3400

R-3 87-6

FINAL REPORT
OF THE
1981 PILOT PROJECT

OPERATIONAL USE OF A BIOLOGICAL INSECTICIDE: _BACILLUS THURINGIENSIS_ FOR CONTROL OF THE WESTERN SPRUCE BUDWORM IN NORTHERN NEW MEXICO

JUNE 1987

By

Jesus A. Cota

USDA Forest Service, Southwestern Region
State and Private Forestry
Forest Pest Management
517 Gold Avenue, SW
Albuquerque, New Mexico 87102

ACKNOWLEDGEMENTS

My appreciation is extended to the many individuals who made contributions during this project. This includes: staff members of the Carson National Forest, state personnel from the New Mexico Department of Natural Resources, Division of Forestry and the New Mexico Department of Agriculture, Division of Agricultural and Environmental Services, and technical representatives from Abbott Laboratories and Sandoz Corporation.

A special thank you is extended to Michael Marsden, Methods Application Group U.S. Forest Service, for his assistance in the statistical analysis of data.

TABLE OF CONTENTS

ABSTRACT

In 1981 an aerial application project was conducted in Northern New Mexico to evaluate the operational use of Bacillus thuringiensis (B.t.) against the western spruce budworm. Two formulations of this biological insecticide, Thuricide 16B and Dipel 4L, were applied by fixed-wing aircraft at a rate of one gallon per acre with 8 BIU's per gallon. To determine insecticide efficacy, pest population and host tree damage data was collected for 3 years after treatment, 1981-1983.

Both B.t. formulations tested lowered larval populations to the effective control threshold (5 larvae per 100 buds) during the year of treatment. However, adjusted larval mortality was not as high as expected. Differences in larval densities were found in samples taken at different time intervals after treatment indicating that the effect of Thuricide 16B on larval populations occurs about 7 days earlier than the effect of Dipel 4L. Egg mass densities were highly variable each year collected with no statistical difference found between treated and check blocks for two of three years. During the third year, differences were found between the Dipel 4L and Thuricide 16B; and between the Thuricide 16B and the Check areas. When host damage (percent defoliation) was analyzed, neither formulation provided foliage protection during the year of application. Host damage did decrease the second and third year after application.

