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Yield and quality of burley tobacco as affected by feeding of adult tobacco flea beetles, Epitrix hirtipennis (Melsheimer) (Coleoptera : Chrysomelidae)

John Reid Evans

To the Graduate Council:

I am submitting herewith a thesis written by John Reid Evans entitled "Yield and quality of burley tobacco as affected by feeding of adult tobacco flea beetles, Epitrix hirtipennis (Melsheimer) (Coleoptera : Chrysomelidae)." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Biology.

Charles D. Pless, Major Professor

We have read this thesis and recommend its acceptance:

C. J. Southards, R. R. Gerhardt

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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We have read this thesis and recommend its acceptance:

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YIELD AND QUALITY OF BURLEY TOBACCO AS AFFECTED BY FEEDING OF ADULT TOBACCO FLEA BEETLES, *EPITRIX HIRTIPENNIS* (MELSHEIMER) (COLEOPTERA: CHRYSOMELIDAE)

A Thesis

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ABSTRACT

Insecticidal treatments applied to both early and late planted burley tobacco significantly reduced adult flea beetle populations, but no measureable differences in leaf yield or value were observed. Beetle numbers peaked near the end of July and again in mid-August, reaching maximum numbers of 13 beetles per plant in untreated plots. Beetle population densities were positively correlated with rainfall quantity for both one and two week periods before each count.

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CHAPTER I

INTRODUCTION

The major insect pests of tobacco in the field are: the tobacco hornworm, *Manduca sexta* (Johannson); the budworms, *Heliothis* complex; and the tobacco flea beetle, *Epitrix hirtipennis* (Melshimer) (Chamberlin and Madden, 1942). Of these, the tobacco flea beetle has been considered the most damaging to tobacco throughout the tobacco-growing regions of the United States (Howard, 1900). For example, Dominick (1968) reported that during July and August flea beetles may cause severe damage on maturing leaves of flue-cured tobacco in Virginia. However, in Tennessee the tobacco hornworm is normally the most serious tobacco pest. The tobacco flea beetle may be the most serious tobacco pest in some seasons in Tennessee resulting in a second grade product (Marcovitch and Stanley, 1937).

The adult flea beetle injures plants by eating small holes either partly or entirely through the leaf (Figures 1 and 2). Tobacco in the seed bed is fed upon from the upper surface of the leaf; while in the field flea beetles usually feed from the lower surface (Morgan and Gilmore, 1924). Even as early as 1918 losses of 15 percent of the value of the crop were recorded for cigar wrapper tobacco in one county in Georgia. In this severe outbreak of flea beetles late planted tobacco suffered the worst damage (Chamberlin and Tenhet, 1923). Flea beetle larvae also cause damage by feeding on roots and stems of host plants. In the Piedmont area of Virginia and North Carolina newly transplanted tobacco plants wilted and died from damage by flea beetle

Figure 1. Tobacco flea beetles on tobacco leaf.

Figure 2. Flea beetle damage on newly transplanted tobacco plant.

larvae. Damaged plants often contained ten to twelve larvae in the stem (Schoene, 1938).

To improve controls for the flea beetle much research has been devoted to life history studies. Migration studies by Dominick (1940) reported that over-wintering adult beetles emerge from litter beside fields from the last of March until the last of May. Flea beetles usually migrate to the field when the tobacco plants are transplanted and remain in the field until the crop is harvested. Host plant studies by Levin (1940) showed that before the tobacco is transplanted to the field, flea beetles feed and breed on solanaceous plants such as Jimson-weed, night-shade, or chickweed. They are especially abundant in potato fields or unprotected tobacco seed beds. Once in the field new flea beetle generations occur about a month apart but overlap to such an extent that generations are indistinct (Morgan and Gilmore, 1924).

Control of the tobacco flea beetle has taken many forms in the past. Metcalf and Underhill (1919) recommended: early plowing, cleaning field borders, early planting, frequent cultivation, and destroying all suckers after harvest to reduce flea beetle populations. Marcovitch and Stanley (1937) reported that at the turn of the century paris green was employed against chewing insects on tobacco. Twenty years later paris green had been replaced by lead arsenate. Arsenicals in turn were challenged by cryolite and barium fluosilicate. With the advent of chlorinated hydrocarbons in the 1940's, insecticides such as DDT and endrin came into wide use against tobacco pests (Dominick, 1962). However, in tests done by Tappan (1965) flea beetles indicated a tolerance to DDT and endrin; while Zectran, a carbamate, gave the best control.

Phosphates such as Supracide, Dasanit, or Imidan were reported to equal DDT in short term control (Mistric and Smith, 1970). Recently much interest has been shown in the use of systemic insecticides for tobacco insect control. Mistric and Smith (1973) found that carbofuran acting as a systemic demonstrated effective control against flea beetles. Until recently foliar sprays have been used exclusively on tobacco and still enjoy wide use. Recent research (Pless, unpublished data, 1975) has shown new insecticides such as acephate used as foliar sprays are generally effective against major tobacco pests.

Most of the recent work done on the tobacco flea beetle has been directed toward their control and not the damage they do. Many of these reports give the size of flea beetle populations on untreated checks from which an idea of normal flea beetle populations can be formed. For example, flea beetle counts made on burley tobacco in Kentucky during 1970, 1971, and 1972 (Jones and Thurston, 1973) reached maximum levels of 35.6, 12.3, and 6.5 flea beetles per plant for each of the respective years at one location. At another location, populations reached 38.2, 13.3, and 10.8 flea beetles per plant for each year. Counts made on flue-cured tobacco in North Carolina in 1969 (Mistric and Smith, 1973) reached a maximum of 27.2 flea beetles per plant. Work done on bright tobacco in Virginia (Dominick, 1967) in 1965 and 1966 showed 21 and 20 flea beetles per plant, respectively, late in the season. A similar report (Dominick, 1965) showed that in check plots maximum populations ranged from 43.7 to 53.9 beetles per plant in 1962, from 29.5 to 56.5 beetles per plant in 1963, and from 19.7 to 25.3 beetles per plant in 1964.

