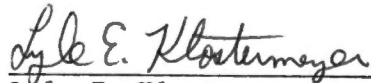
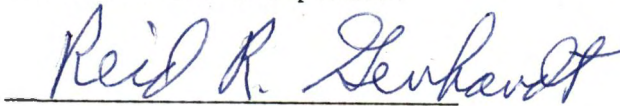


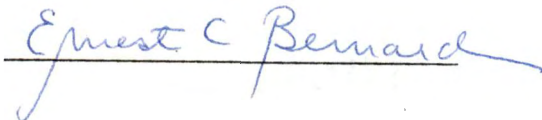
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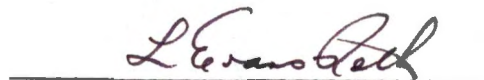
  
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LEAFHOPPERS (HOMOPTERA: CICADELLIDAE) ASSOCIATED  
WITH A MIXED TALL FESCUE PASTURE  
ON THE CUMBERLAND PLATEAU  
IN TENNESSEE

A Thesis  
Presented for the  
Master of Science  
Degree  
The University of Tennessee, Knoxville

Robert Emil Kelly

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## ABSTRACT

In a two year study period (1980-1981) a survey was made to identify the leafhoppers associated with a mixed tall fescue pasture on the Cumberland Plateau in Tennessee. Using a D-Vac<sup>®</sup> suction sampler, a total of 33 species representing 27 genera in 6 subfamilies of Cicadellidae were collected. Eight species were considered abundant: Agallia constricta Van Duzee, Aphrodes serratulae (Fabricius), Dikraneura angustata Ball & DeLong, Forcipata loca DeLong & Caldwell, Latalus sayi (Fitch), Polyamia weedi (Van Duzee), Endria inimica (Say), and Amblysellus curtisii (Fitch). The seasonal abundance of these species was discussed and comparisons were made as to the effect of cutting on these species.

Three insecticides (Counter<sup>®</sup> 15G, Cygon<sup>™</sup> 400, and Malathion 57EL) were evaluated for their effects on leafhopper numbers and forage yield. Both Counter and Cygon significantly reduced total leafhopper numbers on some sample dates. In 1980, yield was significantly greater in the plots treated with Counter than in the untreated check plots. There were no significant yield differences in 1981.

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## CHAPTER I

### INTRODUCTION

In the United States, cropland used strictly for pasture comprises 33.6 million ha (U.S.D.A. 1980). It is upon this area that the beef and dairy industries are dependent. Although the farmer does not usually realize any direct cash flow from pastures, they are nevertheless very valuable because they provide the raw material for the production of his beef and dairy products.

Tennessee ranks sixth in the nation in pastureland with 2.2 million ha out of a total land area of 10.7 million ha. The estimated value of these pasture crops was \$250 million in 1980. Tall fescue, Festuca arundinacea Schreb., is the predominant pasture grass species in this state and comprises 1.3 million ha (Reynolds 1981). Tall fescue commonly is grown in association with other grass and legume species, a combination referred to as a mixed tall fescue pasture.

Insects are an important limiting factor in the production of a pasture crop. Wolcott (1937) has estimated that in a thriving pasture in New York, insects consumed about twice as much grass and clover as did cattle. The larger insects such as grasshoppers, crickets, and white grubs are usually blamed for causing the major losses to a pasture because of the feeding damage they cause. Insects with sucking mouth-parts are less often recognized as causing problems, probably because of their small size and less noticeable feeding habits.

Leafhoppers (Homoptera: Cicadellidae) are usually very abundant in pastures. Osborn (1939) estimated that up to 1.5-2 million leafhoppers may occur in midsummer on 0.4 ha of pasture. Wolcott (1937) collected a total of 6843 invertebrates from a 9.2 m<sup>2</sup> area of grassland in a detailed study conducted in New York. Of these, 1027 were leafhoppers, representing approximately 1/6th of all the invertebrates collected. From this he estimated that some 447,371 leafhoppers occurred on 0.4 ha.

From the numbers of leafhoppers that can be found in pastures, it is possible that these insects may cause extensive yield reductions and therefore warrant further study. The objectives of this study were to determine:

1. the diversity and relative abundance of leafhoppers present in a mixed tall fescue pasture on the Cumberland Plateau in Tennessee,
2. the effects of selected insecticides and periodic cutting on the adult leafhopper populations, and
3. the effects of selected insecticides on forage yield.

## CHAPTER II

### LITERATURE REVIEW

As of 1971, the world literature on leafhoppers covered some 5500 to 6000 species in approximately 700 or more genera (DeLong 1971). Representatives of the family Cicadellidae are known from every major land mass of the world, excepting possibly the extreme Arctic and Antarctic regions (Oman 1949).

#### I. LIFE HISTORY

Reproduction is usually sexual and oviparous, however Black and Oman (1947) established that Agallia quadripunctata (Provancher) reproduces parthenogenetically. Males will usually appear before females of the same brood, and mating normally occurs within a few days after the females appear. Species which overwinter as adults may mate either in the fall or spring (Oman 1949). There is evidence that mating is usually preceded by a mating call produced by an organ homologous with the tymbal organ of the Cicadidae (Ossiannilsson 1946).

The ovipositional period even in the same species will vary from a few days to a few months, with an average of one to two months. The number of eggs produced will average between 100 and 200 per female. Eggs are inserted beneath the epidermis of leaves or stems of plants in slits made by the ovipositor and are usually laid singly but they may be deposited in clusters of up to 20. The incubation period varies greatly

but in most species hatching occurs in about a week during the summer (DeLong 1971). In the case of overwintering eggs, hatching takes place early the following spring (Osborn 1932).

Leafhopper nymphs usually pass through five instars. The length of time necessary for nymphal development varies considerably. There are several species in which development takes about 30 days (DeLong 1971).

The number of generations in each season is variable but there are commonly two generations, in some species probably three, and for a few species only a single generation (Osborn 1932). The number of generations per year of a particular species depends largely upon the geographic area in which it occurs, the host plant upon which it lives, the type of plant tissue in which the eggs are placed, and similar pertinent factors (DeLong 1971).

Most Nearctic leafhopper species overwinter either as adults or as eggs (Oman 1949). The egg is the common overwintering stage for grass-feeding species (Osborn 1932).

## II. FEEDING HABITS

All leafhoppers are plant feeders which puncture the tender plant tissues with their piercing-sucking mouthparts. Most species feed upon the mesophyll causing a white stippled appearance to the foliage, but some species will feed in the phloem. Leafhoppers which vector plant viruses are all phloem feeders; the mesophyll feeders are apparently not virus vectors (DeLong 1948, 1971). Maramorosch and Harris (1979) reviewed leafhopper vectors of plant disease agents.

There are five major types of leafhopper-caused plant injury:

(1) excessive removal of sap and reduced or destroyed chlorophyll in the leaves; (2) interference with the normal physiology of the plant, i.e., by mechanically plugging the phloem and xylem vessels in the leaves so that transport of food materials is impaired; (3) injury to plants by ovipositional punctures; (4) plant diseases whose causal agents are vectored by leafhoppers; and (5) stunting and leaf curling because of the inhibition of growth on the undersurface of the leaves where the leafhoppers feed (Borrer et al. 1976). In general, leafhoppers of a given species have either a single species of host plant or a group of rather closely related host plant species, although some leafhoppers feed upon and are able to complete development on a great variety of plants (Oman 1949).

### III. NATURAL ENEMIES

Several fungal species parasitize specific leafhoppers while other fungi attack several species in different genera. Empusa spp. have been noted as important parasitic fungi of leafhoppers (DeLong 1971). In favorable seasons fungi may play a part in the natural control of the leafhoppers (Lawson 1920).

Spiders are among the most efficient enemies of leafhoppers, and several species have been noted as leafhopper predators (Osborn 1939). Also, many insects are known leafhopper predators. Among these are some Nabidae and Lygaeidae (Osborn 1939), Chrysopid larvae, Pentatomidae and Reduviidae (DeLong 1971) and damselflies (Lawson 1920). Species of

several genera of sand wasps (Nyssoninae) provision their nests with leafhoppers (Evans 1968).

The chief natural enemies of the leafhoppers are the parasitic insects (Lawson 1920). Pipunculidae (Diptera), Dryinidae (Hymenoptera) and Halictophagidae (Strepsiptera) appear to be the most frequently occurring groups of leafhopper parasites (Baldrige and Blocker 1980). Dorst and Davis (1937) observed 60% parasitism of migrating beet leafhoppers by pipunculids. Buyckx (1948) found that a dryinid parasitized up to 73.7% of certain leafhoppers. Oman (1949) reported up to 80% of a population of Aceratagallia fuscscripta Oman parasitized by strepsipterans.

#### IV. CONTROL MEASURES

Because leafhoppers exist in large numbers in pastures and have suctorial mouthparts, they are difficult to control. However, several control techniques have been used. Burning, mowing or cutting, insecticides and resistant plant varieties have all been utilized as control measures.

Burning the grass in the fall or early spring has been found to be an effective means of destroying the overwintering eggs of leafhoppers (DeLong 1916; Osborn 1932, 1939). Osborn (1932) believed burning to be most applicable in the prairie regions.

Mowing of grasses will destroy the eggs and a large proportion of the nymphs (DeLong 1916). Morris (1981) found a May cut to be ineffective, while a July cut severely reduced numbers of most species for an

extended time. Osborn (1939) stated that early cutting would result in the destruction of many eggs and young but would cause adults to migrate to other pastures, perhaps to cause damage there.

The use of insecticides is another approach to leafhopper control. Osborn (1932) advocated the broadcast spraying of insecticides over pasture lands. Byers and Jung (1979) found that leafhopper numbers were reduced significantly on several grass species when treated with carbofuran. Martin et al. (1980) reported no significant reduction in leafhopper numbers on coastal bermudagrass when treated with trichlorfon and parathion. The use of pesticides, especially those requiring repeated applications, may be limited because forage crops have a low margin of return (Holt and Enkerlin 1979). Painter (1960) additionally warned of the hazard from insecticide residues on forage crops.

Resistant plant varieties might provide the most economical and frequently the only viable alternative for control of pest problems in forages (Holt and Enkerlin 1979). However, relatively few insect resistant grass cultivars have been developed and released. Most of the work in the development of resistant grass varieties has been for insect pests other than leafhoppers. Potato, alfalfa, bean, sugar beet, cotton and cranberry are the major crops that have been screened for resistance to leafhopper damage (DeLong 1971). Some screening has been done in clover for leafhopper resistant varieties (Jewett 1932, Poos and Johnson 1936).

## V. SAMPLING TECHNIQUES

Three major techniques for sampling leafhoppers and other arthropods from grassland communities have been: (1) sweep net, (2) suction sampler, and (3) quicktrap + D-Vac<sup>®</sup> (Turnbull and Nicholls 1966). According to Southwood (1978) the advantages of a sweep net are: (1) simplicity and speed; (2) a high return for a small cost; and (3) collection of comparatively sparsely dispersed species. The disadvantages of the sweep net are: (1) samples cannot be referred to clearly defined areas; (2) samples are better representative of the fauna in the upper part of the plant cover than the lower part; (3) errors caused by type, height and density of vegetation and by time of sampling are higher than with a vacuum method; and (4) a greater part of the arthropods evade capture (Heikinheimo and Raatikainen 1962).