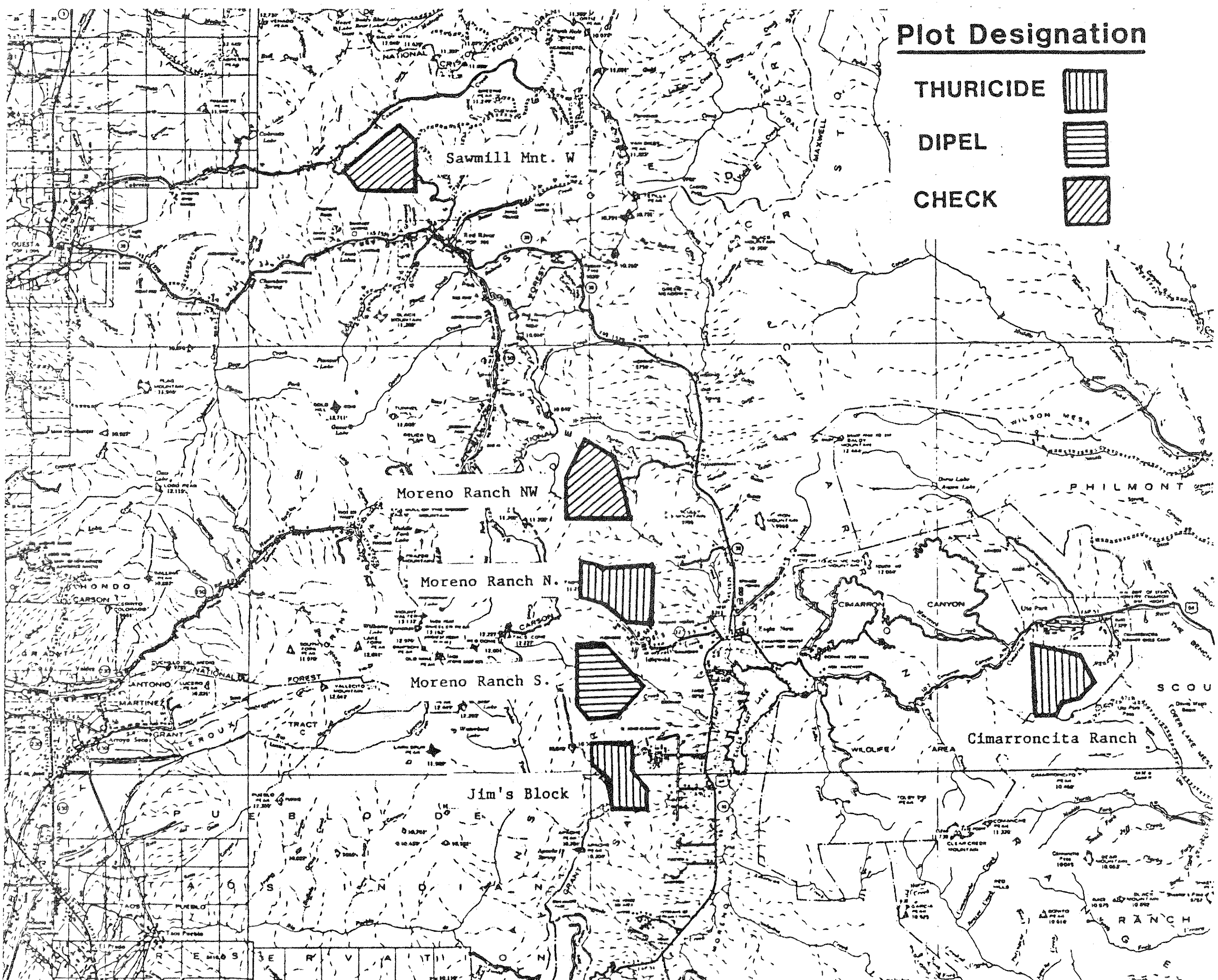


FIGURE 1. Name and location of blocks in the 1981 B.t. Pilot Project.

Table 1--The different types of sampling conducted during each year of the pilot project to assess the operational value of *B.t.* for control of western spruce budworm.

	Type of Sampling Scheme	Year Conducted 1981	1982	1983
1.	Insecticide application sampling			
	A. Spray deposition	x		
2.	Pest Population Sampling			
	A. Larval density - pre-spray	x		
	B. Larval density - post-spray	x	x+	
	C. Egg mass density - post-spray	x	x*	x*
3.	Host Tree Sampling			
	A. Damage assessment (Defoliation)	x	x*	x*
4.	Developmental Sampling			
	A. Larval Development	x		
	B. Host tree (Bud) Development	x		

* This type of sampling was not conducted in Block 9 during this year.
\+ This type of sampling was not conducted in Blocks 3, 4, 9 and 10 during this year.

The aircraft spray systems consisted of 31-32 nozzles (Fulljet 1/8 GGA 8W) and were operated at 40 psi. The insecticide applications were conducted at an aircraft speed of 150 miles per hour with an insecticide release height of 50 feet above the forest canopy and an effective spray swath of 150 feet.

Aircraft were calibrated for 1 gallon per acre, and insecticide atomization was determined by the D-Max method (Dumbauld and Rafferty 1977). The average VMD obtained for Thuricide 16B and Dipel 4L was 221U and 239U, respectively.

Meteorology--During the operation, area forecasts were provided each day by the National Oceanic and Atmospheric Administration Office in Albuquerque, New Mexico.

Prior to, and at 30-minute intervals during treatment, surface observations of temperature, relative humidity, cloud cover, wind speed, and wind direction were taken at the airport. In addition, at 15-minute intervals, temperature, wind speed, direction, and relative humidity were measured from a position within the treatment block.

Spraying was terminated when any of the following conditions exsisted: When wind speed, as measured in the treatment block, exceeded 6 miles per hour; when ambient temperature exceeded 70 degree F; or when thermal lifting of the insecticide spray was noted by the aerial observer. Appendix A shows the dry temperature and relative humidity for each spray date.

RESULTS AND DISCUSSION

I. SPRAY DEPOSITION

Spray deposit data collected during the insecticide applications show that there is less variability in each of the parameters use to characterize spray deposition and coverage for Dipel 4L (Table 2). This indicates that the Dipel 4L applications resulted in more consistent insecticide coverage between blocks inspite of the greater volume of water in the insecticide mixture. For example, the volume median diameters (VMD) for the Dipel 4L blocks were 242u, 231u and 243u compared to 219u, 174u and 271u for the Thuricide blocks. The number median diameters (NMD) also indicate the same consistency of application for Dipel blocks. The NMD's for the treatment blocks were 45u, 42u, 42u for Dipel, and 69u, 100u, 79u for Thuricide.

Differences in evaporation rates between the two formulations could have affected the amount of insecticide deposited in each block due to varing weather conditions during application. Certainly, a large evaporation rate for the Thuricide mixture could explain the variability observed. Dennison and Wedding (1984) determined the evaporation rate of droplets of various pesticide mixtures containing water and oil. In controlled tests with temperature and humidity conditions similar to those occurring during spray operations (RH=30-60%, Temp. -2 to 20 C), these authors reported that a 100u droplet of Thuricide 16B (diluted 1:1 with water) lost 41% of its mass over a time period of 4-9 seconds. Although larger droplets took a longer period of time to evaporate the same percentage of mass loss, all droplets loss maximum mass (60%) before descending 300 feet.

Droplet density for all treated blocks was below (3-17 drops 1 cm^2) the amount normally needed for acceptable results. From operational experience (Morris 1980) it has been observed that acceptable insect control is achieved when insecticide droplet density on Kromekote cards is greater than 21 drops/cm^2. Although Kromekote cards are not a precise indicator of insecticide deposition on foliage, they are a reliable tool for monitoring spray coverage during field operations (Dumbauld and Rafferty 1977).

II. PEST POPULATION DENSITY

Larval Densities

A. Pretreatment Densities--Larval population densities determined from samples taken prior to *B.t.* application ranged from 20.0 to 33.4 larvae per 100 buds. These population densities are considered to be outbreak levels normally causing heavy tree defoliation but the population levels are within the range for which *B.t.* use is recommended (Morris 1980). Larval densities occurring before and after insecticide treatment are summarized for each of the project blocks in Table 3. No significant difference in larval populations was found between blocks prior to insecticide application.

