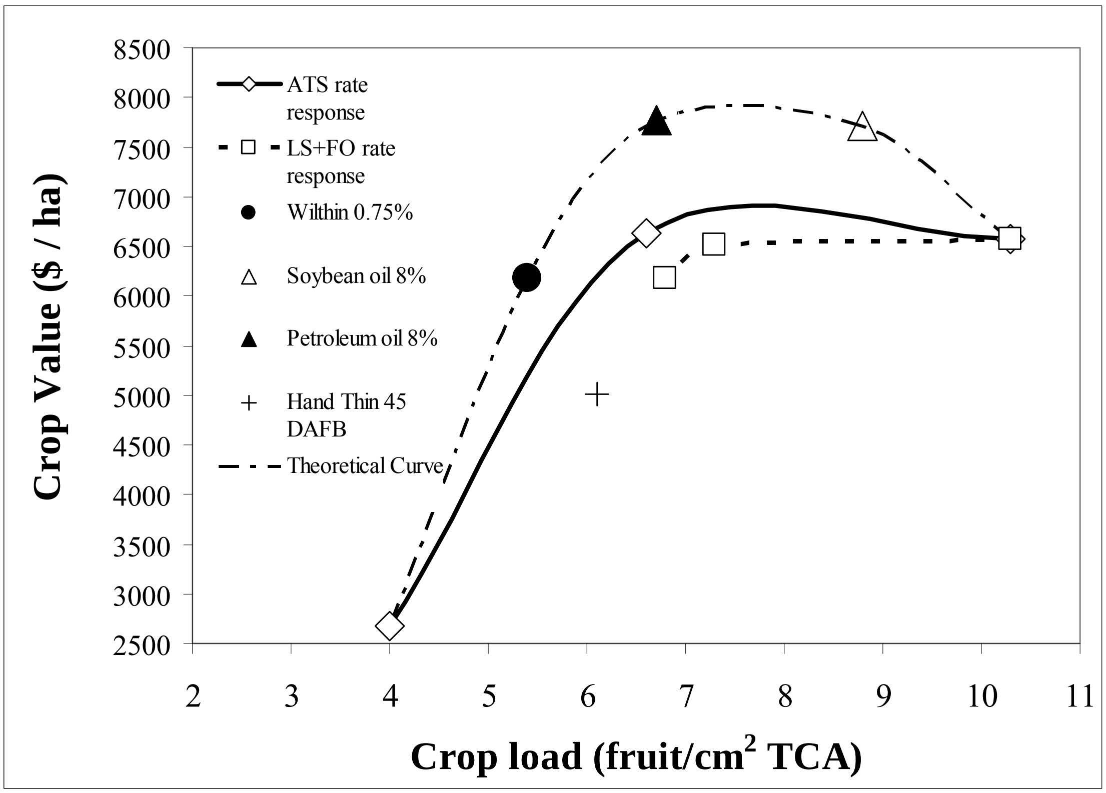

Figure 2.4 Effect of crop load and chemical thinning agents on crop value / ha of 'Rising Star' peach.

Phytotoxicity ratings which were taken one week after blossom thinners were applied to evaluate if thinners caused any foliar "burn" or injury caused significant differences among the treatments (Table 2.4). Both rates of ATS (3.5, 5%) caused the most injury. Untreated and hand thin control trees showed no signs of foliar injury.

Both rates of LS+FO (1,3%), Wilthin, Petroleum oil, and Soybean oil treated trees exhibited minimal damage.

Fruit firmness averaged over the 2 harvests was found to be significantly different among the blossom thinning treatments (Table 2.4). ATS (5%) had the lowest fruit firmness reading at 3.8 Kg of pressure. Untreated control, Petroleum oil, and LS+FO (1%) had fruit firmness levels averaging 4.2 Kg. The remainder of the treatments varied between 3.9 and 4.2 Kg.

Table 2.3 Effect of chemical thinning agents on pack out and crop value of 'Rising Star' peach.

Treatment	Yield by box size category t /ha 120 Count	140 Count	160 Count	Cull Count	Crop Value $/ha
Untreated control	0.4 a	4.4 ab	15.7 ab	14.8 a	6569.00 ab
Hand thin 45 DAFB	0.6 a	3.0 b	14.6 ab	6.3 bc	5008.00 b
Soybean oil (8%)	1.1 a	5.4 ab	15.9 ab	9.9 ab	7707.00 a
Petroleum oil (8%)	0.5 a	6.9 a	14.3 ab	5.6 bc	7773.00 a
LS(1%) + FO (2%)	0.0 a	5.1 ab	14.3 ab	8.5 ab	6516.00 ab
LS(3%) + FO (2%)	0.2 a	0.2 b	16.6 a	5.6 bc	6582.00 ab
ATS (3.5%)	0.3 a	6.4 ab	16.3 a	3.7 bc	6627.00 a
ATS (5.0%)	0.9 a	7.9 a	7.8 c	1.0 c	2682.00 ab
Wilthin 2.8 L	0.8 a	5.1 ab	11.2 bc	4.8 bc	6179.00 ab
Regression analyses					
ATS rate response	NS	NS	NS	NS	NS
LS+FO rate response	NS	NS	NS	L	NS

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

Fruit soluble solids also differed significantly among the treatments (Table 2.4). Untreated control and Petroleum oil had the lowest soluble solids levels at approximately 8.3 %. ATS (5%) had the highest soluble solid level at 8.8%. The remainder of the treatments ranged between and 8.5 and 8.8 % (Table 2.4).

Table 2.4 Effect of chemical thinning agents on fruit soluble solids, fruit firmness, and phytotoxicity rating of 'Rising Star' peach.

Treatment	Soluble Solids (%)	Fruit firmness (kg)	Phytotoxicity rating (1-4 scale[z])
Untreated control	8.2 b	4.2 ab	1.00 d
Hand thin 45 DAFB	8.6 ab	4.2 ab	1.00 d
Soybean oil (8%)	8.6 ab	4.2 ab	1.16 bcd
Petroleum oil (8%)	8.3 b	4.25 a	1.25 bcd
LS (1%) + FO (2%)	8.4 ab	4.2 ab	1.08 cd
LS (3%) + FO (2%)	8.6 ab	3.9 ab	1.50 bc
ATS (3.5%)	8.6 ab	4.2 ab	1.65 ab
ATS (5.0%)	8.7 a	3.8 b	2.06 a
Wilthin 2.8 L	8.6 ab	3.9 ab	1.54 bc
Regressions			
ATS rate response	NS	NS	L
LS+FO rate response	NS	NS	L

[z] Phytotoxicity scale 1= no leaf burn, 2= slight leaf burn, 3= moderate leaf burn, 4= severe leaf burn.[y] Means followed by the same letter are not significantly different using LSD. P≤0.05, n=6.

Discussion

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. Perhaps 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 2.4 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 6.5 and 7.0 fruits per cm^2 TCA. 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 and other liquid fertilizer formulations such as Urea have 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 stone and pome fruit has been commercially practiced in some areas of the USA without registration as a thinning agent. ATS is one of the most effective thinners and easiest to use because it was formulated as a liquid (Byers et al., 2003).

Measuring crop load using TCA has been shown to be unreliable as peach trees age since pruning contains the canopy size yet the TCA continues to increase each year. Thus, the optimum crop load of 6.5 would not be applicable to other age peach trees. Reginato et al., (2007) have shown that estimating crop load using fraction of light intercepted gives a measure of crop load that is not affected by tree age. Future trials on thinning could define an optimum crop load based on fraction of light intercepted that would be broadly applicable to trees of a single variety of various ages. It is also unlikely that different varieties would have the same optimum crop load. Reginato et al. (2007b) have shown that the optimum crop load was different for early, mid-season and late season peaches.

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. The treatments were applied by an air blast sprayer at 900 L•ha^{-1}. Greg Reighard (personal communication) reports that a spray volume of at least 1400 L•ha^{-1} is necessary for adequate coverage and thinning efficacy in the southern USA. 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).

The crop load values for the blossom thinning treatments were typically higher than the hand thin at 45 DAFB. This was not true of Wilthin and ATS (5%) as they carried smaller crop loads as compared to hand thin at 45 DAFB. However, this suggests that early thinning may allow growers to accept higher crop loads with similar or slightly better crop values than hand thinning at 45 DEFB.

The advantages of blossom thinning peaches to increase fruit size and reduce thinning labor are well documented in the literature. Caustic bloom thinners that damage blossoms and pollen offer the advantage of early reallocation of limited photosynthates to fewer sinks (Southwick, 1996). Our results from this trial suggest early partial crop thinning by blossom thinning agents can improve peach fruit size but did not improve crop value in the Northeastern USA of the small fruited ‘Rising Star’ peach. However, with a variety with greater size potential we expect blossom thinning to improve crop value. The most promising chemical from the results of this trial is ATS. It is a potent chemical with a linear rate response in peach blossom thinning.

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CHAPTER 3

CHEMICAL BLOSSOM THINNING INCREASES FRUIT SIZE AND CROP VALUE OF ‘ZEE LADY’ AND ‘ARKANSAS 9’ PEACHES

Abstract

In 2005, we conducted two blossom-thinning trials in Nuevo Casas Grandes Mexico on five-year-old peach trees on Bailey seedling rootstock. The two peach cultivars were a processing peach ‘Arkansas 9’and a fresh market peach ‘Zee Lady’. Treatments included an untreated control; aggressive pruning at full bloom; hand-thin treatment spacing fruits approximately 6 inches apart at 45 days after full bloom; Soybean oil or Horticultural Petroleum oil applied at 8% approximately 25 days before bloom; Ammonium thio-sulfate (ATS) (3.5%, 5%); Lime sulfur (1%, 3%) plus Soybean oil (2%) applied at 20% bloom; Lime sulfur (1%, 3%) plus Soybean oil (2%) applied at 90% bloom; Wilthin (0.5%, 0.75%) per acre applied at full bloom. With ‘Arkansas 9’, Soybean oil (8%), hand thinning at 45 DAFB, Wilthin (0.5%) were the most effective at reducing crop load. Trees which were hand thinned or treated with Soybean oil (8%), ATS (3.5%, 5%), or Wilthin (0.5%) produced the largest fruit size Fruit size was largely a function of crop load. Fruit size, was greatest, with the hand-thin at 45 DAFB treatment, producing an average fruit size of 109 g. The dormant application of Soybean oil (8%) also improved fruit size yielding an average fruit size of 104 grams. ATS (5%) and the low rate of Wilthin (0.5%) produced a statistically similar average fruit size 102 g. ATS (3.5%) yielded an average fruit size of 101 g. Petroleum oil (8%) and Wilthin (.75%) had statistically similar fruit sizes of 98 and 99 g, respectively. LS (1%) plus SO (2%) at both timings, 20% and FB, and LS (3%)

plus SO (2%) produced an average fruit size varying between 92 and 94 g. LS (3%) plus SO (2%) applied at FB produced a slightly smaller fruit size of 89 g. The smallest average fruit sizes were produced by the aggressive pruning and untreated control treatments, producing a modest fruit size of 86 and 85 g respectively.

ATS (3.5%) had the greatest crop value and totaled $3,795.00/ ha while the hand thin at 45 DAFB generated $2,204.00 per hectare. The untreated control and aggressive pruning treatment had the lowest crop values at $632.00 and $175.00 respectively.

With 'Zee Lady' hand-thinning at 45 days after full bloom moderately reduced fruit set to 14.0%. ATS (5%), LS (3%) plus SO (2%) at full bloom, and aggressive pruning were the most effective treatments to reduce crop load. LS (1%) plus SO (2%) at 20% bloom, or at FB, aggressive pruning, or Soybean oil produced the largest fruit size. Wilthin (0.5%) produced smaller fruit size than the untreated control. LS (1%) plus SO (2%) at 20% bloom, or at FB, aggressive pruning, or soybean oil, ATS (3.5%), and Wilthin (0.75%) generated the highest crop values ranging between $12,789.00 and $13,785.00 / ha.

Introduction

Hand thinning at 45 DAFB is the main management practice that is used to adjust crop load to obtain large commercially acceptable fruit size with peach. However hand thinning is expensive and time consuming. Partial crop thinning by chemical blossom thinners has tremendous potential to minimize high hand labor costs, increase fruit size, and improve overall crop value. The objective of this study was to evaluate several blossom thinning chemicals for efficacy in Mexico.

Material and Methods

Plant material

Five-year- old ‘Zee Lady’ and ‘Arkansas 9’ trees on ‘Bailey’ seedling (*P. persica*) rootstock and trained to open center were used in this study. Trees were selected from two blocks in a commercial peach orchard in Nueva Casas Grandes Mexico. Trees were planted at a spacing of 2.4 X 5.0 m or 8 X 16 ft., giving a tree density of approximately 820 trees per hectare or 340 trees per acre acre.

Experimental design

A randomized complete block design with 13 treatments and 5 replications was used in the study for a total of 65 test trees. Each test tree was guarded by an adjacent tree on each side which received the same treatment as the test tree.

Treatments

Treatments were applied with a handgun till runoff at a spray volume of 935 L/ ha or 100 gallons per acre except the dormant applications of soybean and petroleum oils which were applied with an air-blast sprayer at 1870 L/ha or 200 gallons per acre. The treatments were: 1) untreated control; 2) aggressive pruning at full bloom which consisted of removing one third of the length of each shoot on the tree; 3) hand-thinning which spaced the fruits approximately 6 inches apart at 45 days after full bloom, 4) Soybean oil (8%) plus an emulsifier Latron B 1956 (0.8%) applied at 25 days before full bloom; 5) Horticultural oil (8%) applied 25 days before bloom, 6)

Lime sulfur (1%) plus Soybean Oil (2%) plus an emulsifier, Latron B, applied at full bloom; (7) Lime sulfur (1%) plus Soybean Oil (2%) plus Latron B (0.8%) applied at 20% bloom; 8) Lime sulfur (3%) Soybean Oil (2%) plus Latron B (0.8%) at full bloom 90%, 9) Lime sulfur (3%) Soybean Oil (2%) plus Latron B (0.8%) at 20% bloom; 10) ATS (3.5%) applied at 90% bloom; 11) ATS (5 %) applied at 90% bloom, 12) Wilthin (.5%) plus Regulaid (.00125 %) applied at full bloom; 13) Wilthin 2.8 L (.75%) plus Regulaid (.000125%) applied at full bloom.

Measurements

Trunk circumference measurements were taken at 30 cm above the soil and were used to calculate trunk cross sectional area (TCSA). Two limbs per tree were selected at pink bud stage and the flowers were counted. Persisting fruit were counted 45 days after bloom. Fruit set was expressed as percentage of flowers, which developed into persisting fruits. Fruits were harvested in 2 harvests when mature. A sample of fifty fruits were collected from four harvests and evaluated for size and soluble solids. At each harvest, fruits were counted and weighed. Total yield was calculated by summing harvested weight of each data tree over four harvests. 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. For ‘Arkansas 9’ prices used were $8 per bushel of 160 count, $8 per bushel of 140 count, $13 per bushel of 120 count and $13 per bushel of 100 count which are current processing prices. For ‘Zee Lady’ prices used were $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 which are current fresh market prices. The crop value of each treatment was calculated with the assumption of no differences in fruit color between treatments.

Statistical Analysis

Data were analyzed by ANOVA using SAS Proc GLM (SAS Institute, Cary, NC). Significant differences among means were determined by LSD, ($P \leq 0.05$). The effect of treatment on fruit size independent of crop load was determined by adjusting fruit size for crop load (Stover et al., 2001). Rate responses of ATS or LS were determined by regression analysis.

Results

'Arkansas 9'

The greatest reduction in percent fruit set was achieved by the aggressive pruning at full bloom (Table 3.1). Average fruit set for this treatment was 19.1%. The hand thinning 45 days after full bloom (DAFB) treatment reduced fruit set to 22.3%. Petroleum oil (8%), LS (1%) plus SO (2%) applied at 20% bloom, and ATS (5%) reduced fruit set to 23.8, 23.6, and 25.2 percent fruit set, respectively. Soybean oil (8%), and LS (1%) plus Soybean oil (2%), were statistically similar to the untreated control at 27 % fruit set (Table 3.1). LS (3%) plus SO (2%) at both timings, 20% and FB, and Wilthin (.75%), had higher fruit set averages than that of the untreated control at 29%. The two treatments without effect were the low rate of Wilthin (.50%) and ATS (3.5%) at 29.3 and 34% fruit set, respectively.

Regression analysis of ATS rate response indicated that there was a significant quadratic relationship between fruit set and chemical thinner (Table 3.1). However, there was no significant relationship between LS+FO, or Wilthin rate and fruit set.

Table 3.1 Effect of chemical thinning agents on percent fruit set, crop load, and fruit number of 'Arkansas 9' peach.

Treatment	Fruit Set (%)	Crop Load (fruit/cm^2 / LCA)	Fruit Number / Tree
Untreated Control	27.5 abcd	4.9 ab	496 ab
Aggressive pruning	19.1 d	4.0 abcd	402 abcd
Hand thin fruit @ 45 DAFB	22.3 cd	2.8 cd	280 cd
Soybean oil 8% @ 25 DBFB	27.1 abcd	2.5 d	251 d
Horticultural oil 8% @ 25 DBFB	23.8 bcd	3.8 abcd	389 abcd
1% LS+ 2% SO @ 20% FB	23.6 bcd	4.2 abc	424 abc
1% LS+ 2% SO FB	26.4 abcd	3.9 abcd	396 abcd
3% LS+ 2% SO @ 20% FB	28.9 abc	4.0 abcd	405 abcd
3% LS+ 2% SO @ FB	29.6 abc	5.3 a	531 a
ATS 3.5% @ FB	34.0 a	4.3 abc	437 abc
ATS 5% @ FB	25.2 bcd	3.3 bcd	336 bcd
Wilthin (0.5%) @ FB	31.1 ab	3.1 cd	312 cd
Wilthin (0.75%) @ FB	29.3 abc	4.0 abcd	405 abcd
Regression analyses			
ATS rate response	Q	L	L
LS+FO rate response @ 20% FB	NS	NS	NS
LS+FO rate response @ FB	NS	NS	NS
Wilthin rate response	NS	NS	NS

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

Trees treated with Soybean oil (8%) applied 25 days before bloom, carried the lightest crop loads at 2.5 fruits per cm^2 limb cross-sectional area (LCA) (Table 3.1). The hand thin treatment at 45 days after full bloom and low rate of Wilthin (.5%) were moderately effective thinning treatments and reduced crop load to 2.8 and 3.1 fruits per cm^2 limb cross-sectional area, respectively. ATS (5%) reduced crop load to 3.4 fruits per cm^2 LCSA. Aggressive pruning, horticultural oil, LS (1%) plus SO (2%) at FB, LS (3%) plus SO (2%) at 20% bloom, and Wilthin (.75%) all shared intermediate crop loads ranging between 3.9 and 4.05 fruits per cm^2 limb cross-sectional area. Lime Sulfur (1%) plus Soybean oil (2%) at full bloom and ATS (3.5%) carried statistically similar crop loads, 4.24 and 4.37 fruits per cm^2 limb cross-sectional area, respectively. Untreated control trees carried a crop load of 4.96. However, the heaviest crop load was observed on trees treated by LS (3%) plus SO (2%) applied at FB.

