# VARIATION AMONG SIBERIAN ELM IN THEIR SUSCEPTIBILITY TO DEFOLIATION BY THE SPRING CANKERWORM

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## ABSTRACT

Siberian elm, *Ulmus pumila* L., a fast growing tree capable of surviving the harsh environmental conditions of the northern Great Plains, is widely planted in field windbreaks. These windbreaks are often severely defoliated by larvae of spring cankerworms, *Paleacrita vernata* Peck. Occasionally one or more elms in a severely defoliated windbreak are not defoliated because the leaves are not preferred by the larvae. During the spring and early summer of 1979, 1980, and 1981, the relationship of percent defoliation to leaf thickness, leaf area, percent leaf moisture, dry leaf weight, and wet leaf weight from nine preferred and one non-preferred elms was investigated in a single-row field windbreak in North Dakota. Leaf characteristics were measured weekly from the time of bud break until the cankerworm larvae pupated in June. Cluster analysis of these data separated the preferred trees from the non-preferred tree in all 3 years. Stepwise regression analyses revealed that percent defoliation was less for leaves with larger surface areas and was greater for thicker leaves. Growth initiation by the non-preferred tree averaged 2 weeks later than the preferred trees.
Additional keywords: Ulmus pumila, Paleacrita vernata, defoliation, leaf morphology, preferred, non-preferred.

## INTRODUCTION

Siberian elm, *Ulmus pumila* L. is a fast-growing tree capable of surviving the harsh environment of the northern Great Plains. Cold and drought hardiness, tolerance to sodic claypan soils, and fast juvenile growth have made it a popular choice for planting in both field and farmstead windbreaks. In the northern Great Plains, these windbreaks are often severely defoliated by larvae of the spring cankerworm, *Paleacrita vernata* Peck (Lepidoptera: Geometridae).

In North Dakota, spring cankerworms hatch in May or early June depending on weather conditions. The larvae feed on the leaves 4 to 6 weeks before descending to the ground on silken threads and pupating in the soil. The moths emerge when the ground thaws in March, April or May. Mating occurs soon after the moths emerge when the wingless females are crawling to the nearest tree or climbing the trunk. The females lay their eggs in cracks and crevices on the bark of the host tree. Both male and female moths die soon after the eggs are laid. Within a few weeks the eggs hatch and the larvae begin feeding on the newly emergent leaves (Hildahl and Peterson, 1974).

Occasionally one or more elms in a severely defoliated windbreak are not defoliated. The potential genetic resistance to cankerworm defoliation of these trees makes them valuable in a genetic improvement program for Siberian elm. The lack of defoliation of these trees may have resulted from a chance escape, patterns of environmental variation

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within the windbreak, or non-preference by cankerworm larvae or adults. The year-to-year repeatability of non-defoliation exhibited by some of these selected trees led us to conclude that some characteristic of these trees makes them less preferable to cankerworms than neighboring trees which were nearly completely defoliated. The purpose of this study was to investigate the basis for the resistance to cankerworm defoliation exhibited by one such tree. We have reported on the preliminary results of this study earlier (Dix and Cunningham, 1983).

## METHODS

During the spring of 1979, a single-row Siberian elm field windbreak in north central North Dakota was selected for study. All trees in the windbreak except one had been completely ;defoliated by spring cankerworms during May and June 1978. Nine additional elms within 100 meters of this tree were chosen for comparison. The ten trees were numbered from 1 to 10, beginning with the southern-most tree. The non-preferred elm was assigned tree number 4. In 1979, 1980, and 1981, the trees were sampled every 3 to 4 days beginning at least 1 week before bud expansion until the cankerworm larvae dropped to the ground to pupate. A 15 cm long branch was clipped from the following 4 positions on each of the 10 trees; lower west, upper west, upper east and lower east. The branch diameter, number of leaves, number of cankerworm larvae, total leaf area, percent defoliation, and dry weights of the leaves for each of the samples were recorded. A Li-Cor Leaf Area meter and vernier caliper were used to measure leaf area and branch diameter, respectively. The moisture content of the leaves from each branch was calculated on a green-weight basis by weighing the leaves before and after they had been dried at 100°F (38°C) for 60 minutes. Before analysis, means for each variable were calculated for each tree by averaging the data for the four branch samples collected on each sampling date. Leaf thickness was calculated as the ratio of dry weight per leaf to leaf area per leaf. Percent defoliation was a visual estimate of the proportion of leaf material eaten in each branch sample.

