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DISTRIBUTION AND CONTROL OF THE PLUM CURCULIO, *CONOTRACHELUS NENUPHAR* (HERBST)

By

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ABSTRACT

DISTRIBUTION AND CONTROL OF THE PLUM CURCULIO, *CONOTRACHELUS NENUPHAR* (HERBST)

By

Amy Ellen Brown

The plum curculio is one of the five major pests of apples in Michigan. It lays its eggs inside the fruit early in the spring and the larvae tunnel through the fruit, eventually causing the fruit to drop prematurely. Oviposition scars from which larvae do not develop cause cosmetic damage to the apple.

An apple orchard in southwest Michigan was used to conduct studies on the seasonal and spatial distribution of this pest, as well as strategies for its control.

A strong positive correlation was found to exist between oviposition activity and the accumulation of degree-days at a base of 12.8^{o} C. Peak oviposition activity took place during the period from the last week of May through the first week of June in both Jonathan and Northern Spy apple varieties.

Distribution of oviposition scars throughout the tree was found to be fairly uniform. Height and directional

orientation did not have a significant effect on oviposition, according to results of a split-plot analysis of variance.

Results of an experiment varying the rates and times of a spray to control the plum curculio were inconclusive. Control recommendations could not be altered from the current recommendations as cited in "1979 Fruit Pesticide Handbook" (Flore *et al*., 1979).

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INTRODUCTION

The plum curculio was originally described by Herbst (1797) as Curculio nenuphar. It was later assigned to the genus Conotrachelus by Schonberr (1837). A native North American insect, the plum curculio probably existed on wild plums, hawthorn and crabapples before cultivated fruits were introduced. It was considered a serious, though not a regular, pest of apples by the mid-1800's (Crandall, 1905). The plum curculio now attacks a wide range of fruits including apple, plum, peach, quince, apricot, nectarine, pear, cherry, and persimmon.

Considered one of the five most important pests of apple in Michigan, the plum curculio decreases not only the yield but also the quality of fruits remaining at harvest. While feeding punctures may cause some cosmetic damage, egg-laying activity is responsible for the majority of the losses. The typical crescent-shaped puncture made by the female as she oviposits leaves a wound that will eventually scar over. As the fruit grows older, these wounds are often attacked by fungus. If the eggs hatch and larvae survive through the last instar, the fruit will generally fall to the ground within a few weeks after the eggs are laid. Even if the larvae are aborted, the feeding completed before their death will leave dark brown lines of scarred tissue with a bitter taste inside the mature apple (Brooks, 1910).

Orchards where no control method is applied for the plum curculio may show a considerable loss to this pest. Apples on unsprayed trees may be 100% attacked. Glass and Lienke (1971) observed that the apple crop in an orchard where sprays had been discontinued were "commercially worthless after the first year." In a recent appraisal of apple injury data by Hall (1974), the plum curculio alone was found to be responsible for 74.6% of culled apples by harvest.

The current Michigan control program (Flore et al., 1979) consists of a spray at petal fall followed by a second spray 7 to 10 days later. Recommended materials include azinphos-methyl, parathion, phosalone, and phosmet.

The objectives of this study were to determine 1.) whether plum curculio oviposition damage is distributed randomly throughout an orchard, and 2.) whether a spray could be applied only once or at a reduced rate and still effectively control the plum curculio.

LITERATURE REVIEW

Description of Stages

Eggs are laid singly in crescent-shaped cavities in the fruit. The egg is about 0.75 mm long and 0.25 mm wide. When first laid they are pearly white, but they turn yellowish within a short time (Crandall, 1905). They are normally elliptical but sometimes become flattened due to the pressure of the growing fruit (Chapman, 1938).

The larva is creamy white to yellowish, legless, tapered at both ends, and has a brown head capsule. There is a distinct curvature toward the ventral side (Chapman, 1938; Crandall, 1905; Quaintance and Jenne, 1912). Mature larvae average about 6.4 mm long. There are four instars, all of which are spent within the same fruit (Garman and Zappe, 1929; Quaintance and Jenne, 1912). Maturation takes about twenty days (Crandall, 1905).

The pupa is also white to cream colored, and about 5 mm long. The length of time spent in the pupal stage averages eight days (Quaintance and Jenne, 1912).

Adults are brownish-black with white and orange hairs in patches, resulting in a mottled appearance. There are four pairs of ridges on the elytra; the two medial pairs each separated into three distinct humps. The middle humps are bare and are about twice the elevation of the others (Chapman, 1938). The average adult is about 5 mm long. The length of time of this stage is quite variable. The average length of time in the adult stage in the field is not known, but Garman and Zappe (1929) have found that, in the laboratory, they may last up to thirteen months. The sexes may be distinguished by the shape of the hind tibiae (Garman and Zappe, 1929), or by the shape of the first abdominal segment, which is slightly convex in the female but depressed in the male (Thomson, 1932).

Life History

The plum curculio overwinters as an adult in woodlots, orchards, and hedgerows, usually on the ground between decaying leaves and the soil (Johnson and Girault, 1906). Migration to host trees appears to begin after three to four days of a mean temperature between 12.8 - 15.6° C (Quaintance and Jenne, 1912; Whitcomb, 1932). High humidity as well as high temperatures favors emergence from hibernating sites, but neither factor has a direct relationship with beetle emergence (Lathrop, 1949; Smith and Flessel, 1968). There is some delay between emergence from hibernating sites and the appearance of the beetles in the trees (Garman and Zappe, 1929; Lathrop, 1949; Smith and Flessel, 1968). Smith and Flessel proposed that the physiological condition of emerging beetles is unfavorable for immediate migration to host trees. They are highly susceptible to water loss in this stage (Garman and Zappe, 1929; Smith and Flessel, 1968), and may remain in or return to ground cover for soil moisture. Smith and Flessel (1968) also found that, early in the season, the sex ratio favors the males, but the dominance is later reversed.

As soon as the beetles reach the trees, they begin to feed on the leaves and petals as well as on the developing fruits (Brooks, 1910; Garman and Zappe, 1929). Early feeding punctures may cause the fruits to become dwarfed and deformed (Brooks, 1910). Apparently they are about equally active by day and by night with regard to both feeding and egg-laying (Crandall, 1905; Quaintance and Jenne, 1912). Hauschild (1977) has found that plum curculio adults fly much less frequently and are less visually oriented than other apple pests, and that there is little dropping of the beetles from the trees during calm weather. However, Smith and Flessel (1968) have shown data indicating that the beetles are not present in the trees continually. It is generally recognized that adverse conditions such as wind and low temperatures cause the beetles to desert the trees.

As soon as the petals have fallen, sometimes before, the females begin to lay eggs. First, the female chews a small cavity just underneath the epidermal tissue of the fruit. Turning around, she then deposits one egg at the mouth of the tunnel and pushes it into the cavity with either her ovipositor or her proboscis. Then she cuts a crescent in front of the hole, leaving a flap of epidermis (Chapman, 1938; Crandall, 1905; Quaintance and Jenne, 1912). The wound left by creating the flap apparently relieves the pressure of the growing fruit (Chapman, 1938). At the time of peak oviposition, females lay an average of eight eggs per day (Smith, 1957). A single female may lay up to 263 eggs per season; the last eggs may be laid as late as mid-August to September (Crandall, 1905).

Eggs will hatch in three to four days in warm weather, but may take a week or more in cool weather (Quaintance and Jenne, 1912). Newly hatched larvae penetrate the fruit within two to three hours (Quaintance and Jenne, 1912). The course taken by larvae within the fruit is variable (Crandall, 1905). Damage before the fruit has set does not usually reduce yields (Levine and Hall, 1977), but the quality may be considerably affected. As the larvae continue to feed, they release pectinases and a cellulase which have been implicated in the direct causation of abscission of the fruit (Levine and Hall, 1978a; Levine and Hall, 1978b). Fruit abscission is generally necessary for completion of larval development; when abscission occurs as a result of larval infestation, the fruits are usually still small (Levine and Hall, 1977). The period between oviposition and maturation of the larvae ranges from about twenty to thirty-three days, with an average of twenty-six days (Crandall, 1905). A temperature of 24° C appears to be optimum for development (Whitcomb, 1932).