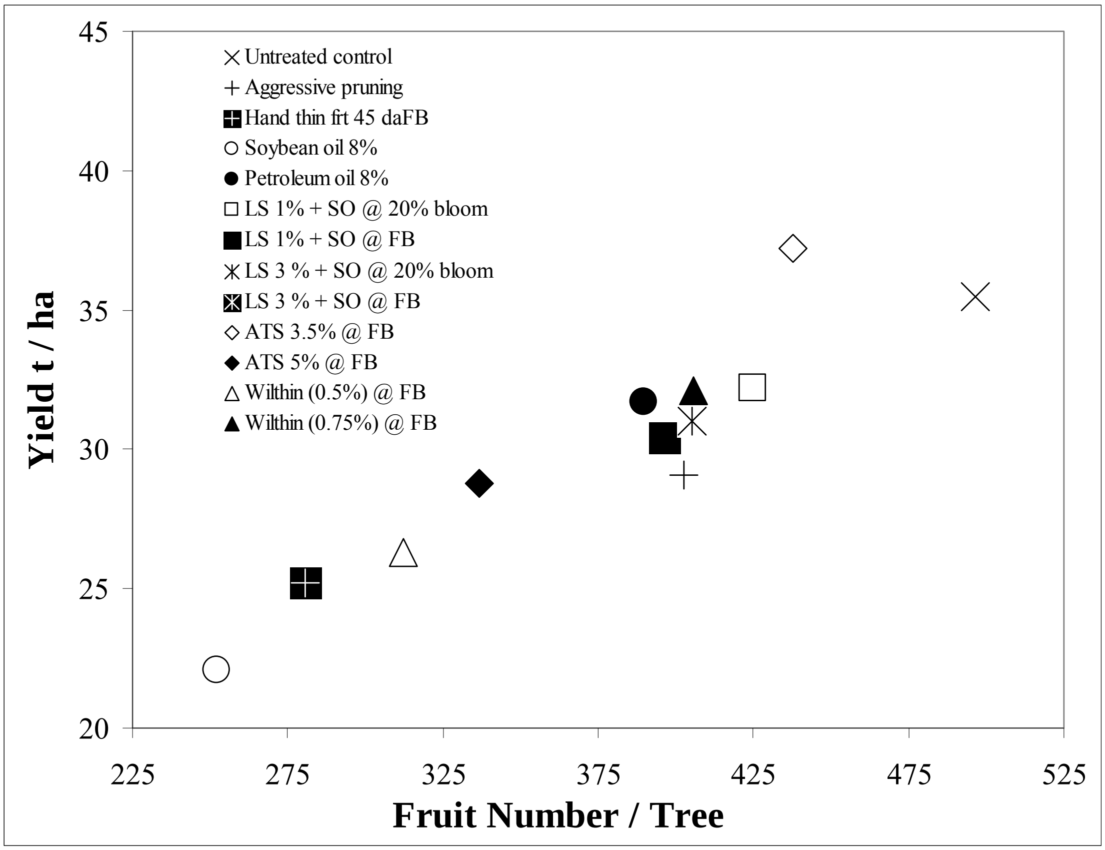

Figure 3.1 Relationship between fruit number per tree and yield per ha of ‘Arkansas 9’ peach.

Regression analysis of ATS rate response indicated that there was a significant linear relationship between rate of blossom thinner and crop load (Table 3.1). However, there was no significant relationship between LS+FO, or Wilthin rate and crop load.

Soybean oil (8%) applied 25 days before bloom significantly reduced adjusted fruit number per tree to 251 fruits (Table 3.1). The hand-thin treatment also significantly reduced fruit number per tree to 280 fruits. Wilthin and ATS (5%) had an intermediate fruit number per tree of 312 and 336 respectively. Lime Sulfur (1%) plus SO (2%) applied at 20% FB and ATS (3.5%) were statistically comparable and had 424 and 437 fruits per tree. Aggressive pruning, Horticultural oil (8%), LS (1%) plus Soybean oil (2%) at FB, LS (3%) plus Soybean oil (2%) at 20% bloom, and Wilthin (6 pt) were statistically similar and produced between 389 and 405 fruits per tree (Table 3.1). Untreated control trees averaged 496 fruits per tree. Lime Sulfur (3%) plus SO (2%) applied at FB did not affect fruit number per tree, 531 fruits.

Regression analysis of ATS rate response indicated that there was a significant linear relationship between rate of blossom thinner and fruit number (Table 3.1). However, there was no significant relationship between LS+FO, or Wilthin rate and fruit number per tree.

The highest yielding treatment was LS (3%) plus SO (2%) at full bloom producing an average of 47.8 t/ha (Table 3.2). There was a positive linear relationship between yield and fruit number per tree (Figure 3.1). ATS (3.5%) was the second highest yielding treatment producing 44.2 t/ha. Untreated control yielded 42.2 t/ha. Aggressive pruning, horticultural oil (8%), LS (1%) plus SO (2%) applied at 20% bloom LS (1%) plus SO (2%) applied at FB, LS (3%) plus SO (2%) at 20% bloom, and Wilthin (.75%)) produced a moderate yield varying between 34 and 38 t/ha. ATS (5%), and the low rate of Wilthin (.5%) yielded 34.2 and 31.3 t/ha respectively. The hand-thin treatment applied 45 days after FB significantly reduced yield to 30 t/ha. Finally, the treatment with the greatest reduction in yield was the dormant Soybean oil (8%) application applied 25 days before bloom, producing an average yield of 26.3 t/ha.

Regression analysis of ATS, LS+FO, or Wilthin rate responses indicated that there were no significant relationships between rate of blossom thinner and yield per hectare (Table 3.2).

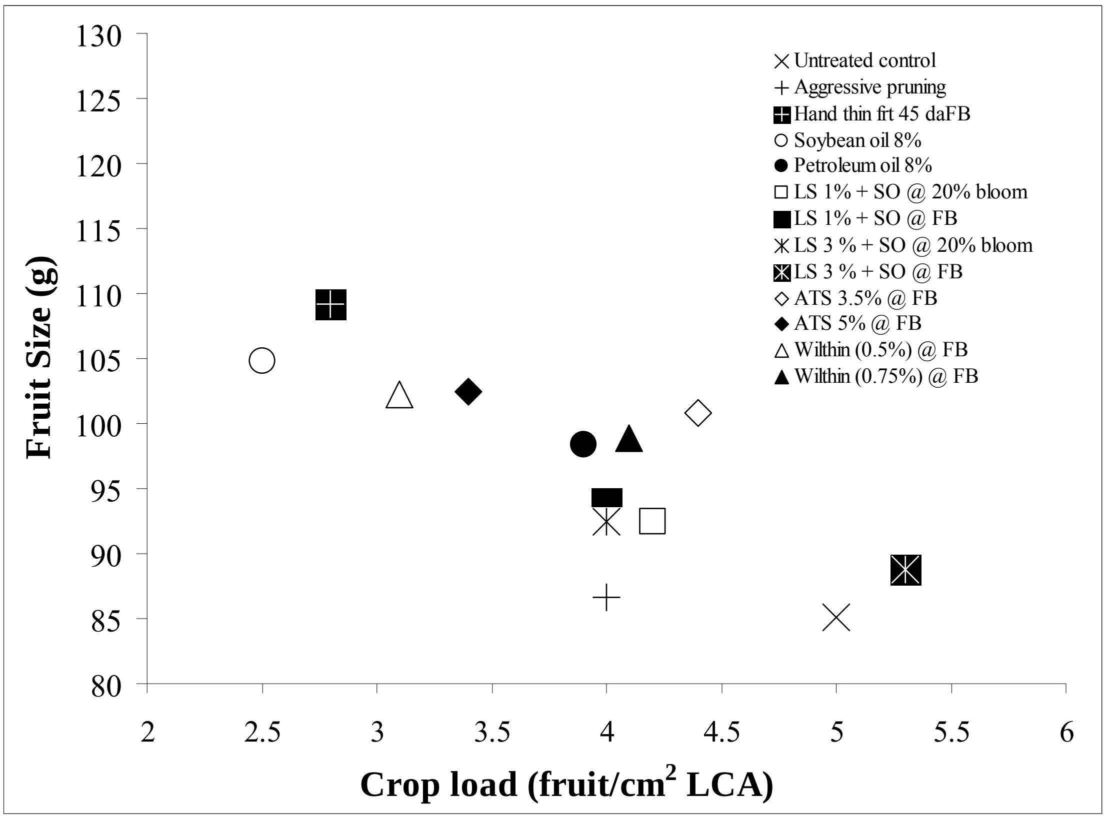

Figure 3.2 Effect of crop load and chemical thinning agents on fruit size of 'Arkansas 9' peach.

Fruit size, was greatest, with the hand-thin at 45 DAFB treatment, producing an average fruit size of 109 g (Table 3.2). The dormant application of Soybean oil (8%) also improved fruit size yielding an average fruit size of 104 grams. ATS (5%) and the low rate of Wilthin (.5%) produced a statistically similar average fruit size 102 g. ATS (3.5%) yielded an average fruit size of 101 g. Petroleum oil (8%) and Wilthin

Table 3.2 Effect of chemical thinning agents on yield, fruit size, and crop load adjusted fruit size of ‘Arkansas 9’ peach.

Treatment	Yield (t/ ha)	Fruit Size (g)	Crop Load Adjusted Fruit Size (g)
Untreated Control	42.2 abc	85 e	92 bc
Aggressive pruning	34.6 abcd	86 de	87 c
Hand thin fruit	30.0 cd	109 a	101ab
Soybean oil 8%	26.3 d	104 ab	95 abc
Petroleum oil 8%	37.6 abcd	98 abcde	98 abc
1% LS+ 2% SO @ 20% FB	38.3 abcd	92 bcde	94 abc
1% LS+ 2% SO @ FB	36.2 abcd	94 bcde	94 abc
3% LS+ 2% SO @ 20% FB	36.9 abcd	92 bcde	93 abc
3% LS+ 2% SO @ FB	47.8 a	89 cde	98 abc
ATS 3.5% @ FB	44.2 ab	101 abcd	103 a
ATS 5% @ FB	34.2 bcd	102 abc	98 abc
Wilthin (0.5%) @ FB	31.3 cd	102 abc	96 abc
Wilthin (0.75%) @ FB	38.2 abcd	99 abc	99 ab
Regression analyses			
ATS rate response	NS	L	NS
LS+FO rate response @ 20% bloom	NS	NS	NS
LS +FO rate response @ FB	NS	NS	NS
Wilthin rate response	NS	NS	NS

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

(.75%) had statistically similar fruit sizes of 98 and 99 g, respectively. LS (1%) plus SO (2%) at both timings, 20% and FB, and LS (3%) plus SO (2%) produced an average fruit size varying between 92 and 94 g. LS (3%) plus SO (2%) applied at FB produced a slightly smaller fruit size of 89 g. The smallest average fruit sizes were produced by the aggressive pruning and untreated control treatments, producing a modest fruit size of 86 and 85 g respectively.

Regression analysis of the ATS response indicated that there was a significant linear relationship between rate of blossom thinner and fruit size (Table 3.2). However, there was no significant relationship between LS+FO or Wilthin rate and fruit size.

The relationship between crop load and fruit size required that crop load be used as a covariate to determine the effect of the chemical thinners on fruit size independent of the crop load effect (Figure 3.3). After covariate analysis it was observed that aggressive pruning had the smallest crop load adjusted fruit size (87 g) which was significantly below most of the treatments in Table 3.2 and Figure 3.3. The untreated control trees also had significantly smaller crop load adjusted fruit size (92 g) than several of the other treatments. The majority of the treatments produced an average fruit size varying between 93 and 98 grams. However, ATS (3.5%),Wilthin (.75%) and hand thin at 45 days after FB seemed to improve fruit size, independent of crop load producing fruit sizes of 103.8, 99.8, 101.5, respectively.

Regression analysis of ATS, LS+FO, and Wilthin rate responses indicated that there were no significant differences between rate of blossom thinner and crop load adjusted fruit size.

The predicted pack-out no treatment produced more than 0.2 tons per hectare of the very large 100 count box size category (Table 3.3).

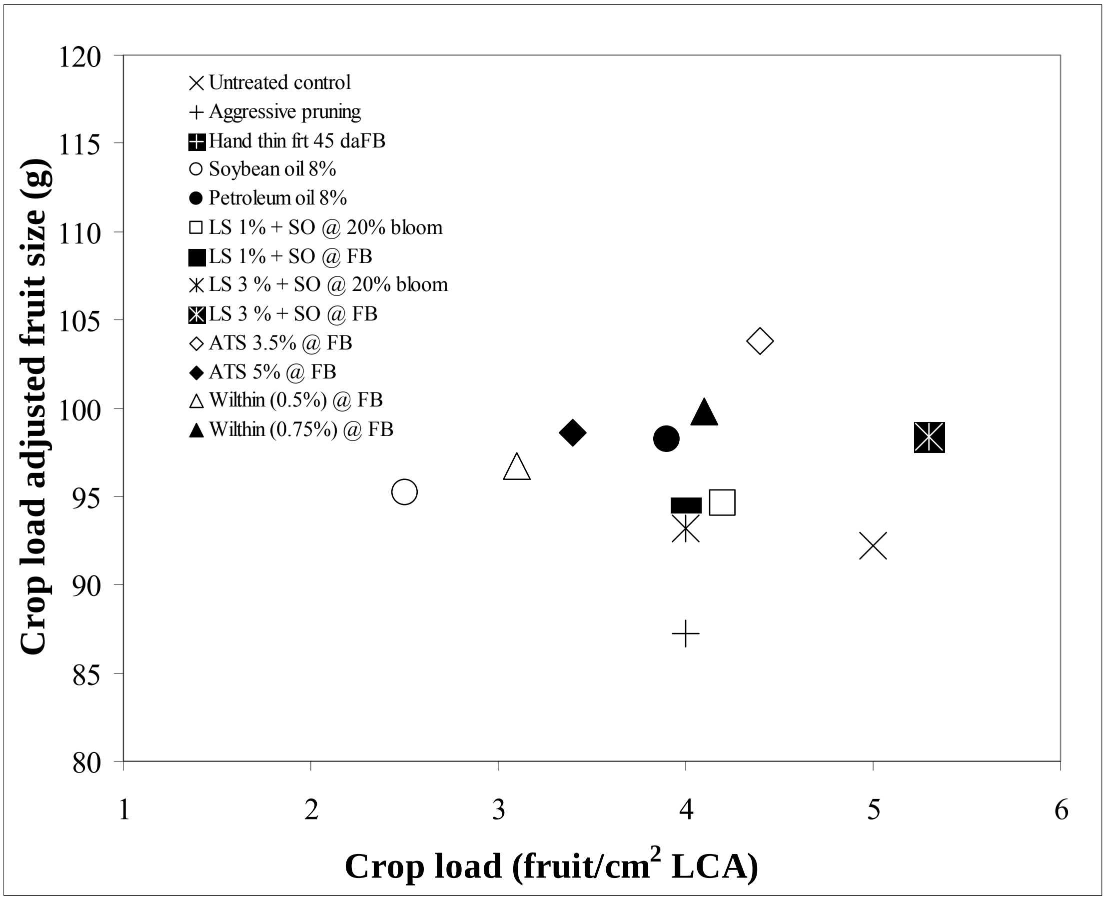

Figure 3.3 Effect of crop load and chemical thinning agents on fruit size adjusted for crop load on ‘Arkansas 9’ peach.

ATS (3.5%) and the hand thin fruit treatment had the greatest proportion of fruit in the 120 box size category producing 2.6 and 2.5 tons per hectare. ATS (5%), Soybean oil (8%), Petroleum oil (8%), and both rates of Wilthin (.5%, .75%) produced between 1.2 and 1.8 t/ha in the 120 box size category. The untreated control, aggressive pruning, and both rates and timings of LS (1, 3%) plus SO (2%) produced between 0.4 and 1.1 tons per hectare in the 120 count category.

ATS (3.5%) had the greatest number of fruit in the 140 count size category yielding approximately 10.4 t/ha (Table 3.3). The hand thin treatment applied 45 DAFB, and ATS (5%) produced 8.1 t/ha in this category. The untreated control, Soybean oil (8%), both timings of LS (1%) plus SO (2%) applied at 20% FB and FB, and both timings of LS (3%) plus SO (2%) applied at 20% FB and FB, produced between 4.8 and 6.7 t/ha in the 140 size category. Petroleum oil (8%) and both rates of Wilthin (.5%, .75%) produced between 6.9 and 7.5 t/ha in the 140 count category. Finally, aggressive pruning produced the fewest proportion of fruit in this size category, 4.1 t/ha.

LS (3%) plus SO (2%) applied at FB and the untreated control yielded the greatest number of fruit, 31.4 and 29 t/ha, in the cull category. LS (1%) plus SO (2%) applied at 20% FB also had significant proportion in the cull size category, producing 24.5 t/ha. Aggressive pruning, petroleum oil (8%), LS (1%) plus SO (2%) applied at FB, LS (3%) plus SO (2%) applied at 20% FB, ATS (3.5%), and Wilthin (.75%) produced between 21.9 and 23.7 t/ha in the cull category. ATS (5 %), hand thin at 45 DAFB, and Wilthin (.5%) produced between 14.3 and 18.4 t/ha in this category. Soybean oil (8%) had the fewest fruits in the cull category producing 13.3 t/ha.

Regression analysis of ATS rate response indicated that there was a significant linear relationship between rate of blossom thinner and yield of box size 120 and cull size categories (Table 3.3). However, there was no significant relationship between LS+FO or Wilthin rate and any of the box sizes.

Crop values were calculated using current processing fruit prices for each box size category. ATS (3.5%) had the greatest crop value and totaled $3,795.00 per hectare while the hand thin at 45 DAFB generated $2,204.00 per hectare (Table 3.3). ATS (5%) had a crop value of $2,774.00 while the Soybean and petroleum oil (8%) and both rates of Wilthin (.5%, .75%) produced moderate crop values ranging between $2,315.00 and $2,406.00. Both timings of LS (1%) plus SO (2%), applied at 20% and full bloom (FB), and LS (3%) plus SO (2%) applied at 20% bloom, had low crop

Table 3.3 Effect of chemical thinning agents on pack out and crop value of 'Arkansas 9' peach.

Treatment	Yield by box size category t /ha: 100 Count	120 Count	140 Count	Culls Count	Crop Value $/ha
Untreated Control	.01 c	0.5 b	4.8 bc	29 a	632.00 cd
Aggressive pruning	.01 c	0.4 b	4.1c	23.7 abc	175.00 d
Hand thin fruit @ 45 DAFB	.20 a	2.5 a	8.1 ab	14.3 bc	2204.00 abcd
Soybean oil 8% @ 25 DBFB	.12 abc	1.7 ab	6.7 bc	13.3 c	2545.00 abc
Petroleum oil 8% @ 25DBFB	.08 abc	1.5 ab	7.5 abc	21.9 abc	2310.00 abc
1% LS+ 2% SO @ 20% FB	.04 bc	0.9 b	5.8 bc	24.5 ab	1312.00 bcd
1% LS+ 2% SO @ FB	.05 bc	1.1 b	6.2 bc	22.3 abc	1616.00 bcd
3% LS+ 2 % SO @ 20% FB	.03 bc	0.9 b	5.8 bc	23.5 abc	1309.00 bcd
3% LS+ 2 % SO @ FB	.02 bc	0.8 b	6.5 bc	31.4 a	1156.00 bcd
ATS 3.5% @ FB	.17 ab	2.6 a	10.4 a	23.5 abc	3795.00 a
ATS 5% @ FB	.10 abc	1.7 ab	8.1 ab	18.4 bc	2774.00 ab
Wilthin (0.5%) @ FB	.12 abc	1.2 ab	6.9 abc	17.2 bc	2406.00 abc
Wilthin (0.75%) @ FB	.16 abc	1.8 ab	7.1 abc	22.3 abc	2315.00 abc
Regression analyses					
ATS rate response	NS	L	NS	L	L
LS+FO rate response @ 20% FB	NS	NS	NS	NS	NS
LS+FO rate response @ FB	NS	NS	NS	NS	NS
Wilthin rate response	NS	NS	NS	NS	NS

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

Table 3.4 Effect of chemical thinning agents on fruit soluble solids of ‘Arkansas 9’ peach.