Of the tobacco growing states only Kentucky's extension service lists flea beetle population levels at which controls should be applied (Gregory, 1975). However, there is a lack of information relating flea beetle infestations to losses of burley yield or value in Tennessee. Economic thresholds need to be established in order that burley growers can protect their crop and avoid the cost of unnecessary insecticide applications. Economic threshold has been defined (Stein et al., 1959) as "the density at which control measures should be determined to prevent an increasing pest population from reaching the economic injury level." The economic injury level being "the lowest population density that will cause economic damage." As part of an effort to establish economic thresholds for the tobacco flea beetle in Tennessee this experiment would hopefully give partial answers to the following questions:

1. Do tobacco flea beetles damage burley tobacco to the point of causing a significant reduction in the yield or value of the crop in Tennessee?

2. At what population levels do flea beetles cause economic damage?

3. In what half of the season is most of the damage incurred?

CHAPTER II

MATERIALS AND METHODS

The two fields used in this experiment were located on the Middle Tennessee Experiment Station. The fields designated as A and B were planted on May 22, and June 13, 1975, respectively, with Virginia 509 burley tobacco. The same experimental design was used in both fields. Each field was approximately 0.4 acres with similar soil types. Throughout the season insecticide treatments (Table 1) were applied weekly, and insect counts were made seven days later. Counts of tobacco flea beetles, tobacco hornworms, and budworms were usually made in the morning and treatments were applied after counts were completed.

Insecticides used in the treatments were: acephate (O, S-Demethyl acetly-phospho-amidothioate) at .75 pounds AI/A (active ingredient per acre), carbofuran 10G (2-3 dihydro-2, 2-dimethyl-7-benzofuranyl methyl-carbamate) at 4 pounds AI/A, and *Bacillus thuringensis* (Berliner) containing 3.2 percent spores at 1 pound/A. All treatments except carbofuran were applied by hand sprayer, and plants were sprayed to near runoff. Carbofuran granules were incorporated into the soil at the time of transplanting.

The thirteen treatments in each field had four replications in a randomized complete block. Each treatment plot, composed of four rows of tobacco, was 15 feet long. Each plot row contained about ten plants. All four rows of each plot received the same treatment, but only the two inside rows were used for insect counts and were harvested for yields. The outside two rows served as a buffer between plots. As plants grew

TABLE 1

LIST OF TREATMENTS

No.	Treatment	Frequency of Treatment	Height of Tobacco Plants
1	Check		
2	Acephate	weekly, full-season	
3	Water	weekly, full-season	
4	*Bacillus thuringensis* Acephate	weekly, early-season weekly, late season	
5	Acephate	weekly, late-season	
6	Acephate *Bacillus thuringensis*	weekly, early-season weekly, late-season	
7	Acephate	weekly, early-season	
8	Hand pick larvae	weekly, full-season	
9	*Bacillus thuringensis*	weekly, full-season	
10	Carbofuran	first of season	
11	Acephate Acephate	1 flea beetle per plant 10 flea beetle per plant	under knee high above knee high
12	Acephate Acephate	3 flea beetles per plant 15 flea beetles per plant	under knee high above knee high
13	Acephate Acephate	5 flea beetles per plant 20 flea beetles per plant	under knee high above knee high

larger, the last plant in each row was removed to visually define the plots.

Insect counts were made by "in situ" methods on twenty plants from the center two rows in the first part of the season. As plants grew larger, ten plants in each plot were counted. The entire plant was observed for tobacco flea beetles, hornworms, and budworms. The first and last plants of the rows were normally not counted. Insect counts were always made on the untreated check plots, treatment 1; the weekly acephate sprayed plots, treatment 2; and the carbofuran plots, treatment 10. Also counts were made for two weeks following mid-season dates on plots with early-season control to observe the resurgence of flea beetle numbers and on plots with late-season control to observe the rate of decrease of flea beetle numbers.

The treatments (Table 1) in this experiment were designed to indicate the degree of damage caused by tobacco flea beetles and when most of the damage occurs. Except for these treatments normal tobacco cropping techniques were employed throughout the season. Two treatments, 1 and 3, received no chemical applications. Treatment 1 was an untreated check; while treatment 3 was sprayed weekly with water only. The two check plots were intended to determine if the physical process of spraying actually had effect on the plants. Similarly in two treatments, 2 and 10, complete insect control was attempted. Treatment 2 was a foliage spray with acephate, and treatment 10 was a systemic insecticide, carbofuran. A comparison between these two treatments should demonstrate any difference in the effectiveness of a foliage spray versus the effectiveness of a systemic insecticide.

Two methods of controlling only lepidopterous tobacco pests were attempted in treatments 8 and 9. In treatment 8, hornworms and budworms were hand picked from the plots. Bacillus thuringensis, a bacterial pathogen specific for lepidopterous larvae, was used to control hornworms and budworms in treatment 9. In treatments 8 and 9 the tobacco flea beetle was the only major tobacco pest; therefore, insect damage in these plots could be attributed to flea beetles unless there was an outbreak of some normally minor tobacco pest.

Four treatments were used for determining the part of the season that most insect damage occurs on burley tobacco. The growing season was arbitrarily divided into two halves, early and late season. The mid-season dates were July 26 for field A and August 2 for field B. Before the mid-season dates, treatment 5 was sprayed weekly with acephate but received no treatment in the late-season. Treatment 7 was the opposite of treatment 5 receiving acephate sprayings only in the late-season. Treatments 5 and 7 were designed to show if insect control on tobacco was more critical in one half of the season than the other half. Similarly, treatments 4 and 6 were to demonstrate which half of the season flea beetles were most damaging. This was done by controlling lepidopterous larvae for half a season with Bacillus thuringensis and spraying with acephate to control the tobacco insect complex the other half of the season. Thus flea beetles were the only major pest to damage the tobacco. The flea beetles could only injure plants of treatment 4 in the early-season and plants of treatment 6 in the late-season.

