Impacts of Pear Thrips on a Pennsylvania Sugarbush: Third Year Results

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Abstract: Pear thrips, *Taeniothrips inconsequens* (Uzel) (Thysanoptera: Thripidae), were first positively identified as causing damage to sugar maple (*Acer saccharum* Marsh.) in forest environments in the United States in 1980. Damage in Pennsylvania from this insect has occurred consistently since 1980, with the most extensive impact in 1988 (0.5 millon ha). Sap characteristics and crown condition were monitored for three years following a 1989 thrips attack in a Pennsylvania sugarbush on 56 trees representing a range of thrips damage. Heavy damage in 1989 was associated with increased crown transparency for two summers following the attack. Calculated syrup production was greatest in all years for trees with light damage and lowest for trees with heavy damage. Reduced syrup production in trees with heavy damage resulted from lower sap volume in all years and lower sap sugar concentration in 1990 and 1992 compared to trees with light damage. The results indicate that pear thrips damage in 1989 had a detrimental impact on sugar maple health and syrup production for three years following the attack.

INTRODUCTION

Until recently, the pear thrips, *Taeniothrips inconsequens* (Uzel) (Thysanoptera: Thripidae), was considered primarily an insect pest of fruit trees (Foster and Jones 1915, Bailey 1944). Pear thrips were first positively identified as causing damage to sugar maple (*Acer saccharum* Marsh.) in forest environments in the northeastern United States in 1980 (Laudermilch 1988). In the 1980's, heavy damage to sugar maple occurred for several years in the Northeast, with the greatest impacts in 1988 and 1989 (Parker 1991). Damage in Pennsylvania from this insect has occurred consistently since 1980, with the most extensive impact in 1988 (0.5 millon ha). Symptoms of pear thrips damage to sugar maple include undersized leaves that are tattered and chlorotic, resulting in an unusually thin crown (Houston et al. 1990, Kolb and Teulon 1991).

Adult pear thrips emerge from the soil in early spring and feed on foliar and flower tissues, often in swollen buds prior to budburst (Bailey 1944, Skinner et al. 1991). Adults oviposit on succulent plant tissues, where larvae develop. Both adult and larval thrips feed by puncturing epidermal and mesophyll cells with a lance-like mandible, followed by insertion of tube-like stylets into which the contents of ruptured cells are drawn (Heming 1978, Chisholm and Lewis 1984, Hunter and Ullman 1989). Factors that promote pear thrips damage to sugar maple leaf area include synchrony between budburst and insect emergence from the soil, and cool temperatures that slow budburst and lengthen the duration of feeding prior to leaf expansion (Kolb and Teulon 1991, Kolb and Teulon 1992).

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Impacts of pear thrips to sugar maple have been addressed in only a few studies. In a greenhouse study, seedlings with heavy pear thrips damage had greater photosynthetic rates under conditions of high light intensity and high soil moisture, but slightly lower rates under conditions of low soil moisture compared with undamaged seedlings (Kolb et al. 1991). Lower root carbohydrate concentrations the fall following attack have been reported for sugar maple trees damaged by pear thrips compared with undamaged trees in studies in Massachusetts (Smith et al. 1991) and Pennsylvania (Kolb et al. 1992). Sugar maples that refoliate following heavy pear thrips damage often have greater fall root carbohydrate concentrations than damaged trees that do not refoliate (Smith et al. 1991, Burns 1991), indicating that refoliation accelerates recovery. While these studies have addressed relatively short-term physiological impacts of thrips damage on sugar maple, longer term effects of thrips damage on sugar maple health and syrup production are poorly understood.

We have measured sap sugar concentrations, sap volumes, and crown conditions of 56 sugar maple trees in a Pennsylvania sugarbush for three years following a pear thrips attack in 1989. Trees in the sugarbush exhibited different degrees of damage, allowing assessment of the impact of damage on trees growing on the same site with similar management history. Results of the first two years of the study were described in Kolb et al. (1992). This paper presents data from the third year of the study and compares temporal variation in sap and crown characteristics over three years following the 1989 attack. In addition, we have studied variation in budburst phenology among these trees to gain insight into how differences in damage severity within the sugarbush occur.

