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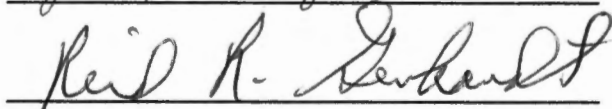
I am submitting herewith a thesis written by Stuart Harris Stein entitled "Grasshoppers (Acrididae) and Other Selected Orthoptera Associated with Tobacco, Pasture and Hayfields at the Tobacco Experiment Station, Greene County, Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Entomology and Plant Pathology.



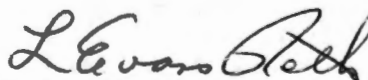
Charles D. Pless, Major Professor

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GRASSHOPPERS (ACRIDIDAE) AND OTHER SELECTED ORTHOPTERA  
ASSOCIATED WITH TOBACCO, PASTURE AND HAYFIELDS  
AT THE TOBACCO EXPERIMENT STATION,  
GREENE COUNTY, TENNESSEE

A Thesis  
Presented for the  
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Stuart Harris Stein

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## ABSTRACT

The seasonal development of Melanoplus femurrubrum (De Geer) and M. differentialis (Thomas) was two weeks shorter in 1980 than 1979, based on time of appearance of the third instar.

Eight species representing three subfamilies of acridids were collected. M. femurrubrum comprised 63.5% of the total adults collected; M. differentialis totaled 13%. Camnula pellucida (Scudder), not previously recorded in Tennessee, was represented by only one female adult.

Adults of three other families represented by six subfamilies, and eleven species were collected and identified. Although Orchelimum pulchellum Davis, a tettigoniid, has not been previously recorded in Tennessee, a total of 173 adults was collected over the two seasons.

Tobacco damage by grasshoppers was not induced in plots with mowed or unmowed borders by cutting surrounding vegetation in 1979 and 1980. Nevertheless, unmowed border vegetation of tobacco plots showed some promise as a trap crop. Significantly fewer grasshoppers (1980) were in sweep-net samples from plot borders treated with acephate, than the adjacent untreated vegetation.

## TABLE OF CONTENTS

| CHAPTER                                    | PAGE |
|--------------------------------------------|------|
| I. INTRODUCTION . . . . .                  | 1    |
| II. LITERATURE REVIEW. . . . .             | 3    |
| Taxonomy . . . . .                         | 3    |
| Life Cycle . . . . .                       | 4    |
| Feeding Habits . . . . .                   | 6    |
| Weather. . . . .                           | 7    |
| Natural Enemies. . . . .                   | 9    |
| Surveys. . . . .                           | 10   |
| Control. . . . .                           | 12   |
| III. MATERIALS AND METHODS. . . . .        | 17   |
| Test and Collection Site . . . . .         | 17   |
| Procedure-1979 . . . . .                   | 19   |
| Procedure-1980 . . . . .                   | 19   |
| Calculations . . . . .                     | 21   |
| Identification . . . . .                   | 21   |
| IV. RESULTS AND DISCUSSION . . . . .       | 23   |
| Development of 2 <u>Melanoplus</u> spp.,   |      |
| Exclusive of Eggs . . . . .                | 23   |
| Third Instars of <u>M. femurrubrum</u> and |      |
| <u>M. differentialis</u> . . . . .         | 27   |
| Effect of Acephate on Acridids . . . . .   | 31   |
| Tobacco Yield. . . . .                     | 32   |
| Notes on Individual Species. . . . .       | 35   |
| V. SUMMARY. . . . .                        | 41   |
| REFERENCES CITED . . . . .                 | 43   |
| APPENDIXES . . . . .                       | 53   |
| Appendix 1 . . . . .                       | 54   |
| Appendix 2 . . . . .                       | 55   |
| Appendix 3 . . . . .                       | 56   |
| Appendix 4 . . . . .                       | 57   |
| Appendix 5 . . . . .                       | 58   |
| Appendix 6 . . . . .                       | 59   |
| Appendix 7 . . . . .                       | 60   |
| Appendix 8 . . . . .                       | 61   |
| VITA . . . . .                             | 62   |

## LIST OF TABLES

| TABLE                                                                                                                   | PAGE |
|-------------------------------------------------------------------------------------------------------------------------|------|
| 1. Sweep Samples Collected in Greene County, Tennessee, 1979 and 1980 . . . . .                                         | 20   |
| 2. Yield of Tobacco from Plots with Different Border Treatments, Greene County, Tennessee, 1979 and 1980. . . . .       | 34   |
| 3. Relative Abundance of the Total of Adult Acridids Collected, Greene County, Tennessee, 1979 and 1980. . . . .        | 36   |
| A-1. Vegetation Identified from the Main Sample Site, Greene County, Tennessee, 1980 . . . . .                          | 54   |
| A-2. Climatological Data, Greene County, Tennessee, 1979 and 1980 (NOAA 1979-1980). . . . .                             | 55   |
| A-3. Seasonal Occurrence of Adults of Selected Acridids and Tettigoniids, Greene County, Tennessee, 1979. . . . .       | 56   |
| A-4. Seasonal Occurrence of Adults of Selected Acridids and Tettigoniids, Greene County, Tennessee, 1980. . . . .       | 57   |
| A-5. Relative Abundance of Adult Tettigoniids Collected, Greene County, Tennessee, 1979 and 1980 . . . . .              | 58   |
| A-6. Identified Orthoptera, other than Acridids, Greene County, Tennessee, 1979 and 1980 . . . . .                      | 59   |
| A-7. Occurrence of the most Abundantly Collected Species of <u>Melanoplus</u> , Greene County, Tennessee, 1979. . . . . | 60   |
| A-8. Occurrence of the Most Abundantly Collected Species of <u>Melanoplus</u> , Greene County, Tennessee, 1980. . . . . | 61   |

## LIST OF FIGURES

| FIGURE                                                                                                                                                                                  | PAGE |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1. Sample sites, Greene County, Tennessee, 1979 and 1980. . . . .                                                                                                                       | 18   |
| 2. Seasonal distribution of the most frequently collected species of <u>Melanoplus</u> , Greene County, Tennessee, 1979 . . . . .                                                       | 24   |
| 3. Seasonal distribution of the most frequently collected species of <u>Melanoplus</u> , Greene County, Tennessee, 1980 . . . . .                                                       | 28   |
| 4. Occurrence of instars of <u>Melanoplus femurrubrum</u> (De Geer) and <u>Melanoplus differentialis</u> (Thomas), combined, Greene County, Tennessee 1979 and 1980. . . . .            | 30   |
| 5. Acridids sampled from unmowed borders surrounding tobacco plots, and the adjacent hayfield (Borders sprayed with acephate in 1980), Greene County, Tennessee, 1979 and 1980. . . . . | 33   |

## CHAPTER I

### INTRODUCTION

Most of the problems caused by grasshoppers in the United States, occur in the western two-thirds of the mainland. The infestations are most damaging to rangelands in semi-arid areas with rainfall from 25.4 cm (10 in) to 76.2 cm (30 in). When rangeland vegetation is scarce and grasshopper populations are high, tobacco, clover, small grains, sugarbeets, cotton, potatoes, and fruit trees are damaged (Anonymous 1975). Grasshoppers have defoliated and killed small orchard trees in Florida (Anonymous 1975, Griffiths and Thompson 1952).

The eastern United States usually has at least 76.2 cm of rainfall and rarely has large outbreaks (Parker and Connin 1964); nevertheless, grasshoppers may damage such important cash crops as tobacco, adding to high production costs. This occurs when other succulent vegetation is not present (Chaplin et al. 1976) or surrounding vegetation like clover and grass are harvested (Metcalf et al. 1962)

Scant literature is available on grasshoppers in Tennessee. Two examples are: (1) Stanley (1933) reported Schistocerca americana (Drury) and Melanoplus femurrubrum (De Geer) caused statewide problems in field crops and pastures, and (2) Marcovitch (1920) constructed a key for Tennessee grasshoppers.

A grasshopper survey was conducted in areas associated with tobacco plots since occasional damage is caused to tobacco in Tennessee. The main objectives of study were to determine:

- (1) seasonal development of the economically important species, Melanoplus femurrubrum (De Geer) and M. differentialis (Thomas),
- (2) relative abundance of acridid adults, and (3) efficacy of trap cropping.

## CHAPTER II

### LITERATURE REVIEW

#### I. TAXONOMY

Family keys for adult grasshoppers (Orthoptera: Acrididae) of North America are by Borror et al. (1976) and Bland (1978). Nymph and nymphal instar keys, descriptions, and comparisons as well as literature reviews were published by Handford, 1946 (Melanoplus spp.); Buxton, 1957 (Melanoplus spp.); Brusven, 1967 (Acridinae); Brusven, 1972 (Cantantopinae and Cyrtacanthacridinae); and Scoggan and Brusven, 1972 (Gomphocerinae and Oedipodinae). Their works are pertinent to Manitoba; Franklin County, Ohio; Kansas; Idaho; and Idaho, respectively.

Shotwell (1941) distinguished the "extra" instar of Melanoplus spp. If the grasshopper has six instars, an extra one appears between the third and fourth of five "normal" instars. Since the extra instar is so morphologically similar to the third (Shotwell 1941), Handford (1946) chose to disregard it in his key. Thus, his fourth and fifth instars referred to the last two immature stages, whether the species had five or six instars.