The last three treatments, numbers 11, 12, and 13, were designed to indicate the levels at which flea beetle populations did significant damage. Kentucky Agricultural Extension Service recommendations for 1975 stated that "applications of recommended insecticides will be worthwhile" with populations of three or more flea beetles per plant on newly transplanted tobacco or with populations of 25 or more flea beetles per plant on knee high or larger tobacco (Gregory, 1975). With this in mind, maximum levels of flea beetle populations were arbitrarily predetermined. During the season, insect levels were estimated from the counts taken in the check plots and the acephate sprayed plots. When flea beetles reached a density of one beetle per plant when plants were under knee high or ten beetles per plant when the plants were larger, the plots of treatment 11 were sprayed with acephate to reduce flea beetle numbers. Treatments 12 and 13 were treated similarly except they were sprayed when flea beetles reached higher densities (Table 1, page 8).

The mature plots of field A were topped and sprayed with sucker control MH-30 on August 11. The remaining plots of field A and all the plots in field B were topped and sprayed on August 27.

Field A was harvested on September 10, and field B was harvested on September 11. By December the tobacco had cured and the stalks were stripped into five field grades. Weights and standard grades for burley tobacco were recorded for each field grade of each plot.

CHAPTER III

RESULTS AND DISCUSSION

I. FLEA BEETLE COUNTS

Weekly insect counts (Figures 3 and 4) revealed that flea beetle populations in both early and late planted fields were at low levels for the first four weeks of their respective seasons. In field A, the population peaked three times: July 5, July 26, and August 16. Flea beetle population in field B did not peak on July 5 but did peak on July 26 and August 16. The July 26 peak was the highest peak for field A; while the August 16 peak was the highest for field B. Generally, the late planted field had a larger flea beetle population and a more obvious difference in flea beetle levels between treatments. This increase in flea beetles on late planted tobacco agrees with prior observations (Chamberlin and Tenhet, 1923) that late tobacco sustains more damage from tobacco flea beetles than early planted tobacco.

Analysis of variance for the average number of flea beetles per plot for the entire season showed a significantly higher number of flea beetles on the check plots, treatment 1 when compared to flea beetle numbers on the two chemical treatments, 2 and 10.

Also, the systemic insecticide, treatment 10, gave significantly better flea beetle control than the foliar spray, treatment 2, in field B; however, the difference was not significant in field A. Flea beetle numbers in the foliar sprayed plots tended to fluctuate more than

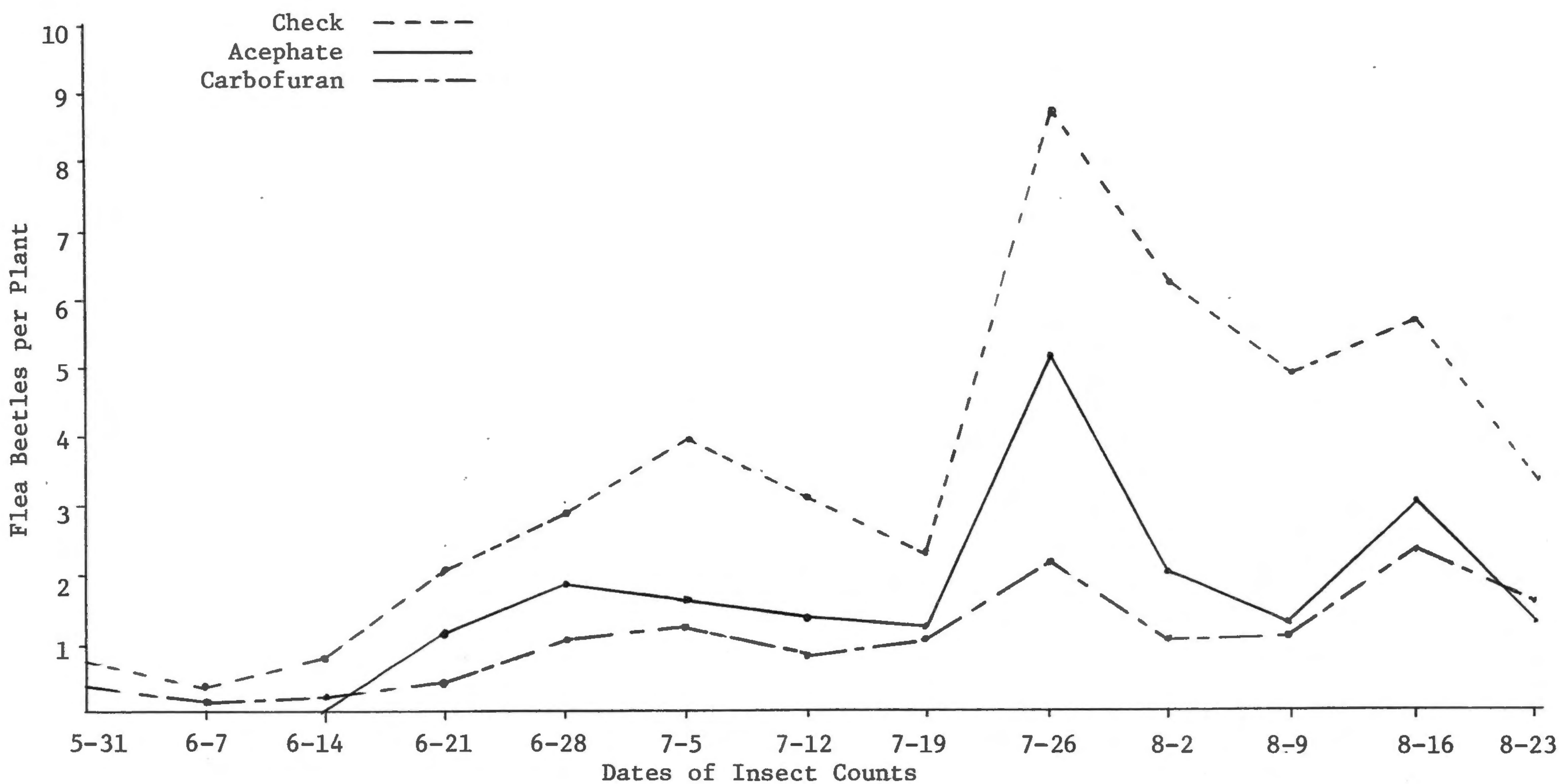


Figure 3. Seasonal flea beetle populations, field A.