Cluster analysis was used to separate the trees into groups, or clusters, of trees having similar attributes. Variables used in the analysis were branch diameter, dry weight per leaf, leaf area per leaf, percent leaf moisture and leaf thickness. Relationships among the leaf variables were examined by correlation analysis of the leaf data collected on the last sampling date before any appreciable defoliation had occurred.

The relationship of the leaf variables to percent defoliation was determined by a step-wise regression analysis. Maximum percent defoliation was the dependent variable and branch diameter, dry weight per leaf, leaf area per leaf, percent leaf moisture, and leaf thickness were introduced into the analysis singly and in combination. Values for the independent variables were for the last sampling date before significant defoliation occurred.

RESULTS

The spring of 1979 was very cold compared to those of 1980 and 1981. The buds on the Siberian elm sample trees did not begin to expand until June 1 (Table 1). In 1980 and 1981 the buds on the preferred trees began growth about May 1. Tree 4 initiated growth later than the preferred trees in all three years. The difference ranged from 7 days in 1979 to 17 days in 1981. Larval counts on tree 4 were very low and it was defoliated the least of any sample tree in all 3 years of the study. Trees 1, 5 and 7 leafed out in synchrony in all three years, 0 to 3 days after the mean date of bud break. This group of trees averaged the highest larval counts and the most defoliation. Trees 2, 3, 6, 8, 9, and 10 leafed out earlier than trees 1, 5, and 7, had lower average larval counts, and received less defoliation. Percent defoliation, averaged over all trees, was highest in 1979 but decreased in both succeeding years (Fig. 1).

Table 1.--Date of bud break, percent defoliation, and number of larvae.

| Year | Date of bud break: Overall Mean | Date of bud break: Subgroup Mean | Dif. | Tree | Mean percent defoliation | Mean number larvae[a] |
|---|---|---|---|---|---|---|
| | - - - - - - - - | days | - - - - - | | | |
| 1979 | 149 | 149 | 0 | 1,2,3,5,6, 7,8,9,10 | 62.3 | 37.2 |
| | | 156 | +7 | 4 | 5.0 | 12.0 |
| 1980 | 121 | 120 | -1 | 2,3,6,9,10 | 38.6 | 101.3 |
| | | 123 | +2 | 1,5,7 | 55.3 | 129.3 |
| | | 136 | +15 | 4 | 6.0 | 8.0 |
| 1981 | 121 | 117 | -4 | 3,10 | 21.5 | 8.0 |
| | | 120 | -1 | 2,6,8,9 | 20.0 | 22.3 |
| | | 124 | +3 | 1,5,7 | 26.0 | 23.7 |
| | | 138 | +17 | 4 | 13.0 | 2.0 |

[a] Mean per tree summed over branches and sampling dates.