B. Post Treatment--In samples taken at different time intervals (7, 14 and 21 days) after treatment during 1981 (Table 3), significant differences in larval densities were found between the latter two sample periods. At 14 days after treatment, there was a significant difference in larval densities between Thuricide and Dipel and between Thuricide and the check. At 21 days after treatment, significant differences occurred between the two insecticide formulations and the check. At the --$\alpha \leq .05$ level, there was no significant difference between the Dipel and Thuricide treatments, however, at the --$\alpha \leq .10$, there is a significant difference between the two treatments.

Differences in larval densities also occurred within treatments through time. It appears that the effect of Thuricide on budworm populations occurs about 7 days earlier than the effect of Dipel. Figure 2 graphically illustrates the changes which occurred in average numbers of larvae per 100 buds from prespray through 21 day postspray for each treatment.

Unadjusted larval mortality in the 21 day samples ranged from 54.5 percent for Check Block 8 to 93.7 percent for Thuricide Block 5. When natural mortality was taken into account, the percent mortality attributed to the effect of *B.t.* applications was not as high as expected for effective control. Percent adjusted mortality was lower in the Dipel blocks ($\bar{x}$=49.6%) than in the Thuricide blocks ($\bar{x}$=70.3%). Even though the percent kill was not high, the actual effectiveness of the *B.t.* applications is reflected by the residual budworm population. Larval populations in 1981 were reduced to the effective control threshold of 5 larvae per 100 buds (Telfer 1982).

In 1982, larval data were again collected in the project area by an associated study. These data was used to determine the effect of *B.t.*

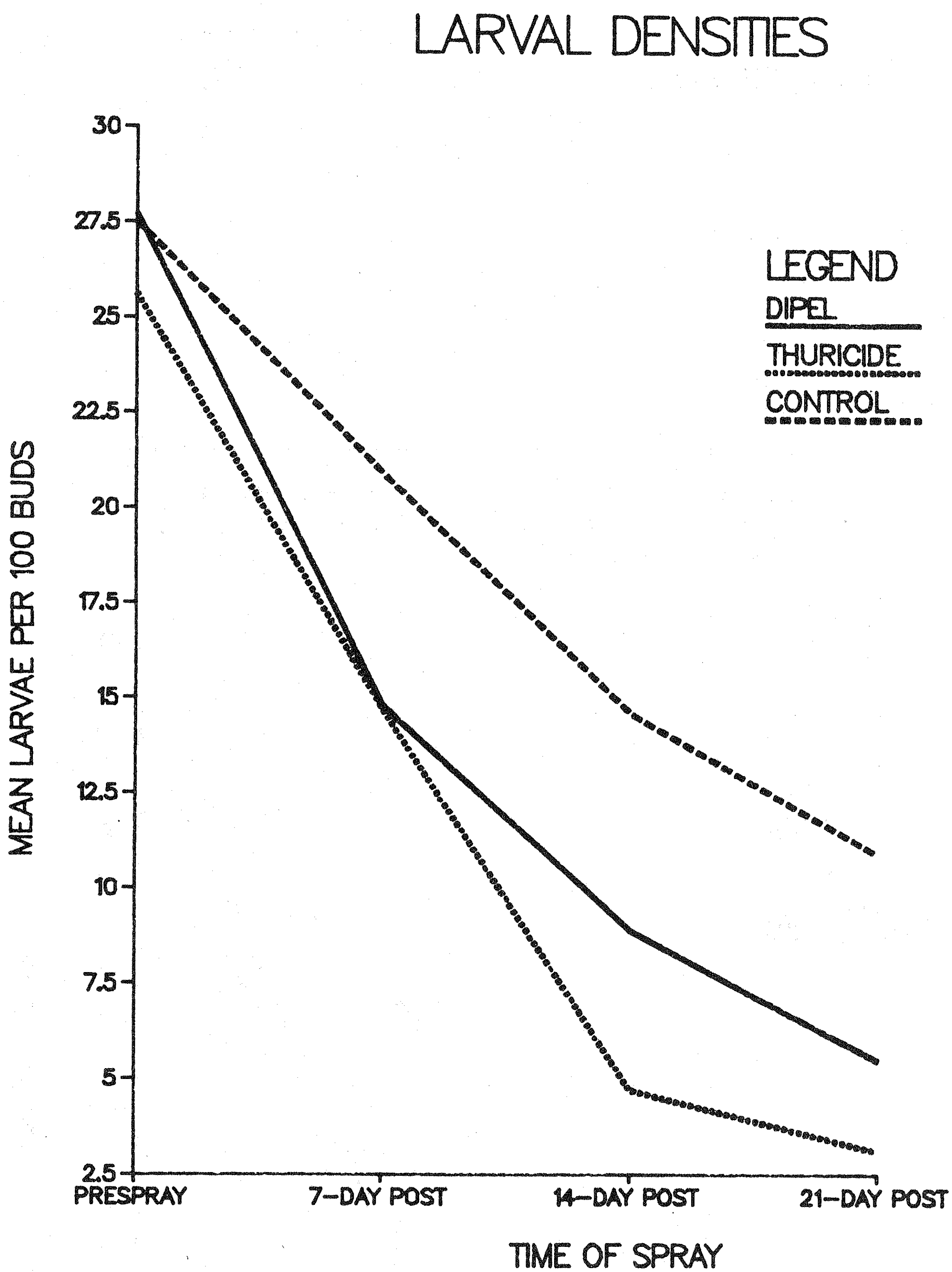


Figure 2. Mean number of larvae per treatment in branch samples taken at different time intervals in the 1981 Pilot Project.