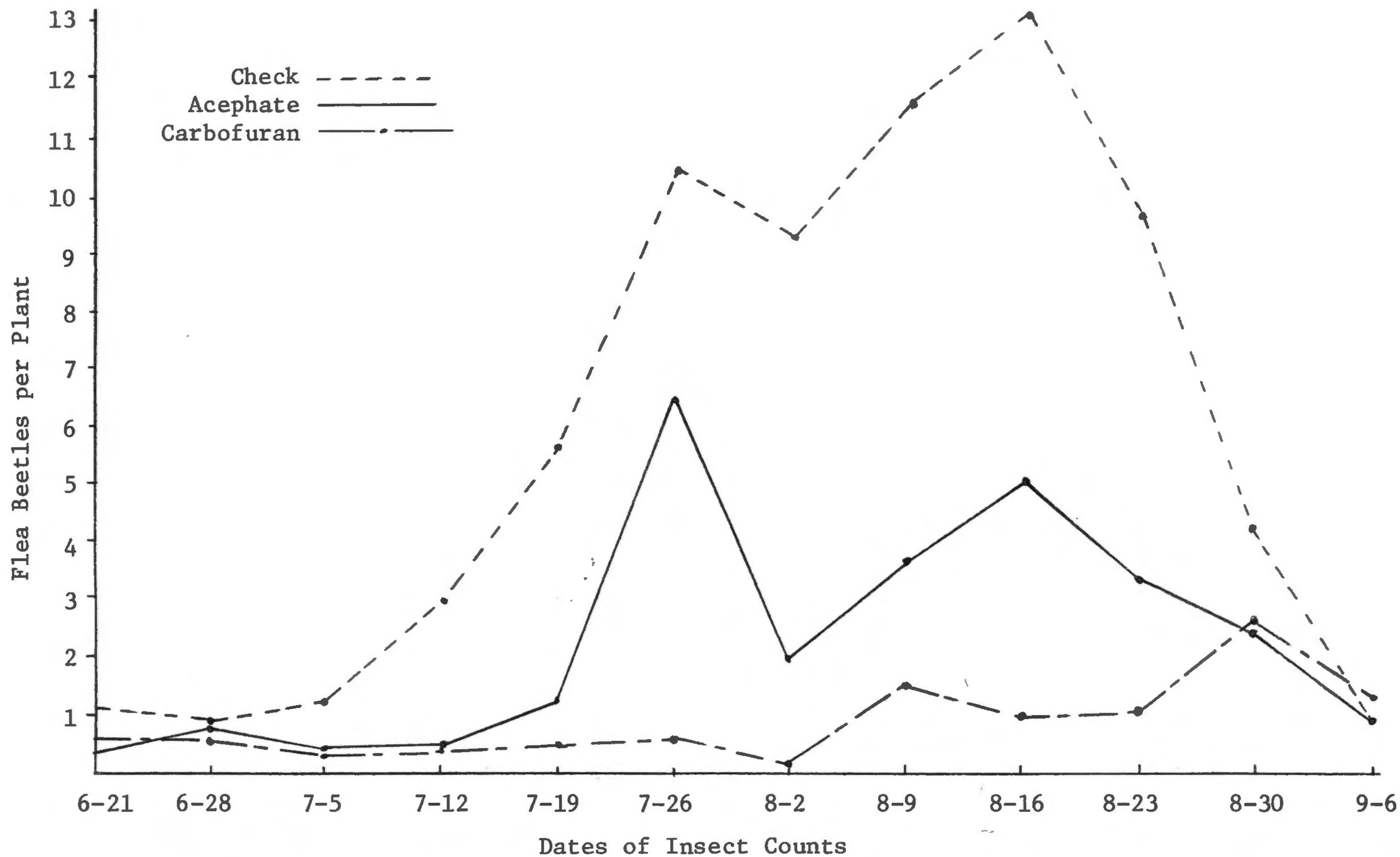


Figure 4. Seasonal flea beetle populations, field B.

in the systemically treated plots. This is probably the result of the foliar spray, acephate, being washed off by rain. Toward the last of the season the systemic insecticide, carbofuran, appeared to lose some of its effectiveness as shown by an increase in the number of flea beetles.

Additional insect counts were made on plots with early and late season control for two weeks following mid-season (Figure 5). Flea beetle numbers rose quickly when acephate sprayings were discontinued, showing acephate to have a short residual effect. Similarly, flea beetle numbers were quickly reduced when weekly late season spraying with acephate started. Generally, within two weeks the two treatments had reserved their positions relative to flea beetle numbers.

The peaks shown in both graphs (Figures 3 and 4) did not coincide with any specific emerging generations. Rather, they appeared to fluctuate with rainfall as observed by Chamberlin and Madden (1942). For the summer of 1975, the flea beetle population was positively correlated to the total rainfall for one and two weeks before the date of each count (Figures 6 and 7). A significant correlation coefficient of .38 was found for both fields using rainfall totals for one week before counts. Higher correlations were found using total rainfall for two weeks before counts with coefficients of .53 for field A and .52 for field B.