Other important North American studies on immature grasshoppers include those of Riley (1878), Criddle (1924, 1926), and Shotwell (1930). An important British work was done by Richards and Waloff (1954).

Keys, species descriptions, and notes on distribution of orthopterans were published by Blatchley, Marcovitch, and Morse in 1920. Nomenclature has changed for many groups, but these older publications are still useful. Blatchley's work is one of the most comprehensive works ever published in North America. Other keys were written by Helfer, 1963 (United States); Froeschner, 1954 (Iowa); Brooks, 1958 (Southern Alberta, Saskatchewan, and Manitoba); and Dakin and Hays, 1970 (Alabama).

Tettigoniids frequent many of the same habitats as acridids. Some taxonomic works for the family Tettigoniidae are by Rehn and Hebard, North America (1914a, b, c; 1915a, b); and Powders and Goodwin, Tennessee (1969). The previously mentioned keys of Helfer (1963) and Dakin and Hayes (1970) are also useful for tettigoniid identification. Morris and Walker (1976) gave recent distribution notes of the Orchelimum spp. in the United States.

## II. LIFE CYCLE

Chemical and cultural control are significantly affected by determination of the occurrence of vulnerable life stages (Gage et al. 1976), like eggs or early instars. Criddle (1933), Shotwell (1941), Dempster (1963), Uvarov (1966, 1977), Hilbert and Logan (1981), and Hinton (1981) reviewed various aspects of grasshopper life cycles.

In the northern United States acridids are mostly univoltine and some are biennial, one example being Melanoplus brunneri Scudder.

Grasshoppers in the southern states may be polyvoltine, as is M. femurrubrum propinquus Scudder, which has at least two generations/year in Florida (Kuitert and Connin 1953).

Reproduction is usually sexual but when parthogenesis occurs egg viability is low (Uvarov 1966). Population trends may thus be affected because cool, cloudy weather curtails mating (Pickford 1972).

Acridids generally deposit (Hinton 1981) egg pods into soil in late summer and early fall, and overwinter as diapausing eggs (Hewitt et al. 1974). An exception is Chotophaga which overwinters as a nymph in Tennessee (Marcovitch 1920). Egg deposition occurs after a tunnel is dug in the soil or sod with the ovipositor valves. Low temperature terminates the egg diapause, and development continues with increased temperature; hatching occurs from May to July. After eclosion, "vermiform larvae" work their way to the surface becoming the first of five or six nymphal instars by shedding their protective or "provisional cuticles" (Uvarov 1966). The number of molts may vary among species as well as within the same species. Melanoplus femurrubrum has five instars, and M. differentialis has six instars, in Montana; M. femurrubrum has six instars in Tennessee (Shotwell 1941). The statement that grasshoppers possess five or six instars is only a generality; Uvarov (1966) listed the number of instars in several species. Adults occur about mid-summer, followed again by sexual maturity, mating, preoviposition, and fall oviposition.

### III. FEEDING HABITS

Food selection and preferences were reviewed by Gangwere (1961), Dadd (1963), Mulkern (1967), and Joern (1979).

In general, Acridinae and Oedipodinae prefer grasses while diets of Cyrtacanthacridinae are more heterogeneous. This heterogeneity may account for such a large proportion of damaging species being in the last subfamily (Gangwere 1961). Two species, M. femurrubrum and M. differentialis, are highly destructive to cultivated crops. Mulkern et al. (1969) reported both species are polyphagous, but forbs are a significant part of their diet. Hewitt et al. (1974) and the USDA (Anonymous 1975) suggested replacing forbs with perennial grasses in such weedy habitats as roadsides to further grasshopper control.

Crop damage may occur as grasshoppers preliminarily bite vegetation for acceptability as food (Dadd 1963) or during actual feeding. Mukerji et al. (1976) reported grasshoppers wasted 6.2 times as much spring wheat foliage as they consumed.

Uvarov (1977) described feeding methods. Generally, grass feeders raise their heads with mandibles open and bite down on the edge as the head is lowered. Repeated biting makes bow shaped patterns and may extend through the midrib. The freed blade is held in the fore legs if consumption continues. Forbivorous grasshoppers either start at the edge or make rounded holes, sometimes, sparing only the main veins. A variation is the removal of epidermis and parenchyma from one side of the leaf.

Acridids damage tobacco when other succulent vegetation is scarce. Uvarov (1977) said water content is often regarded as affecting food selection, more succulent vegetation being preferred. Gupton et al. (1971) concluded susceptibility of burley tobacco to grasshoppers is inversely proportional to the amount of leaf nicotine.

Grasshoppers injure tobacco by eating irregular holes in the leaves (Marcovitch 1920) and can transmit pathogens. Walters (1952) demonstrated transmission of tobacco mosaic, potato ringspot, and tobacco ringspot viruses between tobaccos by M. differentialis.

#### IV. WEATHER

Weather is the determining factor in infestation severity of grasshoppers (Mukerji and Gilkinson 1979). Cool, moist conditions favor plant growth and inhibit grasshopper feeding and development; hot, dry weather slows plant growth and favors grasshoppers (Pickford and Mukerji 1974). Even if it is so dry as to adversely affect grasshopper populations, surviving acridids will cause their "maximum damage" if dryness prevails through the crop season (Gage and Gilkinson 1976). Spring wheat that is stressed by dry weather suffers intensified damage due to lack of moisture; with adequate moisture and late acridid hatching, the wheat recovers from defoliation and has insignificant yield loss (Gage and Mukerji 1978). Grasshopper penetration into crop fields will increase as lack of moisture inhibits growth of crops and roadside vegetation (Gage and Mukerji 1977). The greater the grasshopper density in roadside vegetation,

the greater the penetration and damage of the adjacent crop (Gage and Mukerji 1978). With lack of other succulent vegetation, tobacco may be infested (Chaplin et al. 1976).

Dempster (1963), and Hilbert and Logan (1981) reviewed factors affecting grasshopper populations. Weather affects population size directly and indirectly. The number of eggs deposited is influenced by temperature as well as food quality and quantity. Hot, dry falls have a positive correlation on subsequent yearly population densities (Pickford 1960, Edwards 1964). Acridids are at their lowest number as adults in early July and at their highest as eggs in the fall. Thus, anything affecting oviposition from July to September could seriously affect the spring population (Edwards 1964). Pickford (1960) reported most eggs are produced when temperatures are highest and production decreases as temperature decline; he considered aging an insignificant factor. Eggs hatching earliest in the spring were oviposited soon enough in the previous fall for optimum embryonic development before diapause (Pickford 1966). Although early instars were most vulnerable to inclement weather, earliest hatching grasshoppers had the highest realized fecundity (Pickford 1960). Longer time for oviposition occurred since adults developed earlier. Cool weather may cause starvation in early instars because feeding is inhibited (Dempster 1963).

Dempster (1963) summarized the intricacies of effects of weather:

Differences in survival and fecundity due to variations in weather can cause enormous fluctuation in the number

of some species of Acrididae. Generally warm, dry weather favors both survival and high fecundity; but rainfall is required for development of the eggs and for a supply of green food for the active stages and it is these opposing requirements which make acridid numbers so sensitive to climatic changes.

Current weather conditions are found in "Climatological Data" for Tennessee (NOAA 1979-1980).

## V. NATURAL ENEMIES

Rees (1973) wrote an extensive review of arthropod and nematode enemies of grasshoppers, and Smith (1958) reviewed acridid parasites in western Canada. Lavigne and Pfadt (1966), Parker and Wakeland (1957), and Hewitt et al. (1974) covered natural enemies of grasshoppers in the western United States.

Acridids have a wide variety of natural enemies. Parasites include species within the Diptera, Hymenoptera, Acarina, Nematoda, Gordiacea, and Acanthocephala; pathogenic microorganisms of grasshoppers include fungi, bacteria, protozoa, and viruses. Predators are found in Coleoptera, Diptera, Hymenoptera, Orthoptera, Araneida, Amphibia, Aves, Mammalia, and Reptilia.

Dempster (1963) and Turnock (1977) said grasshoppers lack effective natural enemies and are subject to wide population fluctuations. However, Bland (1976) reported nematode parasitism and suboptimal nutrition appeared to be major factors in maintaining stable populations of Melanoplus femurrubrum. The nematode, Mermis nigrescens Dujardin, caused up to 71% mortality. Poinar (1979) suggested that in areas of sufficient rainfall the nematode,

M. nigrescens, could be useful in acridid control by reducing ovaries or testes, and lifespan. Bland (1976) found no ovary reduction and did not say if testes were affected in grasshoppers he collected from a mixed grass-forb upland field.

Nosema locustae Canning, a microsporidian, is another possible effective enemy. It has been found in high frequency among populations of acridids after spore application to rangelands (Henry and Onsager 1982).

## VI. SURVEYS

Shotwell (1935, 1938) helped standardize survey methods of forecasting grasshopper infestations. He suggested surveying adults and eggs in late summer and fall, and eggs and nymphs in the spring. The number of active grasshoppers per visualized square yard was rated as "normal, light, threatening, severe, or very severe." In addition, special adult collections were made with sweep nets near weather recording stations. The number of egg pods per square yard was rated in the fall and spring. Refinements utilized developmental state and attrition rate. Shotwell (1942) categorized egg development into four convenient developmental stages: clear fluid content, coagulated content, eye presence, and completed body segmentation stage. Active or current grasshopper situations were appraised by nymph surveys to facilitate proper amount and timing of insecticide application.