The suction sampler that has been used most frequently was devised by Dietrick (1961). Called the D-Vac, this device consists of a backpack-mounted gasoline engine with a motor fan adapted to vacuum arthropods from herbage. The advantages of the suction method are: (1) samples are obtained from well-defined areas; (2) arthropods of the different vertical layers in the field strata and even of the ground will be equally and well represented in the samples; (3) representatives of most arthropod groups are caught more quantitatively than by the sweep net; (4) samples can be taken from plots without plant cover or covered by low vegetation; and (5) errors introduced by weather components, time of day, type, density and height of vegetation, and sampler are less than with a sweep net (Heikinheimo and Raatikainen 1962).

Turnbull and Nicholls (1966) found that the D-Vac suction sampler had two disadvantages: (1) it was difficult to operate the machine without disturbing the more active arthropods because of the noise; and (2) the suction was insufficient to pick up heavy-bodied insects, insects that clung tightly to the vegetation, or insects that burrowed under the surface humus.

Another method used to collect leafhoppers from grass is a combination of the D-Vac and a quick-trap. Designed by Turnbull and Nicholls (1966), this method consists of a trap made of netting and a wooden ring that is held above the area to be sampled by a tripod. The trap is connected to tension springs so that it will snap down quickly after being triggered. The D-Vac is used to collect the trapped insects. Southwood (1978) reported that this method is probably the most efficient technique for sampling the fauna of herbage. However, this method is time consuming and prevents the collection of large numbers of samples.

## CHAPTER III

### MATERIALS AND METHODS

#### I. STUDY SITE

The study site for this project was at The University of Tennessee's Plateau Experiment Station, Grasslands Unit, located 12.9 km south of Crossville, Cumberland County, Tennessee. The elevation of the site was 603.5 m above sea level. The predominant soil type of this area is Hartsells loam. A mixed tall fescue pasture, designated as field 5, was selected as the study area. Composed primarily of tall fescue, Festuca arundinacea Schreb., mixed with Kentucky bluegrass, Poa pratensis L., orchardgrass, Dactylis glomerata L., red clover, Trifolium pratense L., and white clover, Trifolium repens L., this pasture had been grazed on an irregular basis by beef cattle. Prior to beginning the experiment the southwest leg of the experimental area was fenced off from the rest of the pasture to separate the plot area from that part of the pasture that would continue to be grazed. The experimental area comprised approximately 0.2 ha and was bordered to the north by a grazed pasture, to the south by a dirt road and woods, to the east by a wooded area, and to the west by a corn field.

#### II. EXPERIMENTAL DESIGN

Plots, 5.5 m by 6.1 m, were laid out in the fenced off section of the pasture. Three treatments were replicated 12 times in a randomized

complete block design. A 1.8 m alleyway separated blocks. In 1980 the three treatments were: (1) Untreated check, (2) Counter<sup>®</sup> 15G (terbufos) applied approximately monthly at a rate of 2.2 kg a.i./ha, and (3) Malathion 57EL applied every two weeks at a rate of 1.1 kg a.i./ha. Application dates for Counter in 1980 were 27 May, 1 July, 19 August, and 16 September; for malathion the dates were 27 May, 10 June, 1 July, 15 July, 19 August, 2 September, and 16 September. In 1981 Cygon<sup>™</sup> 400 (dimethoate) was substituted for the malathion at the rate of 0.6 kg a.i./ha. The same application interval was used. Application dates for Counter in 1981 were 22 May, 24 June, 22 July, and 19 August; for Cygon the dates were 22 May, 24 June, 8 July, 22 July, 5 August, and 19 August. The malathion and Cygon were applied using a bicycle-mounted CO<sub>2</sub>-pressurized 1.8 m long boom sprayer. A constant pressure of 206,844 pascals was maintained. The granular Counter was applied using the "shaker-jar" technique which incorporated the use of baby food jars with perforated lids. The jars containing the Counter were shaken over the respective plots until the granules were evenly dispensed.

In addition to the main plots discussed above, eight side plots, also 5.5 m by 6.1 m, were laid out. These side plots were not treated with insecticides so they could be used to check the effects of cutting on leafhoppers. In order to make comparisons as to the effect of cutting on leafhopper populations, side plots 1, 3, 5, and 7 were cut on 26 August 1980, while side plots 2, 4, 6, and 8 were left uncut. This same procedure was repeated on 18 June 1981.

Samples were taken using a D-Vac suction sampler with a 0.09 m<sup>2</sup> head. Each plot was sampled at five spots diagonally by placing the

D-Vac head down on the ground for 30 seconds at each spot. Therefore, a plot sample consisted of the number of adult leafhoppers taken from a  $0.46 \text{ m}^2$  area. Because this experiment was part of a larger experiment using the same plots, only blocks 2, 4, 6, and 11 of the main plots were sampled. All of the eight side plots were sampled. Also, a sample was taken from the grazed portion of the original pasture to check for the effects of grazing on leafhoppers. In 1980, samples were taken on the same dates as the application of the malathion as well as on 29 July and 7 October. A sample was not taken from the grazed pasture on 15 July 1980 because of equipment failure. In 1981, samples were taken on the same dates as the application of the Cygon, with the exception of 24 June and additional samples were taken on 11 June and 9 September. Samples were always taken prior to the application of the insecticides. Each plot sample was put into individual 0.47 l ice cream cartons in the field. These cartons were returned to the laboratory and frozen until the insects were sorted and counted.

Major insect groups were identified and counted. Adult leafhoppers were identified by the author using DeLong (1916, 1948), Oman (1949), and Beirne (1956) as the primary sources. Confirmation of identification was made by Dr. Paul H. Freytag of the Department of Entomology, University of Kentucky, Lexington.

Yields of plots were determined by clipping them with a 53 cm diameter Sensation<sup>®</sup> lawn mower fitted with a catch bag. Each plot was mowed down to a height of approximately 10 cm. All of the main plots were sampled for yield. In 1980, yields were determined by mowing two

strips (1.1 m by 6.1 m total) in the middle of each plot. In 1981 only one strip (0.55 m by 6.1 m) was mowed from each plot. Green weights were determined in the field using a milk scale hung from a tripod, after which subsamples were removed for drying. Yields were based on dry matter weights.

In 1980 yields were determined only once, on 30 July. In 1981 yields were determined twice, on 12 June and 10 September. After yields were taken from all of the main plots, the remainder of each plot was clean-cut with the same mower and all clippings removed. The main plots were also clean-cut on 10 May 1980 and 17 March 1981. All side plots were clean-cut with the main plots on 17 March 1981.

Leafhopper counts and yield data were subjected to an analysis of variance. Where there were significant F-values, means were separated using the LSD Test.

## CHAPTER IV

### RESULTS AND DISCUSSION

A total of 33 species representing 27 genera in 6 subfamilies of Cicadellidae were collected in this study (Table 1). Quisenberry et al. (1979) identified at least 54 species representing 37 genera in 8 subfamilies collected from 7 different mixed tall fescue pastures in Missouri. In the Tennessee study a species was considered abundant if it represented at least 5% of the total number of leafhopper specimens collected from either the untreated main plots, the cut side plots, the uncut side plots, or the grazed pasture in either 1980 or 1981. Eight species met one of these criteria and will be discussed individually. These species were: Agallia constricta Van Duzee, Aphrodes serratulae (Fabricius), Dikraneura angustata Ball & DeLong, Forcipata loca DeLong & Caldwell, Latalus sayi (Fitch), Polyamia weedi (Van Duzee), Endria inimica (Say), and Amblysellus curtisii (Fitch). Quisenberry et al. (1979) also determined that there were eight species which could be considered abundant. Of these eight species, five were common to both studies. These were: Agallia constricta, Forcipata loca, Latalus sayi, Polyamia weedi, and Endria inimica. The relative abundance of the species determined to be abundant in the Tennessee study is presented in Table 2. These species are listed according to the phylogeny of Oman (1949) and will be discussed in this sequence. However, this discussion

Table 1. Leafhopper species collected with a D-Vac from a mixed tall fescue pasture on the Cumberland Plateau in Tennessee in 1980 and 1981.

---

Agallinae

Agallini

Agallia constricta Van Duzee<sup>1</sup>

Agallia quadripunctata (Provancher)

Aceratigallia sanguinolenta (Provancher)

Aphrodinae

Aphrodini

Aphrodes serratulae (Fabricius)<sup>1</sup>

Xestocephalinae

Xestocephalini

Xestocephalus pulicarius Van Duzee

Tettigellinae

Tettigellini

Tylozygus bifidus (Say)

Draeculacephala antica (Walker)

Graphocephala versuta (Say)

Cicadellinae

Dikraneurini

Dikraneura angustata Ball & DeLong<sup>1</sup>

Forcipata loca DeLong & Caldwell<sup>1</sup>

Empoasca fabae group

Cicadellini

Erythroneura nigra (Gillete)

Deltocephalinae

Scaphytopiini

Cloanthus frontalis (Van Duzee)

Balcluthini

Balclutha abdominalis (Van Duzee)

Macrostelini

Macrosteles divisus (Uhler)

Davisonia snowi (Dorst)

Table 2. Relative abundance (expressed as percent) of the leafhopper species that represent at least 5% of the total collected with a D-Vac from either the untreated main plots, the cut side plots, the uncut side plots, or the grazed portion of a mixed tall fescue pasture on the Cumberland Plateau in 1980 or 1981.

| Species                     | Year | Percent collected from: |      |                   |  | Grazed pasture |
|-----------------------------|------|-------------------------|------|-------------------|--|----------------|
|                             |      | Untreated main plots    | Cut  | Side plots: Uncut |  |                |
| <u>Agallia constricta</u>   | 1980 | 44.4                    | 19.0 | 20.3              |  | 14.9           |
|                             | 1981 | 2.9                     | 6.6  | 4.9               |  | 20.1           |
| <u>Aphrodes serratulae</u>  | 1980 | 1.8                     | 1.6  | 2.9               |  | 0.6            |
|                             | 1981 | 41.0                    | 34.0 | 20.7              |  | 1.2            |
| <u>Dikraneura angustata</u> | 1980 | 3.6                     | 3.7  | 4.2               |  | 0.9            |
|                             | 1981 | 3.9                     | 11.5 | 13.9              |  | 5.3            |
| <u>Forcipata loca</u>       | 1980 | 8.4                     | 11.7 | 10.4              |  | 9.7            |
|                             | 1981 | 4.3                     | 9.5  | 10.3              |  | 1.2            |
| <u>Latalus sayi</u>         | 1980 | 9.1                     | 17.2 | 12.5              |  | 4.6            |
|                             | 1981 | 7.2                     | 7.9  | 4.1               |  | 6.2            |
| <u>Polyamia weedi</u>       | 1980 | 17.3                    | 13.8 | 16.0              |  | 31.2           |
|                             | 1981 | 28.5                    | 20.6 | 18.0              |  | 25.4           |
| <u>Endria inimica</u>       | 1980 | 0.5                     | 0.3  | 0.1               |  | 5.2            |
|                             | 1981 | 7.1                     | 1.8  | 0.5               |  | 19.5           |
| <u>Amblysellus curtisii</u> | 1980 | 6.1                     | 24.8 | 19.8              |  | 18.2           |
|                             | 1981 | 0.3                     | 3.2  | 11.3              |  | 6.2            |
| Total number of             | 1980 | 1024                    | 754  | 767               |  | 330            |
| leafhoppers collected       | 1981 | 883                     | 442  | 556               |  | 338            |

will be preceded by a review of the trends of total leafhopper numbers collected and the effects of the insecticides on total leafhopper numbers and on yield.

#### I. TRENDS OF TOTAL LEAFHOPPER NUMBERS

Greater numbers of leafhoppers were collected from the main plots in 1980 (Fig. 1A) than in 1981 (Fig. 1B). In 1980 leafhopper numbers peaked twice (27 May, 15 July) (Fig. 1A). In 1981 the total number of leafhoppers collected at the start of the season from the main plots was considerably less than in 1980. A large peak in the numbers collected from the untreated main plots occurred on 11 June 1981. This peak was primarily a result of Aphrodes serratulae which comprised 67% of the leafhoppers collected from those plots.