This relationship between rainfall and flea beetle numbers is the best explanation for the decrease in flea beetle populations toward the end of the season when rainfall was light (Figures 3 and 4). Most reports, including a recent report in North Carolina (Mistric and

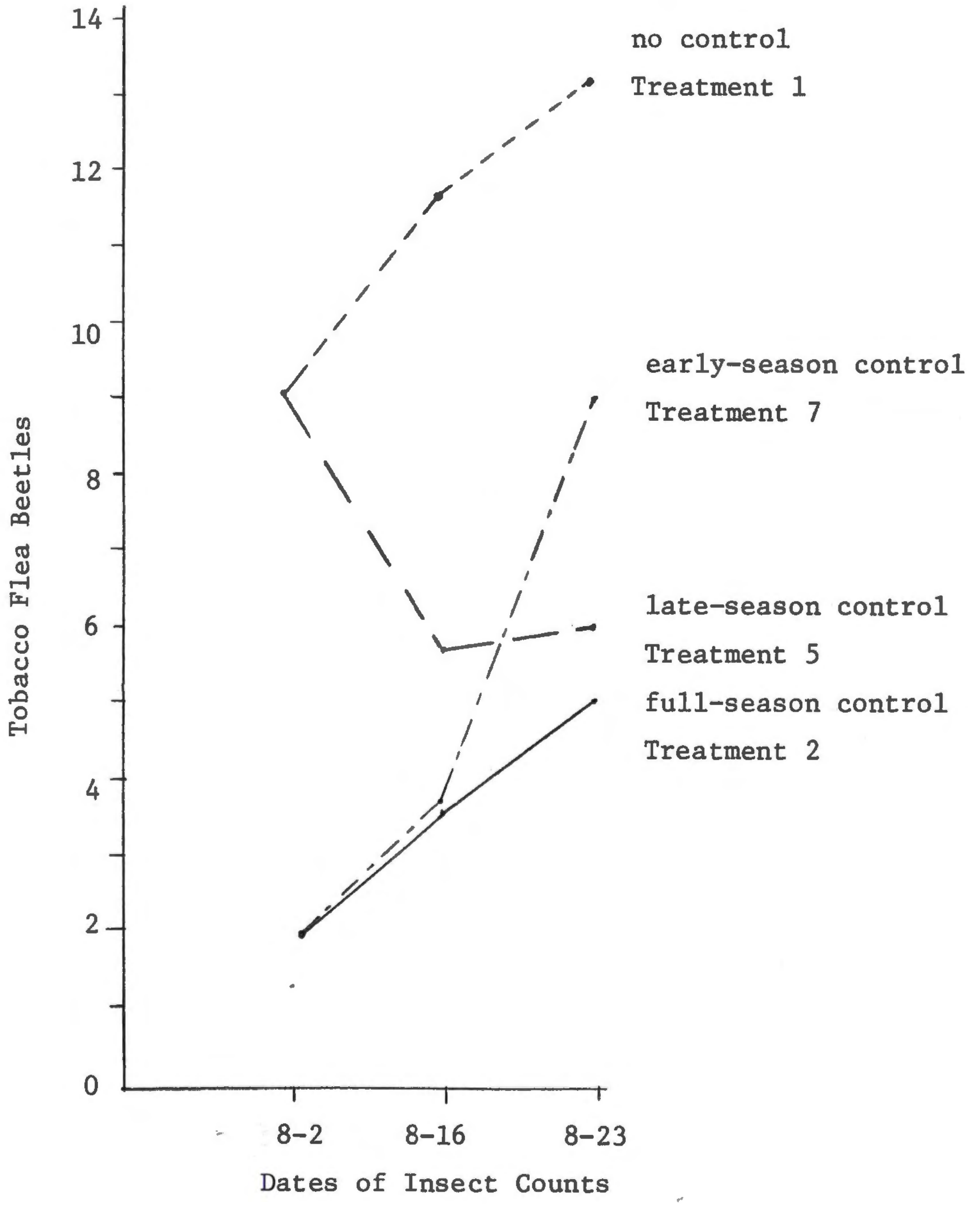
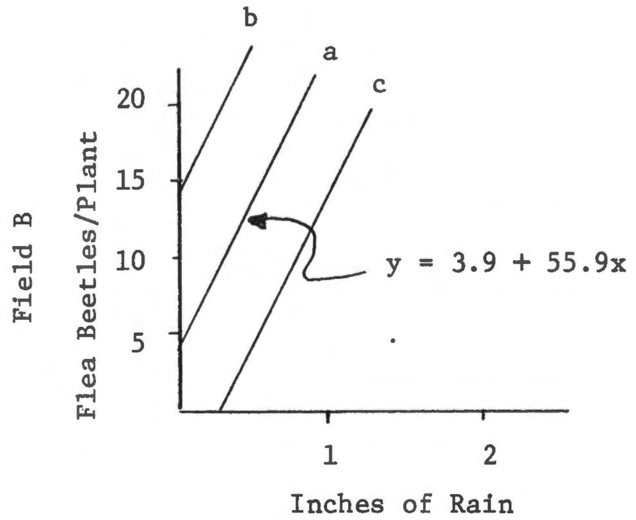


Figure 5. Flea beetles numbers after mid-season, field B.



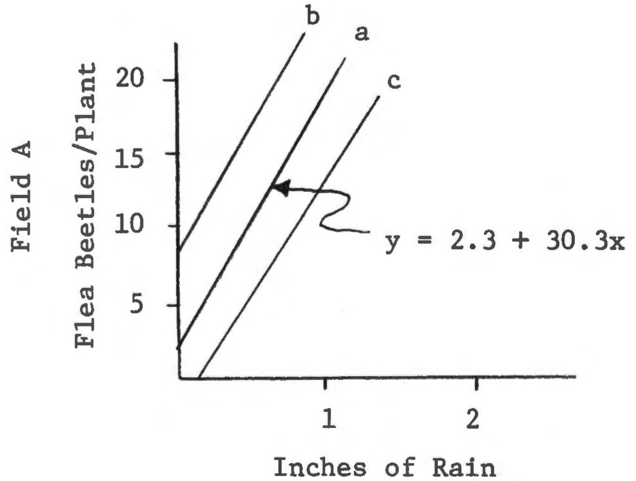


Figure 6. Flea beetles per plant correlated with the accumulative rainfall for one week before each count.

a-correlation line
b-plus two standard deviations
c-minus two standard deviations