Shotwell (1938) and Newton et al. (1954) considered egg surveys to be more accurate than adult surveys. However, more area can be covered in less time with adult surveys since they are visually estimated and eggs have to be located and extricated from soil. Canadians dropped egg surveys because of the required intensity of sampling (Smith and Holmes 1977). Eggs are still sampled in the United States (Pfadt 1971, USDA/APHIS 1978A), as are nymphs and adults. The current USDA/APHIS action threshold on rangelands is 9.57 nymph and adult grasshoppers/m<sup>2</sup> (Onsager et al. 1981).

For estimation of density, Onsager (1977) compared night cages, cage samplers, net samplers (similar to cage types), visual estimates, and pointing. Visual estimates, recommended by Shotwell (1935), and pointing were the easiest. Unfortunately, accuracy was inversely proportional to convenience. Thus, night cages were the most accurate, followed by cage and net samplers. The latter two had similar efficiency. Although subsampling with visual estimates is difficult to standardize, it is quick and adaptable. Hence, the pointer method, a variation of visual estimates, has been used extensively at the Montana Rangeland Insect Laboratory (Onsager 1977).

Hewitt et al. (1974) reported sweep netting and visual estimating were the most widely used techniques in rangeland surveys, and comparisons of insecticidal treatments with controls.

Two recent methods for determining density are the quick trap (Turnbull and Nicholls 1966) and ring methods (Onsager and Henry 1977).

The quick trap utilizes a bottomless cage dropped remotely with a tripod; the cage is later emptied with a vacuum. In the ring method, wire rings delimiting  $0.1 \text{ m}^2$  are placed on the sample site and grasshoppers are counted after a suitable time (Henry and Onsager 1982).

The sweep net is used extensively in grasshopper survey and insecticide work. Much criticism has stemmed from varying efficacies of net collecting in relation to insect species, habitats, weather, time of day, and sweep styles (Ruesink and Kogan 1975). However, it is probably the most used apparatus of collecting insects in vegetation because of its simplicity, speed, high return, low cost, and usefulness in collecting meager and dispersed species (Southwood 1978); sweep netting is a "relative method": measuring "catch per unit effort." Kuitert and Connin (1953), Henry (1972), McKinlay and Burrage (1975), Amaya and Radcliffe (1978), Huggans et al. (1980), and Brandenburg (1982) evaluated insecticide efficacy on grasshoppers by this relative method. Bland (1976) evaluated effect of nematodes on grasshopper population trends as grasshoppers/sweep. The "Cooperative Plant Pest Report" (USDA/APHIS) included grasshopper surveys from different states using various methods. A few examples from 1978 (USDA/APHIS) of the employment of catch/unit sweeps were from Washington (1978b), New Mexico (1978c), and Ohio (1978d).

## VII. CONTROL

Riley (1878), Parker (1952), Schlebecker (1953), and Blickenstaff et al. (1974) provided good prospective on grasshopper damage and

control. Riley (1878) suggested egg destruction by such methods as harrowing, plowing, irrigation, trampling (with domestic animals), and collecting. For nymph destruction, he proposed burning, crushing, trapping, and catching or bagging. Bagging and catching as with nets and diverting grasshoppers with smoke were listed for adult control. Other suggestions included feeding poultry and planting resistant crops. Implements for all phases of control ranged from plows and shovels to sweep nets and hopper dozers.

Riley (1878) gave results of various insecticidal screenings and reported coal-oil was the most effective control agent. Demonstrations of arsenical baits were first mentioned by him (Riley 1878, Shotwell 1942). As mechanical bait spreaders came into use in 1936, arsenical baits became the major method of control. Beginning in 1939 bait could be spread by airplane or, in 1944, by power driven blowers. With the advent of chlorinated hydrocarbons in the late 1940's sprays of chlordane, toxaphene, and aldrin were extensively used. Aldrin was used the most until 1964, when the organic phosphate, malathion, was first applied by the newly developed aircraft ULV technique.

Large scale control efforts have been coordinated with federal cooperative programs, almost annually, since 1937 (Blickenstaff et al. 1974). These programs are mostly employed in the western United States where outbreaks affect large areas of crop and rangelands. In the East outbreaks are generally localized, but Florida has had grasshopper outbreaks warranting a federal cooperative program (Kuitert and Connin 1953).

Where grasshoppers are threatening to crops, the USDA (Anonymous 1975) suggested treating "along roadsides, canal banks and field margins, in idle areas bordering cultivated fields and in the fields themselves." Field borders and other vegetation should be treated in the vicinity of tobacco fields since grasshoppers injuring row crops usually hatch in field margins (Anonymous 1975). Pesticides may be directly applied to tobacco if necessary.

Timing of chemical applications varies in both range and crop lands. Newton et al. (1954) said for effective control with one treatment to apply pesticides after overwintering eggs have hatched but before range forage was damaged and before adults have begun egg laying. Handford (1961) and Hewitt (1980) stated range grasshoppers should be treated by the third (mean) instar since the first three are not very injurious and most eggs will have hatched. The USDA (Anonymous 1975) recommended for row crops, timely treatments of field margins; for tobacco, treat while grasshoppers are immature to protect plant bed, newly set or established tobacco plants.

Insecticides recommended for plant bed tobacco by the USDA (Neal 1979) were acephate (organic phosphate), carbaryl (carbamate), and malathion (organic phosphate). Azinophosmethyl (organic phosphate), carbaryl, diazinon (organic phosphate), malathion, and methomyl (carbamate) were suggested for established tobacco plants.

When dosage ranges are on the insecticide label, low dosages should be used on short, dense, succulent vegetation to kill young

grasshoppers, or in areas where persistence is not necessary (Anonymous 1975). Higher dosages may be used when vegetation is tall and dense, or grasshoppers are adults. High dosages may be needed for barrier strips.

Little scientific literature on testing trap crops around tobacco plots against acridids is available; however, grasshopper literature on vegetation used as trap crops or in barrier strips for crop protection is available. Drake and Decker (1932), and Palmer (1939) suggested leaving a small median strip inside, and a narrower border around alfalfa fields during harvesting so aggregating grasshoppers could be easily poisoned. Shotwell (1941) reported sorghum did not work as barrier borders for corn, but in 1931 these borders were the only fodder left after an outbreak in a district in South Dakota. To stop nymphs, Shotwell (1942) suggested baiting a 100-foot-wide barrier along the crop and adjoining infestation source, extending into the crop and infestation source. Chamberlain (1942) advocated baiting all of the infested tobacco fields in addition to baiting a 100-yard-wide strip of the adjacent infestation source. Kuitert and Connin (1953) recommended spraying or dusting a 50 to 75-foot-wide border between breeding grounds and the crops to stop nymphs, but he said adults could fly over and avoid the barrier. Handford and Putnam (1953) advised using "non-edible vegetation, such as cover crops or grass-sewn borders, as trap crops for poisoning the grasshoppers" which attack vegetable crops and orchards. In 1959, Skoog tested phorate-treated

wheat along field margins. Some promise was indicated, although results were inconclusive and the wheat stand may have been reduced by phytotoxicity of phorate to seeds.

The effect of vegetation borders on row crops was not mentioned in these papers, but it has been noted that weeds can reduce tobacco yield possibly by competition for moisture, nutrients, sunlight, and space (Medlen and Worsham 1978, Lunsford 1980).

Good control of acridids depends on both chemical and cultural techniques. Cultural practices presently include tillage for egg pod destruction, early seeding to reduce plant exposure to damaging grasshopper stages, replacing broadleaf weeds (forbs) with perennial grass to make surrounding vegetation less conducive for egg laying, and planting resistant crops such as the sorghums, sorgo and kafir (Anonymous 1975). Elimination of overgrazing is also beneficial since total grasshoppers may increase as cattle grazing increases (Schwartz 1982, Holmes et al. 1979).

Biological control of grasshoppers is an additional method. Nosema locustae Canning is one of the recommendations of the USDA (Schwartz 1982) for control of grasshoppers on rangelands.

## CHAPTER III

### MATERIALS AND METHODS

#### I. TEST AND COLLECTION SITE

Grasshoppers were collected, and trap-cropping tests were conducted during the tobacco growing seasons of 1979 and 1980 at the University of Tennessee Tobacco Experiment Station 6.4 km south of Greeneville in Greene County, Tennessee. Grasshoppers were collected in mowed and unmowed borders of plots of tobacco (variety Virginia 509), in a hayfield separating two sets of plots, and in the surrounding pasture (Figure 1). A fence enclosing 0.76 ha separated the plots, borders, and hayfield from pasture which sloped moderately up on three sides and was level on the fourth (west pasture), until it reached a pond.

Tall fescue, Festuca arundinacea Schreb., was predominant in the pasture which also contained red clover, Trifolium pratense L., and white clover, Trifolium repens L. Other vegetation was present in the unmowed borders, hayfield, and the pasture (Table A-1, Appendix).