METHODS AND MATERIALS

Stand Condition

The study site is an uneven-aged northern hardwood stand in Somerset Co., Pennsylvania. Aspect is northeast, and elevation is 720 m. Soil in the stand is classified as a Rayne-Gilpin silt loam. Sugar maple has been favored in the stand by periodic cuttings of larger stems of other species. Consequently, almost all dominant or co-dominant trees in the stand are sugar maples approximately 30 m in height. Understory trees include sugar maple, black cherry (*Prunus serotina* L.), red maple (*Acer rubrum* L.), black birch (*Betula lenta* L.), and beech (*Fagus grandifolia* L.). Stand basal area in 1991 averaged 19.7 m^2/ha. Trees in the stand have been tapped yearly for maple syrup production for at least the last 50 years.

Pear Thrips Damage

Light pear thrips damage was first noticed in the stand in 1988. In 1989, counts of adult thrips on branch samples from the middle or upper crown of 10 randomly selected co-dominant sugar maples in the stand averaged 13 per bud on April 28 and 7 per bud on May 12. Previous studies where pear thrips were confined on sugar maple buds and seedlings indicated that five adult thrips per bud is enough to cause foliar damage consisting of a reduction in leaf size, chlorosis, tattered leaf margins, and leaf cupping (Kolb and Teulon 1991, Kolb and Teulon 1992, E. E. Simons - PA Bureau of Forestry - unpublished data). By late-May, many trees in the stand exhibited these foliar symptoms of thrips damage. In some cases, heavily damaged leaves dropped from the crown soon after budburst. Damage could not be explained by weather events such as late frost, and no other biological agents were observed that could have caused this type of damage.

Damage varied widely among sugar maples in the stand, with no apparent relationship between damage severity and location within the stand. In late-June 1989, degree of damage to 56 trees in the stand was evaluated from the ground by two observers using five classes:

very light - <10% of foliage damaged
light - 10% to 30% of foliage damaged
moderate - 30% to 60% of foliage damaged
heavy - 60% to 90% of foliage damaged
very heavy - >90% of foliage damaged

Number of trees in each damage class were: very light - 12, light - 9, moderate - 12, heavy - 18, and very heavy - 5. Diameter at breast height (DBH) of trees in each damage class averaged between 41 and 46 cm (individual tree range 22 to 77 cm), except in the very heavy class which averaged 56 cm (range 30 to 98 cm). Trees in the heavy and very heavy damage classes produced few new leaves (refoliation) in 1989 following damage.

Stresses experienced by all study trees in the stand since the 1989 thrips attack include summer drought in 1991, and heavy flowering in 1992. Pear thrips were present in the stand in 1990 and 1991, but damage was very light to light on all trees. Thrips damage in the stand in 1992 was heavier than in 1990 and 1991, and damage varied widely among trees as in 1989. No other substantial insect damage occurred in the stand from 1989-1992.

Crown Condition

Two measures of crown condition (transparency, dieback) were scored on all study trees in early June 1990-92. Crown transparency is the percentage of full sun light penetrating the crown. Dieback is the proportion of crown volume containing dead branches with tips less than 2.5 cm in diameter (see Bauce and Allen 1991). Both measures were visually scored from the ground by two observers using a 12 percentage class system developed for the North American Sugar Maple Decline Project (Millers et al. 1991). Differences in crown dieback and transparency among classes were analyzed by the Kruskal-Wallis nonparametric test.

Budburst Phenology

Budburst phenology was measured in 1991 and 1992 on all trees every one or two days between early April and mid-May. On each tree, the Julian date that leaf blades were fully visible from the ground with binoculars was recorded for both middle and upper crown positions. Dates were subjected to analysis of variance with 1989 damage class, crown position (middle or upper), and their interaction as factors.

Number of pear thrips oviposition sites, a measure of insect activity, was measured in 1991 and 1992 on leaves sampled from both the middle and upper positions of the crown from the five trees with earliest budburst and the five trees with latest budburst in each year. Samples were collected in early June by removing one or two twigs from each crown position with shotgun blasts. Number of oviposition sites on the underside of the petiole and three major veins was counted (7.5X magnification) on a random sample of five leaves from each crown position. Crown position means from each tree were subjected to analysis of variance with budburst class (early or late), crown position (middle or upper), and their interaction as factors.