Treatment	Soluble Solids (Brix)
Untreated Control	9.81 b
Aggressive pruning	9.92 b
Hand thin fruit @ 45 DAFB	10.37 ab
Soybean oil 8% @ 25 DBFB	11.56 a
Petroleum oil 8% @ DBFB	9.38 b
1% LS+ 2 % SO @ 20% FB	9.08 b
1% LS+ 2% SO @ FB	9.71 b
3% LS+ 2% SO @ 20% FB	9.81 b
3% LS+ 2 % SO@ FB	10.01 b
ATS 3.5% @ FB	9.05 b
ATS 5% @ FB	9.71 b
Wilthin (0.5%) @ FB	9.17 b
Wilthin (0.75%) @ FB	9.92 b
Regression analyses	
ATS rate response	NS
LS+FO rate response @ 20% FB	NS
LS+FO rate response@ FB	NS
Wilthin rate response	NS

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

Table 3.5 Effect of chemical thinning agents on percent fruit set, crop load, and fruit number of ‘Zee Lady’ peach.

Treatment	Fruit Set (%)	Crop Load ($fruit/cm^2$ LCA)	Fruit Number / Tree
Untreated Control	17.7 abc	2.49 ab	330 bcd
Aggressive pruning	9.6 c	1.92 ab	224 d
Hand thin fruit @ 45 DAFB	14.0 bc	2.08ab	310 bcd
Soybean oil 8% @ 25DBFB	16.4 abc	2.24ab	312 bcd
Petroleum oil 8% @ 25 DBFB	19.7 ab	2.41 ab	408 ab
1% LS+2% SO @ 20% FB	14.2 abc	1.85 ab	270 bcd
1% LS+ 2% SO FB	14.9 abc	2.12 ab	244 cd
3% LS+ 2% SO @ 20% FB	19.2 ab	2.11 ab	386 abc
3% LS+ 2%SO @ FB	16.4 abc	1.69 b	282 bcd
ATS 3.5% @ FB	20.2 a	2.09 ab	357 abcd
ATS 5% @ FB	18.1 ab	1.66 b	258 cd
Wilthin (0.5%) @ FB	21.3 a	2.86 a	495 a
Wilthin (0.75%) @ FB	18.7 ab	2.64 ab	347 abcd
Regression analyses			
ATS rate response	NS	NS	NS
LS+FO rate response @ 20% FB	NS	NS	NS
LS+FO rate response @ FB	NS	NS	NS
Wilthin rate response	NS	NS	NS

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

values between $1,309.00 and 1,616.00/ ha. Moreover, LS (3%) plus SO (2%) applied at FB produced slightly less at $1,156.00. Finally, the untreated control and aggressive pruning treatment had the lowest crop values at $632.00 and $175.00 respectively.

Regression analysis of ATS rate response indicated that there was a significant linear relationship between rate of blossom thinner and crop value. However, there was no significant relationship between LS+FO or Wilthin rate and crop value.

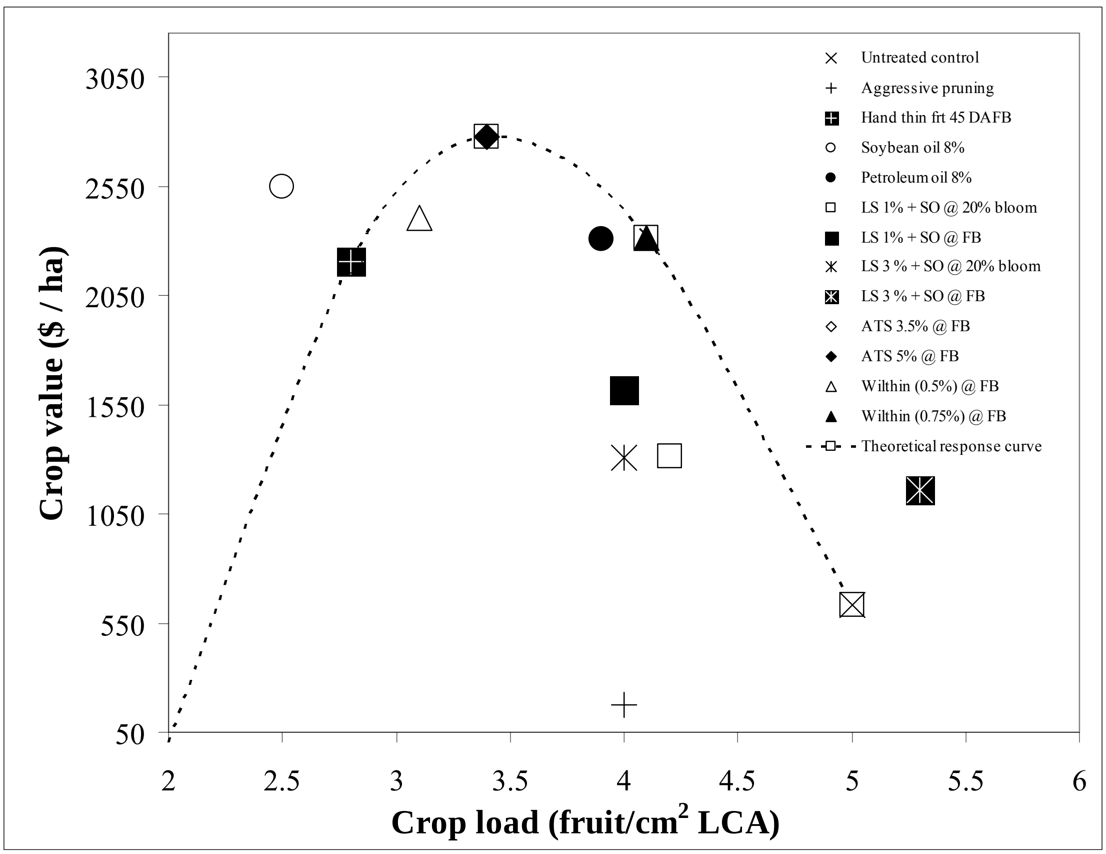

Figure 3.4 Effect of crop load and chemical thinning agents on crop value $ / ha of 'Arkansas 9' peach.

Plotting crop load against crop value and then drawing a theoretical response curve showed that the optimum crop load to achieve maximum crop value was somewhere between 3.0 and 3.5 fruits per cm^2 /TCA (Figure 3.4).

Soluble solids (Brix) was evaluated at 1st harvest. Soybean oil (8%) produced the highest highest soluble solids levels (11.6%) at approximately 11.6 degrees while the hand thin at 45 DAFB had an intermediate level of 10.4%. The remainder of the treatments ranged between 9.1 and 10.0%.

Regression analysis of ATS, LS+FO, and Wilthin rate responses indicated that there were no significant relationship between rate of blossom thinner and fruit soluble solids level.

'Zee Lady'

The aggressive pruning treatment in the 'Zee Lady' experiment reduced fruit set to 9.6% as compared to the untreated control at 17.7% (Table 3.5). Hand-thin treatment at 45 days after full bloom moderately reduced fruit set to 14.0%. The treatments that had a marginal or slight effect on reducing fruit set included SO (8%) at 25 DBFB, LS (1%) plus SO (2%) at 20% bloom, LS (1%) plus SO (2%) at full bloom, and LS (3%) plus SO (2%) at full bloom. Petroleum oil (8%), LS (3%) plus Soybean oil (2%) at 20% bloom, ATS (5%), and Wilthin (.75%) were not different than the untreated control. ATS (3.5%) and the low rate of Wilthin (.5%) were without effect and had higher fruit set averages higher than the untreated control at 20.2 and 21.3% fruit set respectively.

Regression analysis of ATS, LS+FO, and Wilthin rate responses indicated that there were no significant differences between rate of blossom thinner and fruit set.

ATS (5%) and LS (3%) plus SO (2%) at full bloom were the most effective treatments to markedly reduce crop load to 1.66 and 1.69 fruits per cm^2 limb cross-sectional area. The highest crop load was carried by Wilthin (.5%)) treated trees at 2.86 fruits per cm^2 LCSA. The remainder of the treatments had intermediate crop load levels varying from 1.92 to 2.64 fruits per cm^2 limb cross-sectional area.

Regression analysis of ATS, LS+FO, and Wilthin rate responses indicated that there were no significant differences between rate of blossom thinner and crop load.

Aggressive pruning reduced the fruit number per tree most significantly to 224 fruits (Table 3.5). ATS (5%) and LS (1%) plus SO (2%) applied at FB also significantly reduced fruit number per tree to an average of 258 and 244 fruits. Untreated control, hand-thin, SO (8%), Petroleum oil (8%), LS (1%) plus SO (2%) at 20% bloom, LS (3%) plus SO (2%) applied at FB were statistically comparable with an average fruit number ranging from 270 to 330 fruits per tree. ATS (3.5%) and Wilthin (0.75%)) produced statistically similar fruit numbers, 357 and 347 fruits, respectively. The treatment that produced the highest fruit number per tree was Wilthin (0.5%) with 495 fruits. Regression analysis showed a positive linear relationship between fruit number per tree and yield / ha (Figure 3.6).

Trees treated with Wilthin (6 pt) had the highest yields producing 42.9 t/ha (Table 3.6). ATS (5%) and LS (3%) plus SO (2%) applied at FB produced intermediate yields, 28 t / ha. The remainder of the treatments can be statistically categorized into a lower yielding category ranging between 33.9 and 39 t/ha.

Regression analysis of ATS, LS+FO, and Wilthin rate responses indicated that there were no significant relationship between rate of blossom thinner and yield per hectare.

The treatment that had the largest fruit size was LS (1%) plus SO (2%) at 20% bloom, producing an average fruit size of 166 g. The low rate of Wilthin (.05%) yielded the smallest fruit size at 104 grams. The untreated control and petroleum oil (8%) also had small fruit size at 127 and 129 respectively. The remainder of the treatments produced a statistically similar intermediate fruit size varying from 139 to 151 grams.

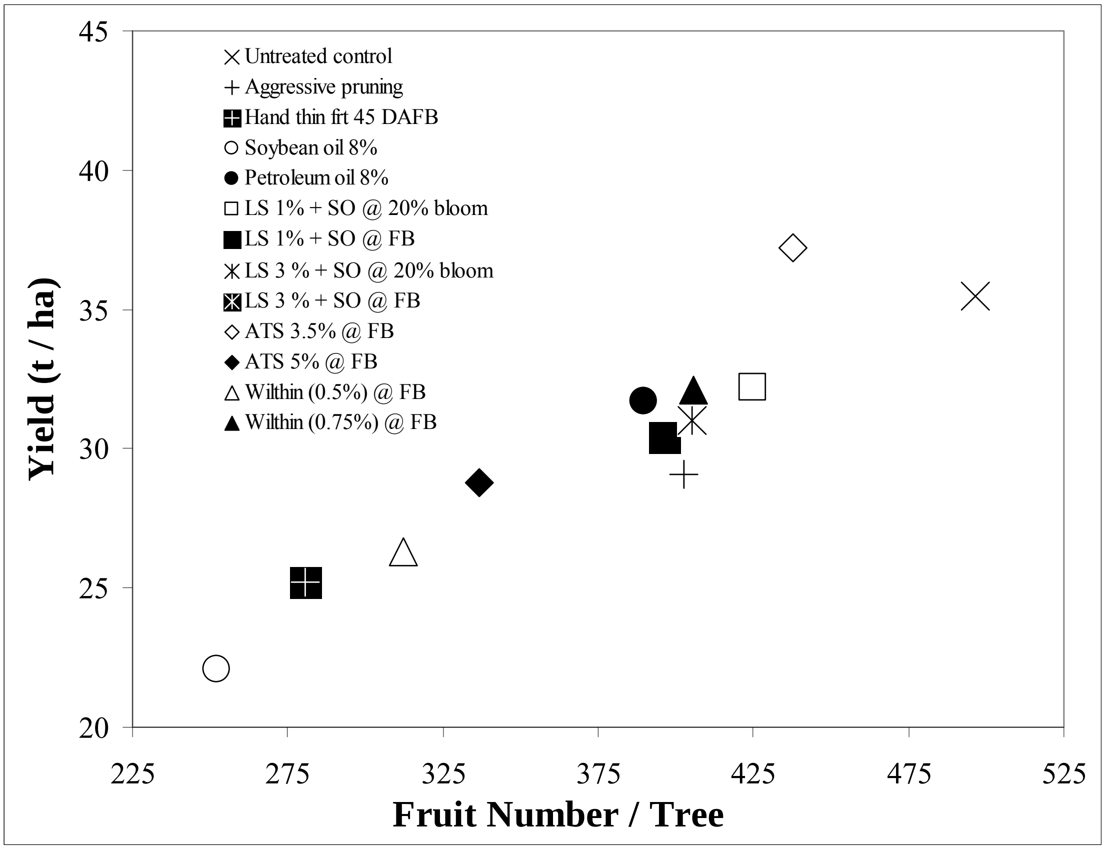

Figure 3.5 Relationship between fruit number per tree and yield per ha of 'Zee Lady' peach.

Regression analysis of ATS, LS+FO, and Wilthin rate responses indicated that there were no significant reationships between rate of blossom thinner and fruit size. A negative linear relationship best expressed the effect of crop load and fruit size (Figure 3.6). In general the treatments that carried the lightest crop loads ATS (5%), 3% LS+ SO (2%) applied at FB, 1% LS+ SO (2%) applied at 20% FB, and aggressive pruning also produced the largest fruit.

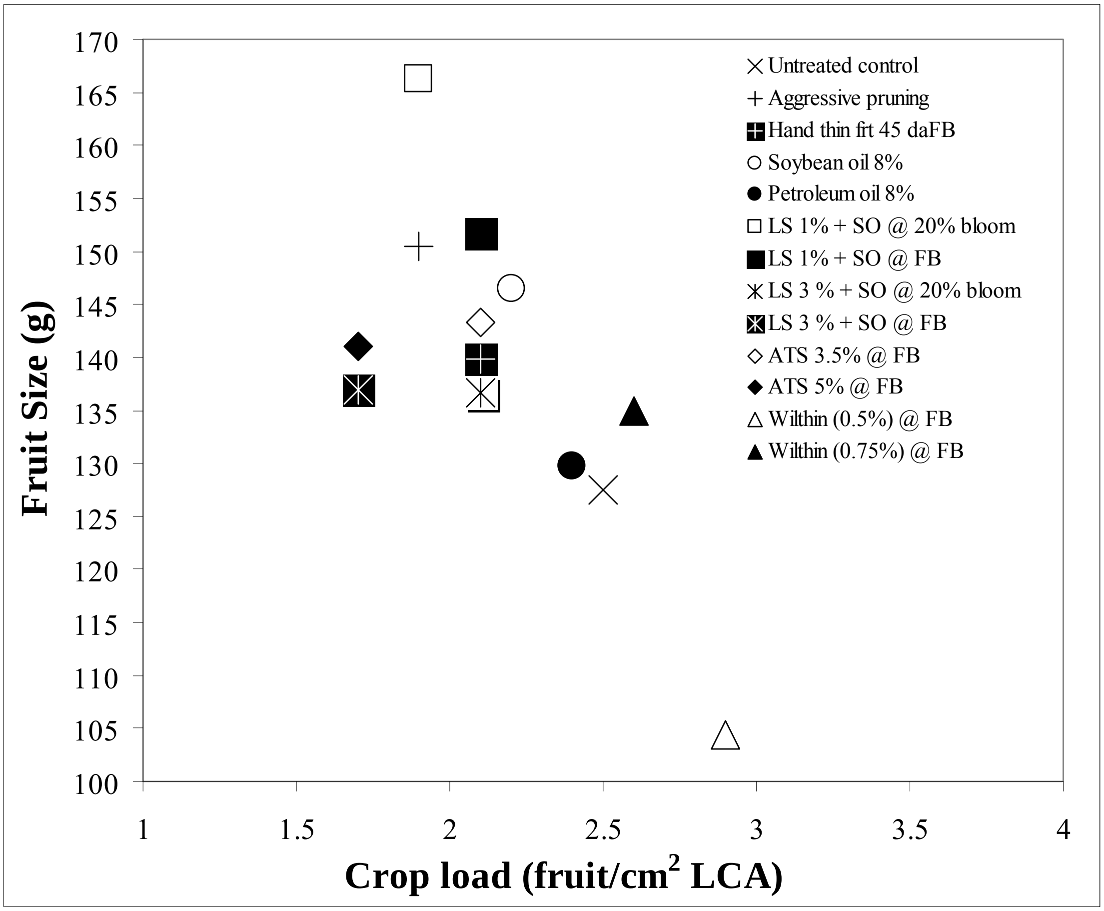

Figure 3.6 Effect of crop load and chemical thinning agents on fruit size of 'Zee Lady' peach.

The significant relationship between crop load and fruit size required the use of crop load as a covariate to evaluate the effect of the chemical thinners independent of the crop load effect (Figure 3.7). Wilthin (0.5%) had the smallest fruit size after adjustment for crop load differences, 122 grams. ATS (5%) and LS (3%) plus SO (2%) applied at FB, also had small crop load adjusted fruit sizes of 129.2 and 125.8 grams, respectively. The majority of the treatments produced an average adjusted fruit size varying between 135.1 and 145.9 grams (Table 3.6). LS (1%) plus SO (2%) applied at 20% bloom had significantly larger crop load adjusted fruit size of 158.8 grams.

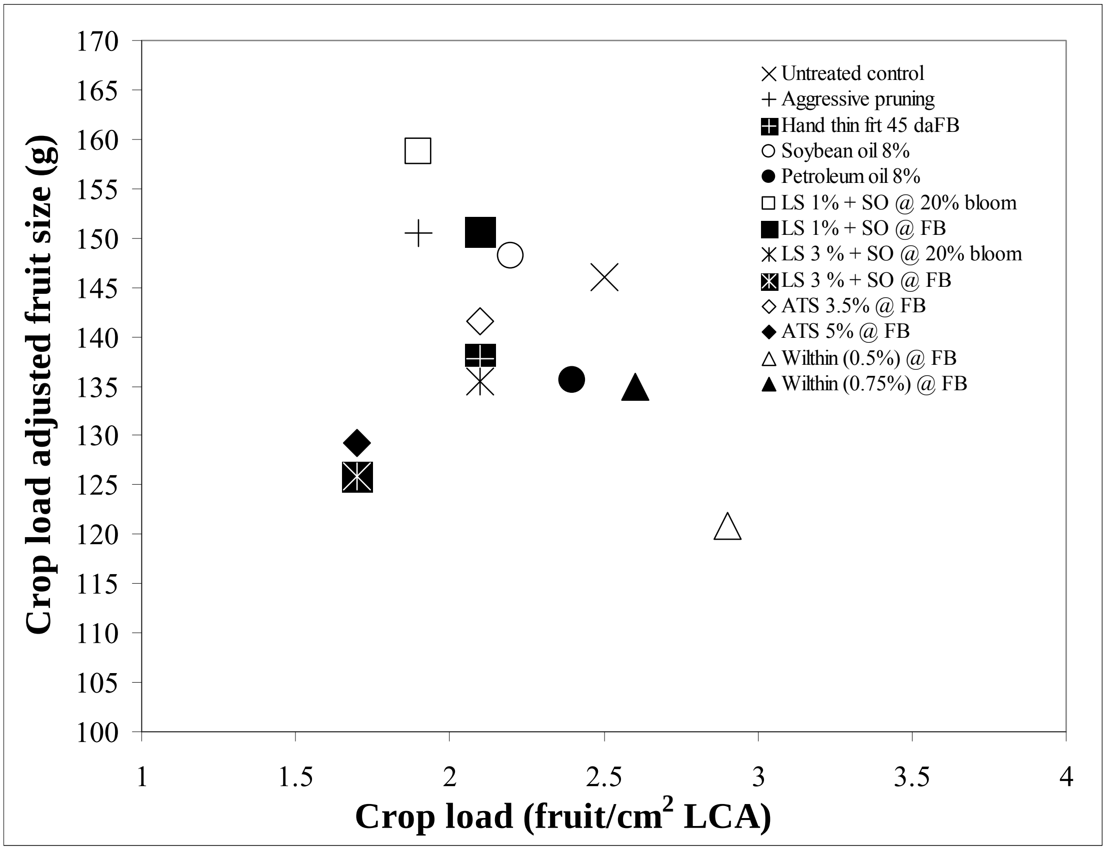

Figure 3.7 Effect of crop load and chemical thinning agent on fruit size adjusted for crop load of 'Zee Lady' peach.