Mature larvae burrow out of the fallen fruits and into the ground to pupate. While they have been found at depths of up to 15.2 cm (Crandall, 1905), 70% may be found within the top 2.5 cm, and 90% within the top 5.1 cm (Dozier *et al.*, 1932; Garman and Zappe, 1929). Burrows are oblique to the surface, and pupae remain with their heads up (Crandall, 1905). The time between entrance into the soil by the larva and emergence of the adult ranges from nineteen to fifty-four days, with an average time of thirty to thirty-one days (Chapman, 1938). In Michigan, the average length of the pupal stage itself is about fourteen days (Quaintance and Jenne, 1912).

Adults emerge in late summer and may cause some fall feeding damage before seeking overwintering sites. In Michigan, a reproductive diapause limits the plum curculio to a single generation per year, but in its southern range there may be a partial second generation (Smith and Flessel, 1968).

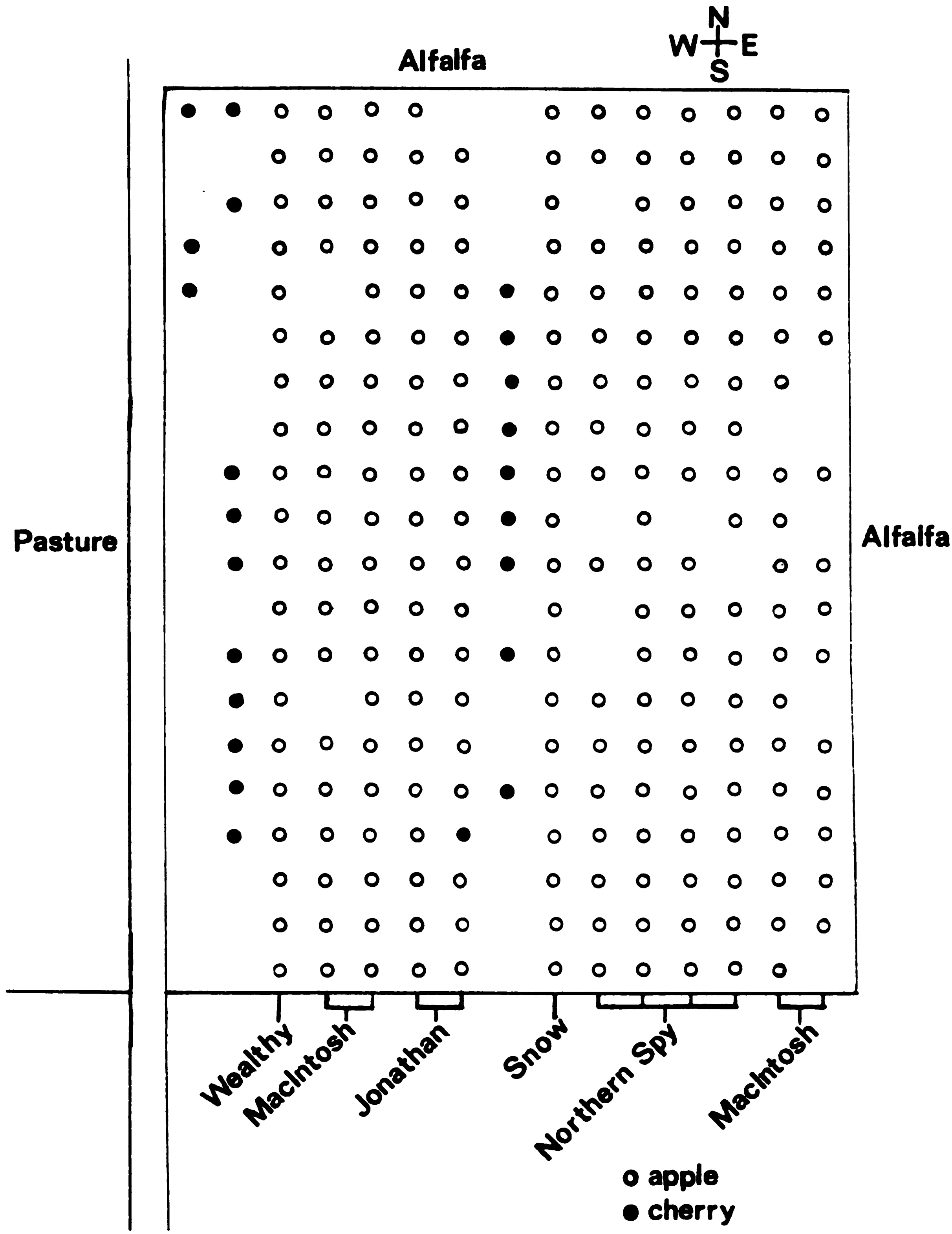


Figure 1. Plan of the Upjohn Orchard.

METHODS AND MATERIALS

Studies were conducted in the Upjohn Company apple orchard in Kalamazoo County, Michigan (Figure 1). There were 224 standard size apple trees and 24 standard cherry trees. No insecticides had been applied in the orchard for 10 years previous to this study, and it was known to have a high incidence of oviposition damage by the plum curculio.

Seasonal Extent of Oviposition Damage

Jonathan apples and Northern Spy apples were chosen as representatives of early and late varieties, respectively. Each variety was divided into three blocks; azinphos-methyl 50% wettable powder was applied at the rate of ½ pound per acre to one block of each variety at petal fall (May 11, 1977), and a second block of each variety at first cover (May 16, 1977). The third block of each variety was left unsprayed, with a buffer zone between the two sprayed blocks and the unsprayed block.

Five trees from each block were chosen for sampling throughout the season (May 11, 1977 - September 7, 1977). The trees were selected for uniformity and heaviness of fruit set as well as for ease of access. Five sites were selected on each tree, starting at the south side and proceeding clockwise. Five clusters were tagged at eye level at each site, and flowers were removed to leave three flowers in each cluster. Thus, there were initially 2250 sampling units. Each week, every apple was examined for oviposition scars. The number of apples remaining in each cluster was also recorded.

Degree-day accumulations were calculated from April 1 until September 7 to determine whether oviposition occurrence could be predicted. A hygrothermograph located in the orchard was used to collect minimum and maximum temperatures for the computations. A base developmental temperature of 12.8°C was chosen (Quaintance and Jenne, 1912). When minimum and maximum temperatures were both above the developmental base threshold temperature, the formula used to calculate degree-days was:

$$^{o}D_{12.8} = \frac{\text{Min. temp.} + \text{max. temp.}}{2} - 12.8$$

When the minimum temperature fell below the base temperature, and the maximum was above it, the Baskerville-Emin method was used (Gage and Haynes, 1974). Percentages of oviposition scars were accumulated and transformed to logistic units (Ruppel and Dimoff, 1978) for linear regression analysis.

Oviposition and Apple Drop

Under each of the 30 apple trees selected for monitoring oviposition damage on the trees, a 1-m^2 area was designated on the ground for collection of dropped apples. Good fruit set above the site was the chief criterion for selecting the site. Where possible (i.e., in 26 out of the 30 cases), sites not directly under tagged apples on the tree were chosen. This was done to help eliminate the possibility of apple drop associated with handling by the experimenter. The areas were marked on the northwest corner if the site was on the south or east side of the tree, and the northeast corner if the site was on the north or west side of the tree. All apples were collected weekly from each site, and each apple was examined to determine the number of plum curculio oviposition scars present. The number of apples collected and the number of stings per apple were recorded. Percent damage was calculated for each block.

Monitoring the Adult Population

Five apple trees from each block (30 trees in all) were selected for adult collection during the 1977 season. Each week, each tree was beaten with a rubber mallet at three sites selected at random. An umbrella was held upside down beneath the beating sites to catch the falling insects. Since plum curculio beetles remain motionless when disturbed, as a defense mechanism, it was relatively easy to separate them from other insects and vegetative matter and record the number at each site. To avoid causing an unnatural disturbance to the trees being used to evaluate the seasonal extent of damage, none of the trees used for that purpose were used for adult sampling.