In the side plots in 1980 there were three peaks (27 May, 15 July, 16 September) in the total number of leafhoppers collected (Fig. 1C). In 1981 there was a major peak on 11 June (Fig. 1D). As in the main plots, there were considerably fewer leafhoppers collected from the side plots at the start of the season in 1981 than in 1980. For several weeks following the cuts in both 1980 and 1981 fewer leafhoppers were collected from the cut side plots than from the uncut side plots. However, in 1981 on the 5 August sampling date (Fig. 1D), more leafhoppers were collected from the cut side plots than from the uncut side plots suggesting that the cut side plots may have provided a better environment.

Fig. 1. Total number of leafhoppers collected with a D-Vac from a mixed tall fescue pasture on the Cumberland Plateau in Tennessee in 1980 and 1981. (Arrows on graphs denote when cuts occurred.)

A - B Total number of leafhoppers collected from main plots in 1980 (A) and 1981 (B).

C - D Total number of leafhoppers collected from side plots in 1980 (C) and 1981 (D).

E - F Total number of leafhoppers collected from grazed pasture in 1980 (E) and 1981 (F).

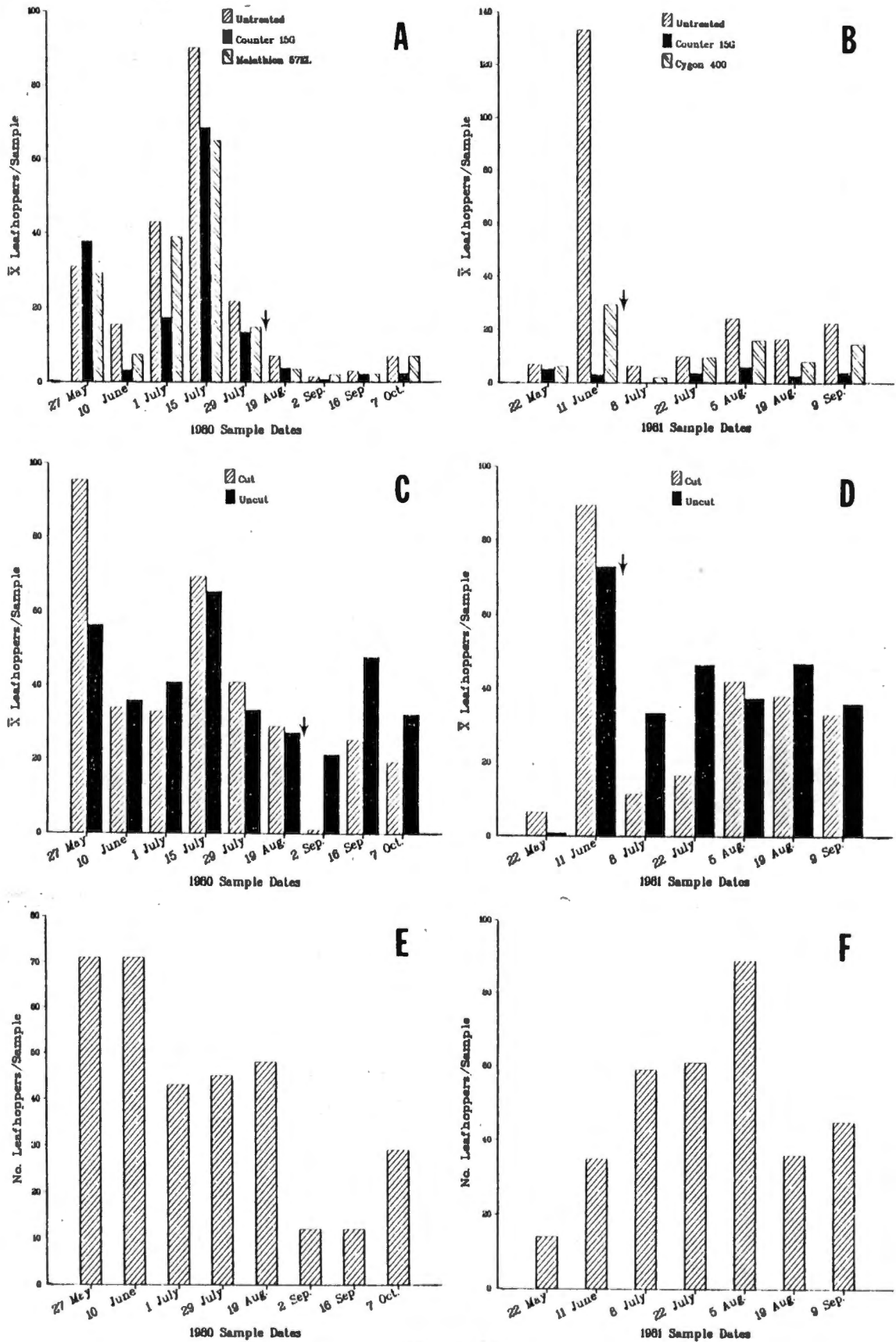


Figure 1.

In the grazed pasture in 1980 there were three peaks (27 May or 10 June, 19 August, 7 October) in the total number of leafhoppers collected (Fig. 1E). In 1981 peak numbers of leafhoppers were collected on 5 August (Fig. 1F).

## II. EFFECTS OF INSECTICIDES ON TOTAL LEAFHOPPER NUMBERS

The major objective of the insecticide test was to determine if the entire leafhopper complex could be significantly reduced in number. The abundant species were also analyzed individually to determine if there were significant differences as a result of the insecticides. This will be discussed in the section entitled "NOTES ON INDIVIDUAL SPECIES."

The 1980 data are presented in Table 3. There were significant differences in leafhopper numbers on only two sampling dates in 1980, 10 June and 1 July. In both cases leafhopper numbers were significantly lower than the untreated check in the plots treated with Counter. The numbers collected from the malathion-treated plots were not significantly different than the untreated check.

The 1981 data are presented in Table 4. Leafhopper numbers were significantly lower than the untreated check in both the Counter-treated plots and the Cygon-treated plots on 11 June and 8 July. Also leafhopper numbers were significantly less in the Counter-treated plots on 5 August and 9 September. It can be noted that significant differences were detected on only those sample dates which were approximately two weeks after the Counter was applied.

Table 3. Effect of insecticides, applied to a mixed tall fescue pasture on the Cumberland Plateau, on leafhopper density, 1980.

| Treatment                                       | Mean <sup>1</sup> leafhoppers/sample on (sample date): |            |           |            |            |            |           |            |           |
|-------------------------------------------------|--------------------------------------------------------|------------|-----------|------------|------------|------------|-----------|------------|-----------|
|                                                 | May<br>27                                              | June<br>10 | July<br>1 | July<br>15 | July<br>29 | Aug.<br>19 | Sep.<br>2 | Sep.<br>16 | Oct.<br>7 |
| Counter 15G <sup>2</sup><br>(2.2 kg a.i./ha)    | 37.8a                                                  | 3.3a       | 17.5a     | 68.5a      | 13.5a      | 3.8a       | 0.8a      | 2.3a       | 2.5a      |
| Malathion 57EL <sup>3</sup><br>(1.1 kg a.i./ha) | 29.3a                                                  | 7.5ab      | 39.0 b    | 65.0a      | 14.8a      | 3.5a       | 2.0a      | 2.3a       | 7.0a      |
| Untreated check                                 | 31.0a                                                  | 15.5 b     | 43.0 b    | 90.0a      | 21.8a      | 7.0a       | 1.5a      | 3.0a       | 7.0a      |

<sup>1</sup>Numbers are the means of four replicates. Column means followed by a common letter are not significantly different by the LSD Test ( $P = 0.05$ ).

<sup>2</sup>Counter applied on 27 May, 1 July, 19 August, and 16 September.

<sup>3</sup>Malathion applied on 27 May, 10 June, 1 July, 15 July, 19 August, 2 September, and 16 September.

Table 4. Effect of insecticides, applied to a mixed tall fescue pasture on the Cumberland Plateau, on leafhopper density, 1981.

| Treatment                                    | Mean <sup>1</sup> leafhoppers/sample on (sample date): |            |           |            |           |            |           |
|----------------------------------------------|--------------------------------------------------------|------------|-----------|------------|-----------|------------|-----------|
|                                              | May<br>22                                              | June<br>11 | July<br>8 | July<br>22 | Aug.<br>5 | Aug.<br>19 | Sep.<br>9 |
| Counter 15G <sup>2</sup><br>(2.2 kg a.i./ha) | 5.3a                                                   | 3.5a       | 0.3a      | 4.0a       | 6.3a      | 3.0a       | 4.3a      |
| Cygon 400 <sup>3</sup><br>(0.6 kg a.i./ha)   | 6.8a                                                   | 20.5a      | 2.3a      | 9.8a       | 16.3ab    | 8.3a       | 14.8ab    |
| Untreated check                              | 7.0a                                                   | 133.0 b    | 6.5 b     | 10.3a      | 24.5 b    | 16.8a      | 22.8 b    |

<sup>1</sup>Numbers are the means of four replicates. Column means followed by a common letter are not significantly different by the LSD Test ( $P = 0.05$ ).

<sup>2</sup>Counter applied on 22 May, 24 June, 22 July, and 19 August.

<sup>3</sup>Cygon applied on 22 May, 24 June, 8 July, 22 July, 5 August, and 19 August.

Of the three insecticides evaluated, Counter significantly reduced the numbers of leafhoppers collected on the most sampling dates. Malathion was replaced with Cygon in 1981 because of Cygon's systemic action and longer residual effect, but neither insecticide was as effective as Counter.

### III. EFFECTS OF INSECTICIDES ON YIELD

Yield data are presented in Table 5. The only significant increase in yield was in the plots treated with Counter on the 30 July 1980 cutting date. This increase may be attributable to the control of other insects as well as leafhoppers because the insecticides used are effective on many different insects.

### IV. NOTES ON INDIVIDUAL SPECIES

#### Agallia constricta Van Duzee

Agallia constricta is one of the very abundant species found in Tennessee (DeLong 1916) and throughout the southern states (Osborn 1939). It apparently has a large variety of host plants but has been noted as particularly abundant on soybeans and other various forage legumes (Osborn 1939). It is a vector of potato yellow-dwarf virus and clover wound tumor virus (Maramorosch and Harris 1979).

Agallia constricta represented the highest percentage (44.4%) of the species collected from the untreated main plots in 1980. It was also abundant in the side plots and the grazed pasture during that year. However, in 1981 the relative abundance of this species was much less in

Table 5. Yields (kg/ha) taken from insecticide treated plots in a mixed tall fescue pasture on the Cumberland Plateau in 1980 and 1981.

| Treatment                          | Mean yield <sup>1</sup> (kg/ha) on (cutting dates): |              |              |
|------------------------------------|-----------------------------------------------------|--------------|--------------|
|                                    | 30 July 1980                                        | 12 June 1981 | 10 Sep. 1981 |
| Counter 15G<br>(2.2 kg a.i./ha)    | 2343.2a                                             | 3340.9a      | 2656.0a      |
| Malathion 57EL<br>(1.1 kg a.i./ha) | 2141.7ab                                            | ————         | ————         |
| Cygon 400<br>(0.6 kg a.i./ha)      | ————                                                | 3201.1a      | 2641.9a      |
| Untreated check                    | 1986.1 b                                            | 2949.5a      | 2502.2a      |

<sup>1</sup>Numbers are the means of 12 replicates. Column means followed by a common letter are not significantly different by the LSD Test (P = 0.05).

the untreated main plots and the side plots, but was higher in the grazed pasture. As the main plots and side plots were clean cut on 17 March 1981, this may be an indication that this species overwinters in the egg stage. An early season cut may destroy many eggs thereby reducing the population.