Sap Characteristics

Sap sugar concentration and volume were measured on all study trees every one to five days (depending on sap flow conditions) during the traditional sap collection season in 1990-92. In late-February of each year, each tree was tapped twice using commercial taps (inside diameter 11 mm). Sap from both taps on a tree drained into a covered plastic bucket (18 liter capacity). Measurements were made on 9 days between March 10 and April 2 in 1990, 28 days between February 24 and April 1 in 1991, and 22 days between February 21 and April 6 in 1992. On each sample day, volume of sap in each bucket was measured in the late-afternoon or evening after the daily sap flow had ceased using a graduated cylinder. The sugar concentration of a representative 25 ml sample from each tree was measured in the laboratory within two hours of collection using a temperature compensating refractometer (Reichert-Jung Mark II, Cambridge Instruments, Buffalo, NY).

Sap volume and sugar concentration for each collection in each year were compared among 1989 damage classes by analysis of variance with DBH as a covariate to remove variation associated with tree size. Total syrup production in each year was calculated for each damage class. In each year, average sugar concentration over all days in each class (adjusted to the same DBH) was used to determine the amount of sap needed to produce a liter of syrup by the "rule of 86" formula, which states that 86 divided by sap sugar concentration equals the number of liters of sap required for one liter of syrup (see Walters 1982). For each class, this quantity was divided into the average seasonal volume collection to calculate yearly syrup production.

RESULTS

Crown Condition

Crown transparency differed significantly among 1989 damage classes for two summers following the 1989 thrips attack (p=0.03 in 1990, p=0.09 in 1991). In both years, average transparency was greater in the very heavy and heavy damage classes compared with the very light, light, and moderate classes (Figure 1). Transparency in all classes decreased from 1990 to 1991, indicating an improvement in crown condition. Changes in transparency from 1991 to 1992 were variable for 1989 damage classes. Transparency increased during this period in the very light, light, and moderate classes and decreased in the heavy and very heavy classes. Transparency in 1992 was greatest in the moderate and light classes compared to other classes, but these differences were not significant (p=0.18). Leaves from trees whose transparency increased from 1991 to 1992 were dwarfed, tattered, and chlorotic in 1992 while those from trees whose transparency was constant or decreased were only lightly chlorotic and near normal in size. This suggests that differences in transparency in 1992 resulted from differences in the severity of pear thrips damage.

Crown dieback in all years did not exceed 11% in any class and differences among 1989 damage classes were not significant (p=0.5, 0.7, 0.9 for 1990, 1991, and 1992, respectively). In both 1990 and 1991, there was a trend of greater dieback with heavier 1989 damage which did not occur in 1992 (Figure 2). Small decreases in dieback occurred in all damage classes from 1990 to 1991, while changes from 1991 to 1992 were variable among classes (Figure 2).

Budburst Phenology

Budburst averaged over all classes in 1991 occurred two days earlier in the middle compared with the upper crown (p=0.04). In contrast, differences in budburst between crown positions in 1992 were less than one day and not significant (p=0.36). Budburst date differed among 1989 damage