Adult Emergence

An emergence cage was placed beneath each of four trees in areas corresponding to the buffer zone. Each trap covered a 1-m^2 area. The traps consisted of a wood and metal frame covered by mosquito netting. A 30.4 cm diam. pan covered with plexiglass and filled with ethylene glycol trapped the insects as they flew or crawled up the sides. Tree varieties selected for this study included one Northern Spy, one Jonathan, and two MacIntosh. Dropped apples beneath the tree canopy were collected weekly from July 11, 1977 through September 7, 1977 and placed inside the cages. All plum curculios were collected and the number recorded each week.

Effects of Spray Timing and Application Rates

To evaluate whether significant differences existed between the spray treatments in 1977, Duncan's Multiple

Range Test was used (Steel and Torrie, 1960).

There was a possibility that a north-south plum curculio distribution gradient existed which would affect the true difference between treatments. Therefore, 4 rows of MacIntosh apples were sampled for oviposition damage on June 20, 1977. Every other tree in each row was sampled in a manner similar to that described on page 9. Five trees were selected in blocks corresponding to the blocks in the Jonathan and Northern Spy apples. Five clusters at each of five sites chosen at random were examined on each tree. The number of apples present in each cluster and the number of oviposition scars on each apple were recorded.

In 1978, both spray rates and application rates were varied. A total of 20 Jonathan trees were used in this test. A 50% wettable powder formulation of azinphos-methyl was applied in five treatments as follows:

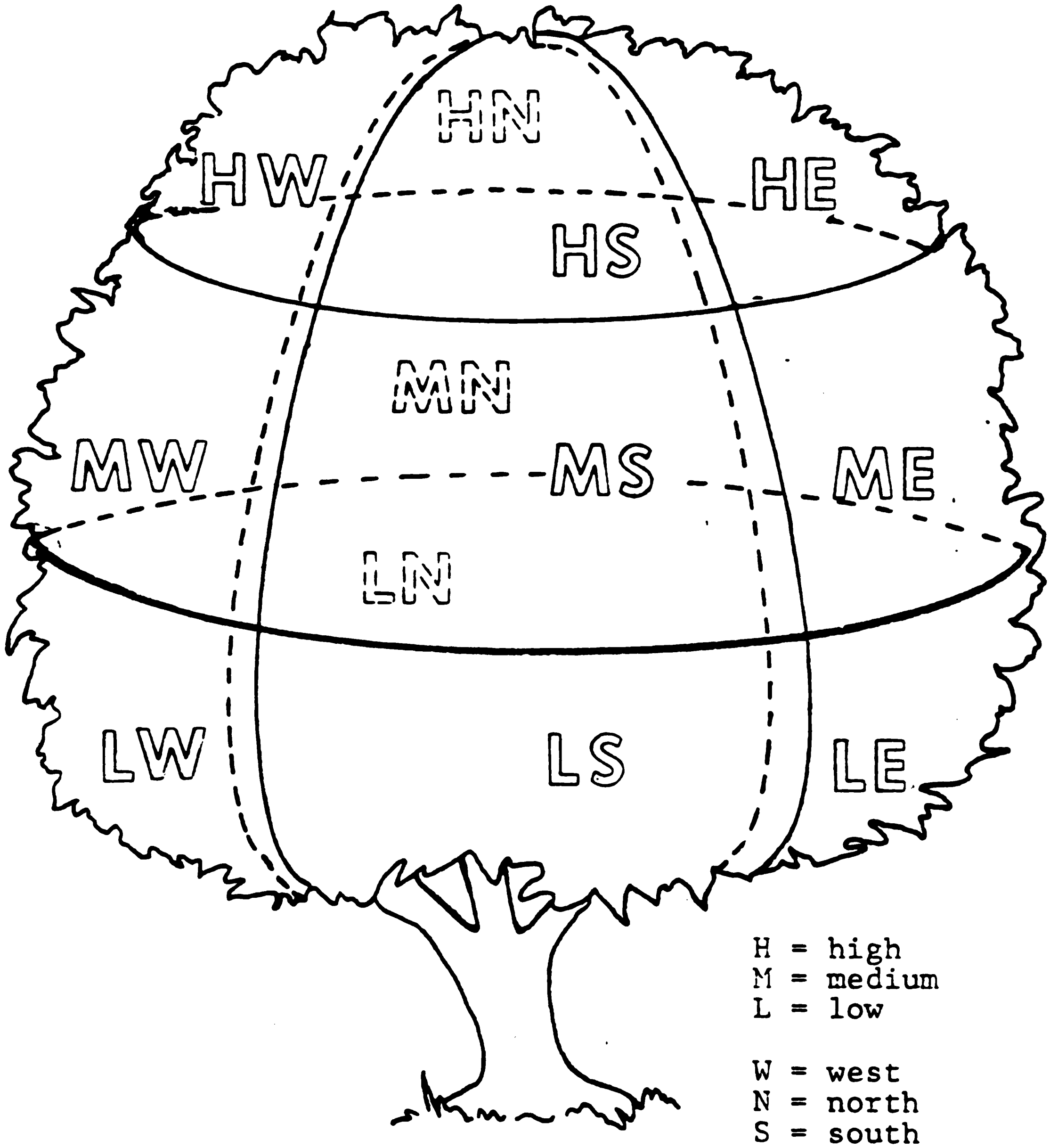
1.) 8 oz./100 gal. applied at petal fall and first cover.
2.) 10 oz./100 gal. applied at petal fall and first cover.
3.) 8 oz./100 gal. applied at calyx only.
4.) 10 oz./100 gal. applied at calyx only.
5.) untreated.

Treatment 1 is the current recommended control procedure for plum curculio (Flore et al, 1979). Trees in the control group were chosen to correspond with a band of unsprayed trees needed for the following study on height and directional orientation (see page 14).

Twenty-five clusters were tagged at random around each tree and four apples were left in each cluster. Apples were examined three times per week for the first three weeks after petal fall, and two times per week thereafter through July 18. Results were analyzed using Duncan's Multiple Range Test (Steel and Torrie, 1960).

Effects of Height and Directional Orientation on Oviposition

A band of trees 4 rows wide was left unsprayed in 1978 so that effects of height and directional orientation could be studied. All varieties in the orchard were used for this study (Wealthy, MacIntosh, Jonathan, Snow, and Northern Spy). Trees examined on each sampling date (sampling for this experiment and for the 1978 study on spray timing and rate was done on the same dates) were chosen at random. The trees were visually divided into 4 sections, east, north, south, and west, and then divided further into low, medium, and high levels (Figure 3). Ten randomly chosen apples were checked at each of the 12 sites on each tree, and the number of oviposition scars per apple was recorded. A split-plot analysis of variance was used to determine the effects of height and directional orientation on oviposition.



H = high
M = medium
L = low

W = west
N = north
S = south
E = east

Figure 2. Schematic drawing of divisions for sampling for height and directional effects.