Insecticide treatments did not significantly reduce the numbers of this species in either 1980 (Fig. 2A) or 1981 (Fig. 2B). The effects of cutting later in the season were inconclusive for this species because the numbers collected were low in the side plots when the cuts occurred both years (Figs. 2C and 2D).

A peak in the collected numbers occurred around mid-July both years in the main plots (Figs. 2A and 2B) and side plots (Figs. 2C and 2D). In the grazed pasture a peak occurred in the numbers collected in late-July 1980 (Fig. 2E) and in early-July in 1981 (Fig. 2F). In preliminary sampling done on 22 April 1980 in the main plots, numerous specimens of A. constricta were collected. Because another peak in the numbers collected did not occur until mid-July, this may indicate that this species can have two generations/year.

#### Aphrodes serratulae (Fabricius)

Information on this species is scarce. Aphrodes serratulae normally occurs on the surface of the ground, among grass roots and under litter, and probably feeds on grasses. All of the North American species in this genus also inhabit Europe, and it is possible that some or all of them may be artificial introductions (Beirne 1956). This may

Fig. 2. Seasonal abundance of Agallia constricta Van Duzee collected with a D-Vac from a mixed tall fescue pasture on the Cumberland Plateau in Tennessee in 1980 and 1981. (Arrows on graphs denote when cuts occurred.)

- A - B Seasonal abundance of A. constricta collected from main plots in 1980 (A) and 1981 (B).
- C - D Seasonal abundance of A. constricta collected from side plots in 1980 (C) and 1981 (D).
- E - F Seasonal abundance of A. constricta collected from grazed pasture in 1980 (E) and 1981 (F).

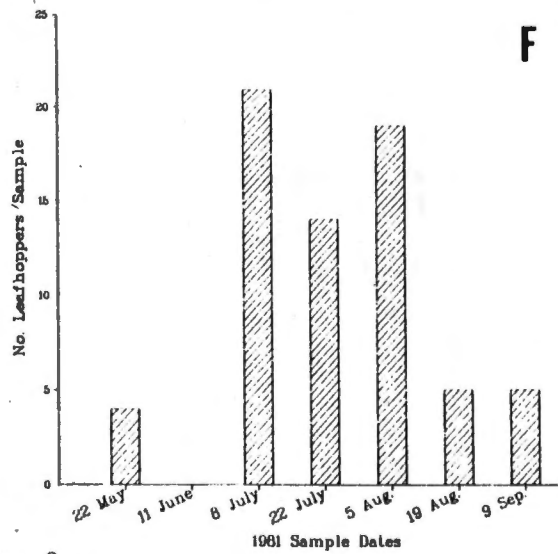
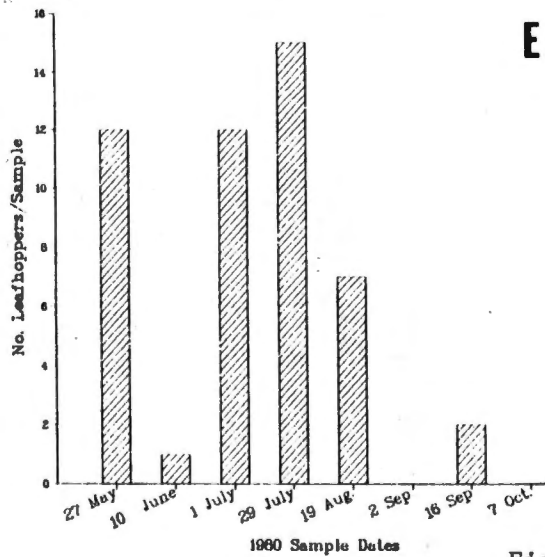
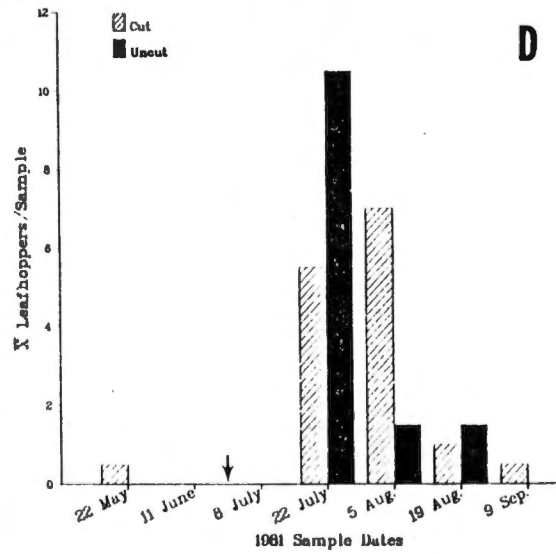
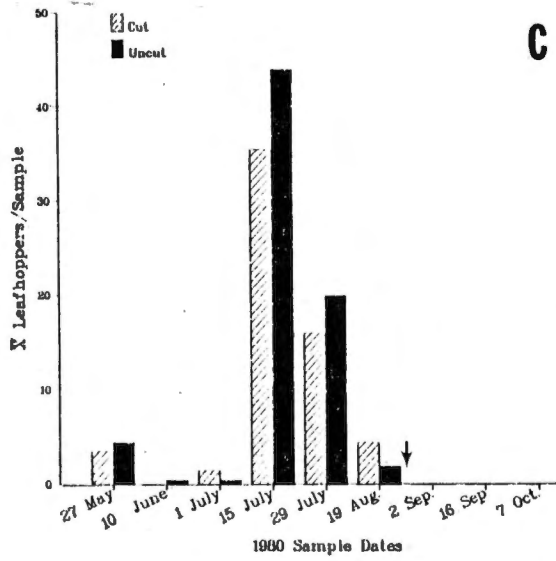
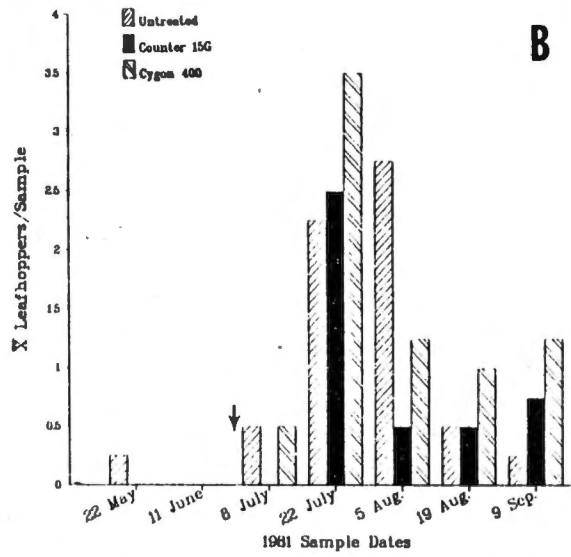
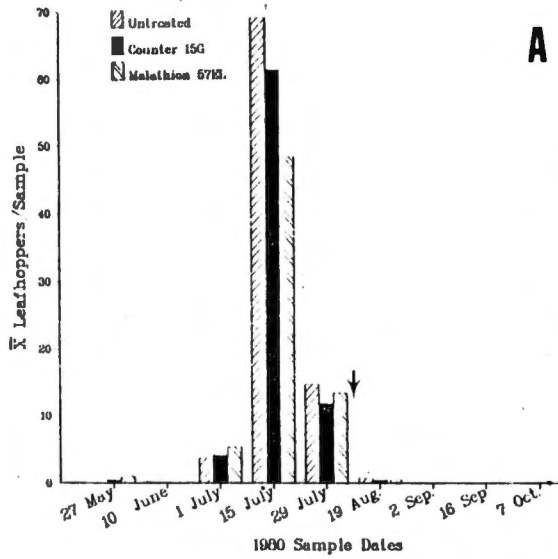


Figure 2.

account for the fact that DeLong (1916) did not find this species in his leafhopper survey of Tennessee.

Aphrodes serratulae represented the highest percentage of the individuals collected in the untreated main plots (41%) and side plots (cut 34%, uncut 20.7%) in 1981. The relative number collected from the untreated main plots and the side plots was very low in 1980, and this was also the case in the grazed pasture both years (Table 2, p. 17).

This species was not significantly reduced in numbers by the insecticide treatments in 1980 (Fig. 3A). However, in 1981 this species was significantly reduced in numbers in both the Counter- and Cygon-treated plots on the 11 June sampling date (Fig. 3B). The numbers collected of this species were very low when the cut occurred in 1980 (Fig. 3C) and were decreasing in 1981 when the cut occurred (Fig. 3D) so a valid conclusion cannot be drawn as to the effect of cutting.

A peak in the numbers collected of A. serratulae occurred on 11 June 1981 in the main plots and side plots and then decreased rapidly (Figs. 3B and 3D). The numbers collected were too low in all other areas sampled to determine when a peak may have occurred. It appears that this species has one generation/year. In 1980 several exuviae were found in the 10 June samples that appeared to be this species, so it is possible that the peak was missed that year. Therefore, to adequately sample for A. serratulae, at least weekly sampling in June would be necessary.

Fig. 3. Seasonal abundance of Aphrodes serratulae (Fabricius) collected with a D-Vac from a mixed tall fescue pasture on the Cumberland Plateau in Tennessee in 1980 and 1981. (Arrows on graphs denote when cuts occurred.)

- A - B Seasonal abundance of A. serratulae collected from main plots in 1980 (A) and 1981 (B).
- C - D Seasonal abundance of A. serratulae collected from side plots in 1980 (C) and 1981 (D).
- E - F Seasonal abundance of A. serratulae collected from grazed pasture in 1980 (E) and 1981 (F).