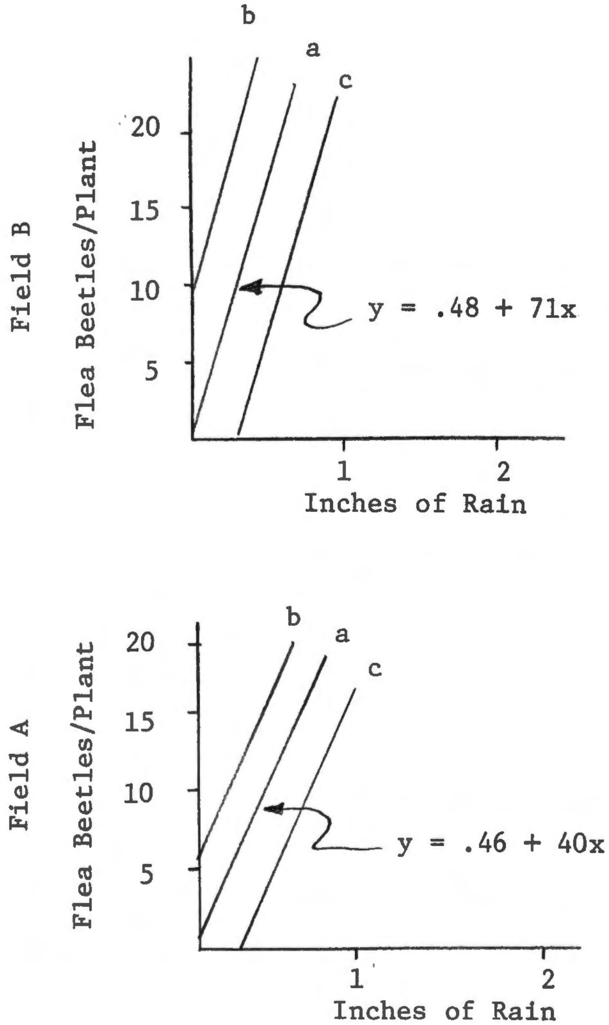


Figure 7. Flea beetles per plant correlated with the accumulative rainfall for two weeks before each count.

a-correlation line
b-plus two standard deviations
c-minus two standard deviations

Smith, 1973), indicate that flea beetle numbers normally remain high through harvest.

On untreated tobacco, flea beetle populations in 1975 reached maximum levels of 8.8 beetles per plant in field A and 13.2 beetles per plant in field B. Compared with reports from other locations, the flea beetle population at the Middle Tennessee Experiment Station did not reach high levels. This deduction is strengthened by the fact that flea beetle populations are correlated to rainfall and that the summer of 1975 was a comparatively dry summer (Table A-1, Appendix).

Besides flea beetles, numbers of budworms and hornworms were recorded weekly. North Carolina Extension Publication (Robertson, 1975) recommends applying controls for either hornworms or budworms when 10 percent of tobacco plants are infested. The budworm population never reached this level in either field; however, hornworms did exceed the 10 percent infestation level in both fields. The late planted field B had twice the hornworm infestation of the earlier planted field. Also, only 12.4 percent of the hornworms in field B were parasitized by Apanteles congregatus (Say) while 23 percent of hornworms in the early planted field were parasitized. On treated plots, all insecticides gave good control for both hornworms and budworms.

II. YIELDS AND STANDARD GRADES

Data from the cured tobacco were analyzed to determine if there were significant yield differences between treatments. The combined weights of the five field grades for each plot were compared by analysis of variance. In both fields A and B no significant difference between yields of treatments occurred even though the number of flea beetles on different treatments had been significantly different and a sizable hornworm population was present on untreated plots. Yields for each treatment are presented in Figures 8 and 9.

The lack of significant difference was unexpected since some treated plots showed enhanced growth in the field (Figure 10). Tobacco in plots treated with either acephate or carbofuran appeared taller and of a darker color in the early season than plots not treated with these chemicals. This observation agreed with an earlier report made at the same location (Pless et al., 1971) that carbofuran treatments resulted in early maturity and increased yields. Although early maturity was observed with treatments of the foliar spray, acephate, and the systemic, carbofuran, yields were not significantly increased.

The possibility is unlikely that this increased growth was due to the physical process of spraying rather than some interaction between the chemical and the plant. Treatment 3 was sprayed with water in the same manner and with the same schedule as the chemically treated plots. In both fields, plants treated with water only did not show stimulated growth and gave yields very similar to the yields of the untreated check.

Unfortunately, the growth of plants in field A was not uniform throughout the field. The first 45 feet of tobacco grew well, but the next 100 feet of plants appeared stunted. This stunting did not appear at the opposite end of the field. Plants of the same variety serving as a border for an immediately adjacent variety test did not show any stunting. Other varieties near this area of stunted plants did not