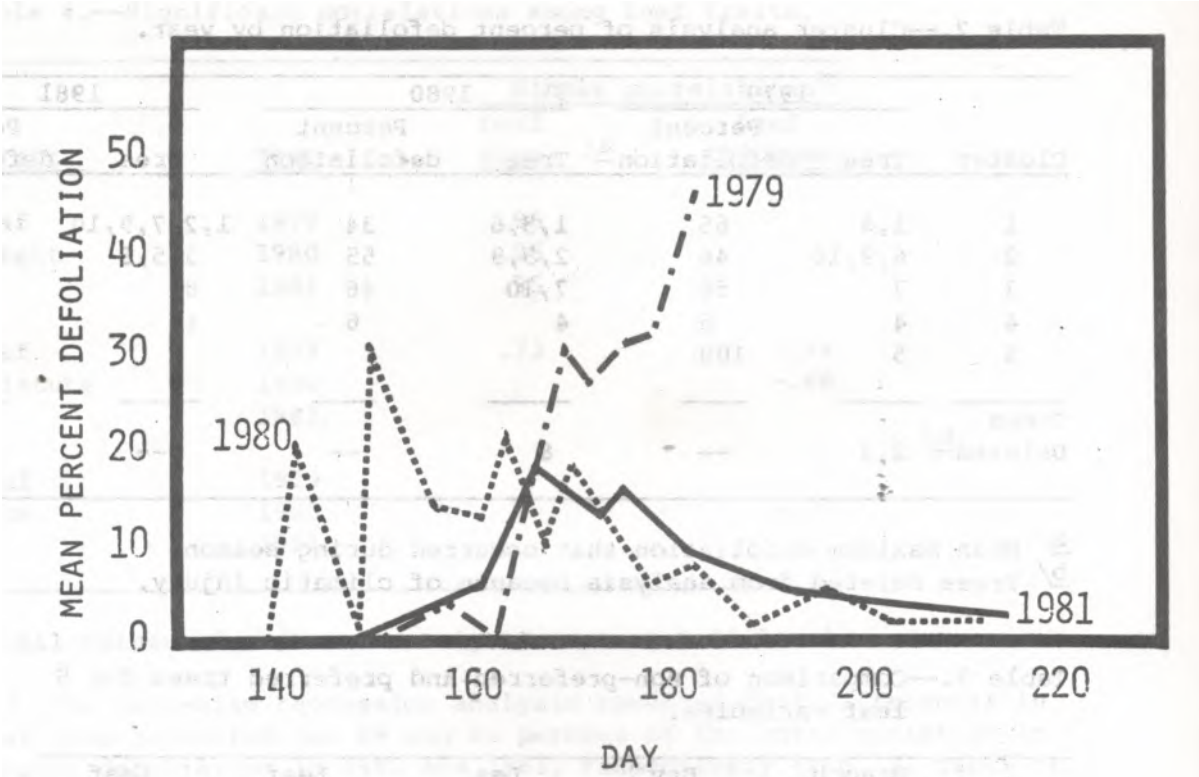


FIGURE 1. MEAN PERCENT DEFOLIATION, ALL TREES, 1979-81.

In the cluster analysis four clusters produced the optimum clustering criterion in 1980 and 1981 (Table 2). Five clusters were optimum in 1979. In each year the non-preferred tree was segregated into a cluster by itself and was arbitrarily designated cluster 4. Cluster means were calculated for each variable used in the cluster analysis. The cluster mean that included the non-preferred tree was compared to the means of the clusters for the preferred trees (Table 3). Branch diameters and leaf thickness of the non-preferred tree were generally smaller than those of preferred trees. Leaf area per leaf of the non-preferred tree was approximately 50 percent greater than the preferred trees in two out of three years. In 1979 leaf size was comparable. Dry weight and percent moisture varied inversely over the three years of the study. In 1979 dry weight per leaf of the non-preferred tree was approximately 20 percent less than the mean of the preferred trees. In 1981 it was 31 percent more than the preferred trees. Leaf moisture of the non-preferred tree was 26 percent greater in 1979 but dropped to about the same value as that of the preferred trees in 1981.