For both 1979 and 1980, unmowed borders were tested as trap-crops to protect tobacco from grasshopper damage. The tall borders and center hayfield were allowed to grow unchecked while other borders were mowed every two to three weeks throughout the two seasons. Concurrently, the pasture was intensely grazed throughout

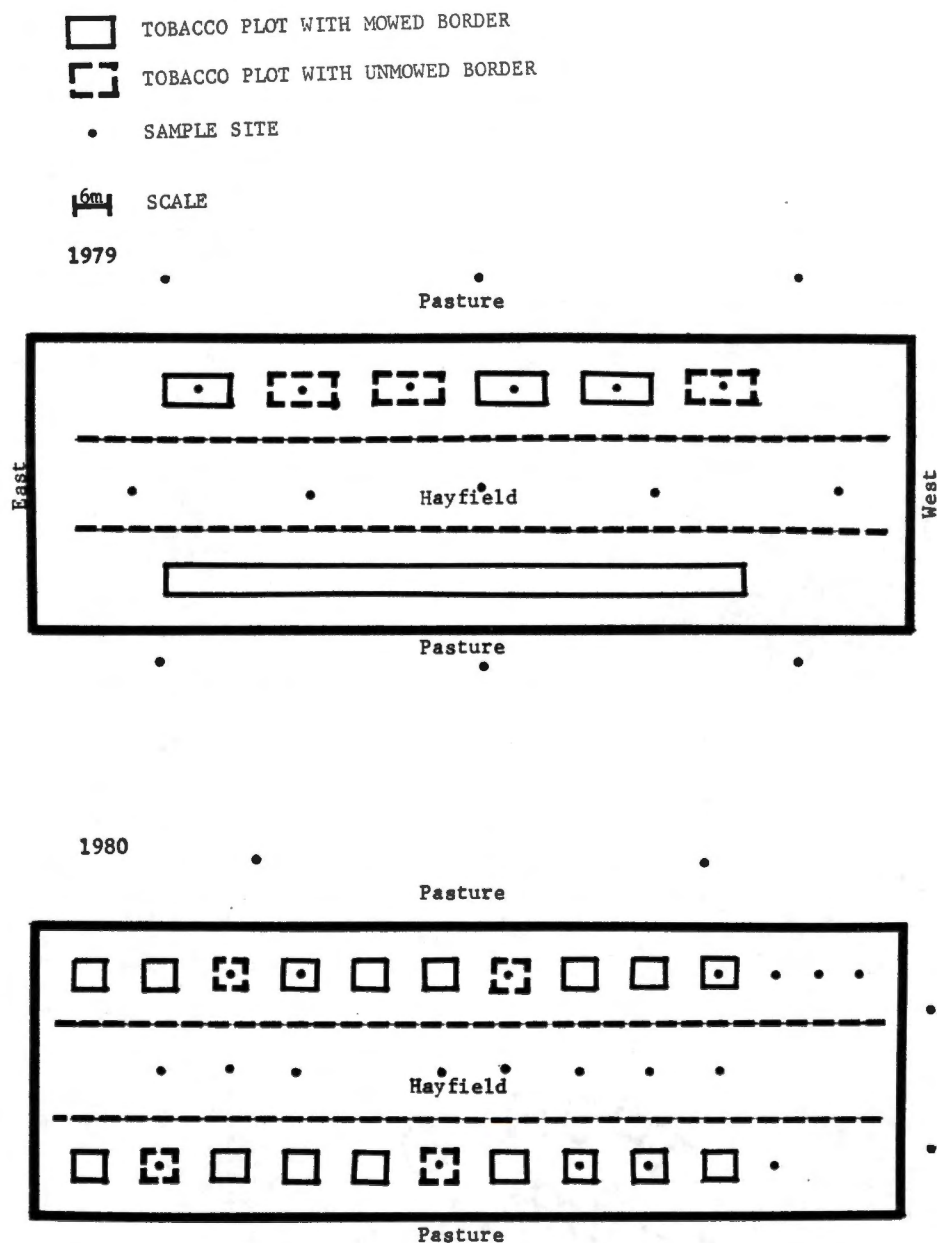


FIGURE 1. Sample sites, Greene County, Tennessee, 1979 and 1980.

the seasons until tobacco matured. At that time the hay was harvested (28 August 1979; after sampling grasshoppers on 26 August 1980) to increase grasshopper pressure on the plots.

## II. PROCEDURE-1979

A randomized complete block design was used with three replicates of mowed and unmowed border treatments. Neither was sprayed with insecticide. Each plot was 4.3 m by 12.1 m and separated from each other by 6.1 m alleys. There was approximately 6.1 m between the plots and fence, and the plots and a hayfield, between this row of six plots and a nonrelated set of test plots (Figure 1).

Grasshoppers were sampled by sweep net (38.1 cm diameter) at least semimonthly from 13 July through 7 September (Table 1). Occasionally, additional samples were made in the test pasture and others of the Station to check for undetected grasshopper species. All specimens were killed with ethyl acetate, transported to the laboratory in paper cartons, separated, and frozen for later identification.

## III. PROCEDURE-1980

As in 1979, a randomized complete block design was used, but beginning on 27 July, four replicates of unmowed borders were sprayed with acephate every two weeks at 0.84 kg A.I./ha. There were four replicates of check plots with mowed borders, and twelve interspersed plots with direct insecticidal sprays (not pertinent to this study)

TABLE 1. Sweep Samples Collected in Greene County, Tennessee, 1979 and 1980

| Sample Site    | 1979                |                 |       | 1980                |                 |       |
|----------------|---------------------|-----------------|-------|---------------------|-----------------|-------|
|                | Replicates/<br>Date | Sweep<br>Number | Total | Replicates/<br>Date | Sweep<br>Number | Total |
| Unmowed Border | 3                   | 20              | 60    | 4                   | 20              | 80    |
| Mowed Border   | 3                   | 20              | 90    | 4                   | 20              | 80    |
| Pasture        | 6                   | 15              | 90    | 8                   | 20              | 160   |
| Hayfield       | 5                   | 20              | 100   | 8                   | 20              | 160   |
| TOTAL          |                     |                 | 310   |                     |                 | 480   |

and mowed borders (Figure 1). All field measurements were as in 1979, except plot lengths were shortened to 6.1 m.

Grasshoppers were sampled by sweeping, approximately weekly, from 9 May, for instar and species determination, until vegetation on the sample site was firmly established. Quantitative sweeps were then taken, at least weekly, from 18 July through 26 August (Table 1). Concurrently, samples (20 sweeps/plot) were made around four nonrandomized plots with lush unmowed borders (Figure 1, west of randomized plots).

#### IV. CALCULATIONS

Grasshopper counts in the hayfield and unmowed plot borders, and yields of appropriate tobacco plots were subjected to analysis of variance. Only hayfield samples adjacent to plots with unmowed borders were analyzed (Figure 1); three hayfield samples in 1979 and four in 1980 were included.

The average instar was calculated by Handford's (1961) method.

#### V. IDENTIFICATION

Nymphs of acridids and tettigoniids were identified to family. Two acridids, Melanoplus femurrubrum (De Geer) and M. differentialis (Thomas), were separated to species beginning with the third instar. These Melanoplus spp. were separated only to genus in the first two instars, except in determining the date when each species first appeared in 1980. The keys of Handford

(1946), Buxton (1957), and Brusven (1972) were used to identify species of nymphs and to separate instars.

Adults of species of the families Acrididae, Tettigoniidae, and Tetrigidae were identified as were members of the subfamily, Oecanthinae (Gryllidae). Other orthopteran families were not included. The keys of Dakin and Hays (1970), Helfer (1963), Blatchley (1920), and Brooks (1958), were the main ones used. Dr. D. A. Nickle of the USDA Agriculture Research Center, Beltsville, Maryland, identified difficult specimens and verified all others.

## CHAPTER IV

### RESULTS AND DISCUSSION

A total of 2,197 acridid nymphs and adults were collected. The following acridid adults were identified from 1979 and 1980 collections:

#### Acridinae

Dichromorpha viridis (Scudder)  
Syrbula admirabilis (Scudder)

#### Cyrtacanthacridinae

Melanoplus differentialis (Thomas)  
Melanoplus femurrubrum (De Geer)  
Melanoplus scudderi (Uhler)

#### Oedipodinae

Camnula pellucida (Scudder)  
Chortophaga viridifasciata (De Geer)  
Hippiscus rugosus (Schdder)

The most abundant species of Melanoplus was M. femurrubrum followed by M. differentialis. Melanoplus differentialis, M. femurrubrum, and Camnula pellucida are three of five acridids which cause 90% of all grasshopper damage to cultivated crops in the United States (Parker and Connin 1964).

Other orthopterans were collected and identified (Table A-6, Appendix).

#### I. DEVELOPMENT OF 2 MELANOPLUS SPP.,

##### EXCLUSIVE OF EGGS

In 1979 (Figure 2), third instars predominated throughout July collections, giving way to fourth instars in early August.