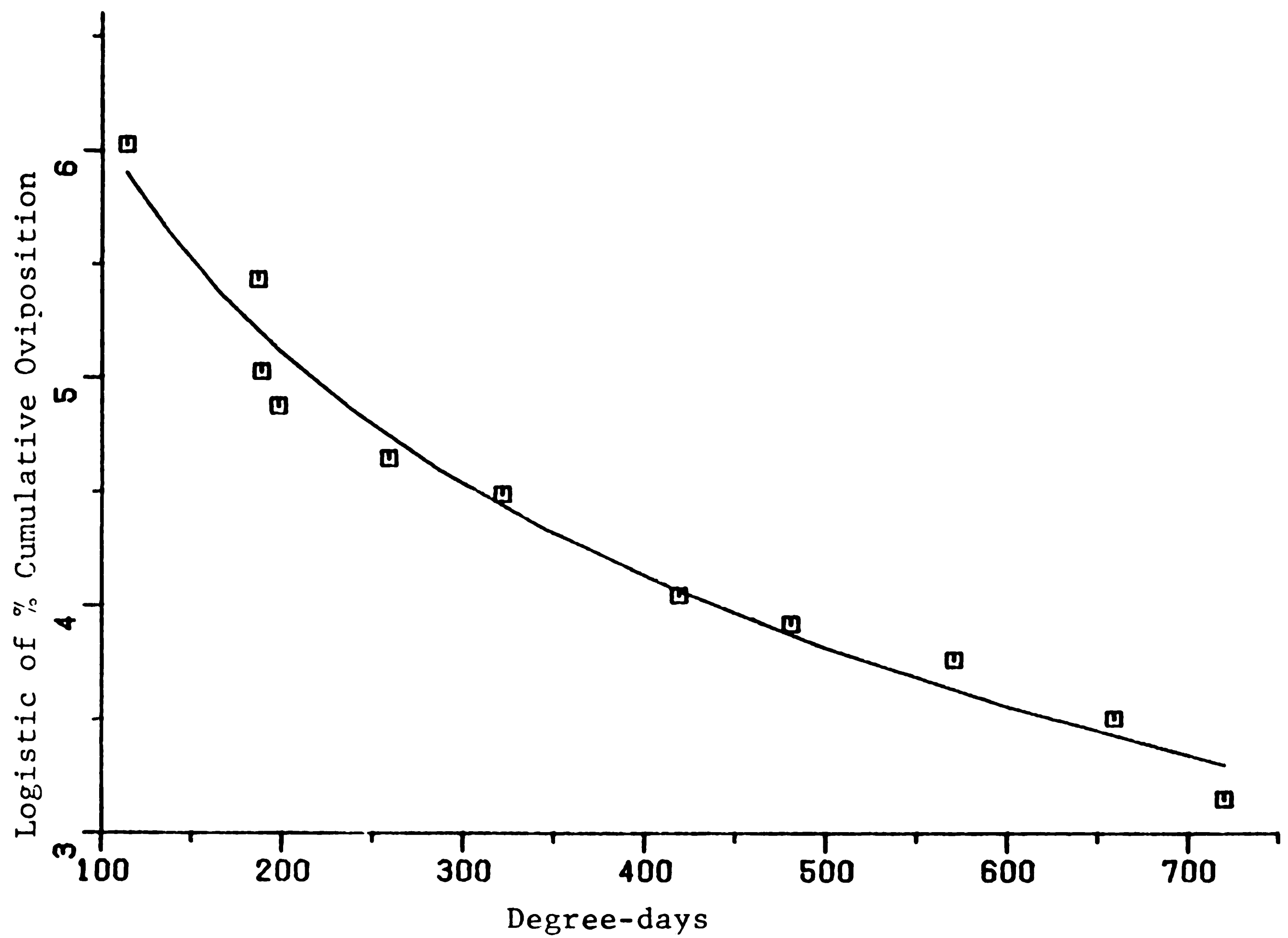


Figure 3. Percentage of cumulative oviposition on degree-days with a base of 12.8° C: Jonathan control.

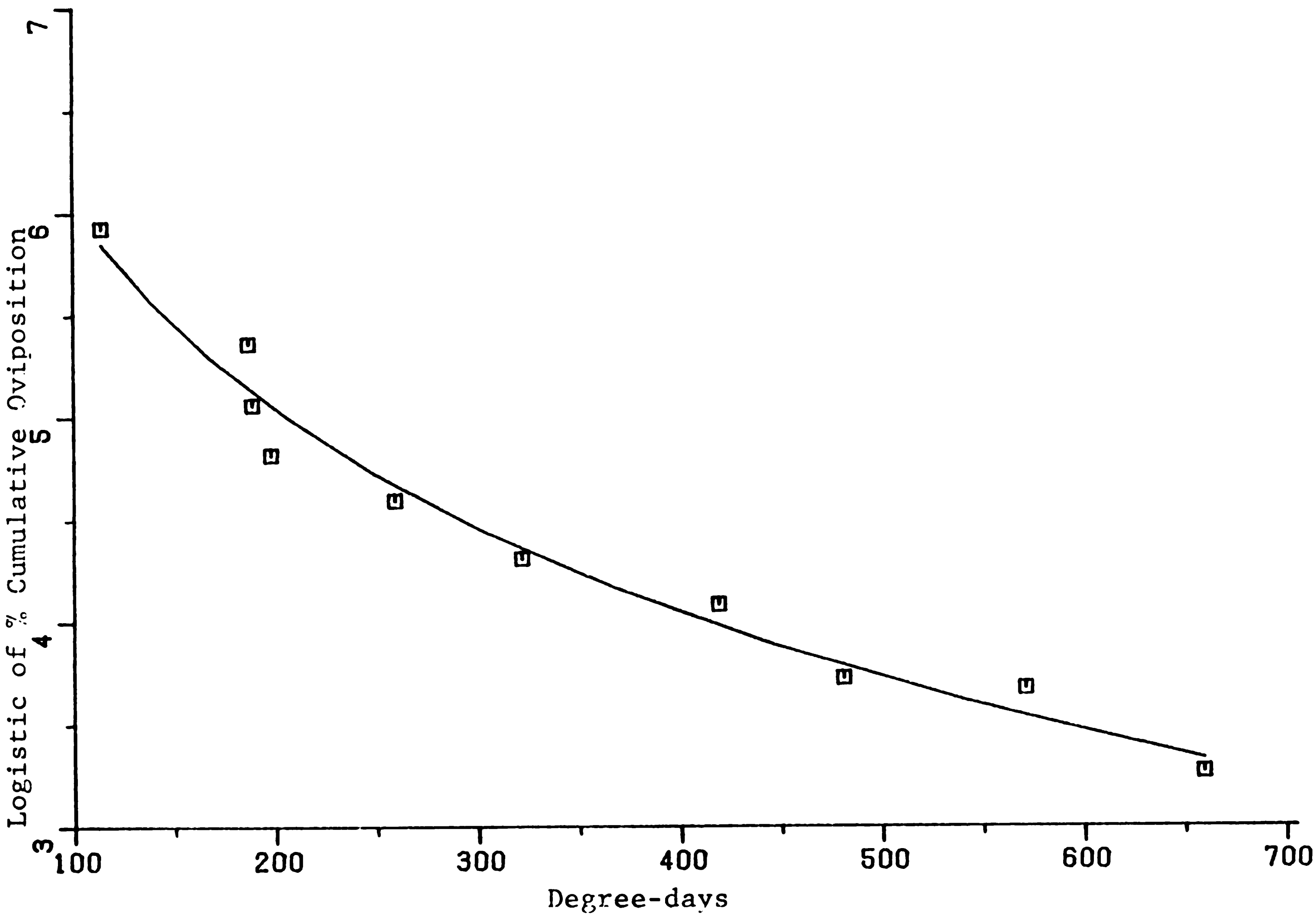


Figure 4. Percentage of cumulative oviposition on degree-days with a base of 12.8° C: Jonathan first cover.