Table 2.--Cluster analysis of percent defoliation by year.

| | 1979 | | 1980 | | 1981 | |
|---|---|---|---|---|---|---|
| Cluster | Tree | Percent defoliation[a] | Tree | Percent defoliation | Tree | Percent defoliation |
| 1 | 1,8 | 65 | 1,3,6 | 34 | 1,2,7,9,10 | 30 |
| 2 | 6,9,10 | 46 | 2,5,9 | 55 | 3,5,6 | 23 |
| 3 | 7 | 50 | 7,10 | 46 | 8 | 16 |
| 4 | 4 | 5 | 4 | 6 | 4 | 13 |
| 5 | 5 | 100 | | | | |
| Trees Deleted[b] | 2,3 | -- | 8 | -- | -- | -- |

[a] Mean maximum defoliation that occurred during season.
[b] Trees deleted from analysis because of climatic injury.

Table 3.--Comparison of non-preferred and preferred trees for 5 leaf variables.

| Year | Branch diameter | Dry weight | Leaf moisture | Leaf area | Leaf thickness |
|---|---|---|---|---|---|
| | percent[a] | | | | |
| 1979 | 91 | 80 | 126 | 103 | 69 |
| 1980 | 88 | 117 | 111 | 153 | 70 |
| 1981 | 96 | 131 | 96 | 160 | 81 |

[a] Percent = (100 x mean of non-preferred)/mean of preferred.

Simple correlations among leaf variables were inconsistent from year to year except for the positive correlation of leaf size and dry weight per leaf (Table 4). Leaf thickness and leaf moisture were negatively correlated in 1979 and 1980. The relationship was still negative in 1981 but was nonsignificant. Leaves with a greater dry weight per unit of leaf area tended to have a lower percentage of moisture. Leaf size and leaf thickness were significantly correlated on only one date--day 149 in 1980 when r = -.77. The leaves of non-preferred tree 4 were among the largest and thinnest of all sample trees during all three years.

Table 4.--Significant correlations among leaf traits.

| Trait | Year | Simple correlations[a/] Leaf size | Leaf thickness |
|---|---|---|---|
| Leaf weight | 1979 | .96 | |
| | 1980 | .95 | |
| | 1981 | .95 | |
| Leaf moisture | 1979 | .73 | -.94 |
| | 1980 | | -.88 |
| | 1981 | | |
| Leaf size | 1979 | | |
| | 1980 | | -.77 |
| | 1981 | | |

2/ All values of r shown are significant at 0.05 level.

The step-wise regression analysis revealed that differences in leaf area accounted for 49 and 41 percent of the total variation in percent defoliation in 1980 and 1981, respectively (Fig. 2, Table 5). Trees with larger leaves tended to be defoliated less than those with smaller leaves. Even though non-preferred tree 4 leafed out 15 and 17 days later than the other trees in 1980 and 1981, its new leaves were not only considerably larger than the new leaves of the other trees, they quickly expanded to larger than average mature leaves (Fig. 3).

Table 5.--Step-wise regression analysis of percent defoliation regressed over several leaf variables.

| Year | Day | Variable | R | Percent defoliation[a/] |
|---|---|---|---|---|
| 1979 | 164 | Leaf thickness | 0.32 | 51 |
| 1980 | 148 | Leaf area | 0.49 | 38 |
| | | Leaf thickness | 0.59 | |
| 1981 | 152 | Leaf area | 0.41 | 25 |
| | | Dry weight | 0.43 | |
| | | Branch diameter & dry weight | 0.71 | |

2/ Mean maximum defoliation that occurred during season.

Percent defoliation was greater among trees with thicker leaves. Leaf thickness explained 59 percent of the variation in defoliation in 1980 (Fig. 4).

In 1981 dry weight per leaf varied inversely with percent defoliation and accounted for 43 percent of the variation in defoliation (Fig. 5).