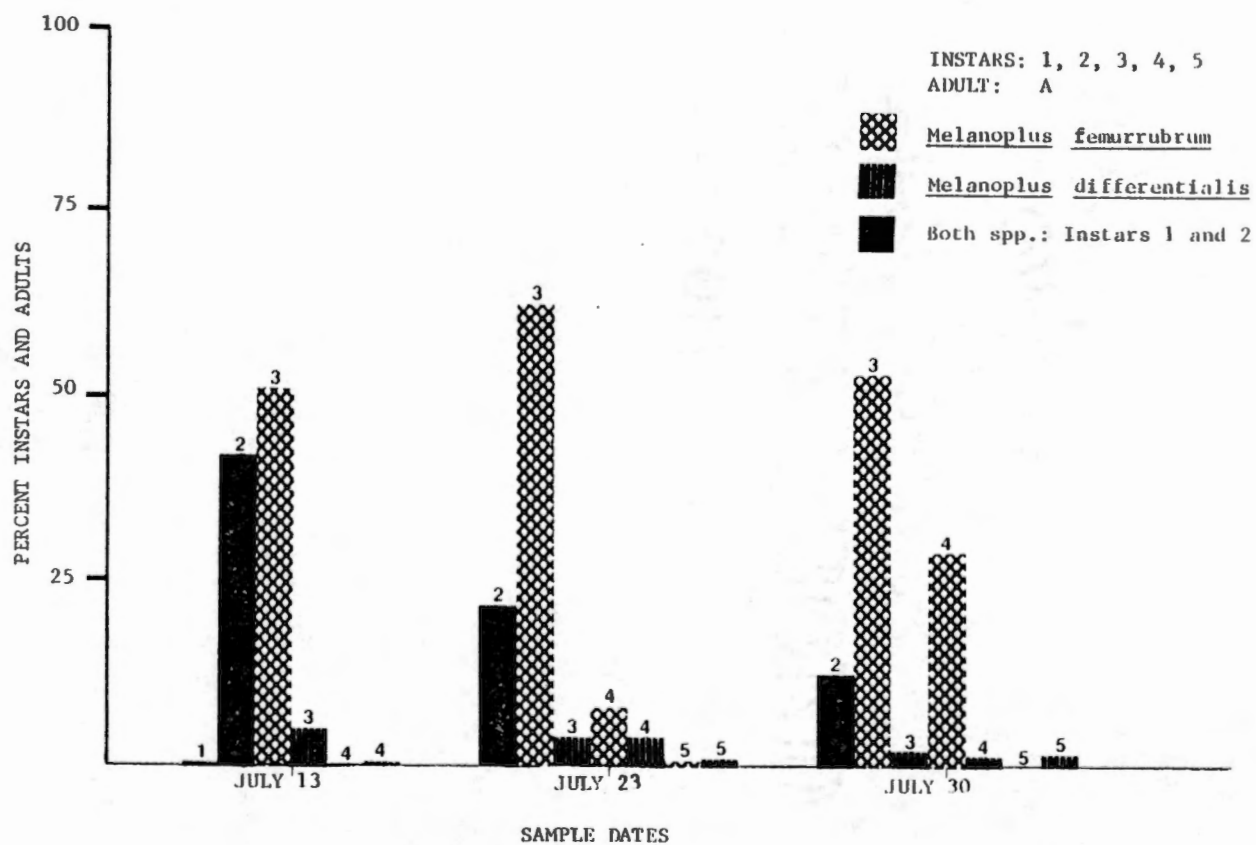


FIGURE 2. Seasonal distribution of the most frequently collected species of Melanoplus, Greene County, Tennessee, 1979.

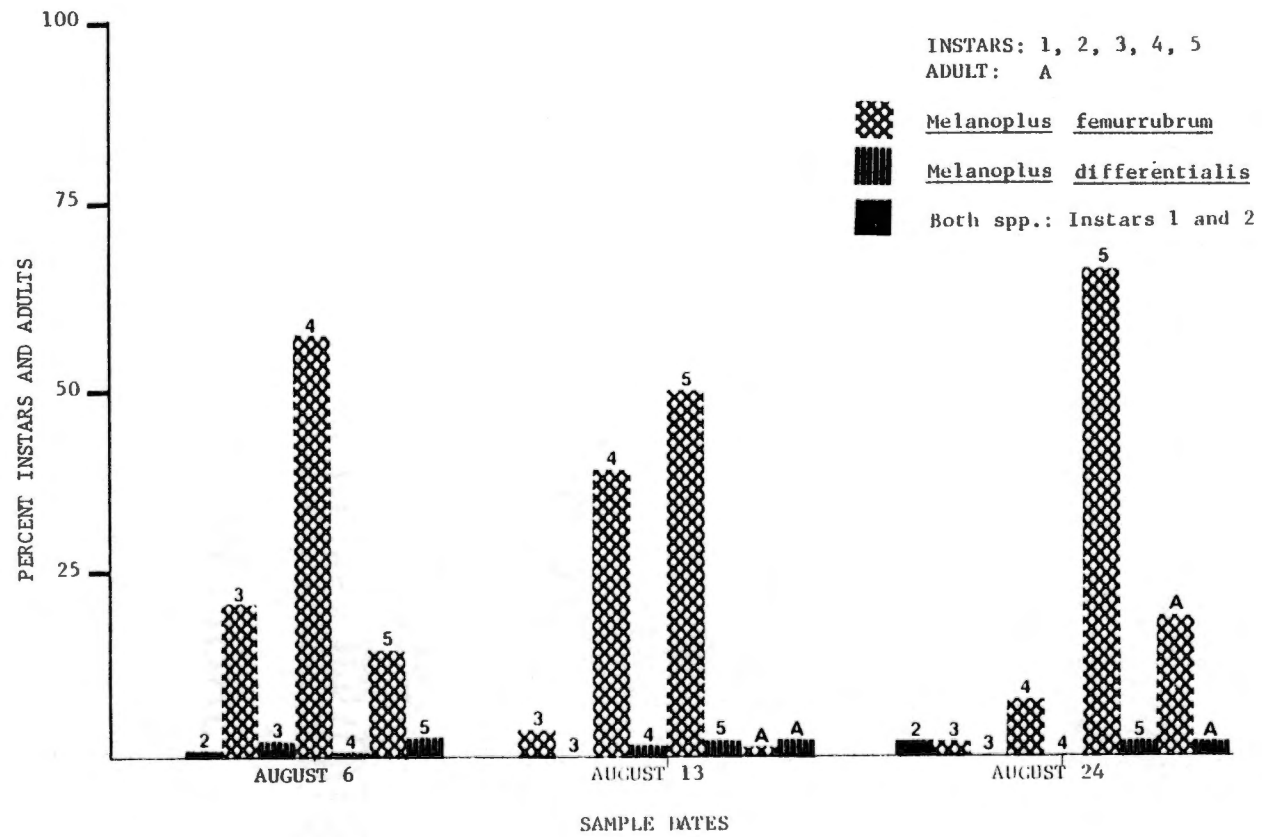


FIGURE 2. (Continued).

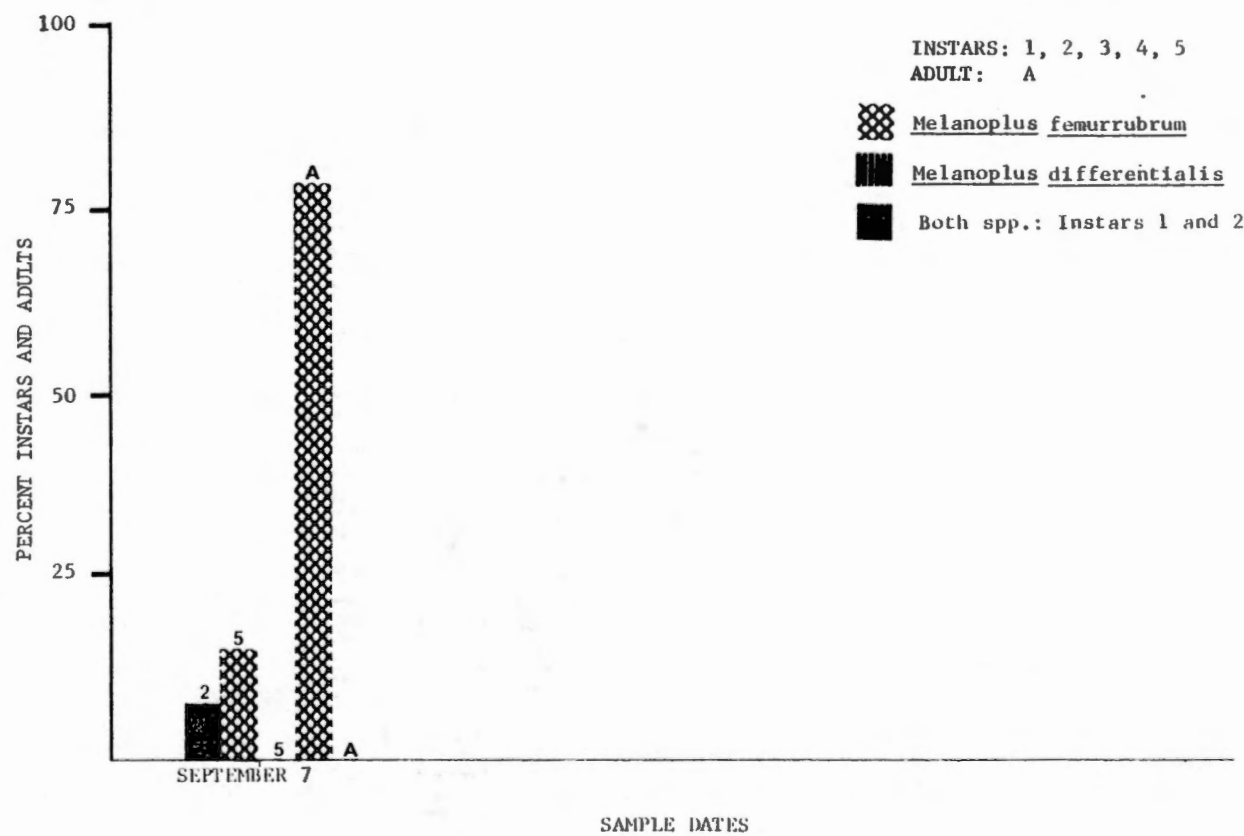


FIGURE 2. (Continued).