Regression analysis of ATS, LS+FO, and Wilthin rate responses indicated that there were no significant differences between rate of blossom thinner and crop load adjusted fruit size. Analysis of the fruit pack out data showed that LS (1%) plus SO (2%) applied at 20% bloom produced 2.4 t/ha in the very large 80 count box size category. The remainder of the treatments was statistically similar and had between .04 and .80 t/ha in this fruit size category (Table 3.7).

LS (1%) plus SO (2%) applied at 20% bloom, had the greatest yield 10.5 t/ha, in the 100 count category. Aggressive pruning treatment also had a large proportion of fruit, 8.6 t/ha, in the 100 count category. LS (1%) plus SO (2%) applied at FB and

Table 3.6 Effect of chemical thinning agents on yield, fruit size, and crop load adjusted fruit size of ‘Zee Lady’ peach.

Treatment	Yield (t/ ha)	Fruit Size (g)	Crop Load Adjusted Fruit Size (g)
Untreated Control	37.8 ab	127 bc	135.1 bcde
Aggressive pruning	35.0 ab	150 ab	144.6 abcd
Hand thin fruit @ 45 DAFB	35.3 ab	140 ab	137.8 bcde
Soybean oil 8% @ 25 DBFB	39.0 ab	146 ab	148.2 abc
Petroleum oil 8% @ 25 DBFB	37.7 ab	130 bc	135.6 bcde
1% LS+ 2% SO @ 20% FB	35.9 ab	166 a	158.8 a
1% LS+ 2% SO FB	39.0 ab	152 ab	150.6 ab
3% LS+ 2% SO @ 20% FB	33.9 ab	137 b	135.5 bcde
3% LS+ 2% SO @ FB	28.1 b	137 b	125.8 de
ATS 3.5% @ FB	36.8 ab	143 ab	141.6 abcd
ATS 5% @ FB	28.9 b	141 ab	129.2 cde
Wilthin (0.5%) @ FB	35.7 ab	104 c	120.7 e
Wilthin (0.75%) @ FB	42.9 a	135 b	145.9 abcd
Regression analyses			
ATS rate response	NS	NS	NS
LS+FO rate response @ 20%	NS	NS	NS
LS+FO rate response @ FB	NS	NS	NS
Wilthin rate response	NS	NS	NS

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

Table 3.7 Effect of chemical thinning agents on pack out and crop value of 'Zee Lady' peach.

Treatment	Yield by box size category (t/ ha) 80 Count	100 Count	120 Count	140 Count	Cull Count	Crop Value $/ ha
Untreated Control	0.04 b	2.4 cd	8.9 ab	13.1 a	14.0 ab	9374.00 abc
Aggressive pruning	0.80 b	8.6 ab	11.7 a	8.1 a	6.9 b	13375.00 ab
Hand thin fruit @ 45 DAFB	0.32 b	5.9 abcd	11.6 a	9.6 a	8.9 b	10872.00 ab
Soybean oil 8% @ 25 DBFB	0.51 b	6.0 abcd	12.7 a	12.6 a	8.4 b	13785.00 ab
Petroleum oil 8% @ DBFB	0.04 b	1.9 cd	9.1 ab	14.6 a	12.6 ab	9745.00 abc
1% LS+ 2% SO @ 20% FB	2.4 a	10.5 a	11.4 ab	7.5 a	5.4 b	15720.00 a
1% LS+ 2% SO @ FB	0.04 b	8.1 abc	15.2 a	10.4 a	6.4 b	15520.00 a
3% LS+ 2 % SO @ 20% FB	0.80 b	6.9 abc	7.7 ab	7.3 a	11.8 ab	10227.00 abc
3% LS+ 2% SO @ FB	0 09 b	2.7 bcd	8.6 ab	10.2 a	7.3 b	8744.00 bc
ATS 3.5% @ FB	0.14 b	4.9 abcd	13.9 a	12.2 a	6.9 b	13306.00 ab
ATS 5% @ FB	0.14 b	3.8 bcd	10.2 ab	9.7 a	5.9 b	10111.00 abc
Wilthin (0.5%) @ FB	0.06 b	0 .75 d	4.0 b	8.8 a	21.7 a	4171.00 c
Wilthin (0.75%) @ FB	0.28 b	4.8 abcd	11.8 a	14.2 a	12.7 ab	12789.00 ab
Regression analyses						
ATS rate response	NS	NS	NS	NS	NS	NS
LS+FO rate response @ 20% FB	NS	NS	NS	NS	NS	NS
LS+FO rate response @ FB	NS	NS	NS	NS	NS	NS
Wilthin rate response	NS	NS	NS	NS	NS	NS

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

Table 3.8 Effect of chemical thinning agents on fruit soluble solids of ‘Zee Lady’ peach.

Treatment	Soluble Solids (%)
Untreated Control	10.25 b
Aggressive pruning	11.46 ab
Hand thin fruit @ 45 DAFB	11.75 ab
Soybean oil 8% @ 25 DBFB	12.33 a
Petroleum 8% @ 25 DBFB	10.10 b
1% LS+ 2% SO @ 20% FB	11.20 ab
1% LS+ 2% SO FB	10.35 b
3% LS+ 2% SO @ 20% FB	11.30 ab
3% LS+ 2% SO @ FB	12.23 a
ATS 3.5% @ FB	11.60 ab
ATS 5% @ FB	10.75 ab
Wilthin (0.5%) @ FB	11.26 ab
Wilthin (0.75%) @ FB	10.80 ab
Regression analyses	
ATS rate response	NS
LS+FO rate response @ 20 FB	NS
LS+FO rate response @ FB	NS
Wilthin rate response	NS

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

LS (3%) plus SO (2%) applied at 20% bloom produced 8.1and 6.9 t/ha in the 100 count category. The hand thin treatment, Soybean oil (8%), ATS (3.5%), and Wilthin (0.75%) produced between 4.8 and 6.0 t/ha in this category. ATS (5%) and LS (3%) plus SO (2%) applied at FB had 3.8 and 2.7 t/ha in the 100 count category. Finally, the untreated control and Petroleum oil (8%) produced 2.4 and 1.9 t/ha. Wilthin (0.5%) had the least fruit in the 100 size category, 0.8 t/ha.

Aggressive pruning, hand thin fruit, Soybean oil (8%), LS (1%) plus SO (2%) applied at FB, ATS (3.5%), and Wilthin (0.75%) had the greatest proportion of fruit in the 120 count box size category producing between 11.6 and 15.2 t/ha. The untreated control, Petroleum oil (8%), LS (1%) plus SO (8%) applied at 20 % bloom, both rates and timings of LS (3%) plus SO (2%), and ATS (5%) yielded between 7.7 and 11.4 t/ha in the 120 box size category.

No significant statistical difference was found among the treatments in the 140 count box size category. The treatments produced between 7.3 and 14.6 t/ha.

Wilthin (0.5%) had the largest amount of fruit into the cull category, yielding 21.7 t/ha. The untreated control, Petroleum oil (8%), LS (3%) plus SO (2%) applied at 20% bloom, and Wilthin (0.75%) also yielded a considerable amount of small fruit, between 11.8 and 14.0 t/ha, in the cull category. The remainder of the treatments produced lower amounts of cull fruits ranging between 5.4 and 8.9 t/ha.

Regression analyses of ATS, LS+FO, and Wilthin rate responses indicated that there were no significant relationships between rate of blossom thinner and yield for any box sizes.

Crop values for 'Zee Lady' were calculated using current fresh fruit prices. Applications of LS (1%) plus SO (2%) applied either at 20% bloom or at FB provided the greatest crop value totaling $15,720.00 and $15,520.00, respectively (Table 3.7).

In general, there was a negative relationship between fruit number / tree and crop value (Figure 3.8).

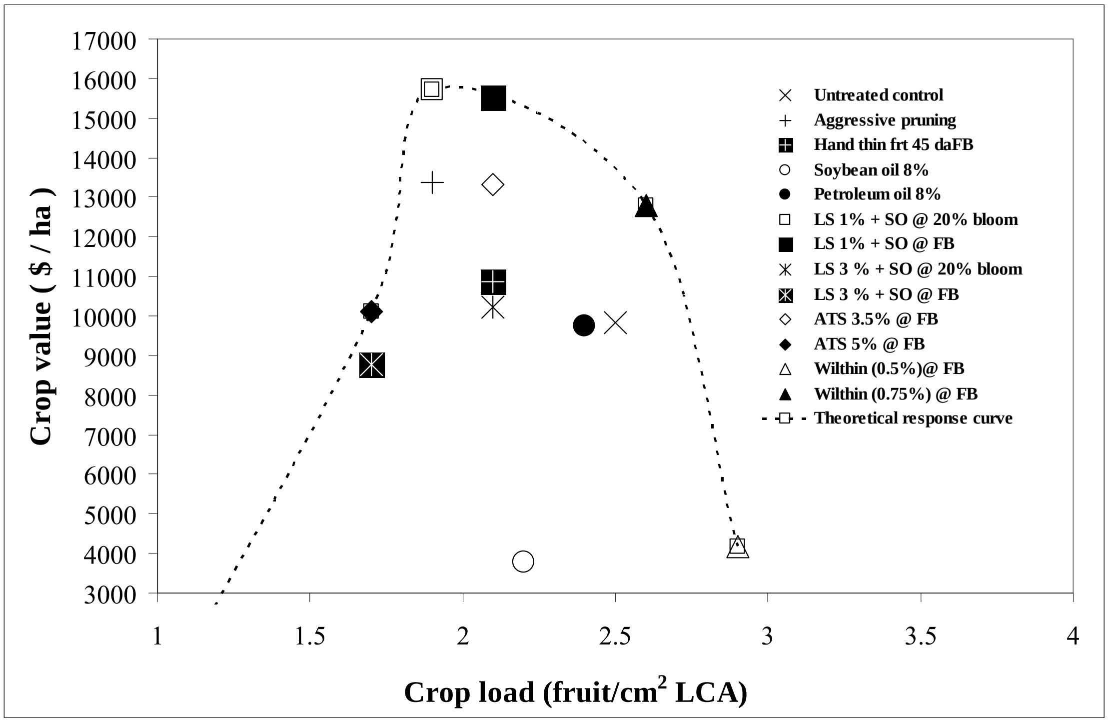

Figure 3.8 Effect of crop load and chemical thinning agents on crop value $ / ha of 'Zee Lady' peach.

Aggressive pruning, hand thinning fruit at 45 days after FB, Soybean oil (8%), ATS (3.5%), and Wilthin (0.75%) generated crop values ranging between $12,789.00 and $13,785.00 per ha while Petroleum oil (8%), LS (3%) plus SO (2%) applied at 20%, and ATS (5%) produced crop values of $9,745.00, $10,227.00, and $10,111.00, respectively. The untreated control and LS (3%) plus SO (2%) applied at FB had lower but similar crop values of $9,819.00 and $8,744.00 respectively and was found to be significantly different. Wilthin (0.5%) yielded the lowest crop value totaling $4,171.00 which was significantly lower than any other treatment.

Regression analysis of ATS, LS+FO, and Wilthin rate responses indicated that there were no significant relationship between rate of blossom thinner and crop value. Plotting crop load against crop value and then drawing a theoretical response curve showed that the optimum crop load to maximize crop value was around 2 fruits / cm^2 TCA.

Fruit soluble solids content was evaluated at the 1st harvest. Soluble solids level was found to be significantly different among the treatments (Table 3.8). Soybean oil (8%) and LS (3%)+ SO applied at FB produced the highest soluble solids levels at 12.3 and 12.2%, respectively. The untreated control, Petroleum oil (8%), and LS (1%) + SO applied at FB had the lowest soluble solids levels at 10.2, 10.1, and 10.3%, respectively. The remainder of the treatments ranged between 10.7 and 11.7%.

Regression analysis of ATS, LS+FO, and Wilthin rate responses indicated that there were no significant relationships between rate of blossom thinner and soluble solids level.

Discussion

The most effective thinning treatments in the 'Arkansas 9' experiment were hand thinning fruit at 45 days after FB and the dormant application of Soybean oil applied 25 days before bloom. Petroleum oil (8%) was not as effective as Soybean oil (8%). ATS (5%) was also effective at reducing crop load in 'Arkansas 9' but ATS (3.5%) was not effective on 'Arkansas 9' and the two different rates of LS (1, 3%) plus SO (2%) at either timing were also not effective as all these treatments carried crop loads between 4 and 5.3 fruits per cm^2 limb cross-sectional area while the untreated control carried 5.0 fruits per cm^2 limb cross-sectional area. Confoundingly, Wilthin (0.5%) was more effective in thinning than Wilthin (0.75%). The treatments were applied with a hand-gun and this may have been due to an error in over spray.

The most effective thinning treatments with the variety 'Zee Lady' were ATS (5%) and LS (3%) plus SO (2%) applied at FB. In fact, ATS (5%), LS (3%) plus SO (2%) applied at FB were the only treatments that were significantly different than the untreated control. Both rates of Wilthin (4, 6 pt) were without effect and actually carried heavier crop loads than the untreated control. However, ATS (3.5%), Wilthin (6pt) and hand thin at 45 days after FB seemed to improve or increase fruit size, producing fruit sizes of 103.8, 99.8, 101.5, respectively. Although application of ATS (3.5%) at FB treatment improved crop load adjusted fruit size the most, it was also one of the treatments with a heavier crop load levels at 4.37 fruits per cm^2 limb cross-sectional area. This suggests that earlier blossom thinning can improve fruit size and growers may tolerate higher crop load levels than hand thinning fruits at 45 days after FB. While the hand thinning treatment also significantly improved fruit size, there was a significant penalty in crop load level, (2.8 fruits per cm^2 LCA).

Overall, there was a general negative linear relationship between fruit size and crop load with both varieties. With 'Arkansas 9' Soybean oil and hand thinning 45 DAFB carried the lowest crop load levels and had the largest fruit size while the untreated control and LS (3%) plus SO had the heaviest crop loads and the smallest fruit size (Figure 3.2). With 'Zee Lady', LS 1% + SO applied at 20% bloom had the largest size and one of the lower crop loads while Wilthin (0.5%) had the smallest fruit size and the heaviest crop load. This is reported in several other studies Stover (2004), Stover (2001), Reginato et al. (2007), and Reighard, (2006).

Differences in crop load explain a substantial amount of variation in fruit size between treatments. However, with 'Arkansas 9', Wilthin (0.75%), and hand thinning at 45 DAFB seemed to improve or increase fruit size independently of crop load producing adjusted fruit sizes of 103.8, 99.8, and 101.5, respectively. It is noteworthy that the ATS (3.5%) at FB treatment improved fruit size the greatest, however, it was also one of the treatments with heavier crop levels at 4.37 fruits per cm^2 limb cross-sectional area. This suggests that earlier blossom thinning can improve fruit size and growers may tolerate higher crop load levels than hand thinning fruits 45 DAFB. While the hand thinning treatment also significantly improved fruit size, there was a significant penalty in crop load level, which was only 2.8 fruits per cm^2 limb cross-sectional area. With 'Zee Lady' the LS 1% + SO at 20% FB had large adjusted fruit size compared to the untreated control while Wilthin (0.5%) had significantly smaller adjusted fruit size than the control indicating that these two treatments affect fruit size (one positively and one negatively) independent of their effects on fruit size. It may be that the Wilthin treatment caused foliar damage which the LS + SO treatments did not. This is likely since Wilthin is known to cause foliar damage and the handgun application likely resulted in more damage than airblast applications. The LS + SO treatment was applied earlier when less foliage was open.

The aggressive pruning treatment involved a detailed pruning and removed one third of the length of all the shoots on the tree. This treatment was not very effective in reducing fruit number or improving fruit size. In fact, this may have had a deleterious effect on the tree as fruit size was nearly as poor as the untreated control, 86 and 85 grams, respectively. It appears that the aggressive pruning treatment removed portions of each shoot with significant leaf area but relatively few fruits. Thus, the trees did not have enough energy to support the surplus of fruits with the reduced leaf area. Aggressive pruning did not have a negative effect on fruit size in 'Zee Lady'. The crop load levels carried on the 'Zee Lady' trees were half the crop loads levels on 'Arkansas 9'. Therefore the reduction in leaf area may not have posed a limitation of carbohydrate supply to developing fruits as this treatment did in

‘Arkansas 9’. However, high rates of ATS (5%) and LS (3%) plus SO applied at FB did have a significant negative influence on fruit size (Figure 3.6).

The integrator of the differing effects of thinning treatments on yield and fruit size is crop value. In the ‘Arkansas 9’ experiment, ATS (3.5%) improved crop value the most followed by hand thinning at 45 DAFB. The ideal crop load to maximize crop value is somewhere between 2.5 (Soybean oil 8%) and 2.8 (hand thin) fruits per cm^2 limb cross-sectional area (Figure 3.4). However, the treatment that increased crop value the greatest was actually at a crop load level of 4.4 fruits per cm^2 LCA. This suggests that blossom thinners can improve crop values at higher crop load levels than that of hand thinning at 45 DAFB. The untreated control and aggressive pruning treatment had the lowest crop values which was the result of most of the fruit being very small which has little value. Similarly, applications of LS plus SO at both rates (1, 3 %) and timings (20%, full bloom) had low crop values. Fruit size was also extremely poor for these treatments with the majority of fruit into the cull category. Another treatment that had a low crop value was the high rate of Wilthin (0.75%) which also had a large proportion of fruit into the cull category. This was likely due to foliage or fruit damage of a high rate of product by the hand gun application.

With ‘Zee Lady’ the low rate of Wilthin (0.5%) had much lower crop value than any other treatment. This also was probably due to foliage damage but no thinning resulted in many small fruits.

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CHAPTER 4

CHEMICAL BLOSSOM THINNING INCREASES FRUIT SIZE AND CROP VALUE OF 'REDHAVEN' PEACH

Abstract

In 2005, we conducted a blossom thinning study on six-year-old 'Redhaven' peach trees on Lovell seedling rootstock. The trees were trained as an open vase at a spacing of 4.25 x 6.1 meters or 385 trees per hectare. Treatments were applied by an air-blast sprayer at a volume of 935 liters/hectare. Treatments included Soybean oil (8%) plus Latron B (0.8%) applied 18 and 25 days before FB, Lime sulfur (2 or 4%) plus Soybean oil (2%), ATS (3.5 or 5.0%), Wilthin (0.5, 0.75%) plus Regulaid (0.125%), Entry (1.5 or 3.0 %), or Tergitol TMN-6 (0.75 or 1.5%) applied at FB. In addition, there were two hand-thin treatments. Hand-thinning at full bloom to a crop load of 7 fruits per cm^2 TCA and a hand-thinning fruit at 45 days after FB to 7 fruits per cm^2 TCA.

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. Fruit diameter measurements in the early season of 2005 showed that ATS 5% and Lime sulfur 4% caused a significant reduction in fruit growth rate for 35 days after application. Tergitol and Soybean oil had a lesser effect on fruit growth.