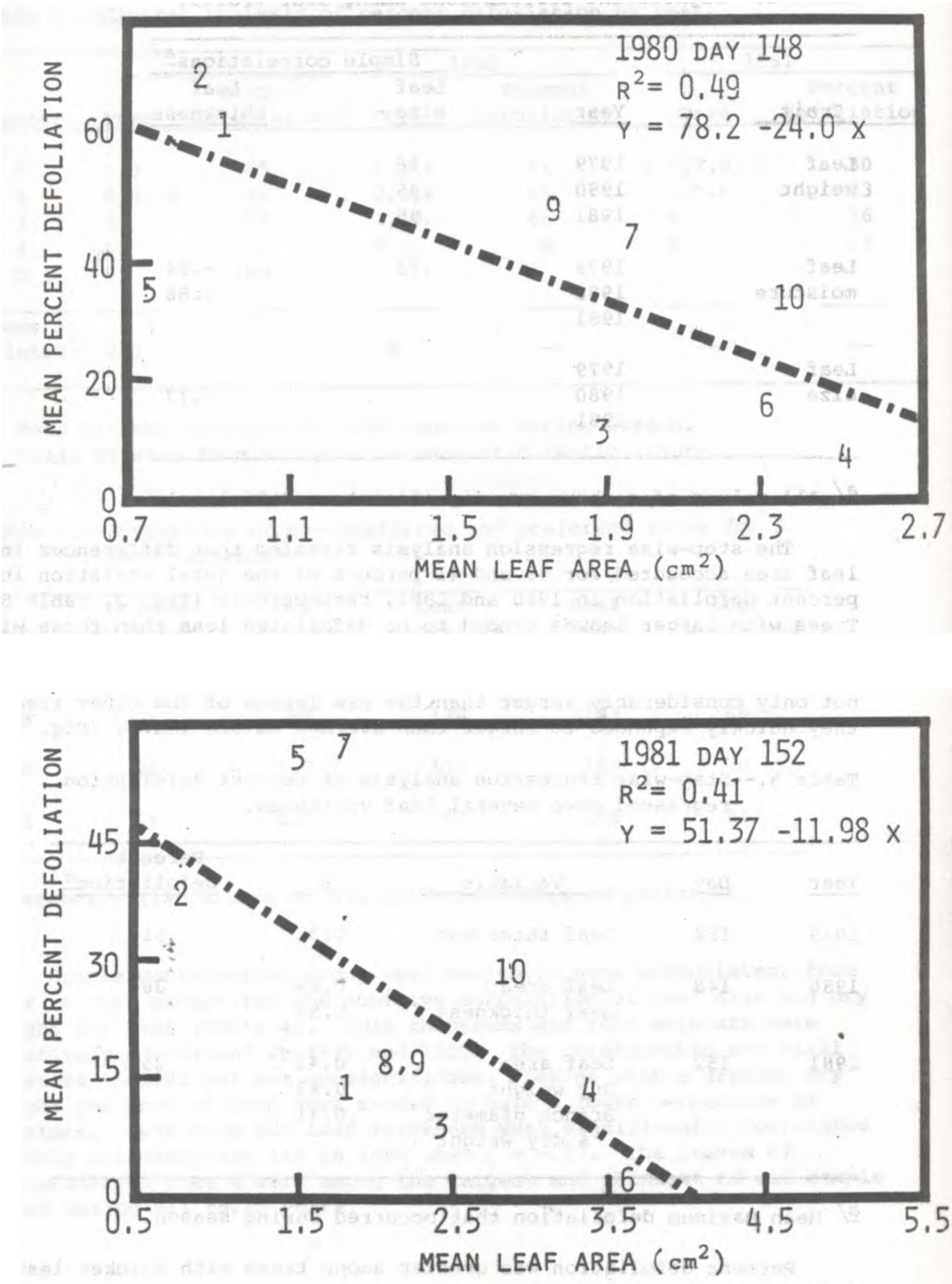


Figure 2.--Regression, of percent defoliation by mean leaf area of sample tree for day 148, 1980 and day 152, 1981.