By mid August, most nymphs were fifth instars, which also predominated in late August, and developed into an adult majority in early September.

In 1980, instars (first) of M. differentialis were collected on 22 May and were the earliest acridids gathered. M. femurrubrum was first collected on 30 May. By 9 June (Figure 3), second instars of Melanoplus spp. began predominating, with ensuing third instars prevailing in late June and mid July. Subsequently, the most numerous stage/collection was the fourth instar in late July, the fifth instar in mid August, and the adult stage in late August.

For both years, the average development of the population of M. femurrubrum was easier to discern than that of M. differentialis, due to the low numbers of M. differentialis collected.

## II. THIRD INSTARS OF M. FEMURRUBRUM AND M. DIFFERENTIALIS

The average instar of 3.1 occurred on 13 July 1979, and 27 June 1980 (Figure 4). On 8 July 1980, the average instar was 3.4 and reached 3.9 by 15 July. Development progressed until the end of August (1980) and early September (1979) at which time they were mostly adults (Figures 2 and 3). At the end of both yearly collections, the late appearance of early instars caused the mean nymphal instar to decline. Possibly eggs laid in the current year had hatched, because second instars (Figures 2 and 3) did not reappear until well after the first adults were collected (Tables A-3, A-4, Appendix).

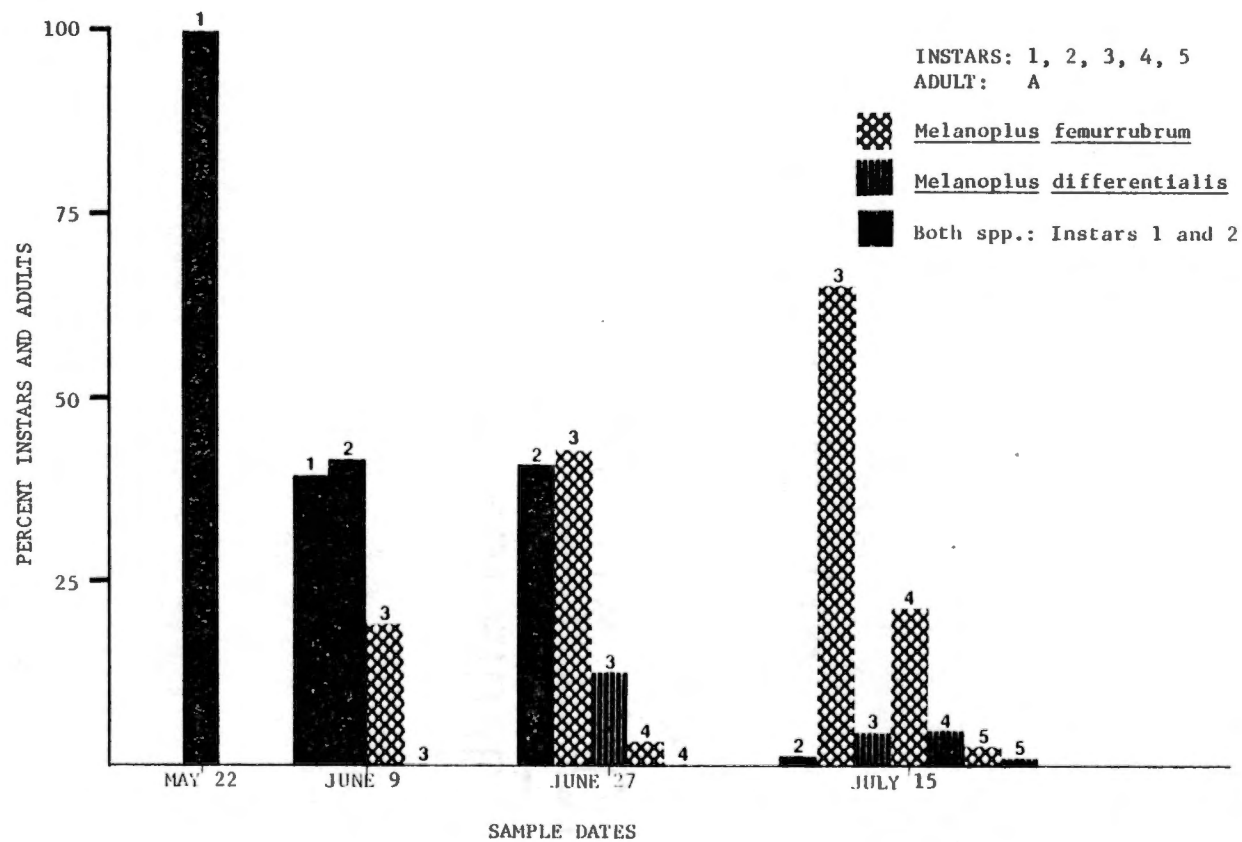


FIGURE 3. Seasonal distribution of the most frequently collected species of Melanoplus, Greene County, Tennessee, 1980.

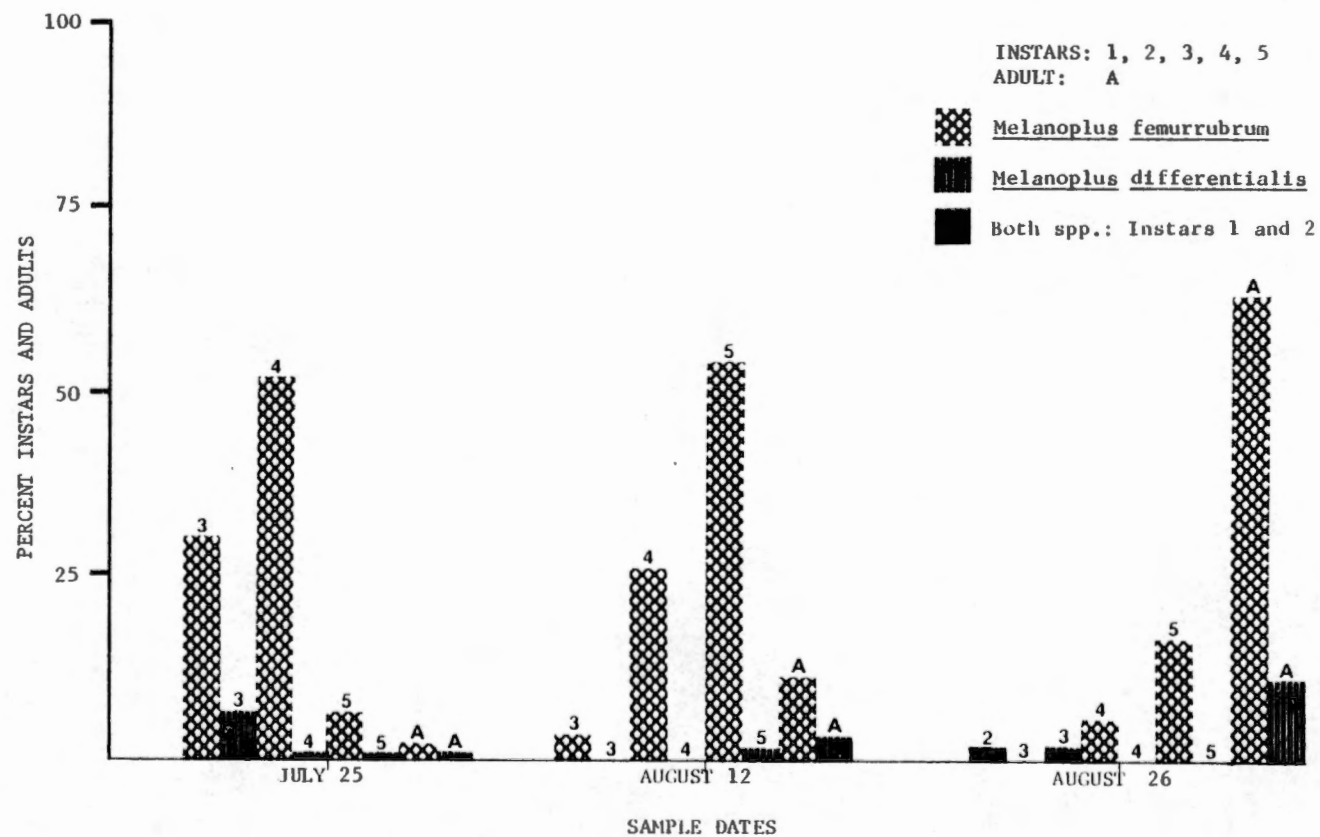


FIGURE 3. (Continued).