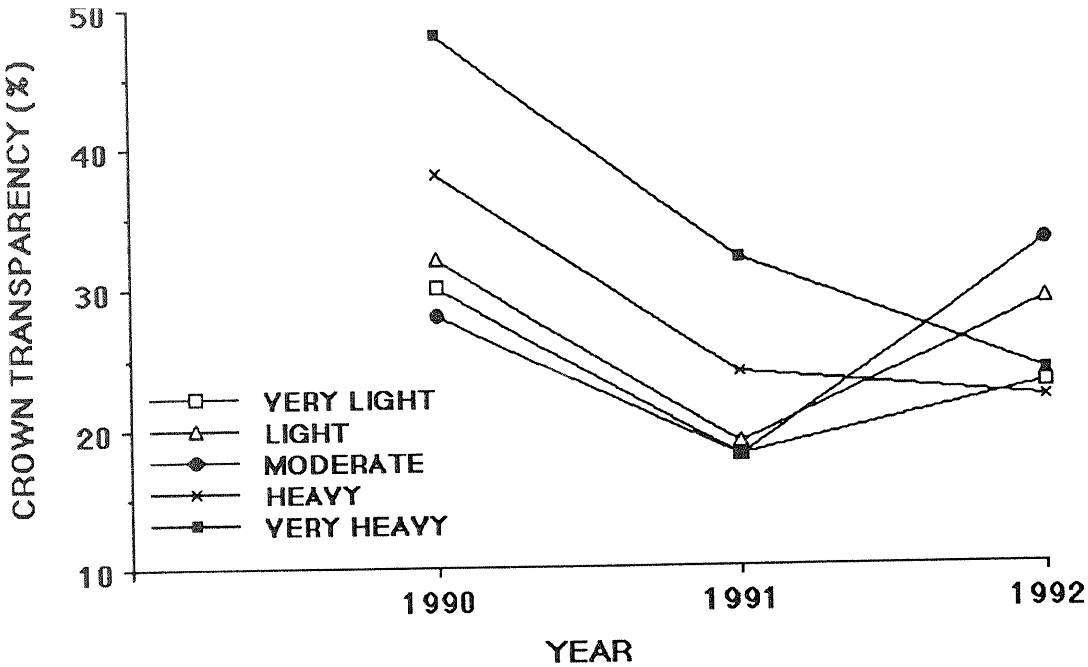

Figure 1.—Crown transparency of sugar maples from five 1989 pear thrips damage classes in June 1990, 1991, and 1992. Each value is the average of 5 to 18 trees.

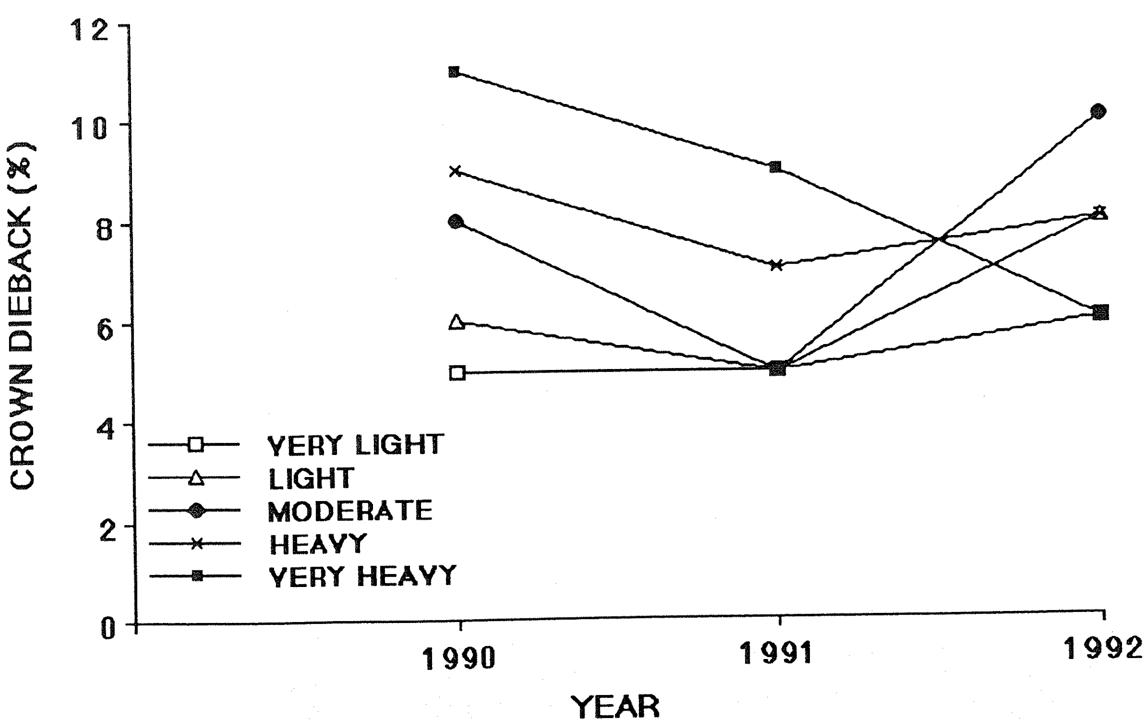

Figure 2.—Crown dieback of sugar maples from five 1989 pear thrips damage classes in June 1990, 1991, and 1992. Each value is the average of 5 to 18 trees.

classes in both years (p=0.0001 in 1991, p=0.03 in 1992), and differences were consistent over crown positions (p=0.97, 0.98 for the class x crown position interaction in 1991 and 1992, respectively). In both years, trees in the very heavy class had the earliest average budburst date (May 2 and 4 for 1991 and 1992, respectively), followed by the heavy (May 4 and 5 for 1991 and 1992, respectively), moderate (May 6 and 6 for 1991 and 1992, respectively), light (May 9 and 7 for 1991 and 1992, respectively) and very light classes (May 9 and 7 for 1991 and 1992, respectively). Individual tree budburst dates in 1991 were positively (r=0.56) and significantly (p<0.01) correlated with dates in 1992.