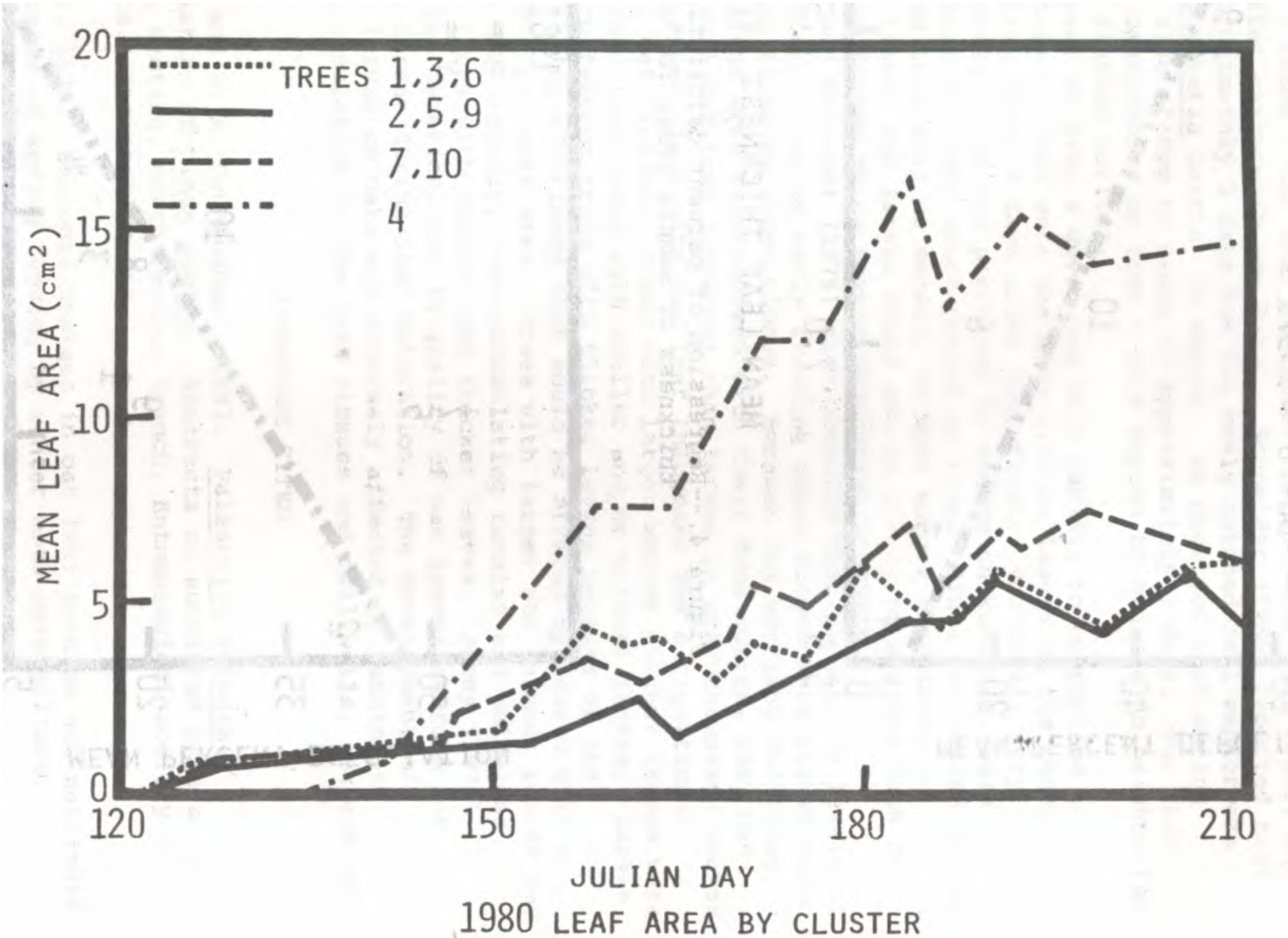


Figure 3.--Mean leaf area by day and cluster means for 1980.