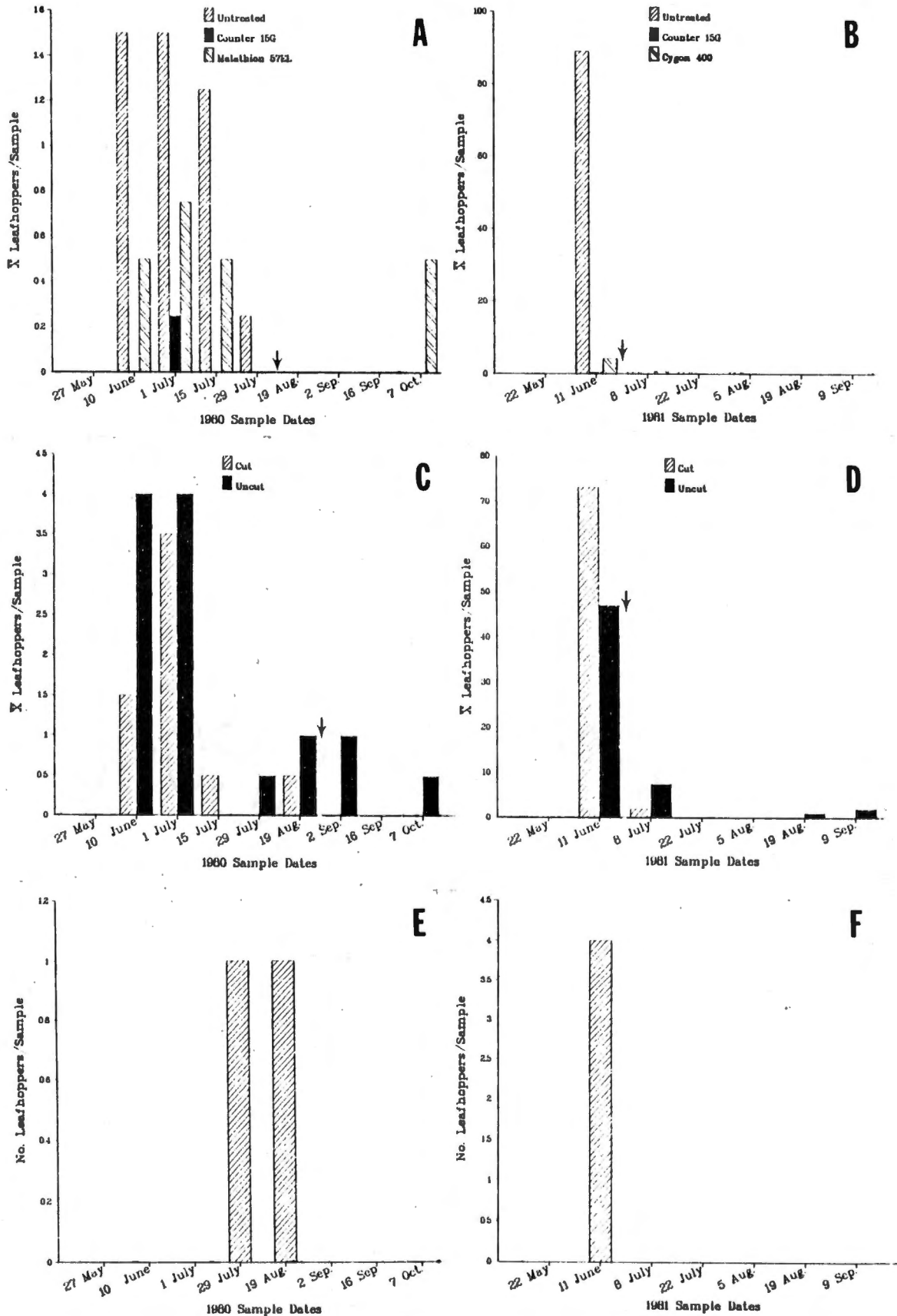


Figure 3.

Dikraneura angustata Ball & DeLong

Dikraneura angustata represented a low percentage of the total collected from the untreated main plots and the grazed pasture both years and from the side plots in 1980 (Table 2, p. 17). Overall, the relative abundance of this species increased in 1981, which was most noticeable in the side plots (Table 2).

Insecticide treatments did not significantly reduce numbers of this species in 1980 (Fig. 4A) or 1981 (Fig. 4B). This species was not present in sufficient numbers when the cut occurred in 1980 in the side plots (Fig. 4C) to determine the effect of cutting, but in 1981 the numbers collected from the cut side plots were noticeably less than from the uncut side plots for several weeks following the cut (Fig. 4D). However, the relative abundance of this species for the season was approximately the same in both the cut and uncut side plots in 1981 (Table 2) so cutting apparently did not have an overall differential effect.

Dikraneura angustata tended to peak earlier in the season (27 May) in 1980 in the main plots (Fig. 4A) and the side plots (Fig. 4C). In 1981, the peak occurred on 19 August in the main plots (Fig. 4B) and the side plots (Fig. 4D). In the grazed pasture in 1980 (Fig. 4E) there were too few specimens collected to determine a peak, but in 1981 (Fig. 4F) a peak in the numbers collected occurred on 5 August.

Forcipata loca DeLong & Caldwell

Forcipata loca was found in large numbers in tall fescue pastures in a study conducted in Missouri (Quisenberry et al. 1979). In growth

- Fig. 4. Seasonal abundance of Dikraneura angustata Ball & DeLong collected with a D-Vac from a mixed tall fescue pasture on the Cumberland Plateau in Tennessee in 1980 and 1981. (Arrows on graphs denote when cuts occurred.)
- A - B Seasonal abundance of D. angustata collected from main plots in 1980 (A) and 1981 (B).
- C - D Seasonal abundance of D. angustata collected from side plots in 1980 (C) and 1981 (D).
- E - F Seasonal abundance of D. angustata collected from grazed pasture in 1980 (E) and 1981 (F).

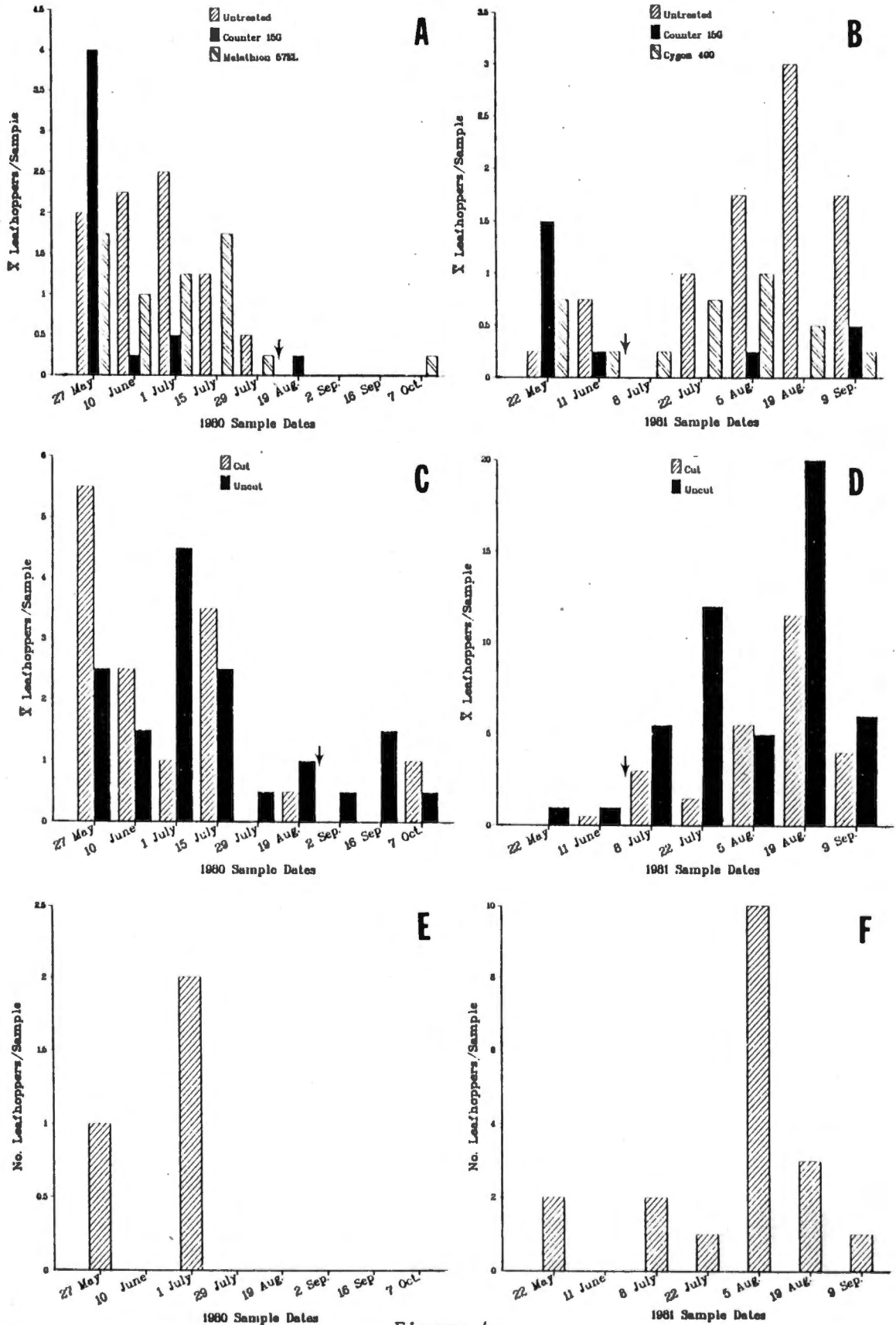


Figure 4.

chamber studies, Quisenberry and Yonke (1981b) determined that at high levels of infestation on tall fescue, this species decreased yield, leaf elongation rates, and the concentration of water soluble carbohydrates in the leaves.

Forcipata loca represented a fairly consistent percentage of the leafhoppers collected from the untreated main plots (8.4%), side plots (cut 11.7%, uncut 10.4%), and grazed pasture (9.7%) in 1980 (Table 2, p. 17). Overall, the relative abundance of this species was less in 1981, especially in the untreated main plots and the grazed pasture.

Insecticide treatments did not significantly reduce numbers of this species in 1980 (Fig. 5A). In 1981 Counter significantly reduced numbers on 19 August (Fig. 5B). Fewer specimens were collected from the cut side plots than the uncut side plots for several weeks following the cut in both 1980 (Fig. 5C) and 1981 (Fig. 5D). However, this species was collected in greater numbers from the cut side plots on 19 August 1981 (Fig. 5D). Because the relative abundance of this species was approximately the same for the season in both the uncut and cut side plots both years (Table 2), cutting apparently did not have an overall differential effect.

The number of F. loca collected peaked around early- to mid-July in all areas sampled in 1980 (Figs. 5A, 5C, and 5E). There was also a smaller peak in the numbers collected in all of the sampled areas on 27 May 1980. In 1981 it was not collected in sufficient quantities in the main plots (Fig. 5B) or the grazed pasture (Fig. 5F) to determine when a peak may have occurred. In the side plots in 1981 (Fig. 5D) this species peaked later in the season (around 19 August) than in 1980.

Fig. 5. Seasonal abundance of Forcipata loca DeLong & Caldwell collected with a D-Vac from a mixed tall fescue pasture on the Cumberland Plateau in Tennessee in 1980 and 1981. (Arrows on graphs denote when cuts occurred.)

- A - B Seasonal abundance of F. loca collected from main plots in 1980 (A) and 1981 (B).
- C - D Seasonal abundance of F. loca collected from side plots in 1980 (C) and 1981 (D).
- E - F Seasonal abundance of F. loca collected from grazed pasture in 1980 (E) and 1981 (F).