Number of pear thrips oviposition sites per leaf averaged over all classes in 1991 did not differ (p=0.34) between middle (mean=1.8) and upper crown positions (mean=1.1) and there was no interaction between crown positions and budburst dates (p=0.83). The five trees with earliest phenology in 1991 broke bud between April 26-30 and had more (p=0.07) oviposition sites per leaf (mean=21.0) than the five trees with latest phenology (mean=7.9) which broke bud between May 12-14. Significant sources of variation in number of pear thrips oviposition sites per leaf differed between 1991 and 1992. In contrast to 1991, greater numbers of oviposition sites in 1992 occurred in the upper (mean=3.4) compared with the middle crown (mean=1.7) (p=0.008), and these differences were consistent over budburst dates (p=0.48 for budburst date x crown position interaction). The five trees with earliest phenology in 1992 broke bud between May 4-6 and had about the same number of oviposition sites (mean=2.7) as the five trees with latest phenology (mean=2.4) which broke bud between May 11-14 (p=0.59).

Sap Characteristics

Total per tree sap volume was considerably lower in 1990 than in 1991 and 1992 (Figure 3). Total per tree sap volume in all years was greatest in the very light 1989 damage class, intermediate in the light, moderate, and heavy classes, and lowest in the very heavy class. These differences were significant (p<0.10) on 13 collection dates in 1991 and 6 dates in 1992, but no significant differences occurred in 1990.

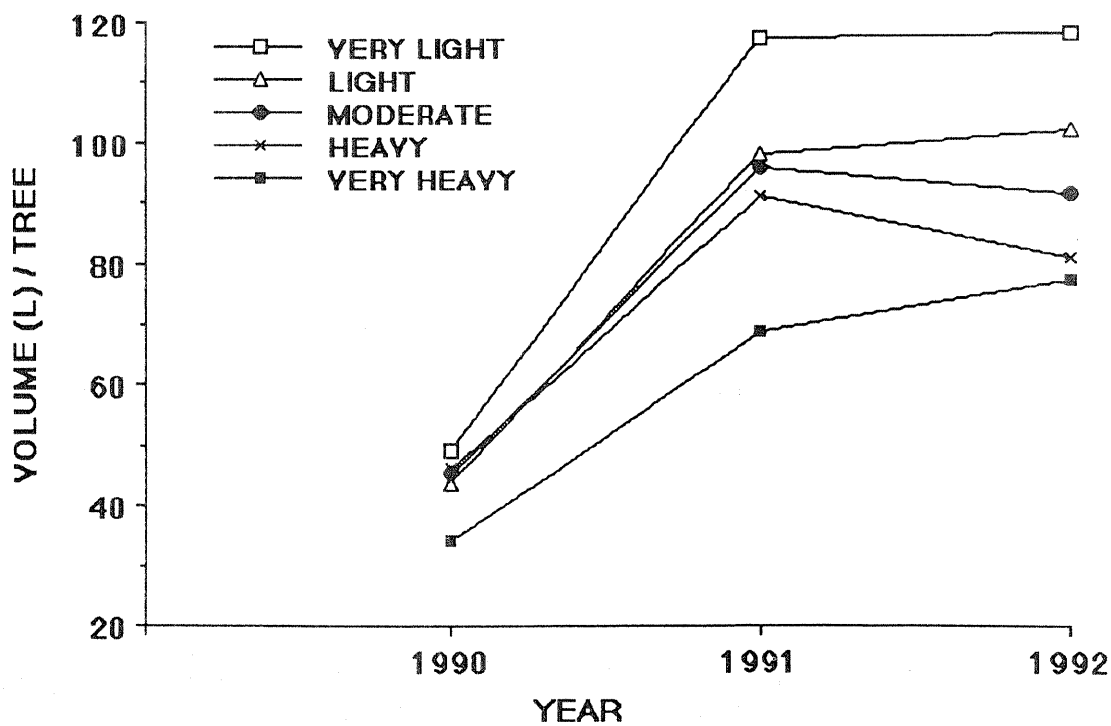

Figure 3.—Total per tree sap volume of sugar maples from five 1989 pear thrips damage classes for the 1990, 1991, and 1992 sap seasons. Values in each year are averages over dates and trees (n = 5-18 trees per class).