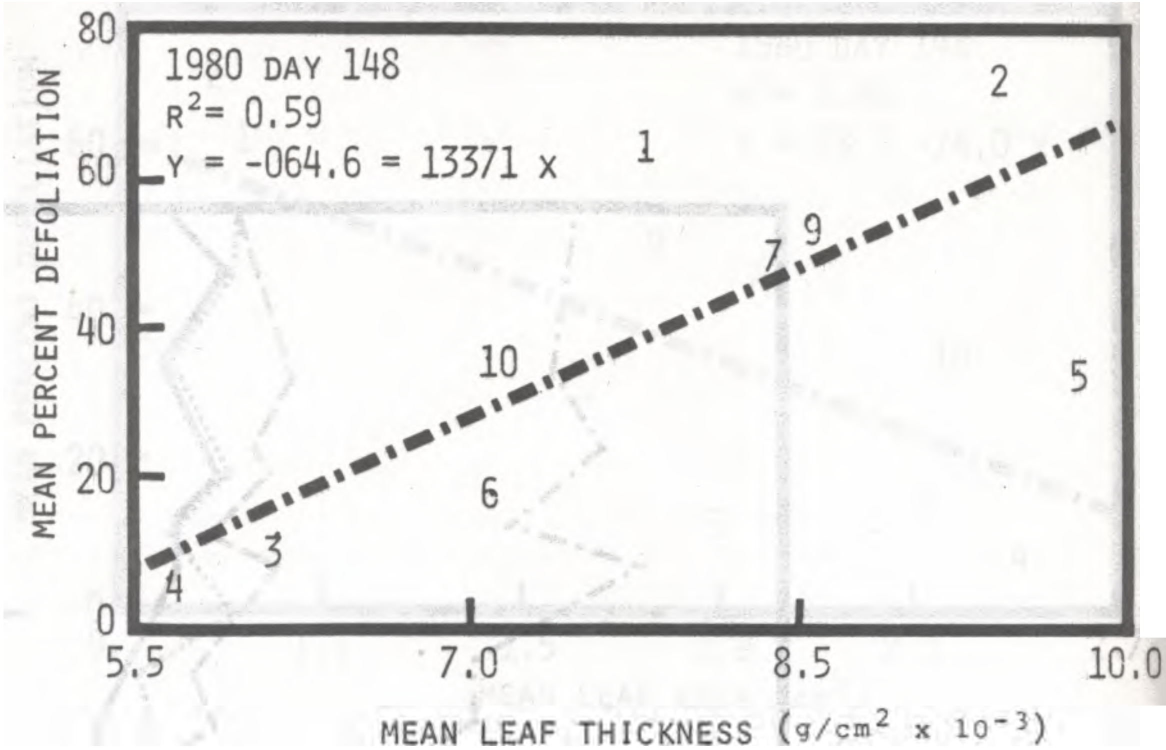


Figure 4.--Regression of percent defoliation by mean leaf thickness of sample trees for day 148, 1980.