on budworm populations one year after application. Due to a suppression project conducted on adjacent private land by the state of New Mexico, larval samples were available for only five of the nine blocks in the project (Table 4). The sampled blocks were: 1 (Dipel), 2 (Dipel), 5 (Thuricide), 7 (Check), and 8 (Check).

Using the available 1982 larval data for these five blocks, Ragenovich (1983) reported a significant difference in larval densities between the *B.t.* treated blocks and the check blocks. The reported significance resulted in spite of an F-value based on only one replication (block) for Thuricide and two replications for Dipel and the Check. In assessing the significance of these results, one must consider the statistical weight of data collected from only one replication. In addition, it must be pointed out that block 5 (Thuricide) was located (Figure 1) in an isolated area which may have had a different rate of adult migration than the Dipel blocks particularly since the latter were adjacent to untreated areas. Nevertheless, when prespray larval populations were compared to postspray larval populations occurring one year after treatment significantly lower larval densities were found on the *B.t.* blocks. The difference in larval densities between the treatment and check blocks can be attributed to a population reduction caused by the biological insecticide.

Egg Mass Densities

Changes in egg mass density by treatment block are given in Table 5 and are graphically illustrated in Figure 3. During each of the project years, egg mass densities were lowest in the Thuricide blocks. In contrast, egg mass densities increased each year in both the Dipel and the Check blocks.

No statistical difference in egg mass densities was found in 1981 and 1983 between the treated and untreated blocks inspite of the large differences in larval densities. These results are somewhat confusing since the reduction in larval populations resulting from *B.t.* applications in 1981 were expected to be followed by a significant difference in egg mass densities between treated and untreated blocks. The lack of significance, in part, may have been due to a large sample variance. It may also have been due to migration of egg laying moths from surrounding infestations.

For 1982, differences in density were found between the two *B.t.* formulations and between Thuricide and the Check. A significant difference in egg mass density was again found between Thuricide and Dipel in 1983.

Table 6 contains the results of Student t tests using block means to determine treatment effects on egg mass density for all three years. In the Thuricide blocks, egg mass densities were significantly lower (≤ 0.10) in 1981 than they were in 1983. The same difference was found between Thuricide in 1981 and the Dipel blocks in 1983. During the latter year, Dipel treated areas had significantly higher egg mass populations than the Thuricide treated blocks for the same year.

As expected, egg mass densities were highly variable during each of the years of the project. Statistical analysis of the egg mass data