The other chemicals did not affect fruit growth rate. ATS (3.5%) produced the largest average fruit size of 195 g. Untreated control had the smallest fruit size of 117 g. ATS (5%) and hand thin flowers at FB improved fruit size to 185 and 188 g respectively. LS (4%) plus SO (2%) 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 DBFB produced statistically similar fruit sizes of 154 and 151 grams. SO (8%) applied 25 days before FB and Wilthin (0.75%) had average fruit sizes of 148 and 150 grams, respectively. Wilthin (4 pt) and Tergitol (0.75%) treatments slightly improved fruit size. SO (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. SO (8%) applied 25 DBFB, untreated control, Wilthin (0.5%) and Tergitol (0.75%) had statistically similar values 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 thin fruit 45 daFB and LS (2%) plus SO (2%) statistically had 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 thin flowers at FB had the lowest crop values, $4,356.00 and $4,193.00.

Introduction

In New York State, peaches are a minor crop, however, they are a high value crop for New York tree fruit growers and provide diversity in their production systems. Hand thinning at 45 DAFB is the main practice that is used to adjust crop load. Partial crop thinning by chemical blossom thinners has tremendous potential to minimize high hand labor costs, increase fruit size, and improve overall crop value. The objective of this study was to evaluate several new blossom thinning chemicals for efficacy in New York State.

Material and Methods

Plant material

Six-year-old 'Redhaven' peach trees on Lovell seedling rootstock were selected from a commercial orchard in Niagara County, NY. The trees were trained to open vase system and were planted at a spacing of 4.25 X 6.1 m or 385 trees per hectare or 14 X 20 feet or 156 trees per acre. The trees were pruned at full bloom.

Experimental design

A randomized complete block design with 15 treatments and 5 replications was used in the study for a total of 75 test trees. Each test tree was guarded by two adjacent trees which received the same treatment.

Treatments

Treatments were applied by an air-blast sprayer at a volume of 935 L/ ha or 100 gal/ acre. The treatments were: 1) untreated control; 2) hand thin flowers to 7 fruits per cm^2 at full bloom; 3) hand thin fruits to 7 fruits per cm^2 at 45 days after full bloom; 4) Soybean oil (8%) plus Latron B (0.8%)applied 25 days before bloom; 5) Soybean oil (8%) plus Latron B (0.8%) applied 18 days before bloom; 6) Lime sulfur (2%) plus Soybean oil (2%) plus Latron B (0.8%); 7) Lime sulfur (4%) plus Soybean oil (2%) plus Latron B (0.8); 8) ATS (3.5%); 9) ATS (5%); 10) Wilthin (0.5%) ; 11) Wilthin (0.75%) ; 12) Entry (1.5%); 13) Entry (3.0%); 14) Tergitol TMN-6 (0.75%); and 15) Tergitol TMN-6 (1.5 %). Treatments were applied at full bloom unless otherwise stated.

Measurements

Trunk circumference measurements (TCSA) were taken at 30 cm above the soil and were used to calculate trunk cross-sectional area (TCA). Two limbs per tree were selected at pink bud stage and the flowers were counted. Persisting fruit were counted 45 days after bloom. Fruit set was expressed as percentage of flowers, which developed into persisting fruits. Fruit growth measurements of 10 fruits per test tree were collected weekly during the early part of the season and thereafter monthly. Fruits were harvested in 4 harvests when mature. At each harvest, fruits were counted and weighed. Total yield was calculated by summing harvested weight of each data tree over four harvests. A sample of 50 fruits were collected over the 4 harvests and evaluated for size and red color using a commercial MAF RODA Pomone fruit grader to evaluate pack out using 5 size categories. The size category that were used are as follows; 80 box size or a 3.25 inch peach, 100 box size or a 3.0 inch peach, 120 box size or a 2.75 inch peach, 140 box size or a 2.5 inch peach, 160 box size or a 2.25 inch peach, and a cull category in which all fruits that are not equal to or larger than 2.25 inches fall into this category. A sub sample of ten fruit was randomly selected from the 50 fruit sample for evaluation of fruit firmness and soluble solids. The yield and the simulated pack-out were used to calculate farm gate crop value using average prices for western New York in 2006. 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 (20kg) of different fruit sizes. Prices used were $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.

Statistical Analysis

Data were analyzed by ANOVA using SAS Proc GLM (SAS Institute, Cary, NC). Significant differences among means were determined by LSD, ($P \leq 0.05$). The effect of treatment on fruit size independent of crop load was determined by adjusting fruit size for crop load (Stover et al., 2001). Rate responses of ATS or LS+SO were determined by regression analysis.

Results

ATS (5%) reduced fruit set to 4.2% and resulted in severe over thinning (Table 4.1). ATS (3.5%) was also a potent thinning agent reducing fruit set to 8.8%. Hand thinning fruit at 45 DAFB, LS (4%) plus SO (2%), and Tergitol (1.5%) treatments also were found to be highly effective thinning treatments reducing fruit set to 10-11%. The treatments that provided moderate thinning activity included the low rate of Tergitol (0.75%) and the high rate of Entry (3.0%) reducing fruit set to 15% and 13%, respectively. LS (2%) plus SO (2%) reduced fruit set only moderately to 17.6%. Wilthin (0.5%) and Entry (1.5%) were less effective reducing fruit set to approximately 20%. The untreated control trees averaged a fruit set of 22.4%. Dormant applications of SO (8%) at both timings, 18 and 25 days before full bloom

(DBFB), and Wilthin (0.5%, 0.75%) were without effect at 31% and 23.6% fruit set respectively.

Regression analysis of ATS and Tergitol rate responses indicated a significant linear relationship between rate of blossom thinner and fruit set. Regression analysis of LS+FO, Wilthin, and Entry rate responses indicated that there were no significant relationship between rate of blossom thinners and fruit set.

Blossom thinners had a highly significant effect on crop load. ATS (5%) reduced crop load from 0.75 fruits per cm^2 TCA while the untreated control had 5.2 fruits/cm^2 TCA. SO (8%) applied at 18 days before FB, Wilthin (2.8 L), and Tergitol (0.75%) carried statistically similar crop loads of approximately 3.8 to 4.0 fruits per cm^2 TCA, respectively. SO (8%) applied 25 days before FB, Wilthin (0.75%), and Entry (3.0%) treatments moderately reduced crop load levels to between 3.4 to 4.7. fruits per cm^2 TCA. Tergitol (1.5%) dramatically reduced crop load to 2.3 fruits per cm^2 TCA. LS (2%) plus SO (2%) and hand thinning fruit at 45 DAFB over-thinned and carried low crop loads of 1.7 fruits per cm^2 TCA. LS (4%) plus SO (2%) severely over thinned and reduced crop load to 1.1 fruits per cm^2 TCA. Finally, hand thinning flowers at FB, and both applications of ATS (3.5, 5%) reduced crop loads to extremely low levels, 0.75 to 0.87, and would be considered commercially unacceptable. Crop load had a negative effect on fruit size.

Regression analyses of ATS, LS+FO, and Tergitol rate responses indicated a significant linear relationship between rate of blossom thinner and crop load. A quadratic relationship was also found with the ATS and LS+FO rate responses. Regression analysis of Wilthin and Entry rate responses indicated that there were no relationship between rate of blossom thinner and crop load (Table 4.1).

ATS (3.5, 5.0 %) and hand thinning flowers at FB reduced fruit number to 138, 122, and 141 fruits per tree, respectively (Table 4.1). LS (4%) plus SO (2%) at full bloom also markedly reduced fruit number to 189. The hand-thin treatment at 45 DAFB and LS (2%) plus SO (2%) also were quite effective and significantly reduced fruit number to 274 and 273 fruits, respectively. The next best treatment was Tergitol TMN-6 (1.5%) which had an average of 376 fruits per tree. Entry (1.5%) was a less effective thinner producing 495 fruit. Wilthin (0.75%) and Entry (3%) were statistically similar producing 559 and 570 fruits per tree respectively. Soybean Oil (8%) applied 18 days before FB, Wilthin (0.5%), and Tergitol (0.75) were statistically similar and fruit number varied between 624 and 645 fruits per tree. Finally, fruit number of the untreated control was 840 fruits per tree. In general, there was a positive linear relationship between fruit number and yield of 'Redhaven peach'.

Regression analyses of ATS, LS+FO, and Tergitol rate responses indicated a significant linear relationship between rate of blossom thinner and fruit number per tree (Table 4.1). A quadratic relationship was also found with the ATS and LS+FO rate responses. Regression analysis of Wilthin and Entry rate responses indicated that there were no significant relationship between rate of these blossom thinners and fruit number per tree.

The untreated control trees and SO (8%) applied 18 days before FB treatments produced the highest yields, averaging approximately 37 t/ha or 750 bu /acre (Table 4.2). Soybean Oil (8%) applied 25 days before FB, Wilthin (0.5%, 0.75%), Entry (3.0%), and Tergitol TMN-6 (0.75) produced yields similar to the untreated control

Table 4.1 Effect of chemical thinning agents on percent fruit Set, crop load and fruit number per tree of ‘Redhaven’ peach.

Treatment	Fruit Set (%)	Crop Load (fruits per/ cm^2 TCA)	Fruit Number /Tree
Untreated control	25.3 abc	5.20 a	840 a
Hand thin flowers FB	18.6 bcdef	0.87 f	141 f
Hand thin fruit 45 DAFB	10.0 efg	1.70 efd	274 def
SO 25 DBFB	23.6 abcd	3.75 bc	603 bc
SO 18 DBFB	31.0 a	4.01 ab	645 ab
LS (2%) + SO (2%)	17.6 bcdef	1.70 efd	273 def
LS (4%) + SO (2%)	10.6 efg	1.18 ef	189 ef
ATS 3.5%	8.8 fg	0.86 f	138 f
ATS 5.0%	4.2 g	0.75 f	122 f
Wilthin 0.5%	20.2 abcde	3.91 ab	629 ab
Wilthin 0.75%	27.2 ab	3.48 bc	559 bc
Entry 1.5 %	19.8 abcdef	3.08 bcd	495 bcd
Entry 3.0%	13.2 defg	3.55 bc	570 bc
Tergitol 0.75%	15.0 cdefg	3.88 ab	624 ab
Tergitol 1.5%	11.2 efg	2.34 cde	376 cde
Regression analyses			
ATS rate response	L	L,Q	L,Q
LS+FO rate response	NS	L,Q	L,Q
Wilthin rate response	NS	NS	NS
Entry rate response	NS	NS	NS
Tergitol rate response	L	L	L

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

between 32 and 33 t/ha or 650 and 672 bu/acre. Entry (1.5%) treated trees produced 28 t/ha or 574 bu/acre. Tergitol (1.5%) reduced yields to 23.4 t/ha or 476 bu/acre. The hand thin fruit treatment and LS (2%) plus SO (2%) were quite effective at reducing yields and were statistically similar producing 17.9 and 18.1 t/ha or 364 and 369 bu/acre, respectively. LS (4%) plus SO (2%) was very effective and reduced of

ATS (3.5%, 5.0%) reduced yield most dramatically to 8.9 to 10.4 t/ha or 182 yield to 12.9 T/ha or 263 bu/acre. Hand thinning flowers at FB, and both rates to 213 bu acre.

Table 4.2 Effect of blossom thinning agents on yield, fruit size, and crop load adjusted fruit size of 'Redhaven' peach.

Treatment `	Yield (t/ha)	Fruit Size (g)	Crop load Adjusted Fruit Size (g)
Untreated control	37.7 a	117 h	149.8 b
Hand thin flowers FB	10.3 e	188 ab	166.8 ab
Hand thin fruit 45 DAFB	17.9 cde	170 bcdef	159.0 ab
SO 25 DBFB	32.3 ab	148 fg	162.5 ab
SO 18 DBFB	36.9 a	151 efg	169.1 a
LS (2%) + SO (2%)	18.1 cde	174 abcde	162.7 ab
LS (4%) + SO (2%)	12.9 de	182 abcd	164.6 ab
ATS 3.5%	10.4 e	195 a	173.1 a
ATS 5.0%	8.9 e	185 abc	162.1 ab
Wilthin 0.5%	32.2 ab	142 g	158.3 ab
Wilthin 0.75%	32.0 ab	150 fg	161.4 ab
Entry 1.5 %	28.2 abc	155 efg	160.9 ab
Entry 3.0%	32.5ab	159 defg	171.3 a
Tergitol 0.75%	33.1ab	144 g	160.5 ab
Tergitol 1.5%	23.4 bcd	163 cdefg	160.5 ab
Regression analyses			
ATS rate response	L	L,Q	NS
LS+FO rate response	L,Q	L,Q	NS
Wilthin rate response	NS	L	NS
Entry rate response	NS	L	NS
Tergitol rate response	L	L	NS

[y] Means followed by the same letter are not significantly different using LSD. $P \leq 0.05$, n=5.

Regression analyses of ATS, LS+S and Tergitol rate responses indicated a significant linear relationship between rate of blossom thinner and yield per hectare (Table 4.2). A quadratic relationship was also found with the LS+FO rate responses.

Regression analysis of Wilthin and Entry rate responses indicated that there were no significant relationships between rate of these blossom thinners and yield (Figure 4.1)

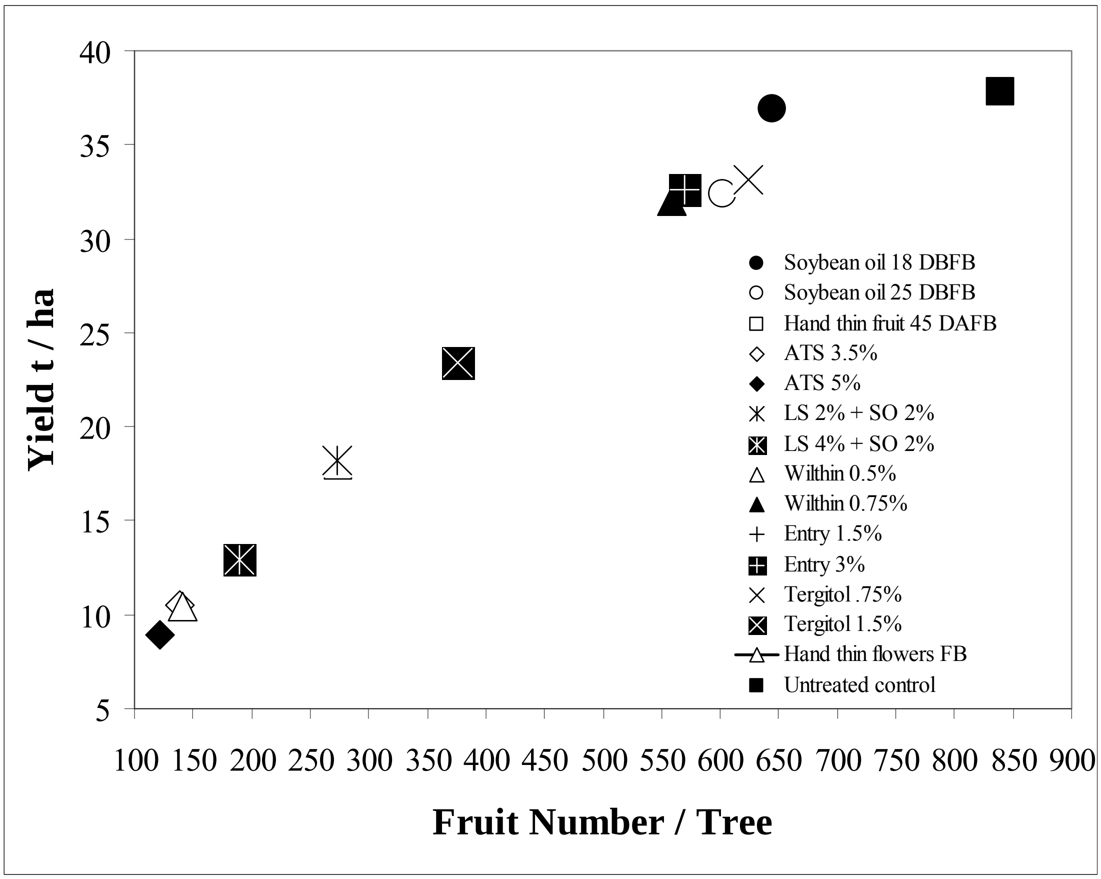

Figure 4.1 Relationship between fruit number per tree and yield per / ha of 'Redhaven' peach.

All thinning treatments increased fruit size compared to the untreated control (Table 4.2). 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 cm^2 TCA. ATS (5%) and hand thin 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.

Regression analyses of ATS, LS+SO, Wilthin, Entry, and Tergitol rate responses indicated a significant linear relationship between rate of blossom thinner and fruit size. A quadratic relationship was also found with ATS and LS+FO rate responses (Figure 4.2).

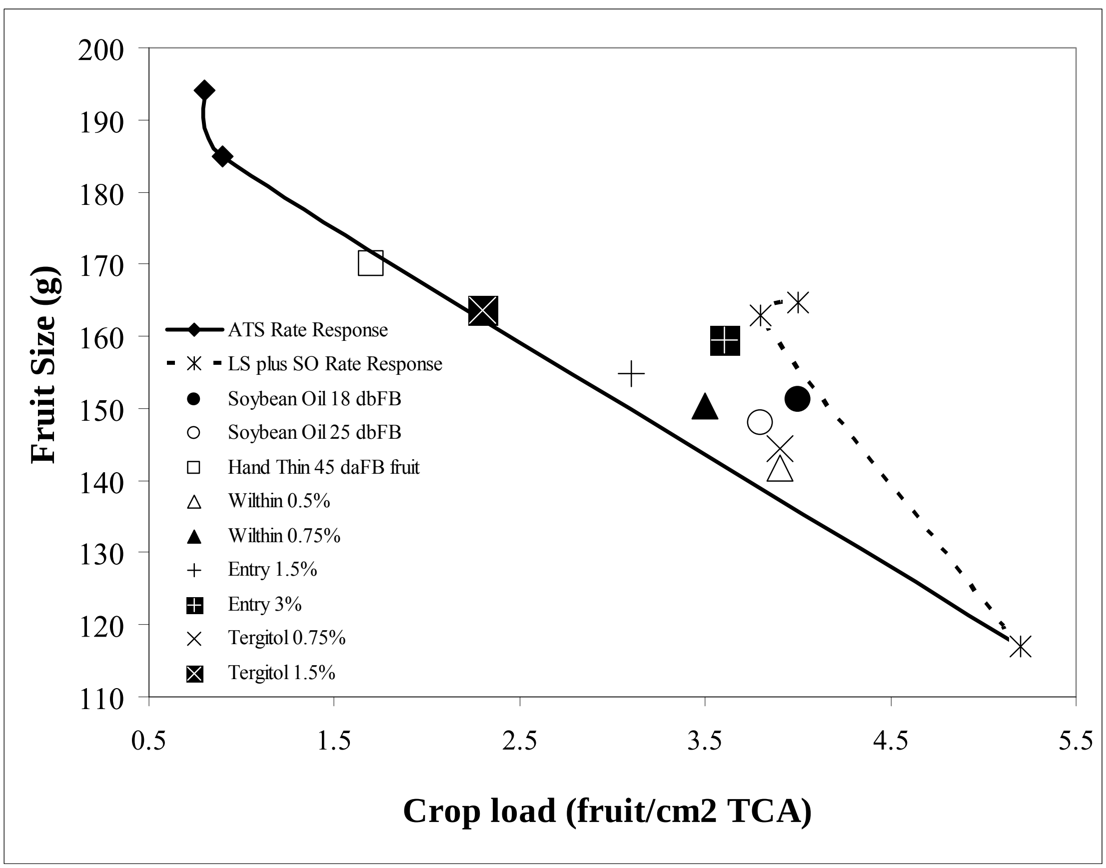

Figure 4.2 Effect of crop load and chemical thinning agents on fruit size of 'Redhaven' peach.