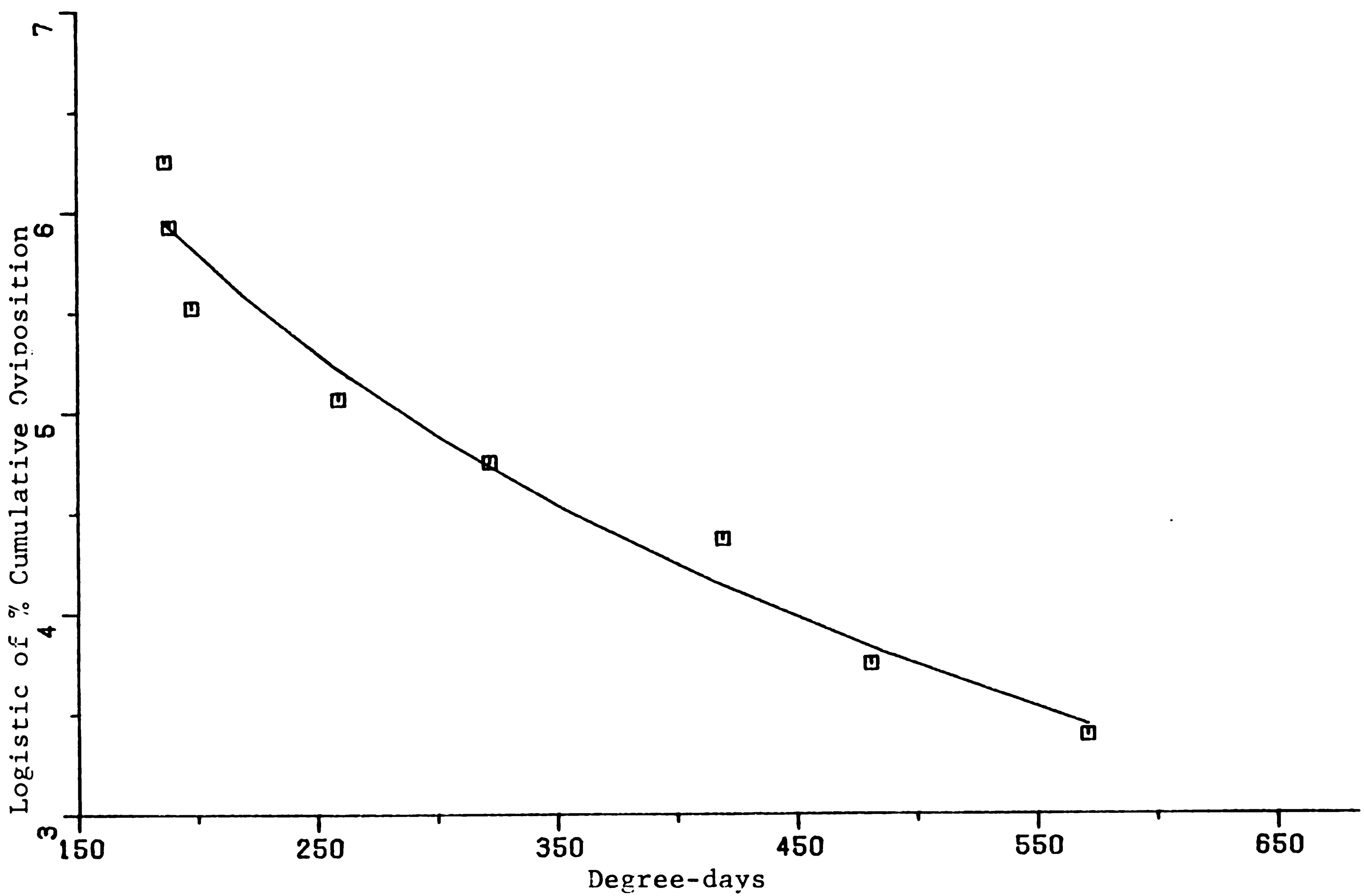


Figure 5. Percentage of cumulative oviposition on degree-days with a base of 12.8° C: Jonathan petal fall.

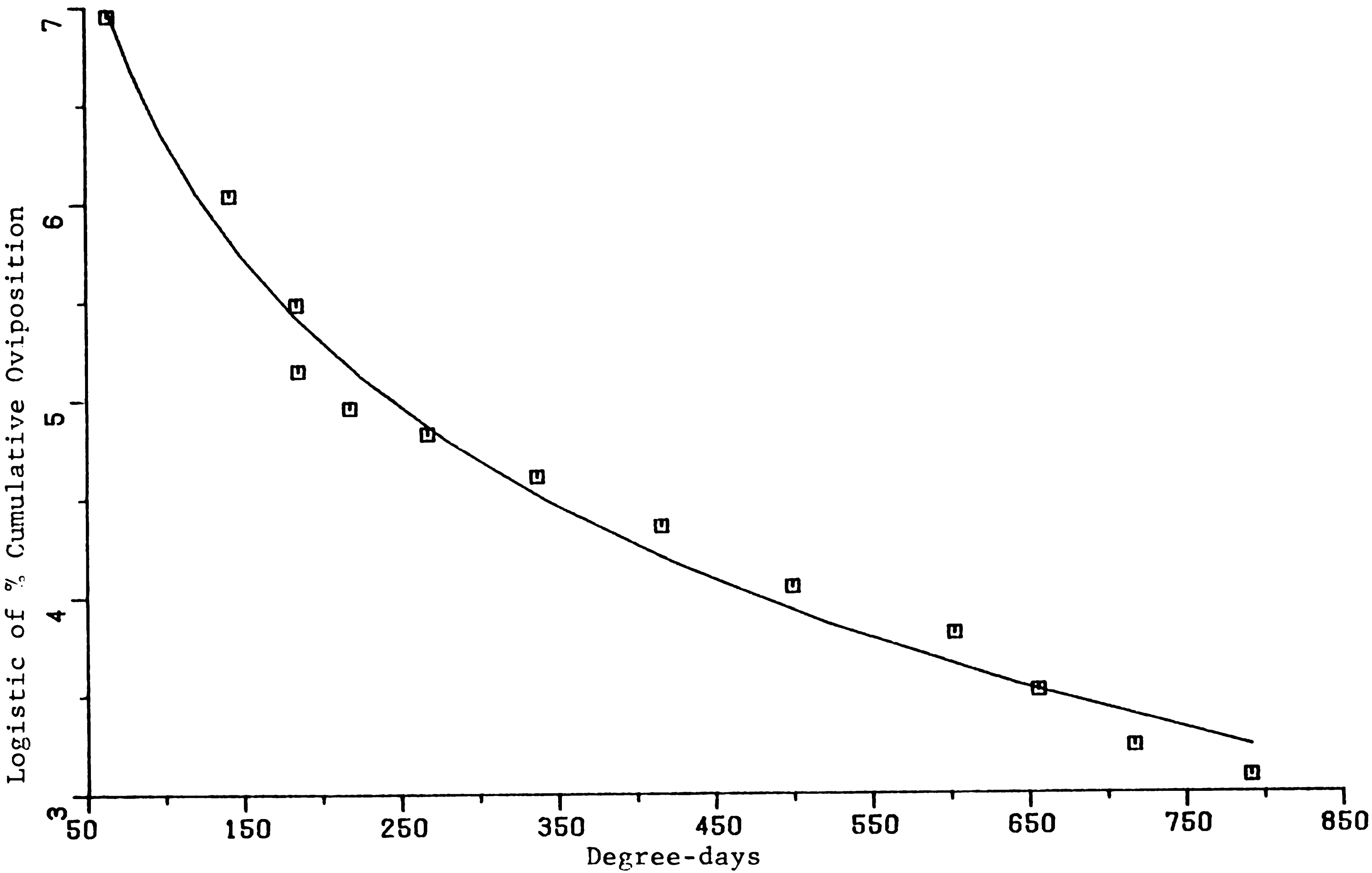


Figure 6. Percentage of cumulative oviposition on degree-days with a base of 12.8^{o} C: Northern Spy control.