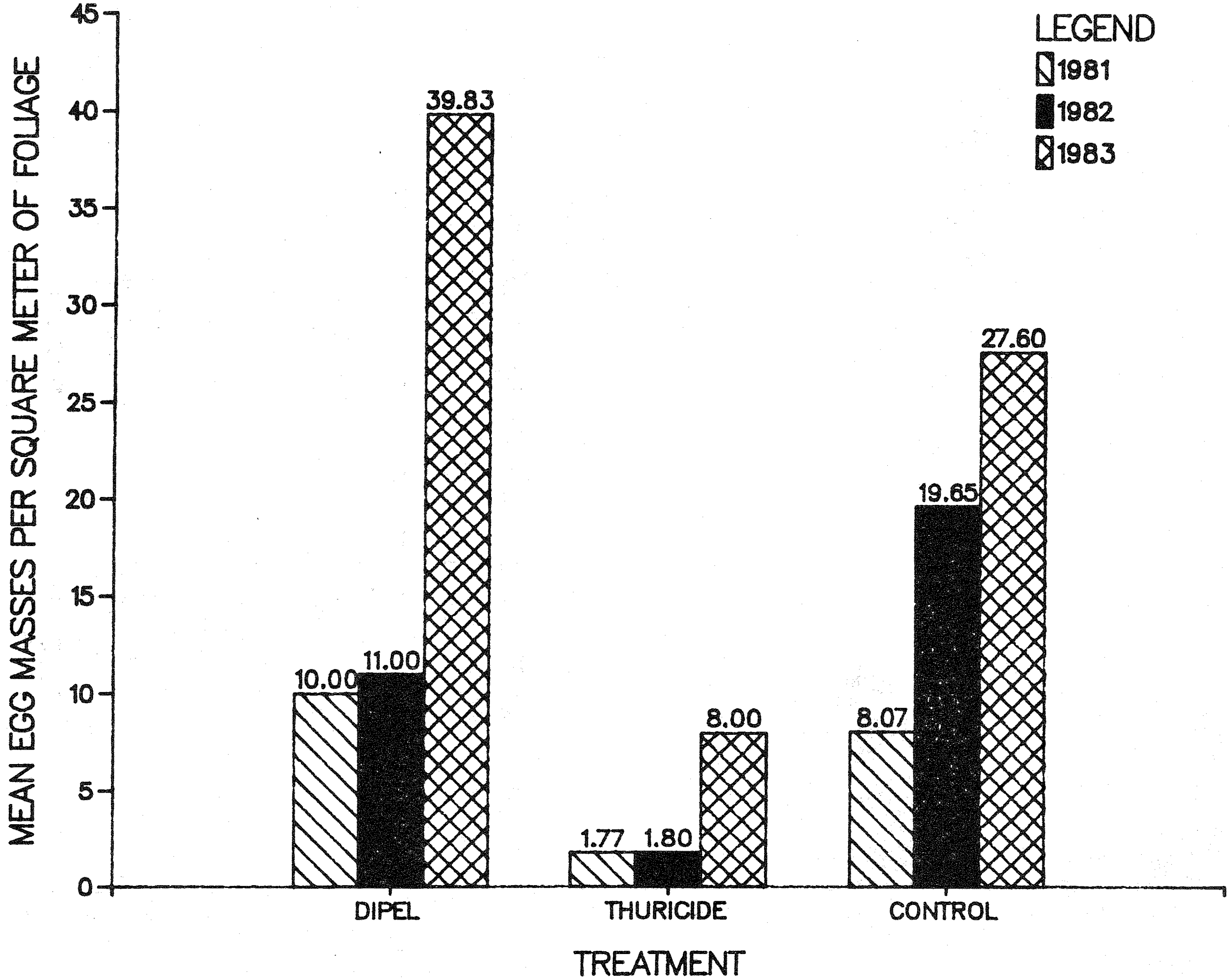


Figure 3. Mean number of new egg masses in each treatment for sample years 1981-1983.

were conducted using both sample point mean density and treatment block mean density. From these analyses, it was learned that egg mass densities varied greatly from block to block and year to year irregardless of data manipulation. Even within blocks, a large variation in densities occurred between sample points for any given year.

This suggests that egg mass densities were not a strong indicator of larval population changes. At low larval density, egg mass sampling may have missed the presence of budworm at a point when the budworm was present. At high larval density, the migration of the budworm may have evened out the egg mass densities in the samples. For this reason, egg mass densities should not be the only factor used in evaluating the success of B.t. applications.

III. FOLIAGE PROTECTION

The amount of tree defoliation occurring during 1981-1983 for each of the project blocks is presented in Table 7 and is illustrated in Figure 4.

When the percent defoliation occurring during the year of treatment (1981) was analyzed, no significant difference was found between the treated and the untreated blocks, indicating that B.t. applications did not provide significant foliage protection in the year of treatment.

A partial explanation for these results may be provided by the larval population data. Although the amount of mortality caused by the insecticidal applications was low (44.4 - 84.3% adjusted) (see Table 3), the residual population densities at 21 day postspray are at or below the effective control threshold (5 larvae per 100 buds) for foliage protection (Telfer 1982). This threshold level is not achieved until 14 days after application for the Thuricide formulation and 21 days for the Dipel formulation. What the data suggests are that the toxic action of both B.t. formulations is not rapid enough to prevent damage by the target population during the year of treatment.

Another explanation for the observed results in the insecticide applications may be understood when one considers the feeding behavior of the insect. Budworm larvae feed exclusively on succulent current year growth. Budworm damage (defoliation) is the result of larval feeding on the growing buds. Developing and fully flushed buds constitute a small percent of the total foliage on a tree and therefore contain a small amount of the insecticide deposited. To ingest a lethal dose of B.t. the larvae must consume a large amount of foliage over a considerable period of time. Consumption of the amount of treated foliage needed to produce toxic effects by B.t. results in extensive tree damage.

Percent defoliation in 1982 decreased from the level occurring the previous year; however, the decrease in defoliation was significantly lower only in the treated blocks (Table 8). Furthermore, a significantly lower amount of defoliation occurred in the Thuricide blocks as compared to the Dipel blocks. The reduction in foliage damage occurring in the treated blocks was was believed to be due to lower residual larval populations (see Table 4) in 1982.