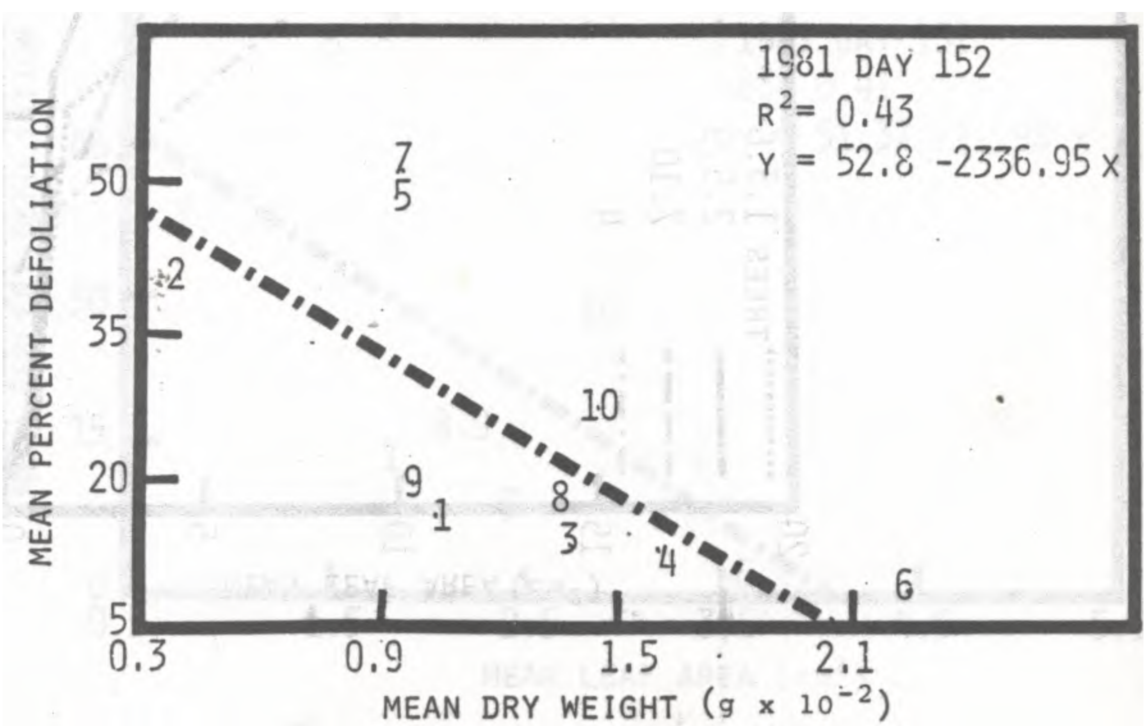


Figure 5.--Regression of percent defoliation by mean dry weight of sample trees for day 152, 1981.

## DISCUSSION

Defoliation of the 10 Siberian elm trees by spring cankerworms appeared to be influenced by several factors including date of leaf flush, leaf thickness and leaf size. The leaves on tree 4 expanded late, about 2 weeks after leaf expansion by the other nine trees, and two weeks after cankerworm egg hatch. Schneider (1980) reported that it takes approximately 3 days for the newly hatched fall cankerworm (*Alsophila pometaria* Harris) to starve. We observed that spring cankerworms also starve to death in approximately 3 days. For this reason, the cankerworms on tree 4 were forced to migrate to neighboring trees which flushed earlier.

The leaves on tree 4 developed very rapidly in comparison to the other nine trees. They were the same size as leaves on the other earlier leafing trees 7 days after leaf flush. The small , very immature leaves, which are preferred by spring cankerworms, were present on tree 4 a very short period of time. Since the leaves on the non-preferred tree were as mature, or more mature than those on neighboring trees, the larvae would not be likely to migrate back to tree 4 unless forced to by severe population pressure.

Witter and Waisamer (1978) also observed that population levels of tortricid caterpillars on early flushing aspen clones were higher than those on late flushing aspen clones. Because the emerging 2nd-stage tortricid larvae were synchronized with their food source, they had higher survival and less dispersal than larvae on unsynchronized leaves.

In our study, leaf size and leaf thickness had a significant influence on defoliation. Trees with larger and/or thinner leaves were defoliated less than trees with smaller and/or thicker leaves. Larvae may prefer to feed on trees with thicker leaves because of the increased feeding efficiency that would be offered by leaves with a greater weight per unit area. Trees with larger and thinner leaves may also mature more rapidly, thus accumulating tannins and cellulose faster than trees with smaller and thicker leaves. Feeny (1970) documented the deterioration in quality of oak leaves as food for Lepidoptera larvae during leaf maturation. The development of Lepidoptera larvae on oaks was adversely affected by tannin and cellulose accumulation in the leaf tissues and cell walls, respectively.

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