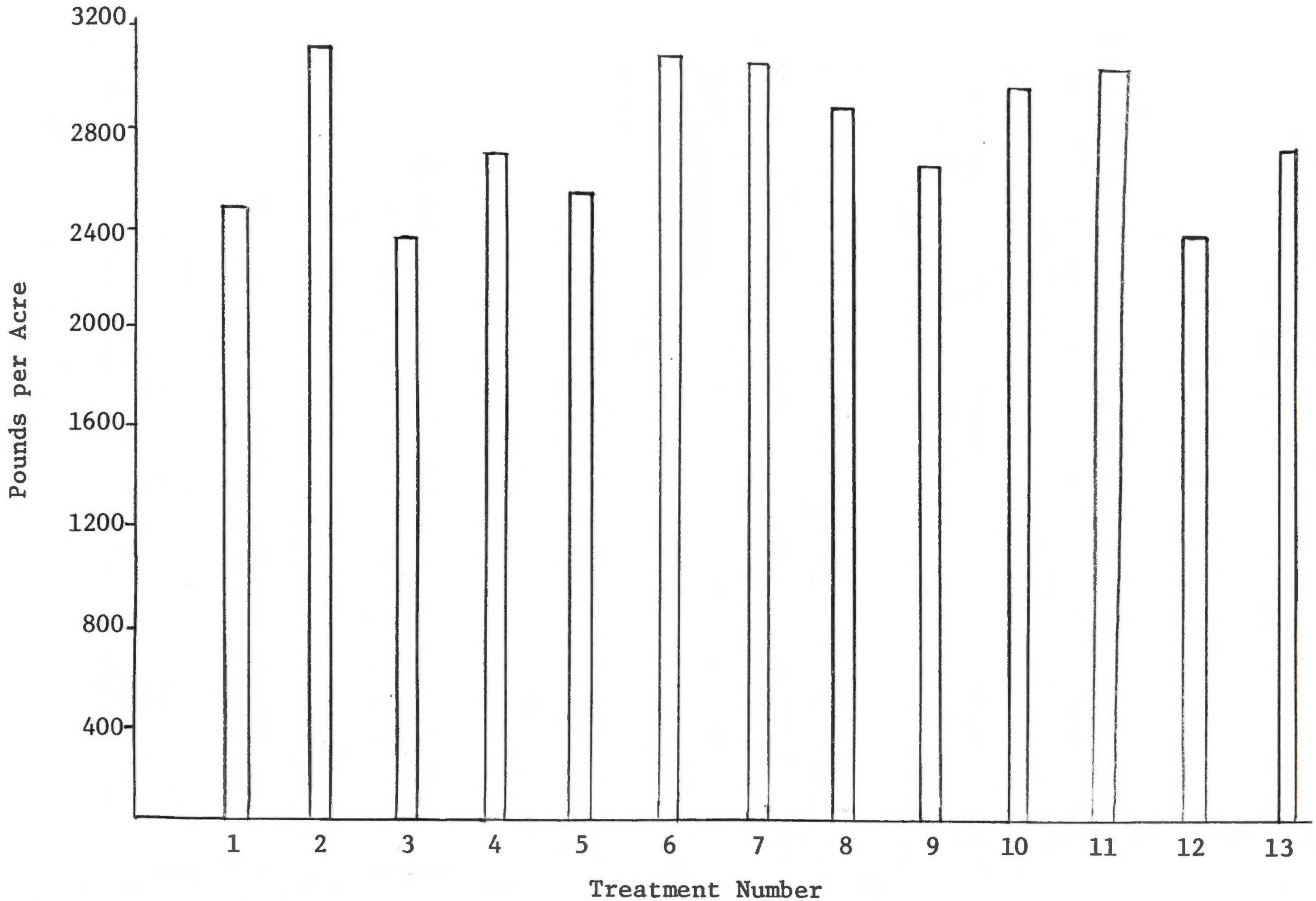


Figure 8. Yields in pounds per acre for each treatment, field A.

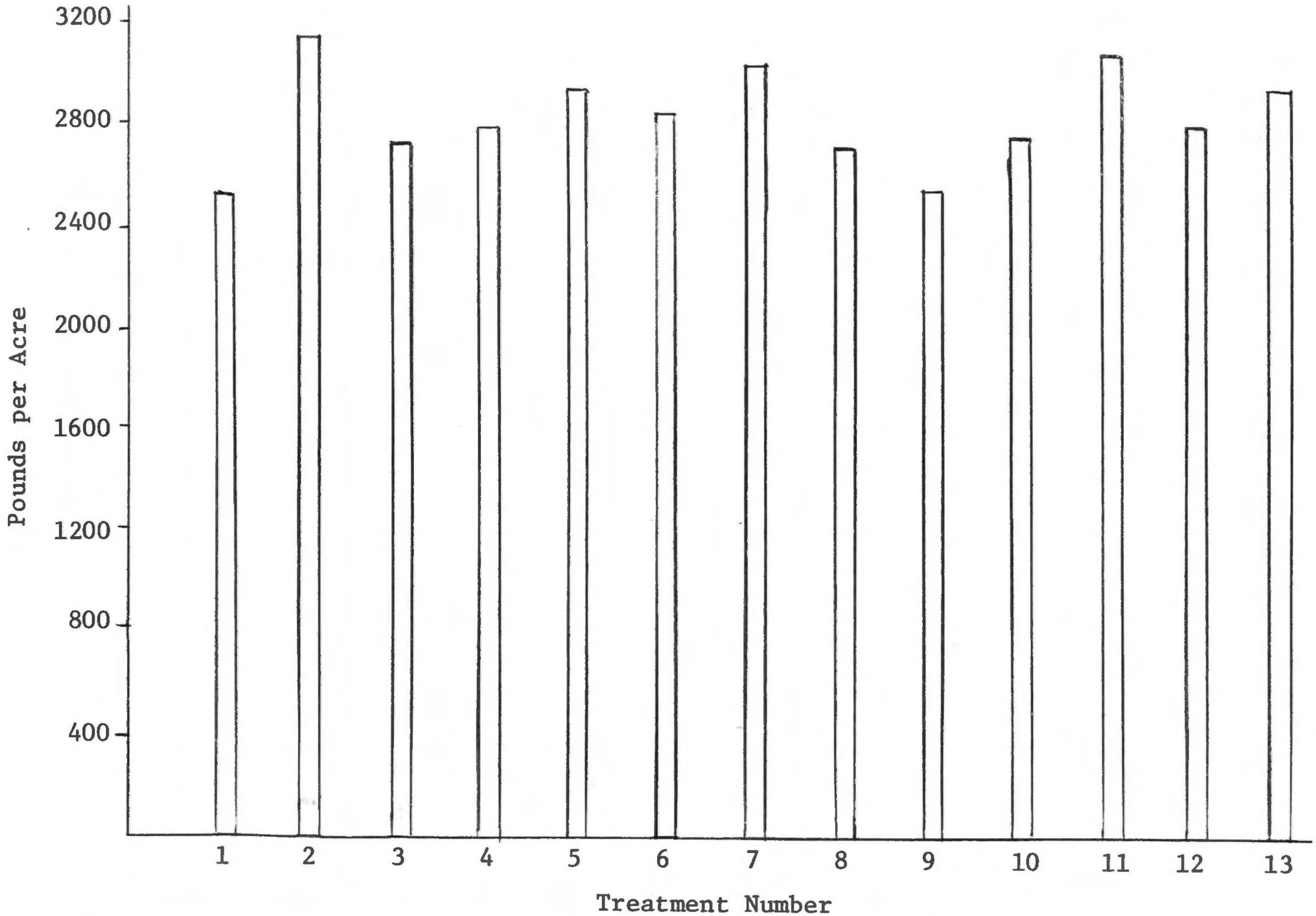


Figure 9. Yields in pounds per acre for each treatment, field B.