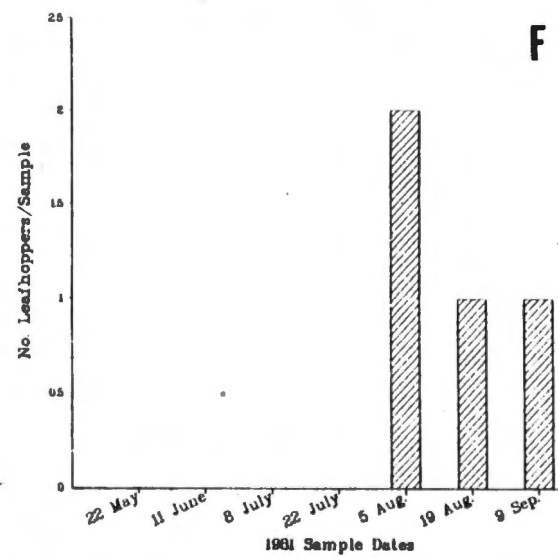
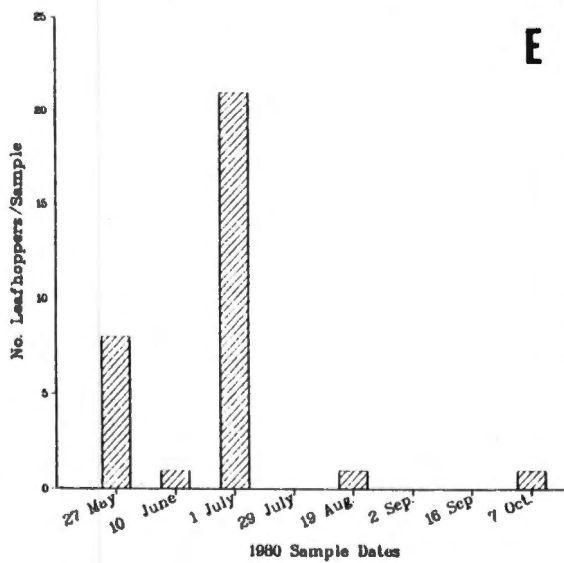
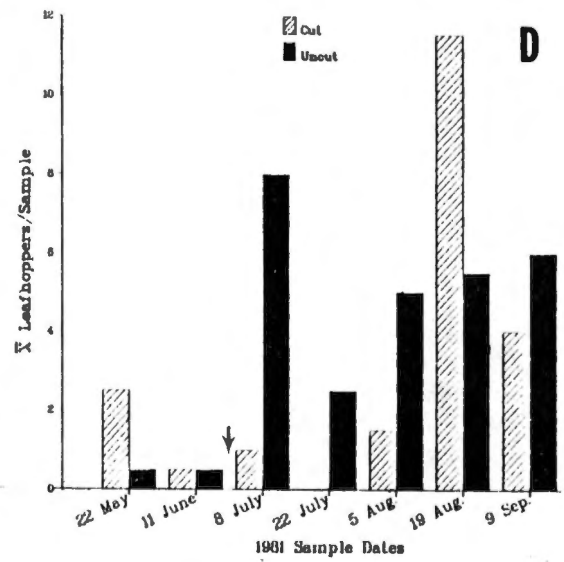
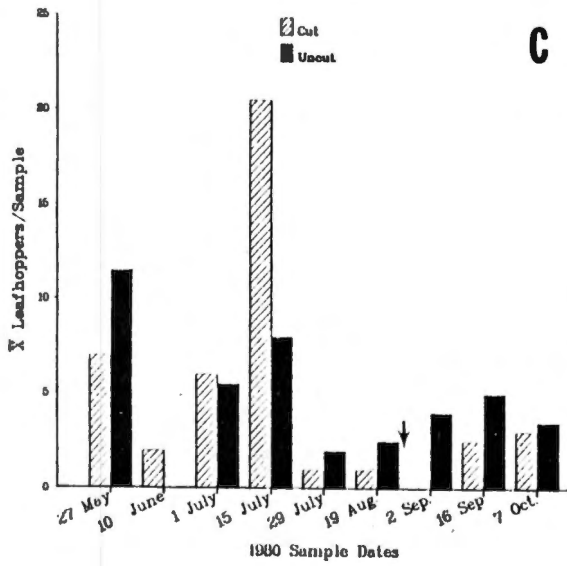
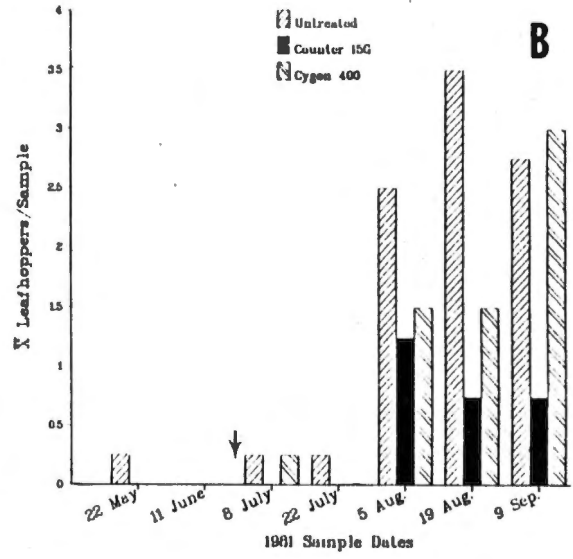
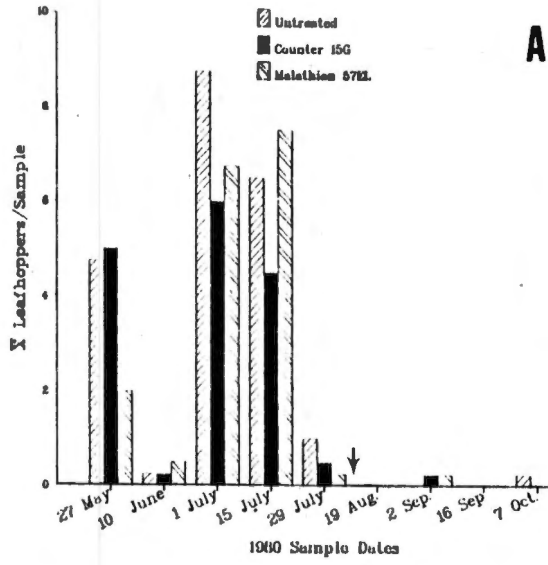


Figure 5.

Latalus sayi (Fitch)

Commonly called Say's leafhopper, L. sayi is a widely distributed species over the eastern and middle western states. This is a common meadow and pasture species occurring on bluegrass and probably several other grass varieties (DeLong 1948). Osborn (1939) reviewed the life history of this species and stated that it was more commonly found in the northern United States. DeLong (1916) found only two specimens of this species in his Tennessee survey.

Latalus sayi represented a fairly consistent percentage of the total leafhoppers collected both years from the untreated main plots (9.1% in 1980, 7.2% in 1981) and the grazed pasture (4.6% in 1980, 6.2% in 1981). However, in the side plots in 1980 the relative abundance of this species was much greater than in 1981 (Table 2, p. 17).

In 1980, Counter and malathion significantly reduced numbers of this species on 1 July, 15 July, 29 July, and 7 October; Counter also significantly reduced the numbers collected on 10 June (Fig. 6A). In 1981, this species was significantly reduced in numbers in the Cygon- and Counter-treated plots on 8 July and 9 September (Fig. 6B). The relative seasonal abundance of this species was greater in the cut side plots than the uncut side plots both years (Table 2), but in 1980 the numbers collected were actually less in the cut side plots than the uncut side plots for several weeks following the cut (Fig. 6C). The reason the percentage figure is greater in the cut side plots in 1980 is because there were greater numbers collected from these plots prior to the cut (Fig. 6C). In 1981 this species was collected in greater numbers from the cut side plots following the cut (Fig. 6D).

- Fig. 6. Seasonal abundance of Latalus sayi (Fitch) collected with a D-Vac from a mixed tall fescue pasture on the Cumberland Plateau in Tennessee in 1980 and 1981. (Arrows on graphs denote when cuts occurred.)
- A - B Seasonal abundance of L. sayi collected from main plots in 1980 (A) and 1981 (B).
- C - D Seasonal abundance of L. sayi collected from side plots in 1980 (C) and 1981 (D).
- E - F Seasonal abundance of L. sayi collected from grazed pasture in 1980 (E) and 1981 (F).

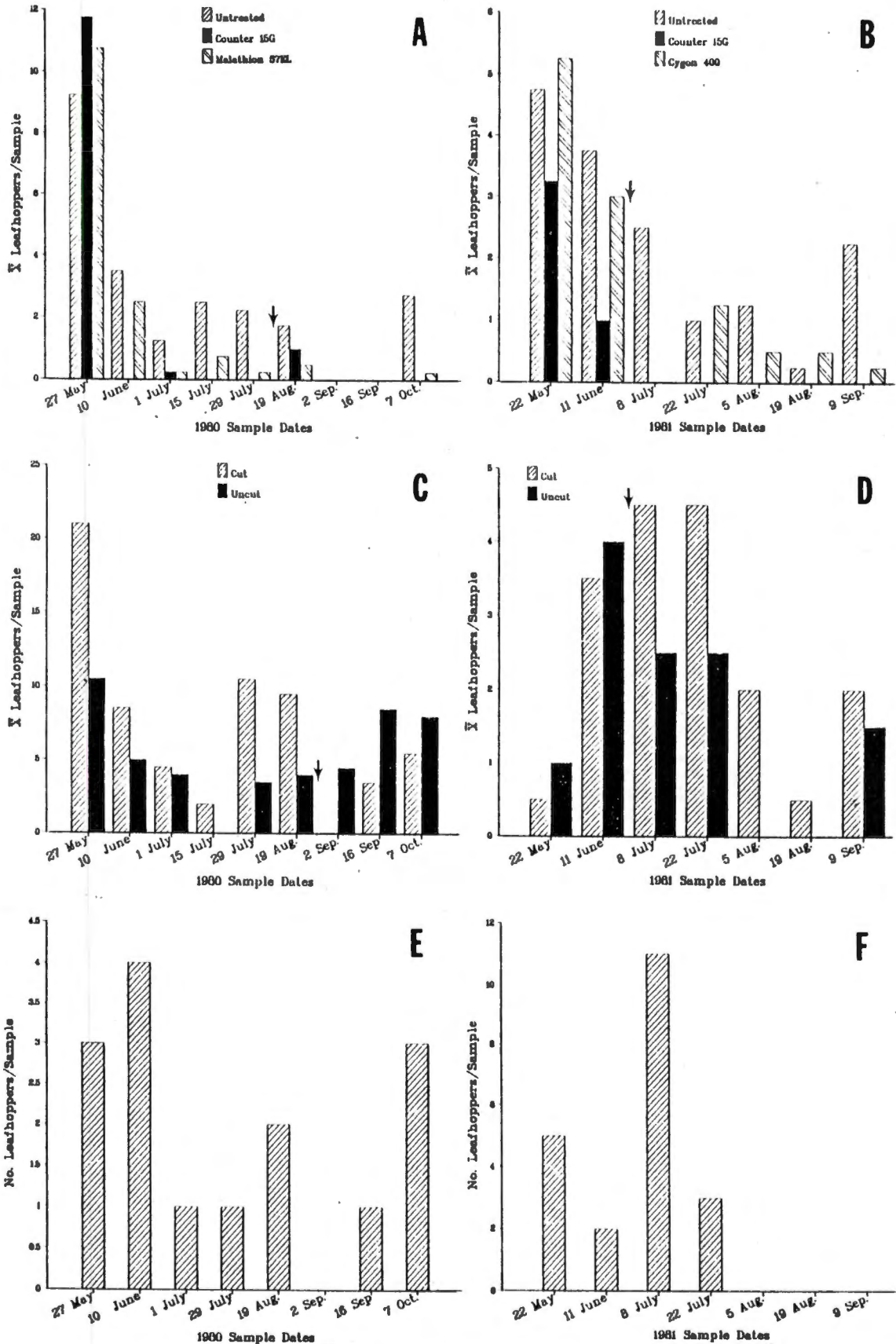


Figure 6.

The numbers collected peaked in late-May in the main plots both years (Figs. 6A and 6B) and in the side plots in 1980 (Fig. 6C). In the side plots in 1981 a peak occurred in mid-July (Fig. 6D). In the grazed pasture this species peaked on 10 June in 1980 (Fig. 6E) and on 8 July in 1981 (Fig. 6F). Because L. sayi was collected in greater numbers at the start of the season and was consistently collected throughout the season, this species probably has more than one generation/year.

Polyamia weedi (Van Duzee)

Polyamia weedi is one of the very common species occurring throughout Tennessee (DeLong 1916) and the eastern United States (DeLong 1948). It does not seem to have a particular host preference and has been found feeding on many different grasses (Brown 1939). DeLong (1916) stated that this is one of the leafhopper pests of most abundance and of greatest economic importance.