Sap sugar concentration averaged over all collection dates increased from 1990 to 1992 (Figure 4). There were small (0.1 to 0.3%) but significant ($p \leq 0.10$) differences in sap sugar concentration among damage classes on two collection dates in 1990, four dates in 1991, and three dates in 1992. In 1990, sap sugar concentration was consistently greater in the very light class compared with heavier degrees of damage. In contrast, sap sugar concentration in 1991 was consistently greater in the very heavy class compared with other classes. In 1992, sap sugar concentration on most collection dates was greatest in the very light and light classes compared with the moderate, heavy, and very heavy classes.

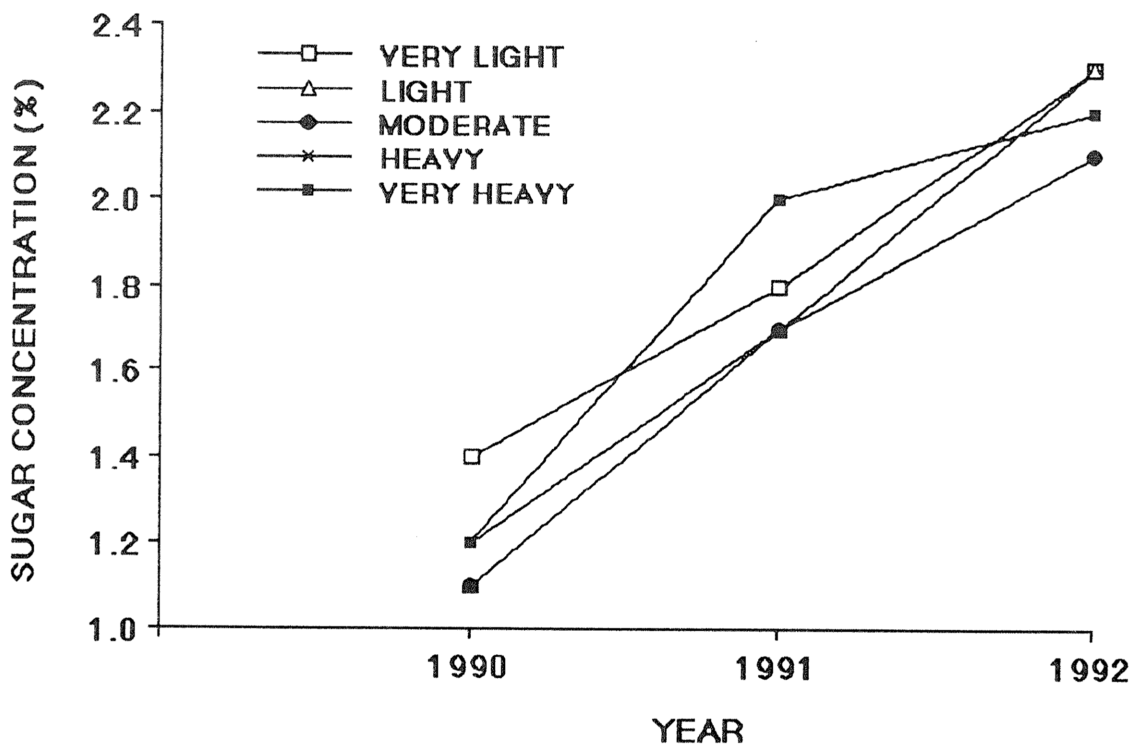

Figure 4.—Sap sugar concentration of sugar maples from five 1989 pear thrips damage classes for the 1990, 1991, and 1992 sap seasons. Values in each year are averages over dates and trees (n = 5-18 trees per class).