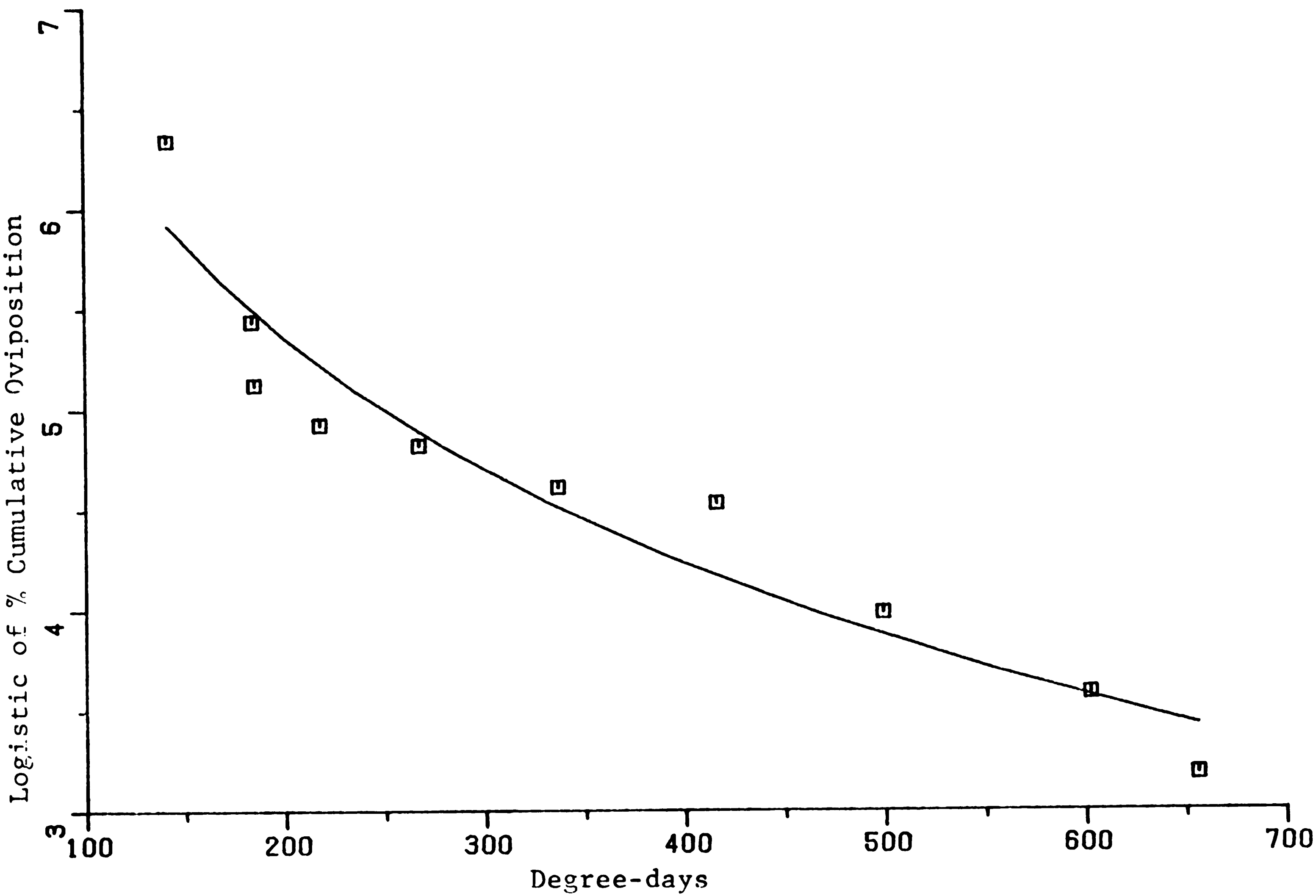


Figure 7. Percentage of cumulative oviposition on degree-days with a base of 12.8° C: Northern Spy first cover.

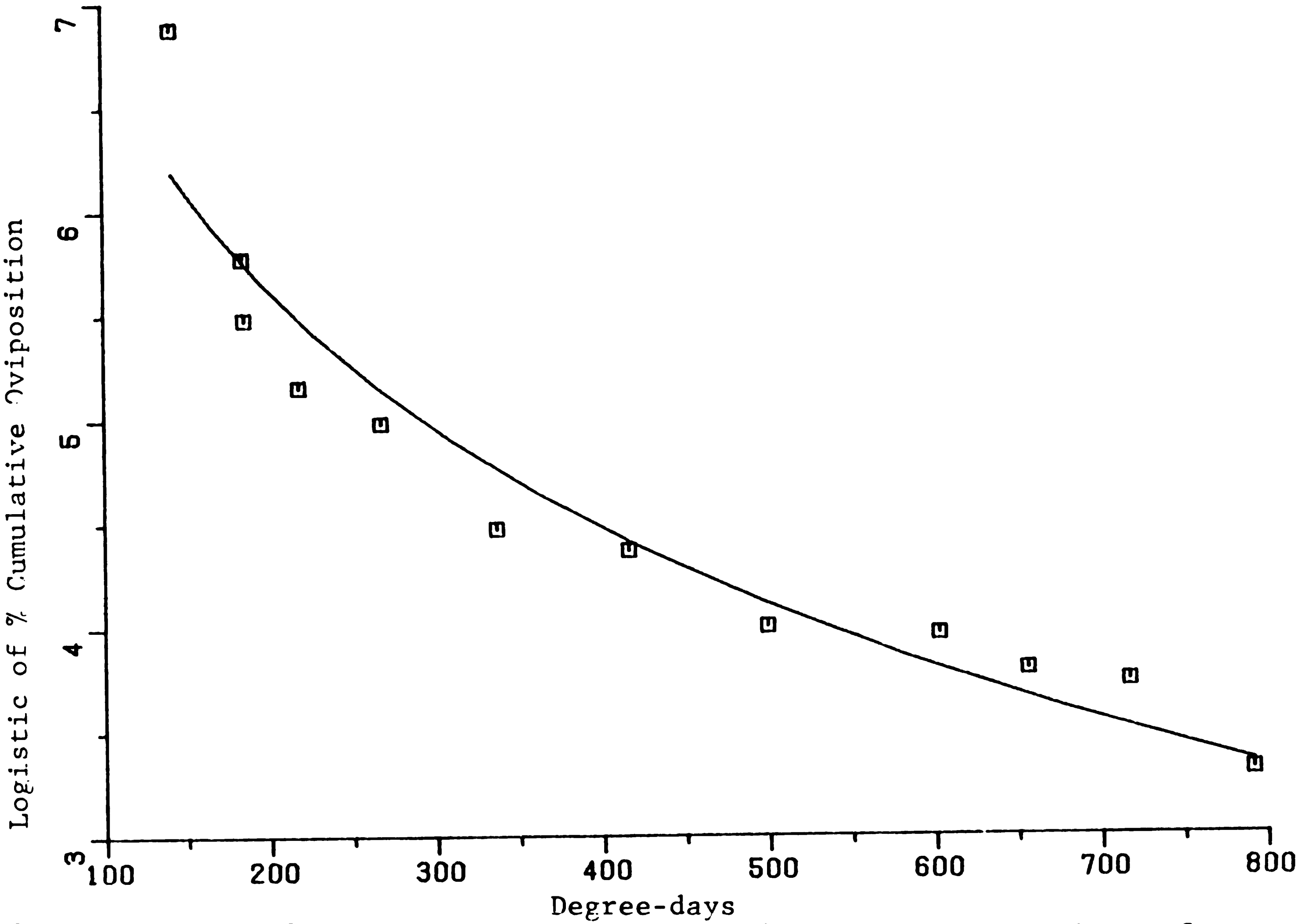


Figure 8. Percentage of cumulative oviposition on degree-days with a base of 12.8^{o} C: Northern Spy petal fall.