This species represented a fairly large percentage of the leafhoppers collected both years from all sample sites (Table 2, p. 17), particularly the grazed pasture in 1980 (31.2%) and the untreated main plots in 1981 (28.5%). In 1980, Counter significantly reduced numbers of this species on 10 June, 1 July, 15 July, 29 July, 19 August, and 7 October; malathion significantly reduced numbers collected on 10 June, 1 July, and 29 July (Fig. 7A). In 1981, both Counter and Cygon significantly reduced the numbers collected on 22 July and 19 August (Fig. 7B). Although the relative seasonal abundance of this species was approximately the same each year in the cut and uncut side plots (Table 2), in 1980 the numbers collected from the cut side plots were

Fig. 7. Seasonal abundance of Polyamia weedi (Van Duzee) collected with a D-Vac from a mixed tall fescue pasture on the Cumberland Plateau in Tennessee in 1980 and 1981. (Arrows on graphs denote when cuts occurred.)

A - B Seasonal abundance of P. weedi collected from main plots in 1980 (A) and 1981 (B).

C - D Seasonal abundance of P. weedi collected from side plots in 1980 (C) and 1981 (D).

E - F Seasonal abundance of P. weedi collected from grazed pasture in 1980 (E) and 1981 (F).

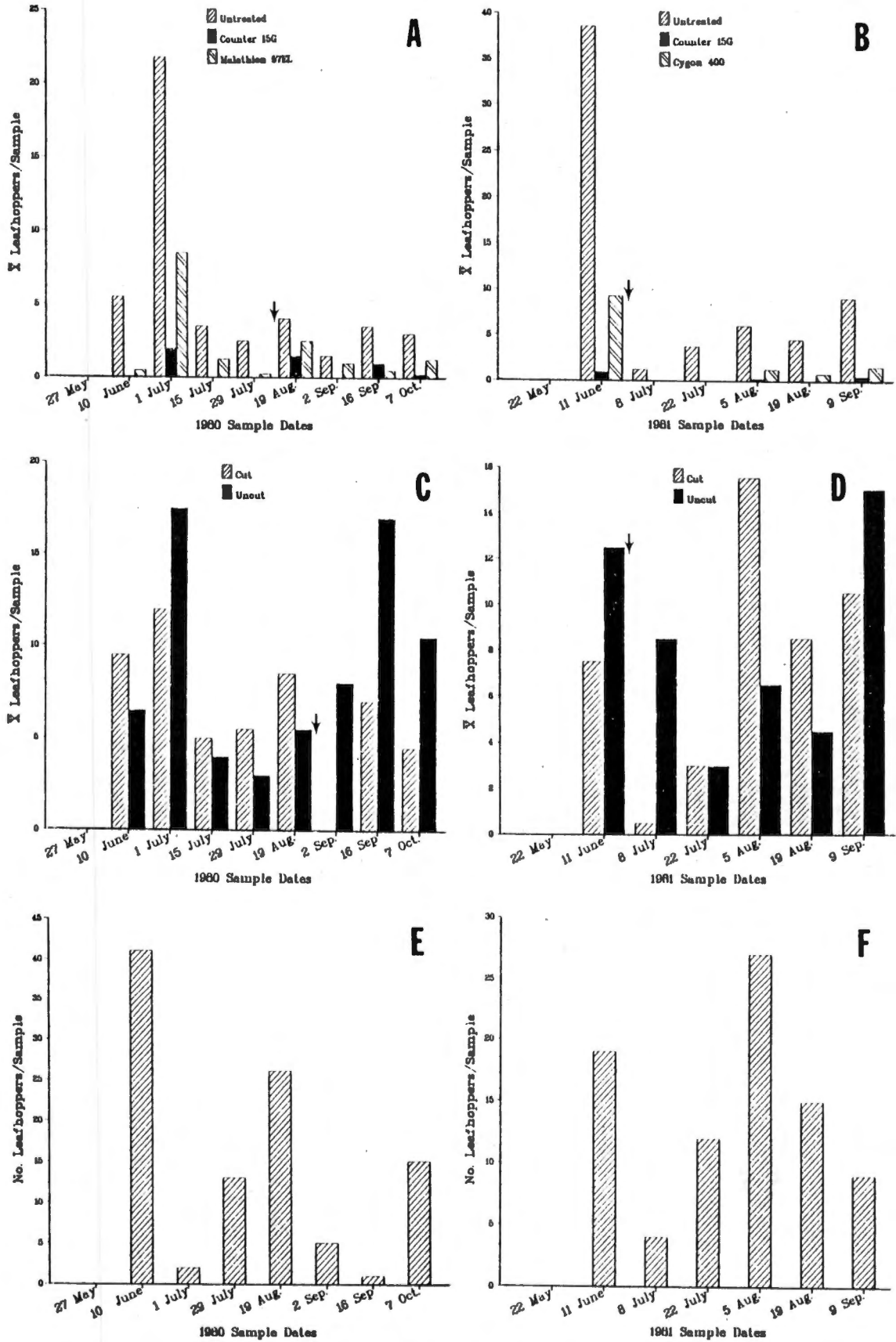


Figure 7.

much less than from the uncut side plots following the cut (Fig. 7C). This was also the case in 1981, but on the 5 August and 19 August sampling dates, this species was collected in greater numbers from the cut side plots (Fig. 7D).

In the main plots there was one major peak in the numbers collected that occurred both years, on 1 July 1980 (Fig. 7A) and on 11 June 1981 (Fig. 7B). In the side plots in 1980 there were two major peaks in the numbers collected, on 1 July and 16 September (Fig. 7C). Three major peaks occurred in 1981 in the side plots, on 11 June, 5 August, and 9 September (Fig. 7D). In the grazed pasture two major peaks occurred both years, on 10 June and 19 August in 1980 (Fig. 7E), and on 11 June and 5 August in 1981 (Fig. 7F). Therefore, P. weedi is probably multivoltine.

#### Endria inimica (Say)

Commonly called the hurtful leafhopper, E. inimica is one of the most common species of North American leafhoppers, and is transcontinental in distribution (DeLong 1948). DeLong (1916) found E. inimica to be one of the most abundant species in Tennessee. Osborn (1939) reviewed the life history of this species and stated that there is perhaps no other species of grass insect of such universal distribution and uniform abundance through the country. Bluegrass appears to be the preferred host (DeLong 1916, Osborn 1939) but the species has been found to feed on many native grasses as well as on wheat, oats, rye, alfalfa, clover, timothy, and other crop plants (Brown 1939). Endria inimica is a vector

of the pathogenic agents causing striate mosaic of wheat and North American aster yellows (Maramorosch and Harris 1979).

This species represented a very low percentage of the leafhoppers collected from the untreated main plots in 1980 and the side plots both years (Table 2, p. 17). The relative abundance of this species was much higher in 1981 in the main plots and the grazed pasture, and it was the third most abundant species in the grazed pasture in 1981 representing 19.5% of the total leafhoppers collected. This may be an indication that grazing has a positive effect on this species.

Insecticide treatments had no significant effects on this species in either 1980 (Fig. 8A) or 1981 (Fig. 8B). As this species was not present in the samples when the cuts occurred both years, and the numbers collected were very low after the cuts (Figs. 8C and 8D), no conclusions could be made on the effects of cutting.

Although E. inimica was collected in low numbers from the main plots and side plots, it could be inferred from the data to be a late season species (Figs. 8A, 8B, 8C, and 8D). In the grazed pasture both years, the numbers collected peaked in late-July (Figs. 8E and 8F). This species appears to have a single generation/year.

#### Amblysellus curtisii (Fitch)

Amblysellus curtisii is quite widely distributed throughout the northern part of the United States (Osborn 1939) but it occurs as well in Tennessee and many parts of the middle West (DeLong 1948). Osborn (1939) briefly discussed the life history of this species. Bluegrass

- Fig. 8. Seasonal abundance of Endria inimica (Say) collected with a D-Vac from a mixed tall fescue pasture on the Cumberland Plateau in Tennessee in 1980 and 1981. (Arrows on graphs denote when cuts occurred.)
- A - B Seasonal abundance of E. inimica collected from main plots in 1980 (A) and 1981 (B).
- C - D Seasonal abundance of E. inimica collected from side plots in 1980 (C) and 1981 (D).
- E - F Seasonal abundance of E. inimica collected from grazed pasture in 1980 (E) and 1981 (F).

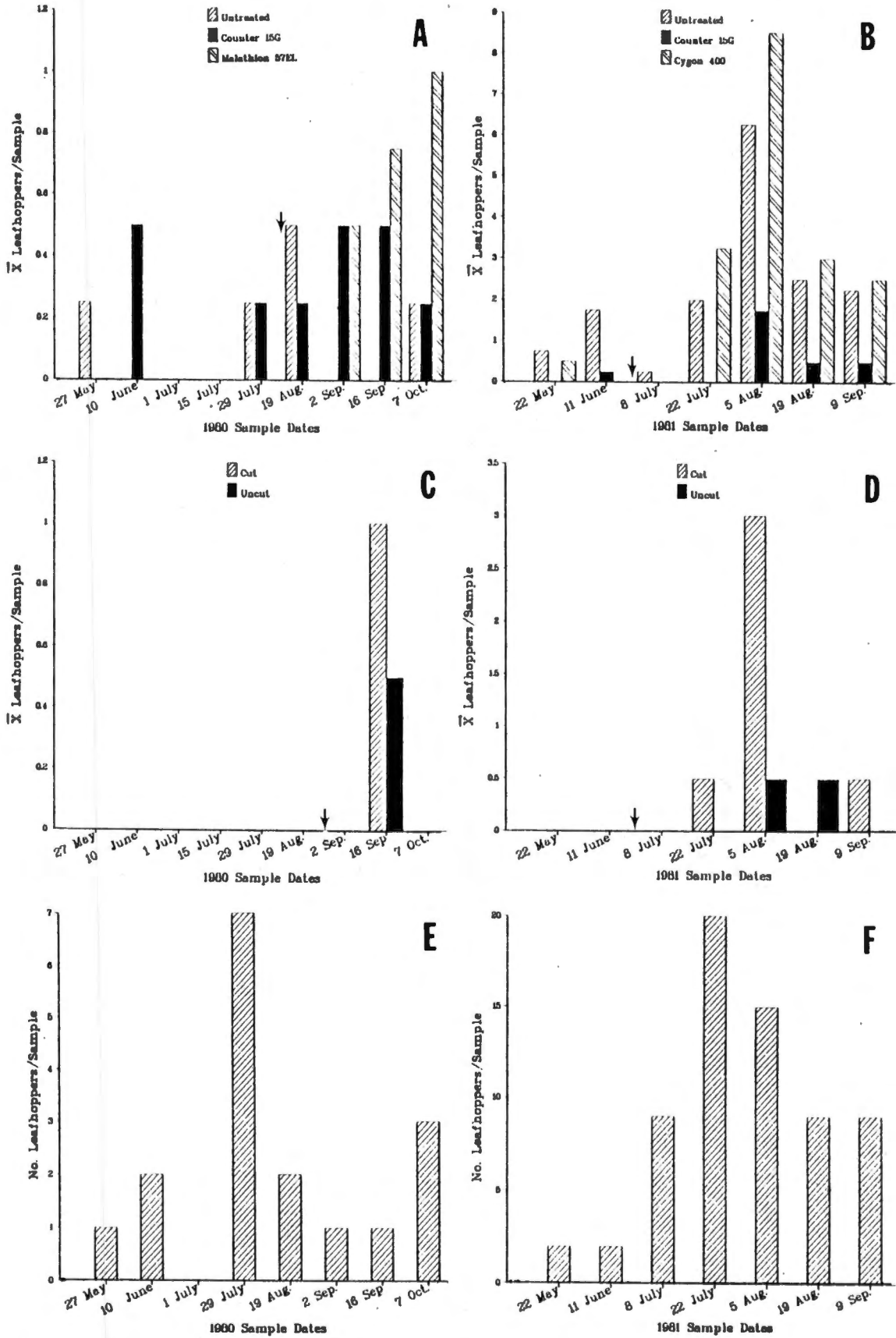


Figure 8.

appears to be the preferred host (Garman 1926, Brown 1939) but it has been found also on small grains and legumes in Illinois (DeLong 1948).