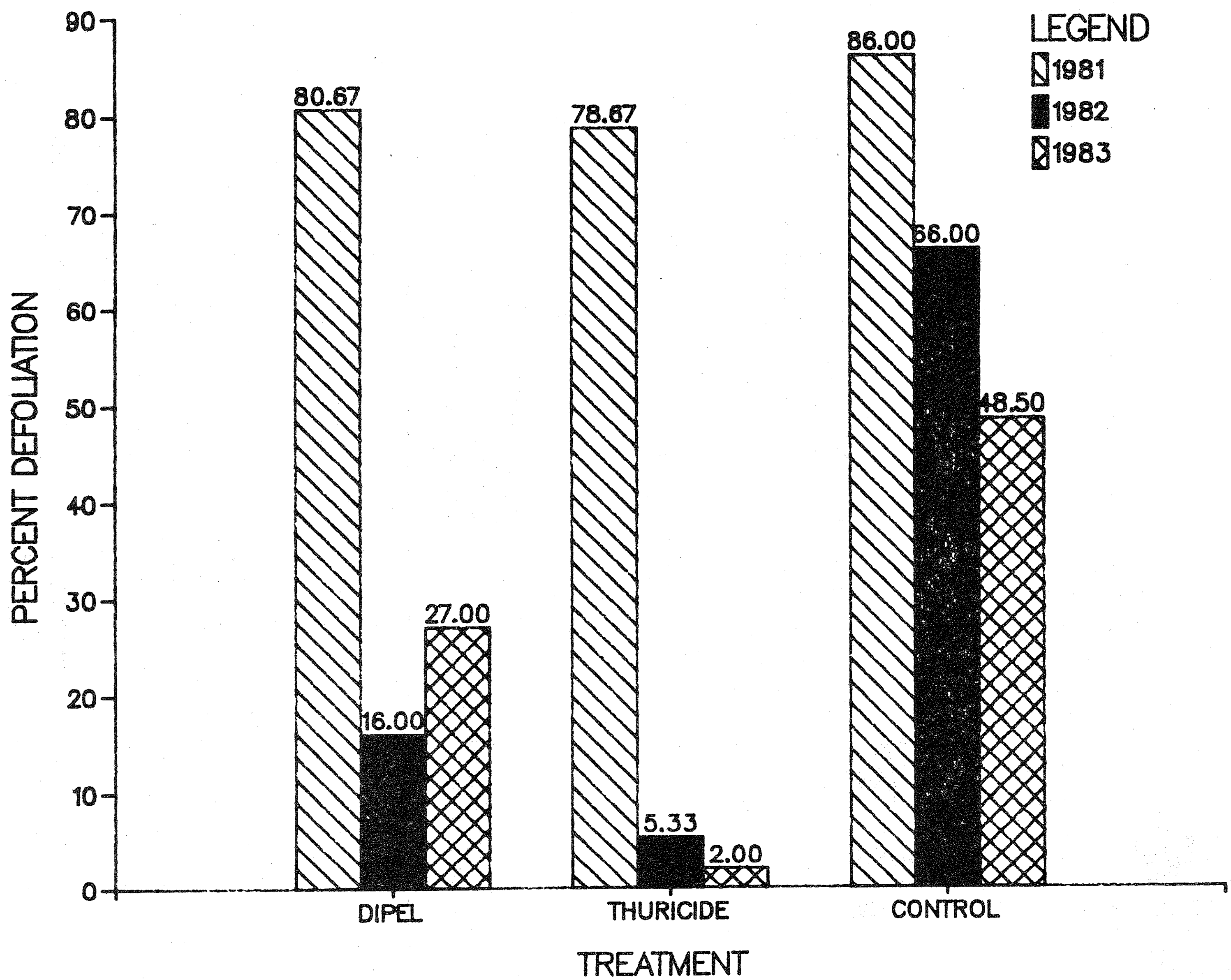


Figure 4. Changes in mean defoliation occurring during 1981-1983 for each treatment in the 1981 Pilot Project.

Defoliation for 1983 remained low in the Thuricide treated blocks. In the Dipel blocks, it increased significantly over the previous year but remained the same in the Check blocks. Since no determination of larval populations was conducted for this year, it is assumed that these differences occurred because of increasing populations which can be predicted from the egg mass densities occurring in 1982.

CONCLUSIONS

In the 1983 progress report, Ragenovich made several conclusions and recommendations which were based on the 1981-82 data. After consideration of all the data available, the following conclusions are made:

1. Applications of *Bacillus thuringiensis* are effective in maintaining budworm larval populations at a low level for two consecutive years. A comment should be made concerning this conclusion. The second year data which was used to support the conclusion of second year population reduction is based on larval densities in samples taken from only one Thuricide replication, a fact which weakens the reliability of the data.

2. No significant reductions in population levels were found in samples taken 7 days posttreatment; therefore, this sample period could be eliminated from the evaluation sampling scheme. Since treatment effect showed up earlier (at the 14-day sample) for Thuricide than for Dipel timeing of the sampling may depend on the formulation.

3. No operational problems with mixing or loading of either insecticide product were encountered. However, evaporation of the diluted formulation indicates that application parameters are very important and can affect the insecticide coverage and deposition. By applying these products undiluted (Neet) more consistent application between blocks may be achieved.