The strong relationship between fruit size and crop load required the use of crop load as a covariate to evaluate the effect of the chemical thinners independent of the cropload effect. After adjustment for crop load there was not a significant relationship between adjusted fruit size and crop load. However, two treatments had significantly larger adjusted fruit size than the untreated control (Table 4.2). ATS (3.5%) and the late timing of SO (8%) at 18 DBFB both improved fruit size more than that expected from their effect on reducing crop load. In the case of ATS (3.5%) there was a massive reduction in crop load and a very large increase in fruit size. In the case of late Soybean oil application at 18 days before FB crop load was only moderately reduced and was higher (4.01) than the earlier timing at 25 days before FB (3.75) yet fruit size was slightly larger; 151grams (18 DBFB) versus 148 grams applied 25 (DAFB).

Regression analyses of ATS, LS+FO, Wilthin, Entry, and Tergitol rate responses indicated no significant relationship between rate of blossom thinner and crop load adjusted fruit size (Figure 4.3).

Fruit diameter measurements in the early season of 2005 showed that ATS (5%) and LS (4%) plus SO (2%) caused a significant reduction in fruit growth rate for 40 days after FB (Table 4.3). Average fruit size for both treatments of ATS (3.5, 5%) were approximately 17 mm while the LS (2,4%) plus SO treated trees had an average fruit size of 19mm. The remainder of the treatments averaged between 21 and 23 mm. Tergitol (1.5%) and Soybean oil had a lesser effect on early fruit growth. The other chemicals did not affect fruit early growth rate.

Analysis of fruit packout data showed that Soybean oil (8%) 18 DBFB had the greatest fruit into the largest size category, 100 count, at 6.2 t/ha (Table 4.4). ATS

(5%) and Tergitol (1.5%) produced the lowerst amount in this category with 2.4 and 2.6 t/ ha, respectively. The remainder of the treatments produced an intermediate amount between 3.4 and 4.7 t/ha.

Regression analyses of ATS, LS+FO, Wilthin, Entry, and Tergitol rate responses indicated no significant relationship between rate of blossom thinner and yield in the 100 box category.

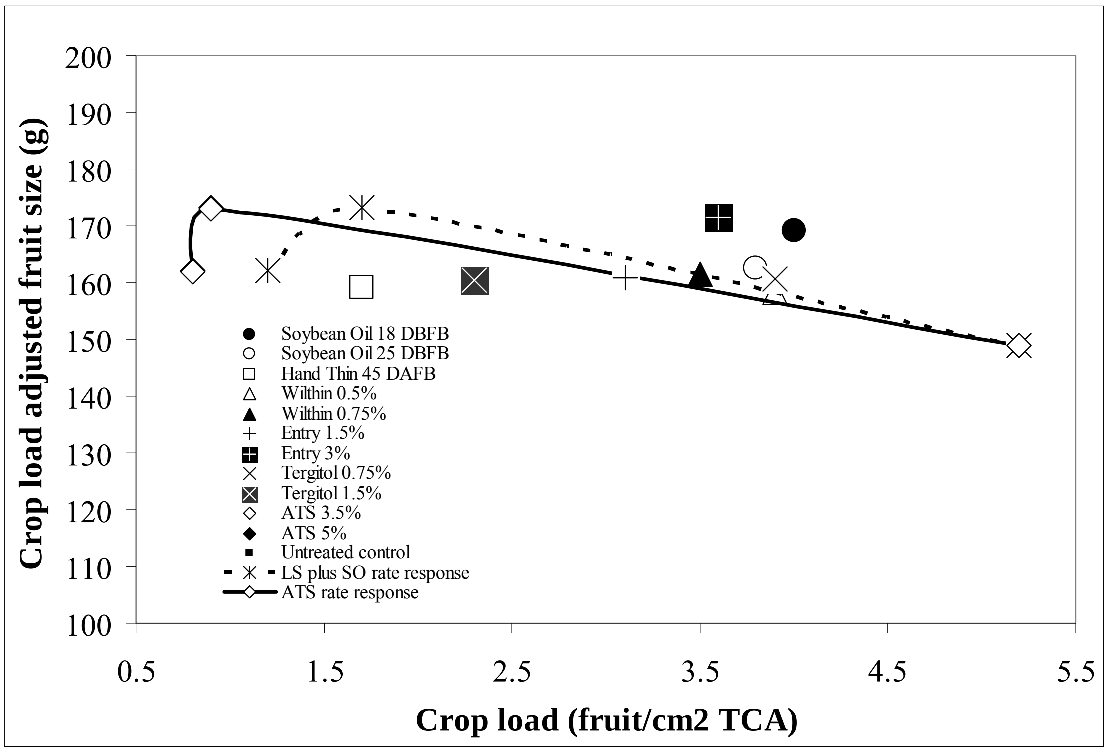

Figure 4.3 Effect of crop load and chemical thinning agents on fruit size adjusted for crop load of 'Redhaven' peach.

Soybean oil (8%) 18 DBFB, Wilthin (0.75%), and Entry (3.0%) had the greatest amount of fruit in the 120 box size category producing between 12.7 and 13.1 t/ha. Tergitol (0.75%) had 11.8 t/ha. Soybean oil (8%) applied at 25 DBFB and Entry (1.5%) yielded a statistically similar yield of 10.2 and 10.6 t/ha in the 120 box size category. The untreated control, Wilthin (0.5%), and Tergitol (1.5%) yielded between 8.7 and 9.2 t/ha in the 120 box size category. The hand thinning fruit treatment produced 7.4 tons per hectare in the 120 box size category while the LS (2%) and LS (4%) produced 6.5 and 4.6 tons per hectare respectively. Hand thinning flowers and both rates of ATS had the lowest yield in this size category at 3.2 and 3.1 tons per hectare.

Regression analysis of ATS rate response indicated a significant linear relationship between rate of blossom thinner and yield of fruit in the 120 box size category. All other rate responses were found to be not significant.

Table 4.3 Effect of blossom thinning agents on fruit growth rate of 'Redhaven peach'.

Treatment	Fruit Diam 21 daFB (mm)	Fruit Diam 31 daFB (mm)	Fruit Diam 40 daFB (mm)
Untreated control	7.1 a	14.8 a	23.7 a
Hand thin flowers FB	6.8 ab	14.7 ab	23.7 a
Hand thin fruit 45 DAFB	7.1 a	14.5 ab	22.6 ab
SO 25 DBFB	7.1 a	14.5 ab	23.7 a
SO 18 DBFB	6.5 ab	14.1 ab	21.6 ab
LS (2%)+ SO (2%)	6.9 ab	13.1 bcd	19.2 bcd
LS (4%)+ SO (2%)	6.7 ab	13.2 abcd	19.0 bcd
ATS 3.5%	6.6 ab	12.1 cd	17.4 cd
ATS 5.0%	6.3 b	11.8 d	16.9 d
Wilthin 0.5%	6.9 ab	14.6 ab	22.2 ab
Wilthin 0.75%	7.0 ab	14.8 ab	22.5 ab
Entry 1.5 %	6.9 ab	14.4 ab	22.2 ab
Entry 3.0%	6.9 ab	14.5 ab	22.8 ab
Tergitol 0.75%	6.7 ab	13.9 ab	21.3 ab
Tergitol 1.5%	6.6 ab	13.7 abc	21.1 abc

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

The untreated control produced the greatest quantity of fruit in the 140 box size category, 17.8 t/ha. Soybean oil 18 DAFB yielded 13.8 t/ ha in this category while

SO 25 DBFB and Wilthin (0.5%) produced 13.0 and 13.3 tons/ha respectively. Wilthin (0.75%), Entry (3%), and Tergitol (0.75) yielded between 9.9 and 10.6 t/ha. Entry (1.5%) and Tergitol (1.5%) produced 8.9 and 6.8 t/ha in the size category respectively. The remainder of the treatments produced less than 5 t/ha.

Regression analyses of ATS, LS+SO, Entry and Tergitol rate responses indicated a significant linear relationship between rate of blossom thinner and yield of fruit in the 140 box size category. In addition, quadratic relationships were found among the ATS and LS+SO rate responses. The rate response of Entry was not significant.

The untreated control yielded the greatest number of fruit in the cull category, 8.5 t/ha. Entry (1.5%), SO 25 DBFB, and Tergitol (0.75) were statistically similar and yielded 6.0, 6.5, and 6.7 t/ha. SO 18 DBFB, Wilthin (0.75%), Entry (3.0%), and Tergitol (1.5%) were also statistically similar and produced from 4.6 to 5.0 t/ha in the cull size category. ATS (3.5, 5%), LS (4%) + SO, and hand thin flowers at FB yielded the lowest number of fruit in the cull size category ranging between 1.0 and 1.8 t/ha.

Regression analyses of ATS, LS+SO, and Wilthin rate responses indicated a significant linear relationship between rate of blossom thinner and yield of fruit in the cull box size category. In addition, a quadratic relationships were found with both the ATS and LS+FO rate responses. Entry and Tergitol rate responses were not significant.

The treatment that generated the highest crop value was SO (8%) applied 18 DAFB at $14,949.00 ha (Table 4.4). The second highest crop values were Entry (3.0%) and Wilthin (0.75%) which generated crop values of $12,866.00 and $12,552.00 / ha respectively. SO (8%) applied 25 DBFB, the untreated control, Wilthin (0.5%) and Tergitol (0.75%) had statistically similar values and varied between $11,191.00 and $11902.00/ha. Entry (1.5%) and Tergitol (1.5%) had a moderate crop value of $9,864.00 and $8,581.00 / ha, respectively. Hand thin fruit 45 @ DAFB and LS (2%) plus SO (2%) statistically had lower crop values at $6,711.00 and $7,371.00/ha, respectively. ATS (3.5%) and LS (4%) plus SO (2%) also had low crop values of $5,250.00 and $5,515.00/ha, respectively. Finally, ATS (5%) and hand thin flowers at FB had the lowest crop values, $4,356.00 and $4,193.00/ha respectively.

Regression analyses of ATS and LS+FO indicated a significant linear relationship between rate of blossom thinner and crop value/ha. Wilthin, Entry and Tergitol rate responses were not significant. A theoretical response curve showing potential crop value was drawn by connecting the means of the unthinned trees, SO 18 DBFB, Entry (3%), and ATS (3.5%). Plotting crop load against crop value and then drawing a theoretical response curve showed that the optimum crop load to maximize crop value was around 4 fruits/ cm^2 TCA (Figure 4.4).

Discussion

In 2005, ATS (5.0%) and LS (4%) plus SO (2%) markedly and significantly suppressed early fruit growth of 'Redhaven' peach during the first 40 DAFB.. This is not a desirable attribute of an effective thinner because the inhibitory effect on fruit growth is too dramatic for an extended period. Lime sulfur has been reported to reduce photosynthesis and fruit growth for several weeks in apple. Unpublished data by Schupp, Lakso, and Robinson (2004) found that 2 applications of LS (2%) plus FO (2%) treatments 2 days apart could reduce Pn by up to 65% and had not fully recovered 2 weeks later. In our study, Lime sulfur (2%) plus SO (2%) and ATS

(3.5%) similarly showed an extended suppression in fruit growth rate in peach. In 2005, both rates of ATS (3.5, 5%) proved to be an effective blossom-thinning agent on 'Redhaven' but at high concentrations (3.5%, 5%) resulted in severe over-thinning. Entry (3%) was not as effective as the low rate of Entry (1.5%). This thinner dose response was not linear with rate and may have been due to foaming in the spray tank as the higher rate of Entry (3%) produced an excessive amount of foam in the spray tank and when the product was applied; simply not enough material reached the tree canopy.

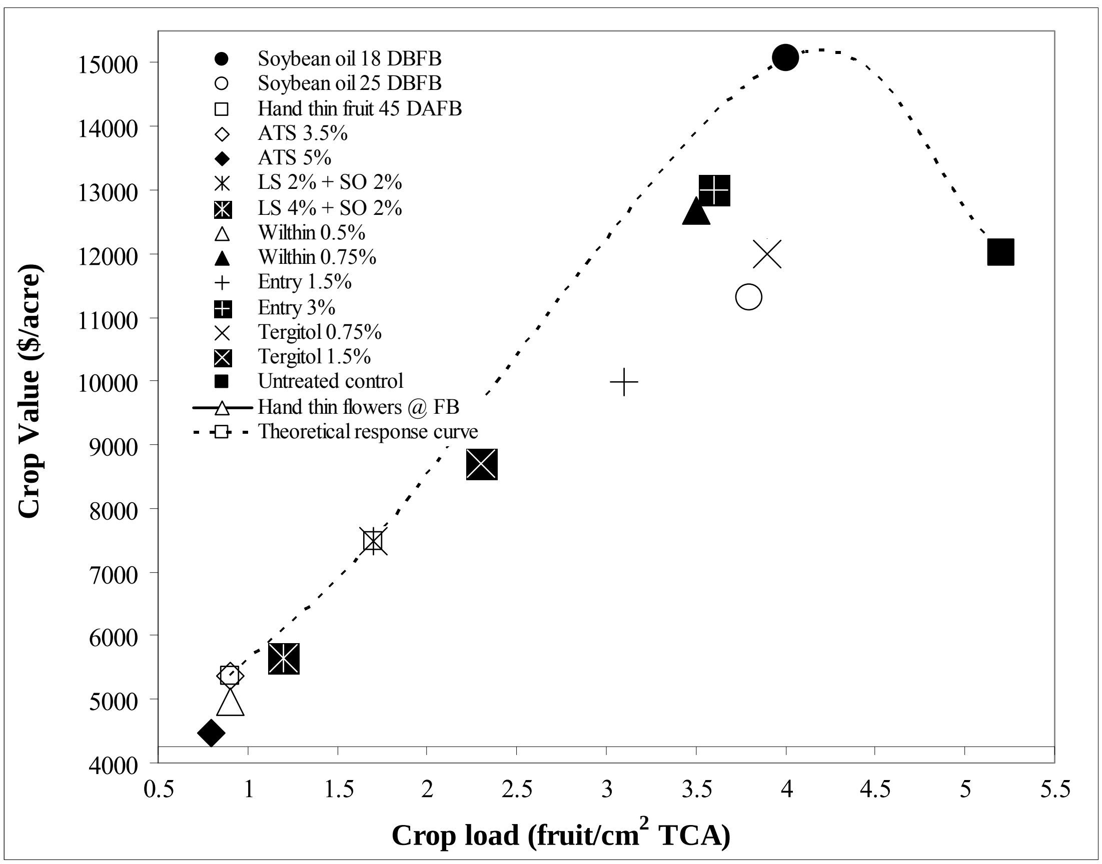

Figure 4.4 Effect of crop load and chemical thinning agents on crop value $ / ha of 'Redhaven peach'.

Table 4.4 Effect of blossom thinning agents on fruit pack out and crop value of 'Redhaven' peach.

Treatment	Yield by box size category (t / ha) % 100 Count	% 120 Count	% 140 Count	% Culls Count	Crop Value $/ha
Untreated control	3.9 ab	9.0 abcd	17.8 a	8.5 a	12107.00 abc
Hand thin flowers FB	2.8 ab	3.2 e	2.3 fg	1.2 e	4193.00 f
Hand thin fruit 45 DAFB	3.4 ab	7.4 bcde	4.7 efg	2.6 ed	6711.00 def
SO 25 DBFB	3.1 ab	10.2 abc	13.0 abc	6.5 ab	11191.00 abcd
SO 18 DBFB	6.2 a	13.1a	13.8 ab	4.6 bcd	14949.00 a
LS (2%) + SO (2%)	3.8 ab	6.5 cde	4.2 efg	3.3 cde	7361.00 cdef
LS (4%) + SO (2%)	3.1 ab	4.6 de	2.9 fg	1.8 e	5515.00 ef
ATS 3.5%	3.6 ab	3.1e	1.2 g	1.1 e	5250.00 ef
ATS 5.0%	2.4 b	3.1e	1.3 g	1.0 e	4356.00 f
Wilthin 0.5%	4.7 ab	9.2 abcd	13.3 abc	5.4 bc	11902.00 abc
Wilthin 0.75%	4.1 ab	13.0 a	9.9 bcd	5.0 bcd	12552.00 ab
Entry 1.5 %	3.4 ab	10.6 abc	8.9 cde	6.0 ab	9864.00 bcde
Entry 3.0%	5.0 ab	12.7 a	10.4 bcd	4.9 bcd	12866.00 ab
Tergitol 0.75%	4.5 ab	11.8 ab	10.6 bcd	6.7 ab	11875.00 abc
Tergitol 1.5%	2.6 b	8.7 abcd	6.8 def	4.8 bcd	8581.00 bcdef
Regression analyses					
ATS rate response	NS	L	L,Q	L,Q	L
LS+FO rate response	NS	NS	L,Q	L,Q	L
Wilthin rate response	NS	NS	L	L	NS
Entry rate response	NS	NS	NS	NS	NS
Tergitol rate response	NS	NS	L	NS	NS

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

Considerable research by Reighard et al. (2006) suggests that soybean oil can be an effective fruit thinner when applied at the proper dosage and applied after chill hours are met. In our trials, soybean oil applications were ineffective. This may have been due to less than optimum spray volumes. Our sprays were delivered by an air-blast sprayer at 935L/ha. However, spray volumes greater than 935 L per hectare may be required to achieve adequate thinning. Reighard (2006) reports that a spray volume of at least 1400 L/h is necessary for adequate coverage and thinning efficacy. Furthermore, the cool spring conditions in New York may not be conducive to weather conditions required for the thinning effect of the oil to reduce respiration in flower buds during warm periods reported in southern climates.

In 2005, several treatments including both rates of ATS (3.5%, 5.0%) reduced fruit number per tree below the optimum. Dan Sievert, orchard manager and owner where this trial was conducted reported that based on tree size and age that the trees should carry approximately 325 fruits per tree. The treatment that came close to this number was Tergitol TMN-6 (1.5%) reduced fruit number per tree to 376 fruits. Although the grower estimated the optimum fruit number per tree was 325 our data showing crop value indicates the optimum fruit per tree was significantly higher between 500-700. This translates into a crop load of 3.5-4.0 fruits per cm^2/TCA. Most thinning trials do not calculate crop value thus making it difficult to predict optimum fruits/tree and to make any inferences for other orchards. A recent paper by Reginato et al. (2007) has calculated optimum crop loads for early, midseason, and late season peach cultivars. Our measure of crop load was different than the work done by Reginato et al. (2007) as we used fruits per cm^2/TCA and Reginato et al. calculated crop value based on light interception data per unit land area.

Although, the importance of blossom thinning to maximize fruit size at harvest has been recognized for many years (Havis, 1962). Previous work with caustics or desiccants for bloom and post bloom thinning of peaches has led to mixed results and no commercial use of Wilthin® (Meyers et al. 1993); Elgetol (Hibbard and Murneek, 1944); urea (Zilkah et al. 1988); fertilizers (Byers and Lyons, 1984); soybean oil (Myers et al. 1996); and growth regulators (Southwick, 1995). While thinning can be done if thinners are applied anywhere from pink to full bloom, the greatest response is when applications are made near bloom (Byers and Lyons, 1984). Our results from the trials in 2005 suggest early partial crop thinning by blossom thinning agents can improve fruit size, and improve crop value in 'RedHaven' peach.