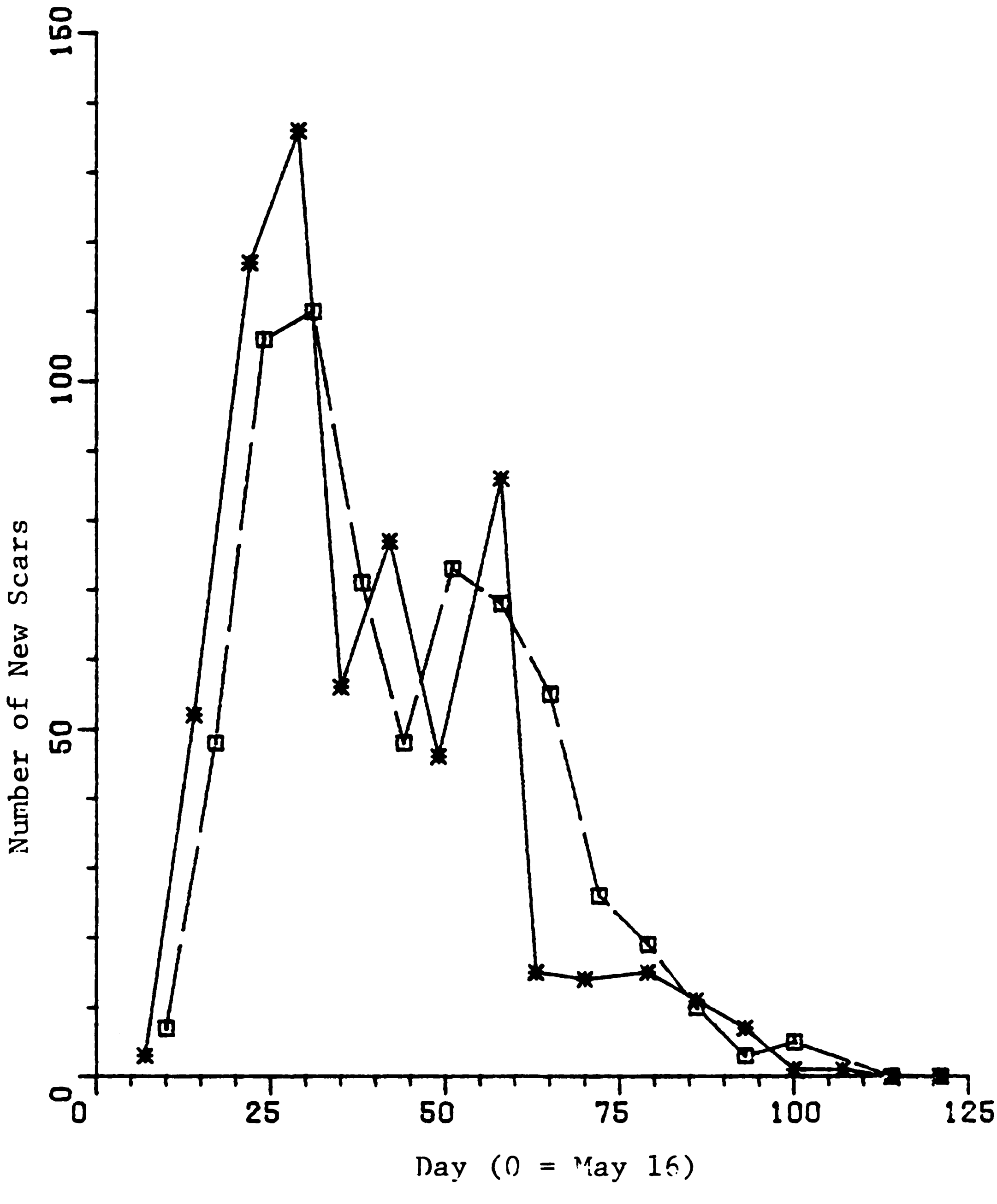


Figure 9. Number of new oviposition scars occurring during 1977 season.

RESULTS AND DISCUSSION

Seasonal Extent of Oviposition Damage

As illustrated in Figures 3 - 8, there is a very good correlation between degree-day accumulation and percentages of total plum curculio oviposition. The correlation coefficient ranged from 0.962 - 0.988 for the six different plots. The equation used to compute the curves was:

$$y = a + b(\log x)$$

The positive relationship of oviposition to temperature is further supported by Whitcomb (1932) who found that the number of egg-laying punctures per day increased as maximum daily temperature increased.

In the Jonathan variey there was 30% less oviposition damage in the plot sprayed at first cover and 74% less oviposition damage in the plot sprayed at petal fall when they were compared to the unsprayed plot. The Northern Spy variety showed 58% less damage in the plot sprayed at first cover and 77% less damage in the plot sprayed at petal fall.

The heaviest period of oviposition activity occurred at comparable times for both Jonathan and Northern Spy

Table 1. Date by which 10, 50, and 90% of total oviposition damage was attained (1977).

Plot	10%	50%	90%
*JC	5/23	6/8	7/6
JFC	5/23	6/8	7/7
JPF	6/6	6/21	7/9
SC	5/27	6/14	7/13
SFC	5/28	6/13	7/13
SPF	5/31	6/21	7/12

*JC = Jonathan control
JFC = Jonathan first cover
JPF = Jonathan petal fall
SC = Northern Spy control
SFC = Northern Spy first cover
SPF = Northern Spy petal fall

Table 2. Dropped apples damaged by plum curculio oviposition.

Plot	No. apples damaged by plum curculio oviposition	% apples damaged by plum curculio oviposition	Avg. no. oviposition stings per damaged apple
JC	141	66.82	3.08
JFC	137	57.56	1.88
JPF	136	18.40	1.65
SC	43	55.84	4.30
SFC	48	25.67	2.64
SPF	65	23.72	1.85

(Figure 9). The dates by which 10, 50, and 90% of oviposition activity had taken place were also very close for the two varieties (Table 1). The delay between varieties averaged 4.5 days in every case except 10% damage in the plots sprayed at petal fall. The Jonathan apples reached accumulated damage percentage earlier than Northern Spy apples. The actual number of oviposition scars accumulated during the season was 637 in the Jonathan control plot and 652 in the Northern Spy control plot, indicating that the developmental stage of the fruit plays a larger role than other varietal differences.

Oviposition and Apple Drop

Since developing plum curculio larvae have been shown to cause premature fruit abscission (Levine and Hall, 1978a and 1978b), it was expected that more apples damaged by plum curculio oviposition punctures would drop in the unsprayed plots than in the sprayed plots. The average number of oviposition punctures per damaged apple was also expected to be higher in the unsprayed plots. Actually, the number of dropped apples with oviposition punctures was about the same for all three plots within the two varieties of apple (Table 2). However, the percentage of plum curculio-damaged drops was consistently higher in the unsprayed plots as was the average number of egg-laying punctures per damaged apple. It seems likely, therefore, that inter- and intra-specific competition for food and space greatly decreases the plum curculio larva's chances of survival. Larvae that die early do not secrete enough enzymes to cause the apples to drop prematurely. The feeding that does take place before the larvae die limits the size of the apples on the unsprayed trees, whereas apples on sprayed trees grow quickly. It is probable that a larger number of apples fall from sprayed trees because the trees cannot support so many large fruits. Thus, the percentage of apples dropping with plum curculio damage is decreased in sprayed plots compared to unsprayed plots.

Monitoring the Adult Population

Monitoring the plum curculio adult population by beating the trees was found to be a highly unsatisfactory method. The number collected (Table 3) did not correlate well with temperature at the time of collection, the number of new egg-laying scars, or degree-day accumulation. The number collected is certainly not representative of the number actually present during the season. Smith and Flessel (1968) observed that some adults are apt to take flight when disturbed if the temperature is high, and they theorized that the beetles may not occupy the trees continuously even when temperatures are favorable. It is generally thought that the beetles leave the trees to seek shelter

Table 3. Number of adults collected from plots (1977).

Date	JC	JFC	JPF	SC	SFC	SPF	Total
5/11	8	7	6	0	5	0	26
5/16	3	1	0	0	0	0	4
5/19	0	0	0	0	0	0	0
5/23	2	1	0	0	0	1	4
5/26	7	3	0	2	0	0	12
5/31	2	0	1	0	0	0	3
6/2	0	0	0	3	0	0	3
6/7	3	0	0	0	1	0	4
6/9	0	0	7	0	0	0	7
6/13	0	0	0	1	0	0	1
6/16	0	0	0	0	0	0	0
6/20	0	0	0	0	0	0	0
6/22	1	0	0	0	0	0	1
6/27	0	0	0	2	0	1	3
6/29	0	0	0	0	0	0	0
7/6	0	0	0	0	0	0	0
7/11	0	0	0	2	0	0	2
7/13	1	0	0	0	0	0	1
7/18	0	0	0	0	0	0	0
7/20	0	0	0	0	0	0	0
7/27	0	0	0	0	0	0	0
8/3	0	0	0	0	0	0	0
8/10	0	0	0	0	0	0	0
8/17	0	0	0	0	0	0	0
8/29	0	0	0	1	3	5	9
8/31	2	0	2	4	0	0	8
9/7	0	0	0	0	0	0	0

Table 4. Adult emergence from cages (1977).