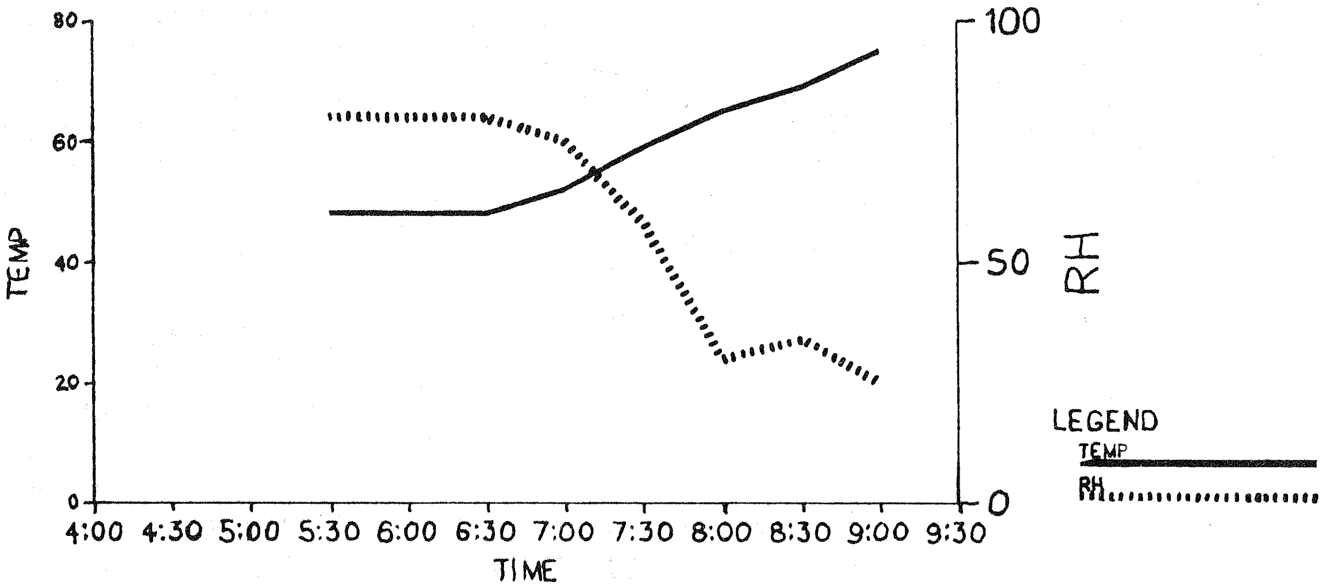
4. No significant reductions in defoliation were found during the year of treatment; therefore, no foliage protection was achieved the first year after application of *B.t.* The amount of defoliation occurring in treated areas does appear to be lower in the second and third year after treatment.

5. Statiscally, treatment and block variation increased with time making the detection of treatment differences impossible. This could be an indication that treatment effects over a period of three years are masked by other factors that treatment benefits cannot be evaluated unless the areas are very similar and located directly adjacent to each other.