This species represented a fairly high percentage of the leafhoppers collected from the side plots (cut 24.8%, uncut 19.8%) and the grazed pasture (18.2%) in 1980. In 1981 A. curtisii was less abundant in all of the areas samples (Table 2, p. 17).

In 1980 both Counter and malathion significantly reduced numbers of this species on 15 July (Fig. 9A), however, there were very few specimens collected on this date. In 1981 the insecticide treatments had no significant effects on this species (Fig. 9B). There were fewer specimens collected from the cut side plots than the uncut side plots following the cuts both years except for 8 July 1981 (Figs. 9C and 9D).

A peak in the numbers collected occurred on 27 May 1980 in all of the areas sampled (Figs. 9A, 9C, and 9E). In 1981 there were too few specimens collected from the main plots to determine when a peak may have occurred (Fig. 9B). In the side plots in 1981 a peak occurred on 5 August (Fig. 9D). In the grazed pasture in 1981 a peak in the numbers collected occurred on 8 July (Fig. 9F). This species appears to have a single generation/year.

- Fig. 9. Seasonal abundance of Amblysellus curtisii (Fitch) collected with a D-Vac from a mixed tall fescue pasture on the Cumberland Plateau in Tennessee in 1980 and 1981. (Arrows on graphs denote when cuts occurred.)
- A - B Seasonal abundance of A. curtisii collected from main plots in 1980 (A) and 1981 (B).
- C - D Seasonal abundance of A. curtisii collected from side plots in 1980 (C) and 1981 (D).
- E - F Seasonal abundance of A. curtisii collected from grazed pasture in 1980 (E) and 1981 (F).

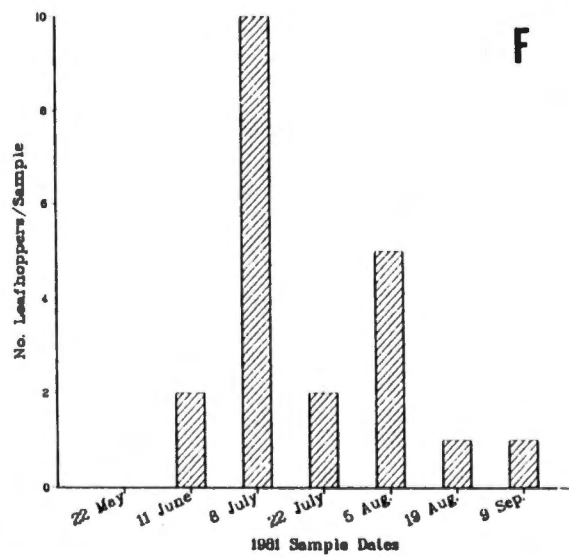
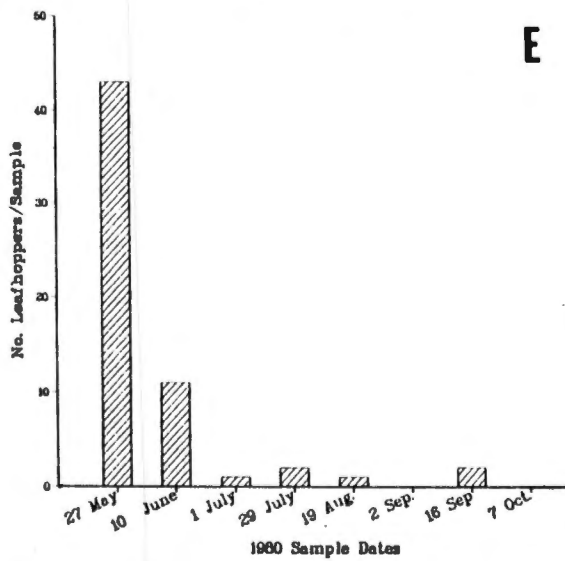
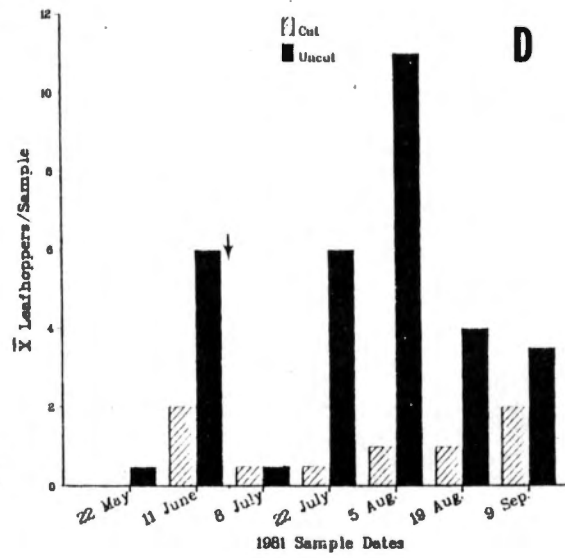
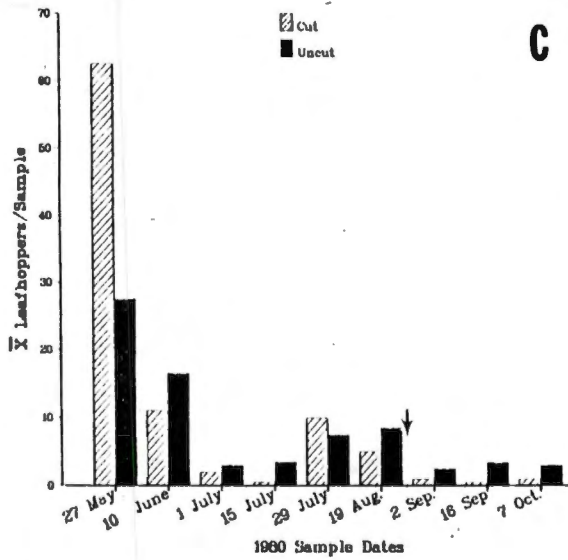
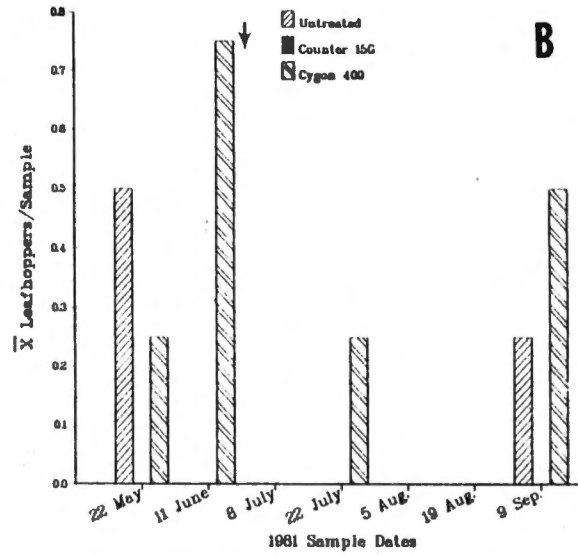
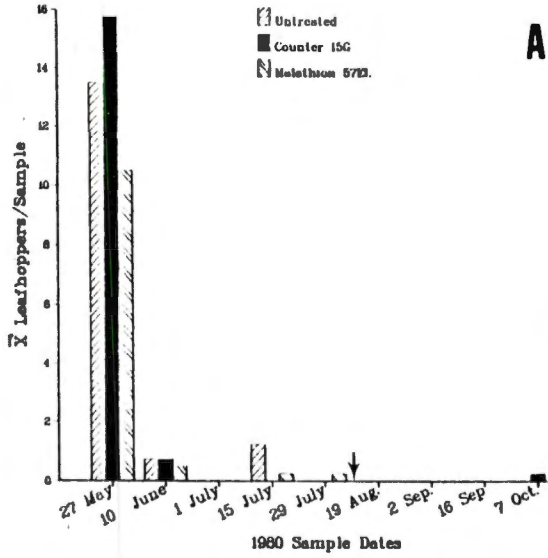


Figure 9.

## CHAPTER V

### SUMMARY AND CONCLUSIONS

This study of the leafhoppers associated with a mixed tall fescue pasture on the Cumberland Plateau in Tennessee resulted in the collection of 33 species representing 27 genera in 6 subfamilies of Cicadellidae. Five of the species that were determined to be abundant in this study were also determined to be abundant in mixed tall fescue pastures in Missouri by Quisenberry et al. (1979). These species were: Agallia constricta, Forcipata loca, Latalus sayi, Polyamia weedi, and Endria inimica. Because these species are widespread in their abundance, they should be the targets of more advanced studies such as those conducted by Quisenberry and Yonke (1981a, b).

In the Tennessee study being discussed, it can be seen from the data when and to what extent the peaks in the numbers collected occurred for the major species. It must be pointed out that these data are probably not definitive; they should be used as a guide on which to base further studies. It is felt that a sampling program for leafhoppers should be on a weekly basis rather than once every two weeks as followed in this study. This may be the reason why Aphrodes serratulae was not found in large numbers in the samples in 1980 but represented 67% of the leafhoppers collected from the untreated main plots on 11 June 1981.

In many instances cutting seemed to reduce leafhopper numbers for several weeks following the cut. This can be seen in the 1981 side plot data for total leafhopper numbers (Fig. 1D, p. 20) as well as for

Dikraneura angustata (Fig 4D, p. 34), Forcipata loca (Fig. 5D, p. 37), and Polyamia weedi (Fig. 7D, p. 43). However, in all of the cases just mentioned, there seemed to be a resurgence of leafhoppers in the cut plots such that greater numbers were collected from these plots than from the uncut plots. Possibly this resulted from the new growth of grass providing a more lush food source for the leafhoppers. It was also seen that cutting may have the reverse effect on some species. In the case of Latalus sayi (Fig. 6D, p. 40) greater numbers were collected from the cut plots than the uncut plots immediately following the cut.

It has been reported that grazing results in a reduction in leafhopper numbers (Whitmore et al. 1981). Endria inimica seems to have shown a positive response to grazing in this study. It was collected in much greater numbers in 1981 from the grazed pasture than from the main plots and side plots. This may indicate that grazing actually provides a better environment for some species.

As previously mentioned, the main objective of the insecticide study was to determine if the entire leafhopper complex could be significantly reduced. In 1980 there was a significant reduction in total leafhopper numbers with the use of insecticides on only two sampling dates. In 1981 there appeared to be more success in reducing total leafhopper numbers with insecticides in that significant reductions were noted on more occasions than in 1980. It is felt that weather conditions probably play an important role in the effectiveness of insecticides on leafhoppers in pastures. Although some of the major species, i.e. Latalus sayi and Polyamia weedi, were significantly

reduced in numbers by the insecticide treatments, in most cases the numbers collected were too small to draw inferences. However, there was one notable exception to this; on 11 June 1981, Aphrodes serratulae (Fig. 3B, p. 31) was present in large numbers in the untreated plots and was practically negligible in the treated plots. In spite of this, the author concurs with Holt and Enkerlin (1979) in that pesticides are not the best approach to increasing forage crop yields and that the use of resistant plant varieties should be investigated more fully. The author also agrees with Painter (1960) in that insecticide residues on forage crops could be potentially hazardous.

This study determined that pasture yields can be significantly increased through the use of insecticides. However, this increase was noted only once out of three separate cutting dates. To determine if this increase was economical a cost/benefit analysis would have to be performed.

In conclusion, it is believed that leafhoppers do play an important role as pests of mixed tall fescue pastures on the Cumberland Plateau in Tennessee. The author encourages others to take over where this study leaves off and answer the questions that have been raised.

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