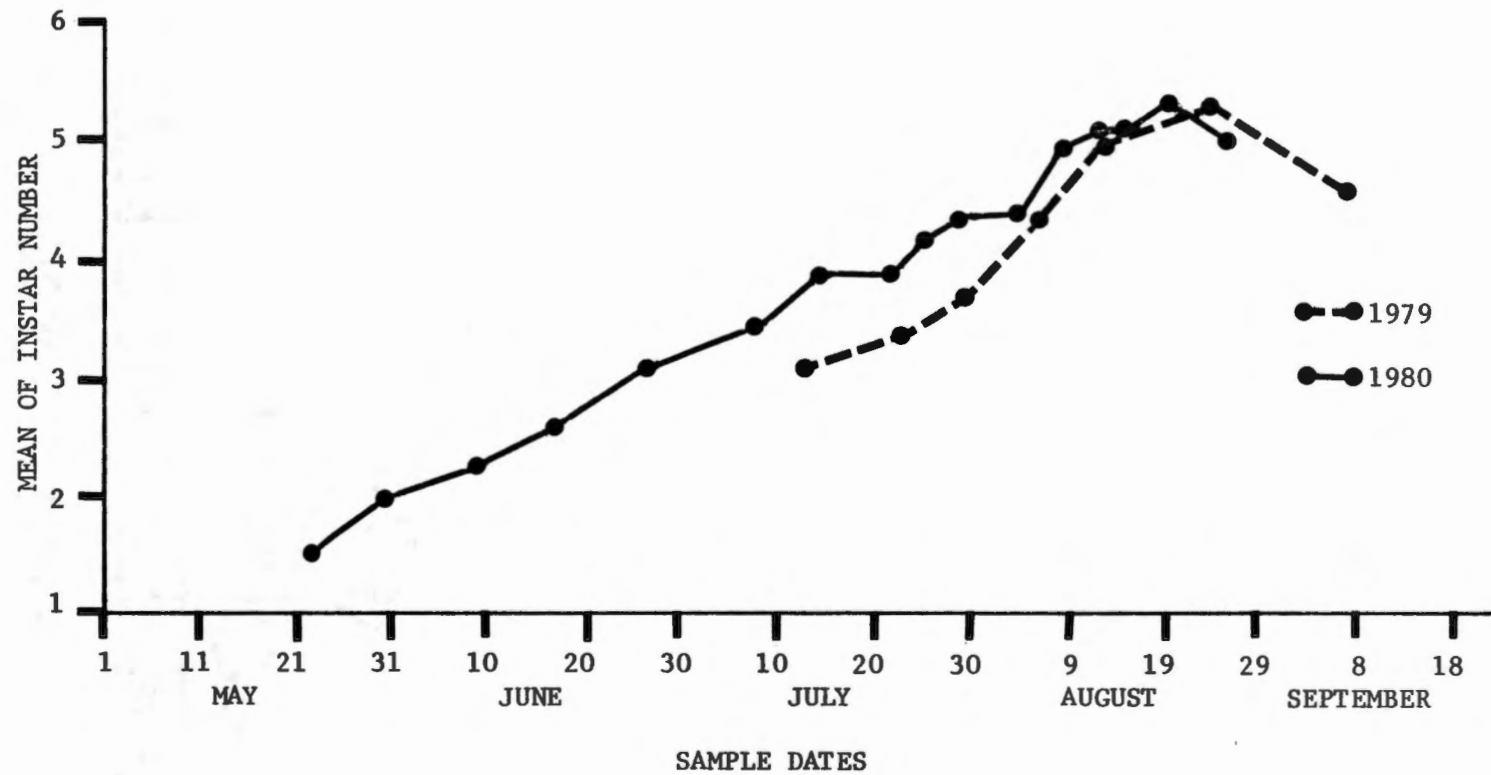


FIGURE 4. Occurrence of instars of Melanoplus femurrubrum (De Geer) and Melanoplus differentialis (Thomas), combined, Greene County, Tennessee 1979 and 1980.

Some acridids, such as Melanoplus spp., "lay both diapause and non-diapause eggs often mixed within the same egg-pod" (Dempster 1963). A few M. femurrubrum hatched in the laboratory at uncontrolled room temperature in 1979 and 1980. The eggs had been oviposited in sand by adults collected in Greene County.

Since warm dry weather favors acridid development (Parker 1930, Shotwell 1941, Dempster 1963), conditions in June and July of 1980 might have been more favorable for rapid development than those of 1979. Although the weather conditions were similar in May of both years, respective averages of 11.7 cm (4.6 in) and 5.7 cm (2.2 in) more rain/month fell in June and July of 1979 than 1980. The corresponding temperature averages for both months were 0.9°C (1.6°F) and 2.7°C (5.0°F) more in 1980 than 1979 (Table A-2, Appendix).

The first appearance of acridids was not determined for 1979 but variation of annual hatching dates may be an additional factor. Weather is probably the overriding element since fall weather affects acridid hatching dates in subsequent years (Edwards 1964, Gage et al. 1976). If one were chemically treating to control grasshoppers by the mean third instar (Handford 1961, Hewitt 1980), application could have begun about two weeks later in 1979 than 1980.

### III. EFFECT OF ACEPHATE ON ACRIDIDS

Although grasshoppers fed little in all the tobacco plots, some promise was shown in controlling them with chemically treated

borders. In 1979, samples from unmowed borders had larger numbers of acridids than hayfield samples (Figure 5), but they were significantly ( $P=0.05$ ) so only on 24 August. The trends were reversed in 1980, as the unmowed borders had been treated with acephate (Figure 5). In nine out of twelve sample dates, hayfield samples were significantly ( $P=0.05$ ) higher in acridids than the sprayed borders. Only samples on 18 July, 8 August, and 15 August were not significantly different. More testing would be needed to determine efficacy of trap crops for protecting tobacco from grasshoppers.

#### IV. TOBACCO YIELD

For both years, cutting of hayfield and pasture seemed to induce acridid movement, but there was neither an appreciable number of grasshoppers nor resulting damage in plots.

In an unrelated test, an infestation was accidentally prompted when an alfalfa field was cut in close proximity to another tobacco field on the Station. Grasshoppers, primarily fourth-instar, moved up and through a six-foot-wide strip of unmowed grass and caused considerable damage to tobacco (C. D. Pless 1980, personal communication; Pless and Shamiyeh 1980).

Tobacco yields for both years were higher in check plots than those with unmowed borders; they were significantly ( $P=0.05$ ) so in 1980 (Table 2). Possibly the unmowed borders had the same effect as weeds which can compete for light and moisture (Medlen and Worsham 1978, Lunsford 1980). Because it was hotter and drier

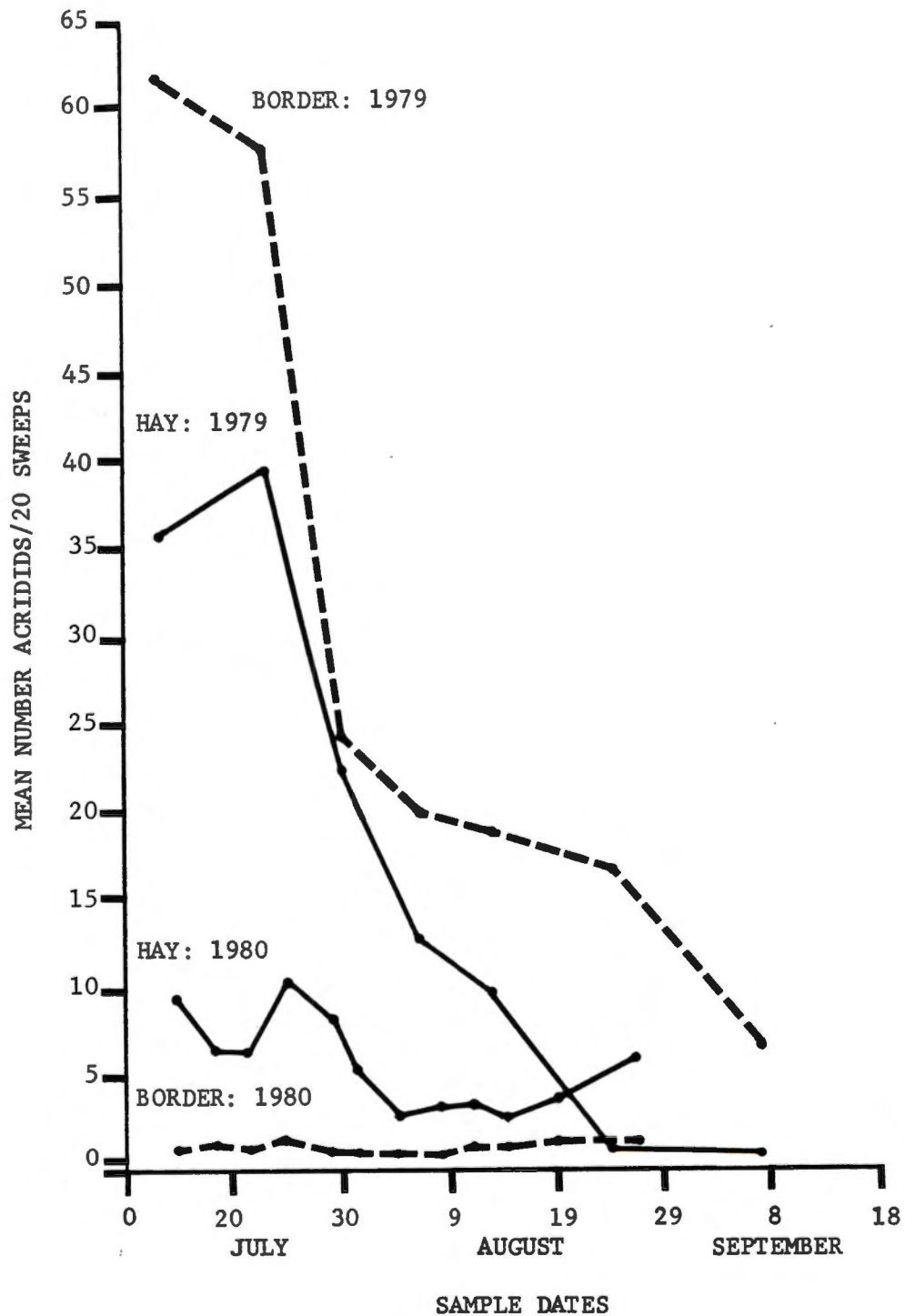


FIGURE 5. Acridids sampled from unmowed borders surrounding tobacco plots, and the adjacent hayfield (Borders sprayed with acephate in 1980), Greene County, Tennessee, 1979 and 1980.