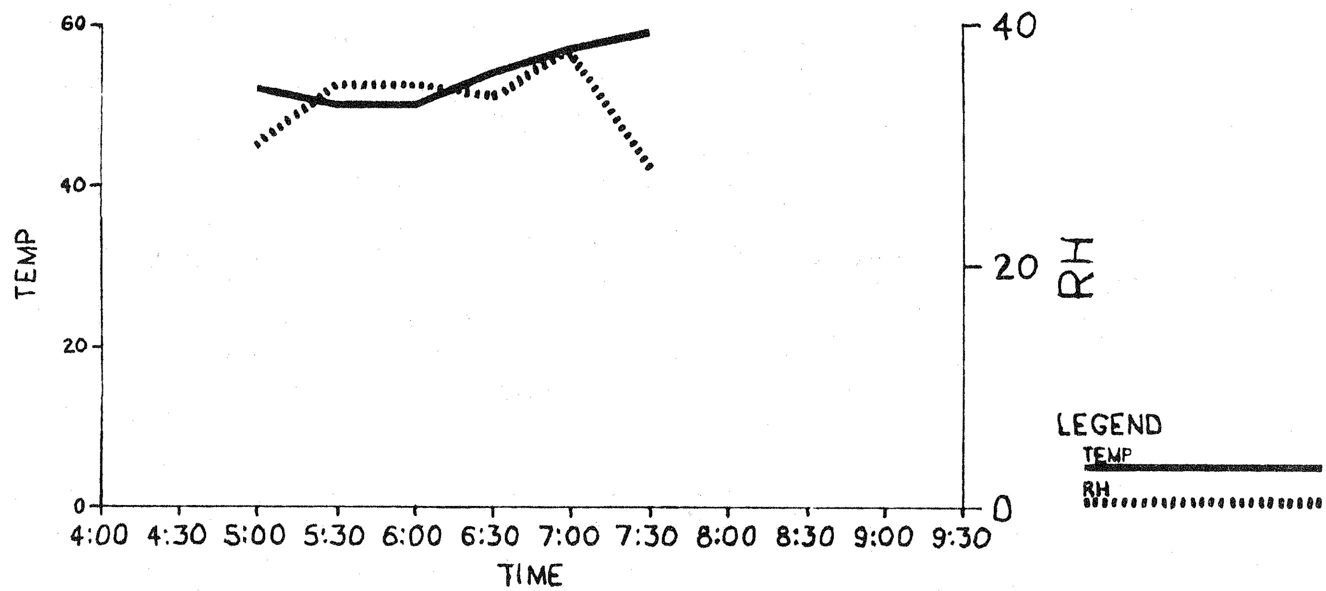
APPENDIX A

METEOROLOGICAL CONDITIONS DURING SPRAY OPERATIONS

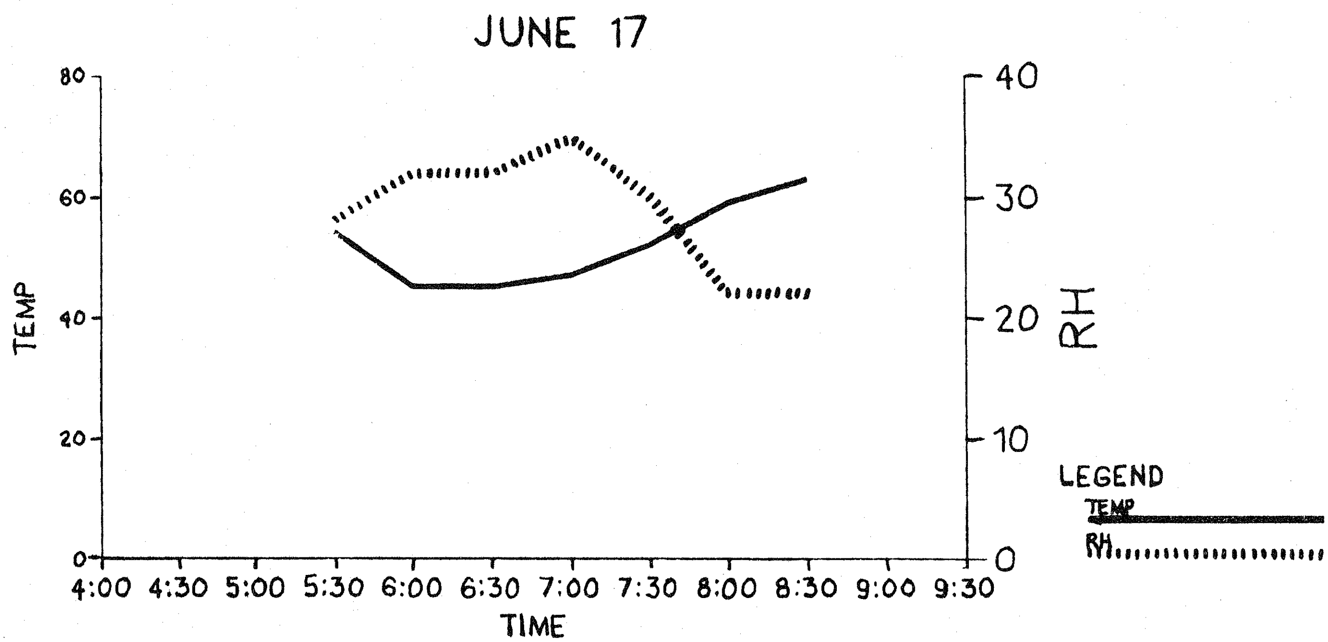
JUNE 12

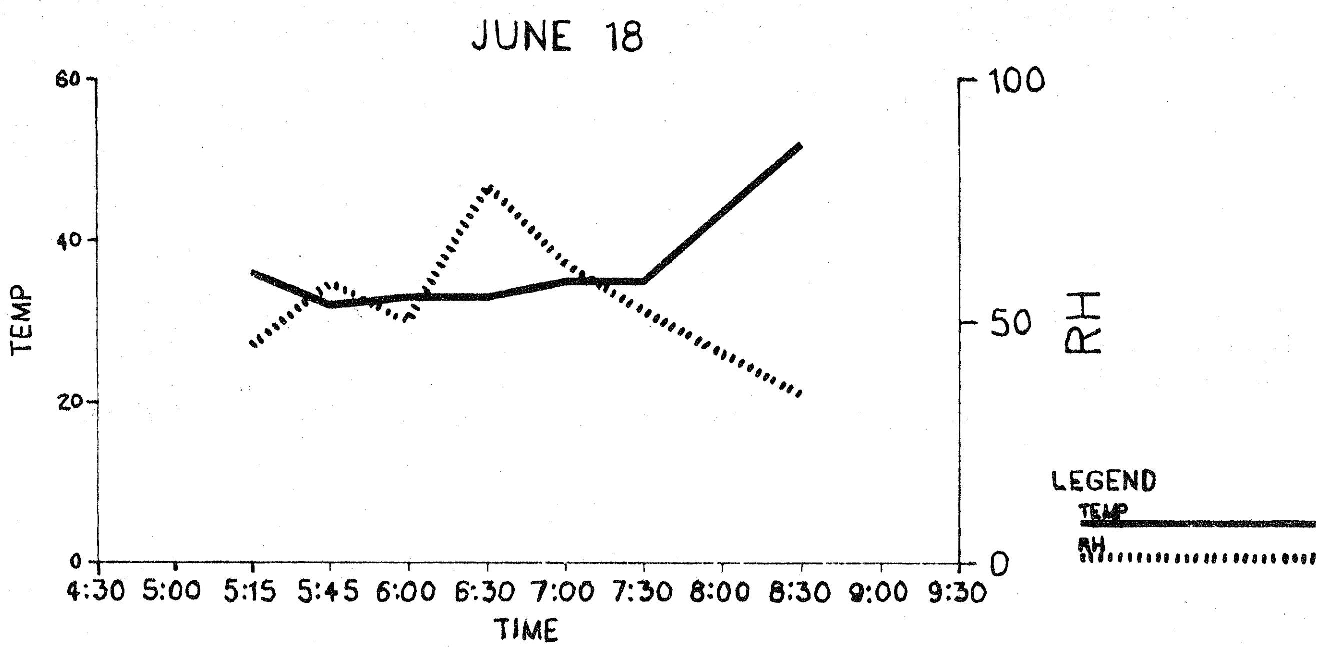


JUNE 13



APPENDIX A.--Relative humidity and temperature charts for days of spray application





APPENDIX A.--Relative humidity and temperature charts for days of spray application--continued