Figure 10. Untreated plants in foreground; plants in background received weekly sprayings with acephate.

show other recognizable disease symptoms nor were plant parasitic nematodes or other phytophagous organisms found feeding on the tobacco roots in significant numbers. Possibly, this stunting could have been caused by some micro-nutrient deficiency or the washing of some chemical into the area from nearly plots, but the abrupt borders formed around this stunted area would make either of these possibilities unlikely.

In the area of stunted plants, tobacco treated with carbofuran or acephate in the early season appeared to grow more normally than untreated plants. It is possible that these chemical treatments acted to offset the stunting in the area. For example, plot 307 was an untreated check plot; while adjacent plot 308 was sprayed weekly with acephate. The acephate treated plot yielded 7.8 lbs. while the neighboring check plot yielded only 5.05 lbs. In addition, the price per pound of the acephate treated plots averaged two cents higher than the check plot's price based on government support prices.

Both fields averaged similar yields even though field B was planted later and had a higher level of insect infestation. Despite the lower than normal rainfall in 1975 (Table A-1, Appendix) the yields were somewhat higher than yields in the previous two years. In 1973, Virginia 509 yielded 2,459 lbs./A. at the Middle Tennessee Experiment Station; while in 1974 it yielded 2,576 lbs./A. In 1975, yields were 2.742 lbs./A. for field A and 2,815 lbs./A. for field B.

The standard burley tobacco grades assigned to each field grade indicated the quality or desirability of the leaves. The standard grade is composed of two letters and a numeral. The first letter indicated the group or position on stalk; the numeral represents the quality; and the last letter indicates the color. An example would be T4F meaning tips of fair quality with tan color. Each grade was assigned a corresponding government support price. This price reflects the desirability of the tobacco and the overall market condition (Table A-2, Appendix).

An estimate of the value of tobacco in each plot was obtained by summing the products of each grade's support price and each grade's weight. Analysis of variance of the support price of each plot showed no significant difference between treatments. Trends between treatments were very similar to the trends of the yields. The support price in field A ranged from $.99/lb. to .98/lb. and in field B from $1.00/lb. to .99/lb. Thus a significant difference in the number of flea beetles between treatments did not result in a significant difference in the value of the tobacco based on government support prices just as it did not result in a difference in yields.

Although these prices would be what the United States government would pay for the tobacco, the actual market price would undoubtedly differ since it is affected by a number of independent variables. For example, the support price for T4F is $.93/lb. However, for the week of December 18, 1975, the average price paid on the market was $1.05/lb.; while the seasonal average was $1.04/lb. for this standard grade.

It should also be pointed out that the amounts of tobacco harvested and weighed for yields may not have been large enough to give optimum results. In addition, amounts of harvested leaves were inconveniently small to handle properly.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Tobacco flea beetle populations in two burley tobacco fields at the Middle Tennessee Experiment Station were observed during the 1975 season. In addition to weekly insect counts, tobacco yields and crop values for each of thirteen insect control treatments were recorded.

Flea beetle populations peaked in both fields on July 26 and August 16 with flea beetle density reaching a maximum of 13 beetles per plant on untreated plots. A positive correlation was found between flea beetle numbers and the accumulative rainfall for either one or two weeks before each counting date. The total rainfall for two weeks before each count had the highest correlation. Flea beetle numbers on check plots were always significantly greater than flea beetle numbers on plots treated with synthetic insecticides. In one field flea beetle numbers on plots treated with the systemic carbofuran were significantly less than beetle numbers on plots sprayed with acephate.

Weights of the harvested tobacco were not significantly different between treatments although numbers of flea beetles had been significantly different between treatments. Similarly, using standard grades for burley tobacco and the corresponding government support prices, the value of the tobacco was not measureably different between treatments.

Tobacco flea beetles in numbers of 13 beetles per plant in the late season did not cause economic damage to burley tobacco. More research needs to be done to determine where the economic threshold is for burley tobacco.

Interestingly, untreated plots which had relatively high infestations of tobacco hornworms along with the flea beetles and a few minor tobacco pests were not significantly different in crop yield or value from plots where tobacco insect pests were controlled. This raises the question of just how important hornworm control is to burley tobacco production.

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TABLE A-1

SUMMER RAINFALL TOTALS FOR MIDDLE TENNESSEE EXPERIMENT STATION IN INCHES

Month	1973	1974	1975
May	13.03	5.98	4.38
June	3.78	8.28	3.83
July	6.73	2.04	3.15
August	2.20	4.51	3.53
September	2.16	7.31	5.91
Total	27.72	27.94	20.80

TABLE A-2

STANDARD GRADES FOR BURLEY TOBACCO AND CORRESPONDING SUPPORT PRICES FOR 1975 USED IN EXPERIMENT

Type of Leaf	Dollars Per 100 lbs. of Burley
Flyings	
X2L	101
X3L	100
X4L	98
X5L	96
X2F	101
X3F	100
X4F	98
X5F	96
Lugs	
C2L	101
C3L	100
C2F	101
C3F	100
C4F	98
C5F	96
Leaf	
B2F	101
B3F	100
B4F	98
B5F	96
B3FR	99
B4FR	97
B5FR	95
B5K	88
Tips	
T4FR	92
Nondescript	
N1L	91

QUALITY	COLOR
1-Choice	L-Buff
2-Fine	F-Tan
3-Good	FR-Tannish Red
4-Fair	R-Red
5-Low	K-Variegated

VITA

John Reid Evans was born on March 12, 1952, in Columbia, Tennessee, the son of Billy Vaughn and Jean Reid Evans. He attended elementary school in Spring Hill and graduated from Columbia Central High in 1970. Thereupon, he entered the University of Tennessee, Knoxville, where he received his Bachelor of Arts in Cell Biology in 1974.

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