Total per tree syrup production increased from 1990 to 1992 (Figure 5). Syrup production in all years was greatest in the very light class, intermediate in the light and moderate classes, and lowest in the heavy and very heavy classes. Compared with the very light class, light damage reduced total syrup production by 26% in 1990, 19% in 1991, and 16% in 1992; moderate damage reduced total syrup production by 23% in 1990, 24% in 1991, and 30% in 1992; heavy damage reduced total syrup production by 19% in 1990, 28% in 1991, and 39% in 1992; and very heavy damage reduced total syrup production by 40% in 1990, 35% in 1991, and 39% in 1992.

DISCUSSION

Our analysis of pear thrips impact in this study assumes similar background stresses on trees in different damage classes prior to the 1989 pear thrips attack. Unfortunately, we do not have data on sap production or crown condition of these trees prior to 1989. Further, we cannot rule out the involvement of other pathogenic agents associated with thrips damage in causing differences in

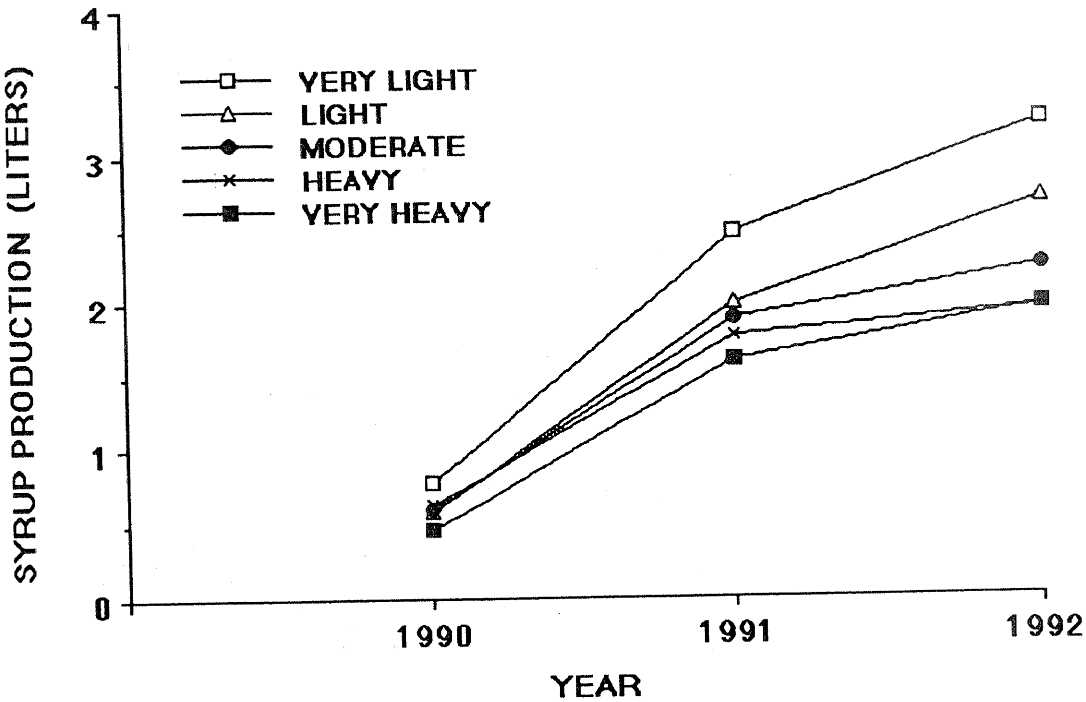

Figure 5.—Tatoal per tree syrup production of sugar maples from five 1989 pear thrips damage classes for the 1990, 1991, and 1992 sap seasons. Values in each year are averages over dates and trees (n = 5-18 trees per class).

syrup production and crown condition. For example, sugar maple leaves damaged by pear thrips can be infected by anthracnose fungi (Nash et al. 1991), which could further damage leaf area and function. Defoliation can also predispose sugar maples to attack by the fungus *Armillaria mellea* (Wargo 1972). With these caveats, our data suggests that heavy pear thrips damage in 1989 reduced maple syrup production in this sugarbush over the next three years following attack.