Variety	8/3	8/10	8/17	8/24	8/31	9/7
MacIntosh	8	0	33	24	6	14
MacIntosh	1	0	32	24	2	34
Jonathan	0	0	1	1	1	0
Northern Spy	0	0	0	1	0	3

under such unfavorable conditions as heavy rains, low temperatures, or high winds. Hauschild et al. (1977) determined that both sticky traps and funnel traps are also unreliable indicators of plum curculio population dimensions.

Adult Emergence

The first adults emerged from the cages during the week of July 28 through August 3 (Table 4). Peak adult emergence occurred from August 11 through August 24, with a secondary peak during the first week of September. Using the average time necessary for development from egg to adult in Michigan (fifty-seven days - Quaintance and Jenne, 1912), peak egg-laying would have occurred June 16 through 29, with a secondary peak July 7 - 13. Comparing these dates with the number of new scars found in unsprayed Jonathan and Northern Spy plots shown in Figure 10, the dates calculated using Quaintance and Jenne's figure appear to be two to three weeks later than the observed peak of new scars, and about one week later than the observed secondary peak. This discrepancy indicates that either: 1) the length of time necessary for development really averaged about seventy-seven to eighty-one days, or 2) peak oviposition in MacIntosh apples occurred two to three weeks later than peak oviposition in the Jonathan and Northern Spy varieties. The average daily temperature reached 24^{o} C only 21 times during the period from the end of May through the third week of August; according to Whitcomb (1932), 24° C is the optimum temperature for plum curculio development. Cool temperatures might be expected to account for some extra time, but it seems unlikely that it would cause a two to three week delay in emergence. Since most of the beetles collected were from cages of MacIntosh apples which were not surveyed weekly for oviposition damage to apples on the trees, it is possible that peak egg-laying in this variety occurred later.

Effects of Spray Timing and Application Rates

Duncan's Multiple Range Test showed significant differences in means at the 5% level between applications of azinphos-methyl at petal fall, at first cover only, and no spray. There were no significant differences between plots of MacIntosh apples (all unsprayed). Therefore, it was concluded that significant control of the plum curculio was attained by applying the sprays and that the lower average number of oviposition scars in sprayed blocks was not due to a north-south gradient in the distribution of the plum curculio adults over the orchard. Since the means of plots sprayed at petal fall were significantly lower than means of plots sprayed at first cover, it appears that a spray at first cover results in control that is not as good as a spray at petal fall only.

In 1978 there were no significant differences between the means of any of the five plots. There are at least two factors that help to explain this result. First, the early season was quite cool; degree-day accumulation during the sampling period being about 400 degree-days behind the accumulation for the same period in 1977. Second, broad spectrum sprays were used on every other tree throughout the orchard, except on rows four and five, in connection with a separate study. The extremely low number of oviposition scars observed, compared to similar data from 1977, suggests that the other sprays may have affected the plum curculio population as it migrated into the orchard from overwintering sites and as the beetles moved from tree to tree within the orchard. By the end of the survey period only 10.33% of the apples in the unsprayed plot had shown at least one oviposition scar. On the same date in 1977, 77.07% of the unsprayed apples had exhibited damage.

Effects of Height and Directional Orientation on Oviposition

When the data in Tables 5 and 6 was analyzed by split-plot analysis of variance, no significant differences were found between the number of apples stung or the number of oviposition punctures per apple with regard to height or direction. This finding is supported by Oatman's conclusion that the distribution of injury on individual fruit trees appears to be random (Oatman and Legner, 1968). Calkins _et_ _al_. (1976) found that fruits placed six feet above the ground were preferred over fruits placed at three feet above the ground. Since none of the apples surveyed in the 1978 study were lower than four feet from the ground and since Calkins _et_ _al_. did not place any fruits higher than six feet, the findings of this study do not conflict with Calkins' results.

Table 5. Percent of apples with oviposition scars (1978).

Date	Total no. apples examined	Height	South	West	North	East
6/2	720	H	10.00	20.00	13.33	11.67
		M	1.67	3.33	1.67	3.33
		L	6.67	0	0	0
6/5	960	H	15.00	6.25	11.25	13.75
		M	3.75	7.50	3.75	7.50
		L	0	1.25	0	2.50
6/7	600	H	38.00	32.00	46.00	46.00
		M	28.00	32.00	40.00	30.00
		L	34.00	34.00	30.00	28.00
6/9	720	H	45.00	41.67	46.67	33.33
		M	33.33	41.67	36.67	26.67
		L	40.00	33.33	31.47	30.00
6/12	1200	H	32.00	50.00	49.00	31.00
		M	54.00	58.00	42.00	29.00
		L	46.00	43.00	49.00	42.00
6/14	720	H	50.67	52.33	51.00	37.00
		M	52.33	43.00	48.00	39.33
		L	57.67	47.00	48.33	49.67
6/18	1200	H	60.00	61.00	51.00	32.00
		M	51.00	58.00	41.00	36.00
		L	53.00	58.00	46.00	45.00

Table 6. Average number of oviposition scars per scarred apple (1978).

Date	Total no. apples examined	Height	South	West	North	East
6/2	720	H	1.50	1.08	1.00	1.00
		M	1.00	1.00	1.00	1.00
		L	1.25	0	0	0
6/5	960	H	2.17	1.00	1.00	1.00
		M	1.50	1.00	1.33	1.33
		L	0	1.00	0	1.00
6/7	600	H	1.22	1.44	1.65	1.70
		M	1.31	1.19	1.30	1.27
		L	1.19	1.65	1.33	1.14
6/9	720	H	1.25	1.28	1.46	1.25
		M	1.40	1.32	1.33	1.25
		L	1.25	1.75	1.32	1.17
6/12	1200	H	1.38	1.38	1.50	1.36
		M	1.44	1.42	1.22	1.33
		L	1.43	1.34	1.34	1.12
6/14	720	H	1.42	1.32	1.32	1.36
		M	1.61	1.40	1.41	1.36
		L	1.43	1.37	1.34	1.20
6/18	720	H	1.83	2.02	1.29	1.67
		M	1.75	1.89	1.36	1.33
		L	1.88	1.74	1.36	1.33
6/20	1200	H	2.02	2.18	1.86	1.22
		M	1.86	2.22	1.20	1.03
		L	1.73	1.98	1.73	2.00

CONCLUSION

This study has been an attempt to determine the seasonal and spatial distribution of the plum curculio with regard to oviposition damage, and to determine the optimum time and rate for the application of a spray for control.

Although it was apparent from the 1977 experiment that one full rate spray at petal fall does a better job of controlling the plum curculio than one full rate spray at first cover, the 1978 follow-up study was inconclusive. At this time, the current conventional control recommendations as cited in the "1979 Fruit Pesticide Handbook" (Flore et al., 1979) cannot be improved upon.

However, the combined results of the studies on seasonal extent of damage and spatial distribution of oviposition within the tree may be used to sample the damage and predict the outcome more efficiently. In Massachusetts, oviposition damage is surveyed in predetermined blocks of an apple orchard and a recommendation of whether or not to apply a spray is made based on this information. Since the results of this study indicate that oviposition is fairly uniform throughout the tree, fewer sampling sites can be used, thus decreasing considerably the amount of time necessary for the survey. Having a better understanding of the complicated relationship between air temperature and oviposition, combined with such a survey, would enable us to make more accurate recommendations.

The ability to predict the need for a control spray application from sampling the adult plum curculio population would be ideal, as this would eliminate any confusion as to the cause of punctures that marginally resemble plum curculio oviposition scars. Unfortunately, the only scheme currently feasible, i. e., beating the trees and catching the falling insects, cannot be shown to have any consistent relationship to the amount of damage present. Studies on possible attractants for the adults are currently under way in Massachusetts and Ontario, Canada.

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