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CHAPTER 5

CHEMICAL BLOSSOM THINNING INCREASES FRUIT SIZE AND CROP VALUE OF 'BABYGOLD 5' PEACH

Abstract

In 2006, we conducted a blossom thinning study on 'Babygold 5' peach trees on Lovell seedling rootstock. The trees were four-years-old and trained to a quad-V at a spacing of 3.65 x 6.1 m or 336 trees per hectare or 12 x 20 feet or 136 trees per acre. Treatments were applied by an air-blast sprayer at a volume of 935 liters/hectare. Treatments included untreated control, hand thin flowers to 1 fruit/TCA @ 35 DAFB, hand thin flowers to 2 fruits/TCA @ 35 DAFB, hand thin fruits to 1 fruits/TCA @ 50 DAFB, hand thin fruits to 2 fruits/TCA @ 50 DAFB, Tergitol (0.75%) applied at two timings 35% and 85% FB, Tergitol (1.5 %) applied at both 35% and 85% FB, Tergitol (0.75%) applied at 85% FB, Tergitol (1.5 %) applied at 85% FB, ATS (2%) applied at 35% and 85% FB, ATS (4%) applied at 35% and 85% FB, ATS (2%) applied at 85% FB, ATS (4%) applied at 85% FB, Wilthin 0.75% applied at 35% and 85% FB, and Wilthin 0.75% applied at 85% FB.

Introduction

In New York State, peaches are a minor crop, however, they are a high value crop for New York tree fruit growers and provide diversity in their production systems. Hand thinning at 45 DAFB is the main practice that is used to adjust crop load. Partial crop thinning by chemical blossom thinners has tremendous potential to reduce high hand labor costs, increase fruit size, and improve overall crop value. The objective of this study was to evaluate appropriate rates and timings of three of the most promising blossom-thinning chemicals, ATS, Tergitol and Wilthin, for chemical peach thinning in New York State.

Material and Methods

Plant material

Five-year-old 'Babygold 5' peach trees on Lovell seedling rootstock at the New York State Agricultural Experiment Station in Geneva NY were used in this study. The trees were trained to a quad V system at a spacing of 3.65 X 6.1 m or 12 X 20 feet giving a tree density of 336 trees per hectare or 136 trees per acre.

Experimental design

A randomized complete block design with 15 treatments and 5 replications was used in the study for a total of 75 test trees. Each test tree was guarded by an adjacent tree which received the same treatment as the test tree.

Treatments

Treatments were applied by an air blast sprayer at a volume of 935 L/ha or 100 gallons/acre. Treatments included untreated control, hand thin flowers to 1 fruit/TCA @ 35 DAFB, hand thin flowers to 2 fruits/TCA @ 35 DAFB, hand thin fruits to 1 fruits/TCA @ 50 DAFB, hand thin fruits to 2 fruits/TCA @ 50 DAFB, Tergitol (0.75%) applied at two timings 35% and 85% FB, Tergitol (1.5 %) applied at both

35% and 85% FB, Tergitol (0.75%) applied at 85% FB, Tergitol (1.5 %) applied at 85% FB, ATS (2%) applied at 35% and 85% FB, ATS (4%) applied at 35% and 85% FB, ATS (2%) applied at 85% FB, ATS (4%) applied at 85% FB, Wilthin 0.75% applied at 35% and 85% FB, and Wilthin 0.75% applied at 85% FB.

Measurements

Trunk circumference measurements (TCA) were taken at 30 cm above the soil to calculate trunk cross-sectional area. Two limbs per tree were selected at pink bud stage and the flowers were counted. Persisting fruit were counted 45 days after bloom. Fruit set was expressed as percentage of flowers, which developed into persisting fruits. Fruit diameter measurements of 10 fruits per test tree were measured weekly during the early part of the season and thereafter monthly. Fruits were harvested in 4 harvests when mature. At each harvest, fruits were counted and weighed. Total yield was calculated by summing harvested weight of each data tree over four harvests. A sample of 50 fruits were collected over the 4 harvests and evaluated for size and red color using a commercial MAF RODA Pomone fruit grader to evaluate pack out using 5 size categories. The size category that were used are as follows; 80 box size or a 3.25 inch peach, 100 box size or a 3.0 inch peach, 120 box size or a 2.75 inch peach, 140 box size or a 2.5 inch peach, 160 box size or a 2.25 inch peach, and a cull category in which all fruits that are not equal to or larger than 2.25 inches fall into this category. A sub sample of ten fruit was randomly selected from the 50 fruit sample for evaluation of fruit firmness and soluble solids. The yield and the simulated pack-out were used to calculate farm gate crop value using average prices for western New York in 2006. 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. New York processing prices in 2006 and were as follows: $8 per bushel of 160 count, $8 per bushel of 140 count, $13 per bushel of 120 count and $13 per bushel of 100 count and $13 of 80 count. The crop value of each treatment was calculated with the assumption of no differences in fruit color between treatments.

Statistical Analysis

Data were analyzed by ANOVA using SAS Proc GLM (SAS Institute, Cary, NC). Significant differences among means were determined by LSD, ($P \leq 0.05$). The effect of treatment on fruit size independent of crop load was determined by adjusting fruit size for crop load (Stover et al., 2001). Rate responses of ATS or Tergitol were determined by regression analysis.

Results

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 5.1). 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.

Regression analysis of the rate response of the double application of ATS and Tergitol indicated a significant linear relationship between rate of blossom thinner and fruit set. There were no significant relationships in rate response of a single application of ATS or Tergitol.

All the blossom thinners reduced crop load with the greatest reduction from Tergitol 1.5% applied twice at 35 and 85% bloom which had a crop load of .11 fruits / cm^2 TCA (Table 5.1). The untreated control had a crop load of 1.43 fruits / cm^2 TCA. Tergitol (0.75%) applied at 35 and 85%, Tergitol (1.5%) applied at 85% bloom, and ATS (2, or 4%) applied at 35 and 85% bloom also carried extremely low crop loads and varied from 0.19 to 0.25 fruits per cm^2 TCA. ATS (2%) and Tergitol (.075%) applied at 85% bloom and hand thinning flowers (1 and 2 fruits per cm^2 TCA) had slightly higher crop load levels but were statistically comparable and varied between 0.36 and 0.52 fruits per cm^2 TCA. Hand thinning fruits at 45 DAFB (1 fruit per cm^2 TCA), ATS (4%), and Wilthin (0.75%) applied at 35 and 85% and Wilthin (0.75%) applied at 85% bloom had crop load levels between 0.59 and 0.93 fruits per cm^2 TCA. Hand thinning of fruits @ 45 DAFB (2 fruits per cm^2 TCA) carried a crop load of 1.16.

Regression analyses of Tergitol rate response indicated a significant linear relationship between rate of blossom thinner applications and crop load whether applied once or twice. A significant linear relationship was found with ATS rate response with two applications. There was no significant relationship of ATS rate response with a single application of ATS.

Tergitol (0.75) applied at 35 and 85% bloom, Tergitol (1.5%) applied at 35 and 85% bloom, Tergitol (1.5%) applied at 85% bloom, and ATS (2 or 4 %) applied at 35 and 85% bloom reduced fruit number the most to between 16 and 36 fruits per tree (Table 5.1). Hand thinning flowers @ FB (1, 2 fruits per cm^2 TCA), Tergitol (0.75%)

applied at 85 % bloom, and ATS (2%) at 85% bloom treatments also markedly reduced fruit numbers to 72, 77, 51, and 74 fruits per tree, respectively. Hand thinning fruits @ 45 DAFB (1 fruit per cm^2 TCSA) and ATS (4%) applied at 85% bloom had an intermediate fruit number of 84 and 86 fruits/tree. Wilthin (0.75%) at both timings (35% and 85% bloom) produced a fruit number of 132. Hand thinning fruits @ 45 DAFB (2 fruit per cm^2 TCSA) yielded a fruit number of 164 fruits/tree. Finally, the untreated control produced 202 fruits.

Regression analyses of Tergitol rate response indicated a significant linear relationship between rate of blossom thinner applications and fruit number whether applied once or twice. A significant linear relationship was found with ATS rate response when applied twice. There was no significant relationship found with rate of ATS when a single application was made.

Yields were extremely low for all treatments including control trees (Table 5.2). Untreated control trees had the highest yields at 17.7 t/ha or 360 bushels to the acre. Hand thin fruit @ 45 DAFB (2 fruit per cm^2 TCA) yielded 15.7 t/ha or 318 bushels to the acre. Wilthin (0.75%) applied at 35 and 85% bloom and Wilthin (0.75%) applied at 85% bloom produced 14.3 and 14.1 t/ha or 291 and 286 bushels per acre, respectively. Hand thin flowers @ FB (2 fruit per cm^2 TCA) and ATS (2%) applied at 85% bloom were statistically comparable at 8.3 and 7.5 t/ha or 168 and 153 bu/acre. The remainder of the treatments produced yields between 2 and 5.5 t/ha or 42 and 108 bu/acre. There was a positive linear relationship between fruit number and yield (Figure 5.1)

Table 5.1 Effect of chemical thinning agents on percent fruit set, crop load, and fruit number per tree of ‘Babygold 5’ peach.

Treatment	Fruit Set %	Crop Load (fruit/ cm^2 / TCA)	Fruit Number / Tree
Untreated control	33 abc	1.43 a	202 a
Hand thin flower 1 frt /TCA @ FB	17 cde	0.51 cd	72 cd
Hand thin flower 2 frt /TCA @ FB	24 bcde	0.54 cd	77 cd
Hand thin fruit 1 frt /TCA @ 45DAFB	36 ab	0.59 bcd	84 bcd
Hand thin fruit 2 frt /TCA @ 45DAFB	29 abcd	1.16 ab	164 ab
Tergitol 0.75% @ 35+85% FB	16 cde	0.22 d	31 d
Tergitol 1.5% @ 35+85% FB	10 e	0.11 d	16 d
Tergitol 0.75% @ 85% FB	21 bcde	0.36 cd	51 cd
Tergitol 1.5% @ 85% FB	16 cde	0.23 d	33 d
ATS 2% @ 35+85% FB	23 bcde	0.19 d	27 d
ATS 4% @ 35+85% FB	12 de	0.25 d	36 d
ATS 2% @ 85% FB	25 bcde	0.52 cd	74 cd
ATS 4% @ 85% FB	22 bcde	0.61 bcd	86 bcd
Wilthin 0.75% @ 35+85% FB	22 bcde	0.93 bcd	132 abc
Wilthin 0.75% @ 85% FB	44 a	0.93 bcd	132 abc
Regression analyses			
ATS applied once rate response	NS	NS	NS
ATS applied twice rate response	L	L	L
Tergitol applied once rate response	NS	L	L
Tergitol applied twice rate response	L	L	L

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

Table 5.2 Effect of chemical thinning agents on yield, fruit size, and crop load adjusted fruit size of ‘Babygold 5’ peach.

Treatment	Yield (t/ha)	Fruit Size (g)	Crop Load Adjusted Fruit Size (g)
Untreated control	17.7 a	219 cd	243 abcd
Hand thin flower 1 frt/ TCA @ FB	7.2 defg	228 cd	226 cd
Hand thin flower 2 frt/ TCA @ FB	8.3 cdefg	237 abcd	236 abcd
Hand thin fruit 1 frt/TCA @ 45 DAFB	9.1 bcdef	241 abcd	242 abcd
Hand thin fruit 2 frt/TCA @ 45 DAFB	15.7 ab	211 d	227 bcd
Tergitol 0.75% @ 35+85% FB	3.2 efg	241 abcd	232 bcd
Tergitol 1.5% @ 35+85% FB	2.0 g	273 a	261 ab
Tergitol 0.75% @ 85% FB	5.3 efg	244 abcd	238 abcd
Tergitol 1.5% @ 85% FB	3.5 efg	233 bcd	224 d
ATS 2% @ 35+85% FB	3.0 fg	240 abcd	229 bcd
ATS 4% @ 35+85% FB	4.0 efg	252 abc	243 abcd
ATS 2% @ 85% FB	7.5 cdefg	235 bcd	234 abcd
ATS 4% @ 85% FB	10.2 bcde	265 ab	267 a
Wilthin .075% @ 35+85% FB	14.3 abc	245 abcd	255 abcd
Wilthin .075% @ 85% FB	14.1 abcd	248 abcd	258 abc
Regression analyses			
ATS applied once rate response	NS	NS	NS
ATS applied twice rate response	L	NS	NS
Tergitol applied once rate response	L	NS	NS
Tergitol applied twice rate response	L	L	NS

[y] Means followed by the same letter are not significantly different using LSD. $P \leq 0.05$, n=5.

Table 5.3 Effect of chemical thinning agents on early fruit growth rate of 'Babygold 5' peach.

Treatment	Fruit Diam (mm) 40 daFB	Fruit Diam (mm) 50 daFB	Fruit Diam (mm) 65 daFB
Untreated control	19.6 b	30.5 abc	36.8 ab
Hand thin flower 1 frt/ TCA @ FB	19.5 b	30.6 abc	37.8 ab
Hand thin flower 2 frt/ TCA @ FB	20.4 b	31.9 ab	37.8 ab
Hand thin fruit 1 frt/TCA @ 45 DAFB	19.3 b	31.0 abc	39.0 ab
Hand thin fruit 2 frt/TCA @ 45 DAFB	19.7 b	29.5 c	35.6 b
Tergitol 0.75% @ 35+85% FB	19.3 b	29.5 c	40.0 a
Tergitol 1.5% @ 35+85% FB	25.1 a	30.5 abc	37.8 ab
Tergitol 0.75% @ 85% FB	20.3 b	31.5 abc	38.1 ab
Tergitol 1.5% @ 85% FB	20.7 ab	31.9 ab	37.1 ab
ATS 2% @ 35+85% FB	18.9 b	31.0 abc	37.6 ab
ATS 4% @ 35+85% FB	19.0 b	29.9 bc	39.0 ab
ATS 2% @ 85% FB	19.7 b	30.6 abc	37.2 ab
ATS 4% @ 85% FB	21.4 ab	32.7 a	37.6 ab
Wilthin 0.75% @ 35+85% FB	19.8 b	31.4 abc	37.8 ab
Wilthin 0.75% @ 85% FB	20.0 b	31.1 abc	38.4 ab

[y] Means followed by the same letter are not significantly different using LSD. $P \leq 0.05$, n=5.

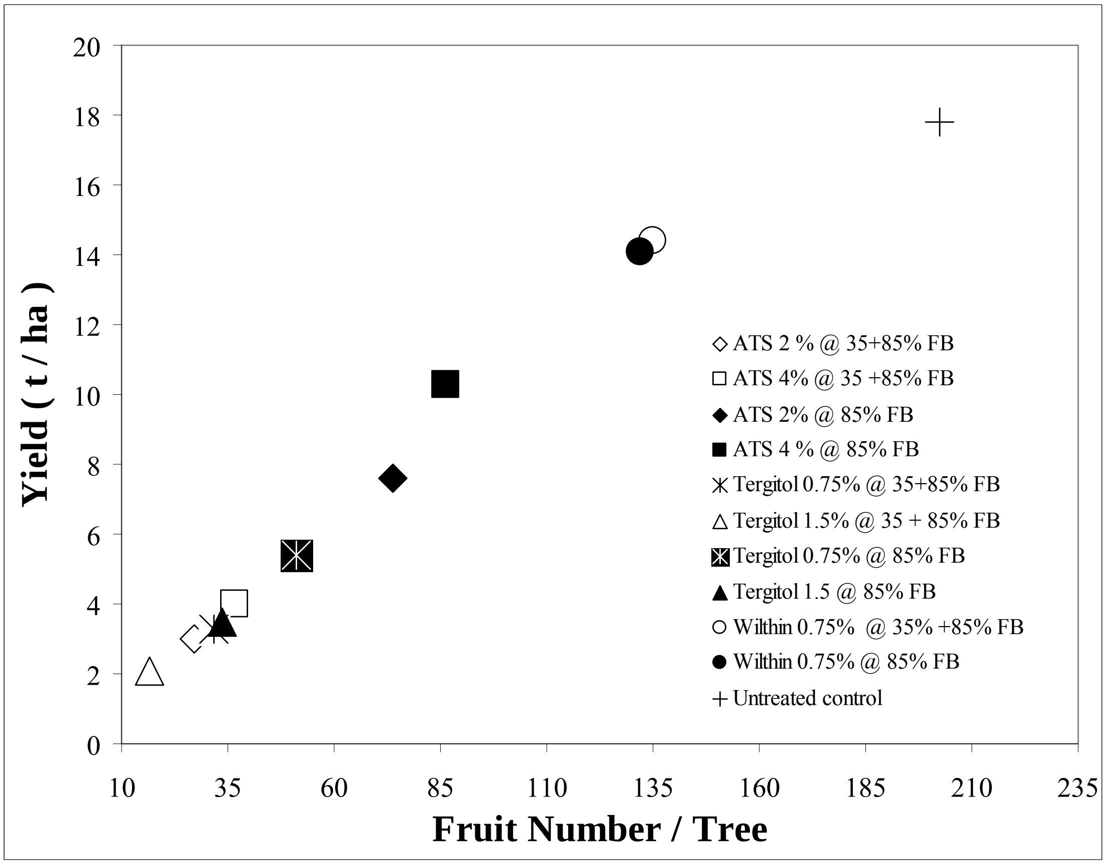

Figure 5.1 Relationship between fruit number per tree and yield/ha of 'Babygold 5' peach.

Regression analyses of ATS rate response indicated a significant linear relationship between rate of blossom thinner when applied twice and yield per hectare. However, when ATS was applied once there was not a significant relationship between rate of thinner and yield per hectare. A significant linear relationship was found with Tergitol rate response applied once or twice.

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 thin fruit @ 45 DAFB (2 fruits per cm^2 TCA) treatments which had fruit sizes of 219 and 211 grams respectively (Table 5.2). 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 thin flowers @ FB (1 fruit per cm^2 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.

Regression analyses of Tergitol rate response indicated a significant linear relationship between rate of blossom thinner and fruit size when Tergitol was applied twice (Table 5.2). There were no significant relationship of rate of ATS (whether applied once or twice) or Tergitol (when applied once) and fruit size (Figure 5.2).

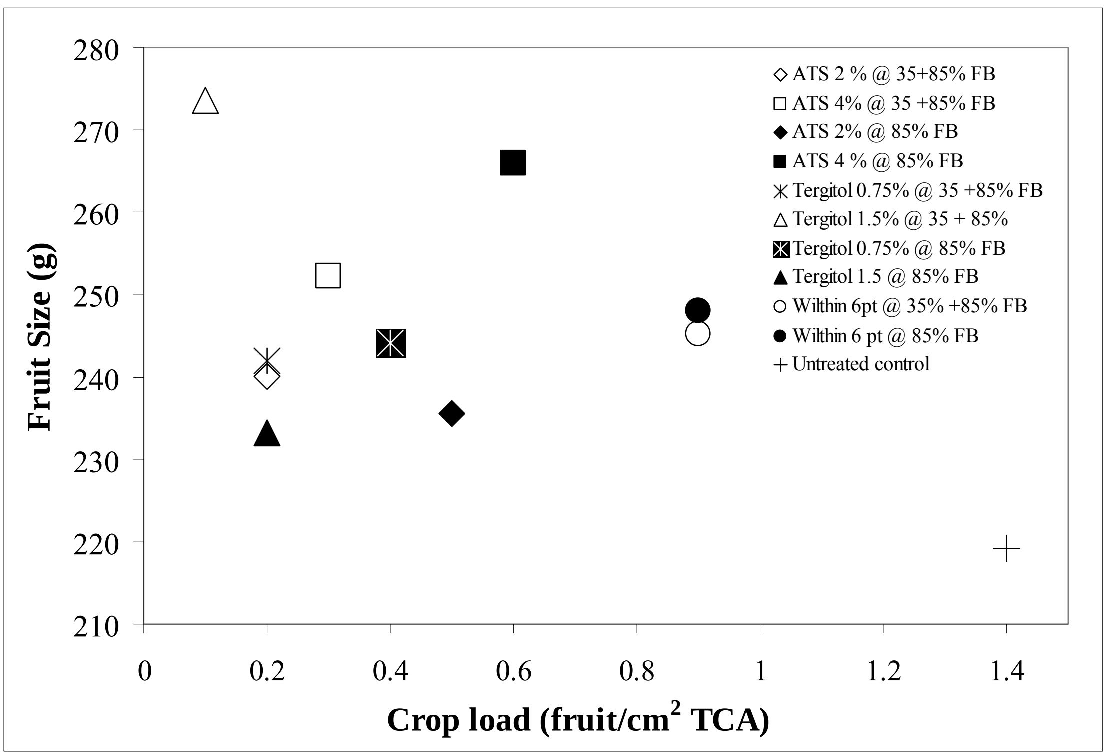

Figure 5.2 Effect of crop load and chemical thinning agents on fruit size of 'Babygold 5'.