Sap volume and sugar concentration in the three years following the 1989 thrips attack were generally greater for trees with light damage compared to trees with heavy damage. Trees in the very heavy damage class were the only exception to this trend, where sap sugar concentration in 1991 was greatest of all classes. Elevated sap sugar concentrations have been previously reported for heavily defoliated or declining sugar maples (Gregory and Wargo 1986, Herrick 1988, Allen et al. in press). Elevated sap sugar concentration may represent a physiological response to defoliation or dieback, perhaps related to mobilization of carbohydrates associated with refoliation and crown replacement. Lower sap volume and/or sugar concentration in trees with moderate to very heavy thrips damage reduced calculated syrup production by 19-40% in the first season following damage, 24-35% in the second season following damagee, and 30-39% in the third season following damage, with the greatest reductions occurring in the most severely damaged trees.

Sap volume, sugar concentration, and syrup production were considerably lower in 1990 than in 1991 or 1992. Many sugarbush operators we interviewed in Pennsylvania stated that syrup production was lower in 1990 than for any year on record. Poor production in 1990 may have resulted from unusually warm temperatures that occurred between late-February and late-March during sap collection. Record high temperatures were measured throughout Pennsylvania on several dates during this period and hard freezes were uncommon. Periodic thawing of frozen xylem is required to sustain dormant-season sap volume flow from sugar maple stems (Tyree 1983, Johnson et al. 1987), and enzymes that convert starch to sugar in sugar maple xylem are active at temperatures slightly above freezing (Marvin et al. 1971). Warm temperatures also promote the growth of micro-organisms in taps and tubing that can reduce sap sugar concentration and volume. Given the results of this study, it is also likely that heavy thrips damage that occurred in many Pennsylvania sugarbushes in 1988 and 1989 also reduced syrup production in 1990.

Trees with very heavy or heavy thrips damage in 1989 had more transparent crowns and slightly more dieback than trees with less damage for two years (1990-91) following the attack. This indicates detrimental impacts of heavy thrips damage on crown vigor in this sugarbush for two years following the attack. In contrast, only small differences in transparency occurred in 1992 among 1989 damage classes, and slightly greater values occurred in the light and moderate 1989 damage classes. Visual observations of trees with a range of crown transparency in the sugarbush in 1992 suggested that high values resulted from heavy thrips damage - foliage was typically undersized, tattered, and chlorotic on trees with the greatest transparency. These observations of damage occurrence indicate a lack of consistency in damage severity to individual trees between attacks in 1989 and 1992.

Severity of thrips damage to individual trees was related to variation in budburst phenology in previous studies on sugar maple seedlings and saplings (Kolb and Teulon 1991), and in this study sugarbush in 1991. In these cases, trees with early budburst were more prone to thrips damage than trees with late budburst because of greater synchrony of early budburst with emergence of adult thrips from the soil. Emergence of pear thrips from the soil in the sugarbush in 1991 was heaviest between April 2-9, and then declined to no emergence after May 1 (D. A. J. Teulon, Penn State University Dept. Entomology, unpublished data). Trees with the earliest phenology in 1991 broke bud between April 26 and April 30 when emergence was still occurring while trees with late phenology broke bud between May 12 and May 14, almost two weeks after emergence had ended. In contrast to 1991, there were no differences in thrips activity (number of oviposition sites) among trees with early and late budburst in 1992. In 1992, emergence of pear thrips from the soil was heaviest between April 10-17, and no emergence was detected after April 24 (D. A. J. Teulon, Penn State University Dept. Entomology, unpublished data). Trees with both early (May 4-6) and late phenology (May 11-14) in 1992 broke bud at least two weeks after emergence had ended, suggesting that budburst date had little influence on thrips feeding intensity in this year.

Flower production by all study trees in the sugarbush was heavy in 1992, while little to no flower production occurred in 1991. We speculate that variation in thrips damage severity among trees in 1992 may have been related to variations in flower production. This interpretation is supported by greater numbers of thrips oviposition sites in the upper compared with the middle crown in 1992, since flowering is typically heavier in upper branches. Pear thrips are voracious pollen feeders and a pollen heavy diet may increase larval production and consequent larval damage.

In our study, one year of heavy pear thrips damage had a detrimental impact on sugar maple health and syrup production for the next three years. The impact of pear thrips damage on other stands, however, may depend on their exposure to previous stress agents and management history.

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