The relationship between crop load and fruit size required that crop load be used as a covariate to determine the effect of chemical thinners on fruit size independent of the crop load effect. After covariate analysis, adjusted fruit size analysis was conducted to evaluate the effect of the majority of the treatments produced an adjusted fruit size between 234 and 255 grams (Table 5.2). Hand thin fruit @ 45 DAFB (2 fruit per cm^2 TCA), Tergitol (0.75%) applied at 35 and 85%, and ATS (2%) applied at 35% and 85% produced slightly smaller adjusted fruit sizes, 237, 232, and 229 grams, respectively. Hand thin flower @ FB (1 fruit per cm^2 TCA) and Tergitol (1.5%) applied at 85% produced the smallest adjusted fruit size, 226 and 224 g, respectively. After covariate analysis there was no relationship between crop load and adjusted fruit size (Figure 5.3).

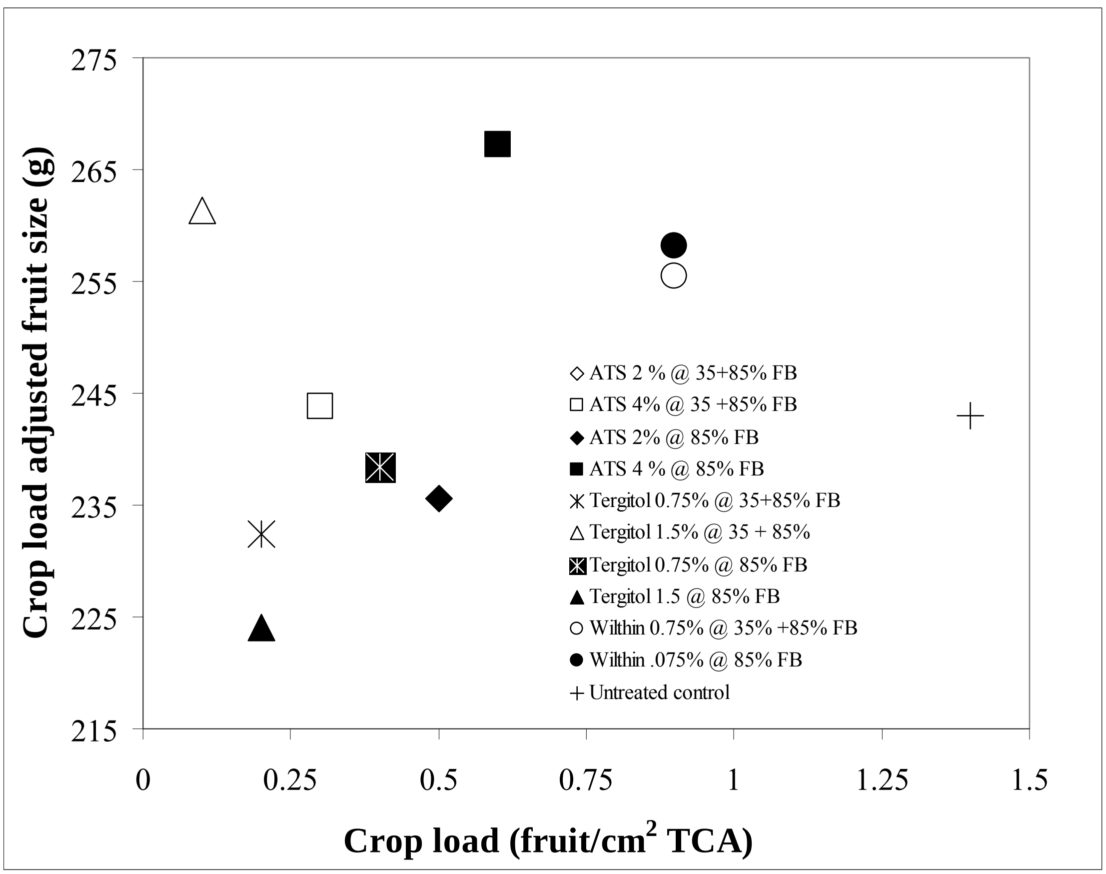

Figure 5.3 Effect of crop load and chemical thinning agents on fruit size adjusted for crop load of ‘Babygold 5’ peach.

Regression analyses of ATS and Tergitol rate responses indicated no significant relationship between rate and blossom thinner and crop load adjusted fruit size.

Fruit diameter measurements at 40, 50, and 65 days after FB showed that Tergitol (1.5%) applied at 35 and 85% bloom had the largest fruit size, 25.1 mm, at 40 days after FB while ATS (4%) 35% and 85% FB had the smallest fruit size, 18.9 mm. Tergitol (1.5%) and ATS (4%) applied at 85% bloom also had slightly but significantly larger fruit size than the remainder of the treatments. The majority of the treatments had an average fruit diameter between 19.0 and 20.4 mm.

ATS (4%) applied at 85% bloom had the largest diameter at 50 days DAFB with a fruit diameter of 32.7 mm. Hand thin fruit @ 45 DAFB (2 fruit per cm^2 TCSA) and Tergitol (0.75%) applied at 35 and 85% also had the smallest fruit diameters of 29.5 mm. The untreated control and the remainder of the treatments had fruit diameters that varied between 30.5 and 31.5 mm.

At 65 DAFB, Tergitol (.075%) applied at 35 and 85% bloom had the largest fruit diameter (40 mm) while hand thin fruit @ 45 DAFB (2 fruit per cm^2 TCA) had the smallest fruit diameter (35.6 mm). The remainder of the treaments varied between 36.8 (untreated control) and 39 mm (ATS 4% applied at 35 and 85% bloom).

Fruit pack out data at harvest showed that Wilthin (0.75%) applied at 85% bloom yielded the greatest number of tons per hectare, (9.6) in the 80 count category, the largest fruit size category (Table 5.4). Wilthin (0.75%) applied at both 35 and 85% bloom, and ATS (4%) applied at 85% bloom produced 7.7 and 6.8 t/ha respectively in this size category. The untreated control and the hand thin fruit @ 45 DAFB (1 fruit per cm^2 TCA) treatments produced 5.9 and 5.6 t/ha into this category. Hand thin flowers @ FB (2 fruit per cm^2 TCSA), Tergitol (.0.75%) applied at 85% bloom, and ATS (2%) applied at 85% bloom produced between 3.3 and 4.0 t/ha into the 80 count category. Hand thin flowers @ FB (1 fruit per cm^2 TCA) and hand thin fruit @ 45 DAFB (2 fruit per cm^2 TCA) yielded 2.6 and 2.8 t/ha in this category. The remainder of the treatments produced between 1.5 and 1.8 t/ha in the 80 count category.

Production of fruits in the 100 count box size category was greatest with the hand thin fruit @ 45 DAFB (2 fruit per cm^2 TCSA) and Wilthin (0.75%) applied at 35 and 85 % bloom treatments, 5.7 and 3.9 t/ha, respectively (Table 5.4). Hand thin flowers @ FB (1, 2 fruit per cm^2 TCA), hand thin fruit @ 45 DAFB (1 fruit per cm^2 TCA), ATS (4 %) applied at 85% bloom, and Wilthin (0.75%) applied at 85% bloom yielded between 1.6 and 2.4 t/ha in this category. The remainder of the treatments produced between 0.1 and 1.5 t/ha of 100 count fruit.

Hand thin fruit @ 45 DAFB (2 fruit per cm^2 TCA) and the untreated control produced the most fruit in the 120 count category (5.2 and 3.9) t/ha respectively (Table 5.4). The remainder of the treatments produced between 0.2 and 1.4 t/ha in this category.

The untreated control also produced the largest yield in the 140 count size category with 4.7 t/ha (Table 5.4). The remainder of the treatments sorted between 0.1 and 0.9 t/ha in this category.

Untreated control contributed the largest yield, (2.7 t/ha), of fruit in the cull category (Table 5.4). Hand thin fruit @ 45 DAFB (2 fruit per cm^2 TCSA), and Wilthin (0.75%) applied at both 35 and 85% bloom produced between 1.4 and 1.5 t/ha in the cull category. The remainder of the treatments produced between 0.2 and 1.0 t/ha in this category.

Regression analyses of ATS and Tergitol rate responses were not significantly for any box sizes (Table 5.4).

Crop values were calculated using current processing market fruit prices. The treatments that generated the highest crop value were both treatments of Wilthin, followed by hand thin fruit @ 45 DAFB (2 fruit per cm^2 TCA) and the untreated control which had values between $7,111.00 and $7,613.00 (Table 5.4). The second group of treatments with intermediate crop values was the high rate of ATS (4%), hand thin fruit @ 45 DAFB (1 per cm^2 TCA), hand thin flower @ FB (1 per cm^2 TCA) which had values between $4,358.00 and $5,438.00/ha. A group of treatments with lower crop values was Tergitol (0.75%) and ATS (2%) applied at 85% bloom produced a range of crop values between $2,730.00 and $3,600.00/ha. The group of 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 generated the lowest crop values varying between 985.00 and 1650.00. In general, the treatments with the highest yields also had the highest crop values.

Plotting crop load against crop value and then drawing a theoretical response curve showed that the optimum crop load was 0.9-1.0 fruits / cm^2 TCA for maximizing crop value in 2006.

Regression analyses of ATS and Tergitol rate response indicated a significant linear relationship between rate of Tergitol applied once and crop value (Table 5.4). A significant quadratic relationship was found between rate, ATS and Tergitol, applied twice and crop value. There were no significant differences found with a single application of ATS. There were no significant relationship found between rate of ATS applied once and crop value (Figure 5.4)

Table 5.4 Effect of chemical thinning agents on pack out and crop value of ‘Babygold 5’ peach.

Treatment	Yield by box size category (t/ ha)					Crop Value $/ha
	80 Count	100 Count	120 Count	140 Count	Culls Count	
Untreated control	5.9 abcd	1.1 c	3.9 a	4.7 a	2.7 a	7111.00 a
Hand thin flower 1 frt/TCA @ FB	2.6 cd	2.2 bc	1.4 b	0.5 b	0.8 b	600.00 bcd
Hand thin flower 2 frt/TCA @ FB	4.0 bcd	2.4 bc	0.9 b	0.3 b	0.9 b	4358.00 abcd
Hand thin frt 1 fruit/TCA @ 45 DAFB	5.6 abcd	1.9 bc	0.7 b	0.3 b	0.8 b	4981.00 abc
Hand thin frt 2 fruit/TCA @ 45 DAFB	2.8 cd	5.7 a	5.2 a	0.9 b	1.5 ab	7341.00 a
Tergitol 0.75% @ 35+85% FB	1.5 d	0.5 c	0.6 b	0.3 b	0.4 b	1405.00 d
Tergitol 1.5% @ 35+85% FB	1.5 d	0.1 c	0.2 b	0.1 b	0.2 b	985.00 d
Tergitol 0.75% @ 85% FB	3.5 bcd	0.8 c	0.5 b	0.1 b	0.6 b	2730.00 bcd
Tergitol 1.5% @ 85% FB	1.8 d	0.7 c	0.4 b	0.2 b	0.3 b	1650.00 cd
ATS 2% @ 35+85% FB	1.5 d	0.4 c	0.2 b	0.3 b	0.2 b	1233.00 d
ATS 4% @ 35+85% FB	1.6 d	0.6 c	0.6 b	0.6 b	0.5 b	1620.00 cd
ATS 2% @ 85% FB	3.3 bcd	1.5 c	1.3 b	0.9 b	0.8 b	3548.00 bcd
ATS 4% @ 85% FB	6.8 abc	1.6 bc	0.9 b	0.3 b	1.0 b	5438.00 ab
Wilthin 0.75% @ 35+85% FB	7.7 abc	3.9 ab	0.8 b	1.2 b	1.5 ab	7588.00 a
Wilthin 0.75% @ 85% FB	9.6 a	2.2 bc	0.7 b	0.9 b	1.4 ab	7613.00 a
Regression analyses						
ATS applied once rate response	NS	NS	NS	NS	NS	NS
ATS applied twice rate response	NS	NS	NS	NS	NS	Q
Tergitol applied once rate response	NS	NS	NS	NS	NS	L
Tergitol applied twice rate response	NS	NS	NS	NS	NS	Q

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

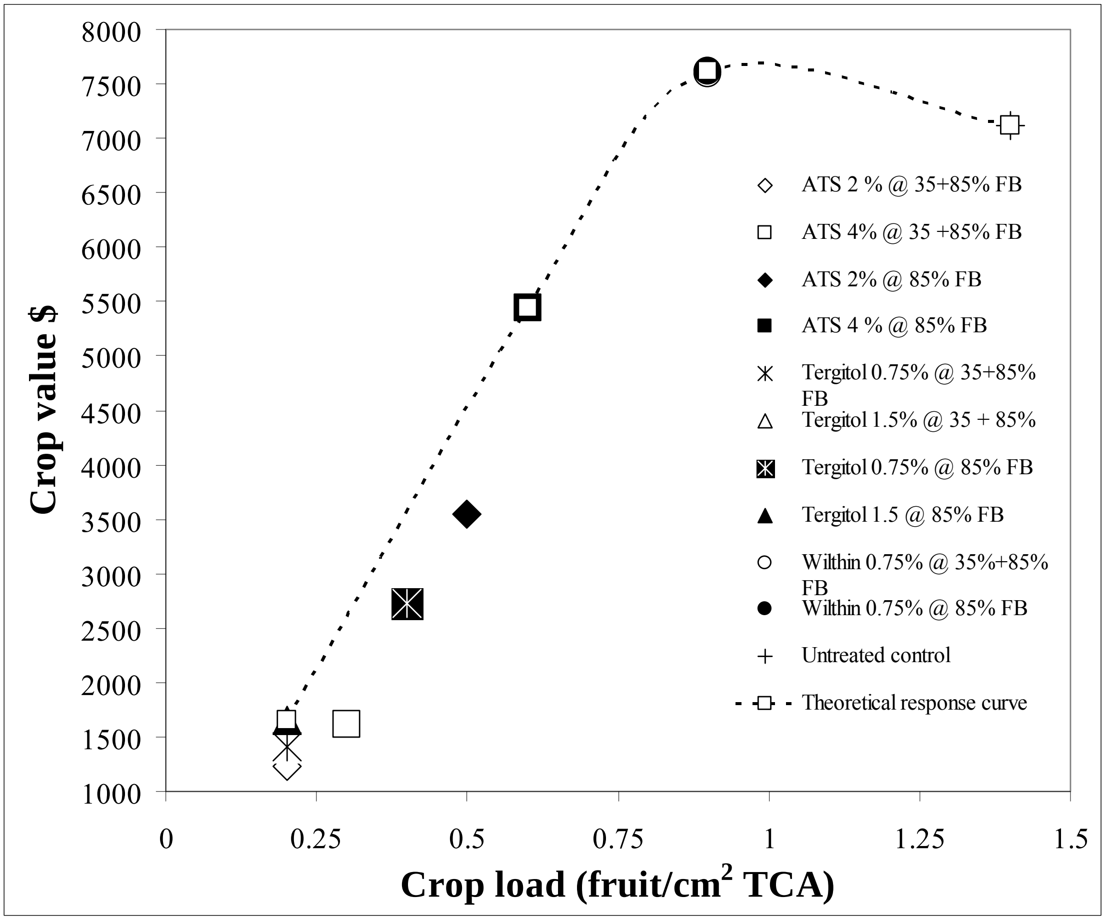

Figure 5.4 Effect of crop load and chemical thinning agents on crop value $ / ha of ‘Babygold 5’ peach.

Discussion

In our 2006 experiment, the high rates of ATS (4%) and Tergitol (1.5%) applied twice at both 35% and 85% bloom caused excessive thinning of ‘Babygold 5’. The low rate of Tergitol (0.75%) applied twice at 35% and 85% bloom and Tergitol (0.75%) applied once at 85% bloom thinned less but also resulted in overthinning. Double applications of Tergitol were more effective than one application.Tergitol-TMN-6 (2,6,8-trimethyl-4-nonyloxypolyethyleneoxyethanol) is a surfactant that has reported to be an effective blossom thinner of peach, nectarine, and plum (Fallahi, 2006). Wilkins et al. (2004) reported that Tergitol effectively reduced fruit set in

‘Fireprince’ peach. In that report, there was no difference in thinning response at full bloom or petal fall, suggesting a wide window of efficacy for this chemical. However, Fallahi et al. (2006) reported that applications of Tergitol at an earlier stage of bloom were more effective than late application. Fallahi (2006) stated, it seems that when about 75% to 80% of blooms are open, and when reasonably good pollination and fertilization conditions exist before application, is an optimum stage for applying Tergitol-TMN-6. Fallahi (2006) reported that a double application of Tergitol-TMN-6 (~35% and 80% to 85% open bloom) was also effective in thinning and seemed to be slightly better than a single application. Finally, higher concentrations of Tergtitol-TMN-6 are needed when the percentage of open blooms is higher (i.e. 85%-100%). Our results from the trial on ‘Babygold 5’ support Fallahi’s data in that the high rate of Tergitol (1.5%) was more effective at reducing fruit set than Tergitol (0.75%) applied at 85% bloom. Furthermore, two applications of Tergitol (0.75,1.5%) applied at 35% and 85% were more effective at reducing fruit set than one application (0.75,1.5%) at 85% bloom.

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. Our study showed that in 2006 only a modest reduction in crop load was needed to maximize crop value this was achieved with Wilthin which thinned very little while the more potent thinner (ATS and Tergitol) overthinned and reduced crop value. The optimum crop load for 2006 was 0.9-1.0 fruits /cm^2 TCA.

The importance of blossom thinning to maximize fruit size at harvest has been recognized for many years (Havis, 1962). Previous work with caustics or desiccants for bloom and post bloom thinning of peaches has led to mixed results and no commercial use, Wilthin (Meyers et al. 1993); Elgetol (Hibbard and Murneek, 1944); urea (Zilkah et al. 1988); fertilizers (Byers and Lyons, 1984); soybean oil (Myers et al. 1996); Tergitol (Fallahi, 2006) and growth regulators (Southwick, 1995).

While thinning can be done if thinners are applied anywhere from pink to full bloom, the greatest response is when applications are made near bloom (Byers and Lyons, 1984). Our results from the trials in 2006 suggest early partial crop thinning by blossom thinning agents can improve fruit size, and improve crop value in ‘Babygold 5’ peach.

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CHAPTER 6

CONCLUSION

Hand thinning of peaches is the single most expensive management practice of growing peaches and can approach $1200.00/ha or $500.00/acre. Over the past four years we evaluated several chemicals for their potential as chemical thinners of peach.

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 reduce overall 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 early 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.

The ability of blossom thinners to reduce hand labor costs is also noteworthy. In 1998, Greene et al. reported that all bloom thinning treatments generally reduced initial set and hand thinning required to reduce crop load to a commercially acceptable level. They reported a reduction in hand thinning between 50% to 80%. Moran and Southwick, (2000) also reported that dormant oil applications (8 to 12% soybean oil) also reduced the time required for hand thinning 40% to 80%.

Future research on blossom thinning should identify key variables that ultimately influence thinning and reduce risk of over thinning; identify appropriate concentrations of the most promising chemical thinners and evaluate consistency of results. Gathering 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. Finally future research should continue to evaluate the relationship between crop load and crop value rather than thinning efficacy and fruit size response.