TABLE 2. Yields of Tobacco from Plots with Different Border Treatments, Greene County, Tennessee, 1979 and 1980

| Treatment      | Mean yield <sup>1</sup> (kg/ha) of tobacco: |                   |
|----------------|---------------------------------------------|-------------------|
|                | 1979 <sup>2</sup>                           | 1980 <sup>3</sup> |
| Mowed Border   | 1957.3a                                     | 2615.6a           |
| Unmowed Border | 1466.7a                                     | 1969.6 b          |

<sup>1</sup>Column means followed by the same letter are not significantly different by the ANOVA (P=0.05).

<sup>2</sup>Means of three replicates.

<sup>3</sup>Means of four replicates.

in June and July of 1980 than in 1979, the tobacco may have been stressed and made more susceptible to competition. Trimming of the borders might be the remedy. In practical application, competition of border vegetation and tobacco probably would be unimportant since more than four rows of tobacco are usually planted in production fields.

#### V. NOTES ON INDIVIDUAL SPECIES

##### Melanoplus femurrubrum (De Geer)

Melanoplus femurrubrum is the most abundant acridid in the southeastern United States (Kuitert and Connin 1953, Pfadt 1971). It is especially damaging to clover and alfalfa (Pfadt 1971) and damages tobacco when other succulent plants are scarce (Chaplin et al. 1976). M. femurrubrum inhabits low lying areas and is common in field margins, pastures, meadows, and roadsides (Blatchley 1920, Pfadt 1971). Marcovitch (1920) stated that the Tennessee species is univoltine, the first adults appearing as early as 23 July.

M. femurrubrum constituted 63.5% of all acridid adults collected (Table 3). Developmental trends (Figures 2 and 3, pages 24 and 28) and adult occurrences in 1979 and 1980 support the statement that it is univoltine. Observations and collections at the Station confirmed their presence in the habitats listed above. Adults were first collected on 13 August 1979, and 18 July 1980, respectively (Tables A-3, A-4, Appendix). No quantitative data

TABLE 3. Relative Abundance of the Total of Adult Acridids Collected, Greene County, Tennessee, 1979 and 1980

| Species                               | 1979 | 1980 | Total |     |
|---------------------------------------|------|------|-------|-----|
|                                       | %    | %    | %     | No. |
| <u>Melanoplus femurrubrum</u>         | 69.1 | 60.7 | 63.5  | 132 |
| <u>Dichromorpha viridis</u>           | 16.2 | 12.9 | 13.9  | 29  |
| <u>Melanoplus differentialis</u>      | 7.4  | 15.7 | 13.0  | 27  |
| <u>Chortophaga viridifasciata</u>     | 4.4  | 6.4  | 5.8   | 12  |
| <u>Syrbula admirabilis</u>            | 2.9  | 1.4  | 1.9   | 4   |
| <u>Melanoplus scudderi</u>            | —    | 1.4  | 1.0   | 2   |
| <u>Hippiscus rugosus</u>              | —    | 0.7  | 0.5   | 1   |
| <u>Camnula pellucida</u> <sup>1</sup> | —    | 0.7  | 0.5   | 1   |

<sup>1</sup>Not previously recorded in Tennessee.

were taken on the rate of parasitism, but mermithid nematodes were observed in some dissected M. femurrubrum (as well as M. differentialis) nymphs and adults from both seasons.

#### Melanoplus differentialis (Thomas)

Melanoplus differentialis is a large, greenish-yellow grasshopper with chevron-like markings on its hind femurs. It has been a problem in the Midwest (Shotwell 1941) causing serious damage to corn, soybeans, alfalfa, clover, and during outbreaks, destroys small grains and other cultivated crops (Pfadt 1971). Its habitat preferences are low, damp, places with rank vegetation, and it is concentrated along roadsides, fence rows, and margins of cultivated fields (Blatchley 1920, Pfadt 1971).

M. differentialis comprised 13%, 27 specimens, of all adult acridids collected (Table 3). Although their numbers were low and they were difficult to observe, M. differentialis (and M. femurrubrum) were more easily flushed into view by walking through the grassy and sometimes damp areas surrounding corn fields. As with M. femurrubrum, the first adults were collected on 13 August 1979, and 18 July 1980, respectively (Tables A-3, A-4, Appendix).

#### Dichromorpha viridis (Scudder)

This green-to-brown grasshopper is mostly brachypterous (short winged) and is dimorphic, the male much smaller than the medium, robust, female. Marcovitch (1920) reported D. viridis was rather common in Tennessee, found in open woodlands and dry

fields; Blatchley (1920) and Helfer (1963) stated they were found in vegetation around fence rows, roadsides, lakes and ponds. In the current study, adult D. viridis represented 14%, 29 specimens, of adult acridids collected (Table 3) and first appeared on 23 July 1979, and 18 July 1980 (Tables A-3, A-4, Appendix).

Chortophaga viridifasciatus (De Geer)

C. viridifasciatus is a dimorphic species with mostly green females and smaller, brown males. They are common throughout Tennessee, causing occasional problems (Marcovitch 1920), and are widely distributed in the United States (Morse 1920). This bivoltine grasshopper is apparently upland or campestral (inhabits open fields) but seems not to stray from areas of moist soil (Cantrall 1943).

In the Greeneville sample areas, adults were first taken on 23 July 1979, and 11 July 1980 (Tables A-3, A-4, Appendix). This species constituted 5.8%, 12 specimens, of the acridid adults collected for both years (Table 3). Although small numbers of adults were collected, the green nymphs were observed in early May before any other acridids (nymph or adult). They were seen in hilly pastures on warm sunny days.

Sybrula admirabilis (Uhler)

Marcovitch (1920) said this was fairly common in Tennessee pastures and grassy fields. In 1979 and 1980, only four total adults were collected at the Experiment Station (Table 3).

Hippiscus rugosus (Scudder)

Hippiscus rugosus was reported as occurring throughout Tennessee (Marcovitch 1920), but only one specimen was collected for both years at the Greeneville Station (Table 3).

Melanoplus scudderi (Uhler)

Melanoplus scudderi was said to be Tennessee's most common brachypterous Melanoplus species and is found particularly in sylvan surroundings (Marcovitch 1920). A total of two was collected for both years at the Greeneville Experiment Station (Table 3). A woodland was near the site where the two specimens were collected.

Camnula pellucida (Scudder)

No Camnula pellucida was found in The University of Tennessee reference collection (B. A. Mullens 1979, personal communication); Virginia is the recorded southern limit in the eastern United States (Blatchley 1920, Helfer 1963, Strohecker et al. 1968). C. pellucida damages rangeland and pastures, and severely injures cereals in both the United States and Canada (Hewitt and Barr 1967, Strohecker et al. 1968, Turnock 1977). Only one specimen (female) of Camnula pellucida was collected for both years at the Station (Table 3).

Tettigoniidae

A total of 2,466 tettigoniids, nymphs and adults, were collected at the Experiment Station. In 1979, acridids outnumbered tettigoniids except those sampled after the mowing of surrounding

vegetation, 7 September, at the sample site. In 1980, tettigoniids outnumbered acridids except on 17 June, and 12, 19, and 26 August; 1980 sampling terminated before vegetation cutting. For both years, tettigoniids were observed in the tobacco plots, but, unlike acridids, feeding on plants was not confirmed.

Orchelimum pulchellum Davis, which was the most abundant of quantified adult tettigoniid species captured in both years (Table A-5, Appendix), has not been reported in Tennessee. The first adults were collected in Greeneville on 13 August 1979, and 18 July 1980, respectively (Tables A-3, A-4, Appendix).

The first adults (Tables A-3, A-4, Appendix) of Conocephalus fasciatus fasciatus (De Geer) were collected on 13 June 1980, and in the first sample of 1979, 13 July. It may have rivaled O. pulchellum in numbers, but adults captured from 13 June through 8 July 1980, were not included in the counts or percentages (Table A-5, Appendix) since they were not quantified. In addition, adults of Conocephalus fasciatus fasciatus probably appeared earlier than 1979 collections began.

## CHAPTER V

### SUMMARY

Nineteen species of Orthoptera were identified, eight of which were acridids. Three of these acridids are major problems in the United States: M. femurrubrum, M. differentialis, and Camnula pellucida. M. femurrubrum comprised 63.5% of all adult acridids sampled. M. differentialis and C. pellucida comprised 13 and 0.5%, respectively. Camnula pellucida has not been previously recorded in Tennessee.

Generally, there were more acridids than tettigoniids in both 1979 collections and in those of the last two thirds of August 1980. Of the tettigoniids, Orchelimum pulchellum Davis has not been previously recorded in Tennessee. A total of 173 adults of this species were collected over both seasons.

Development rate of Melanoplus femurrubrum and M. differentialis varied from 1979 to 1980. The mean instar of both species combined, reached 3.1 more than two weeks earlier in 1980 (27 June) than in 1979 (13 July). Both M. femurrubrum and M. differentialis adults first occurred on 13 August 1979, and 18 July 1980. No data were collected on the first appearance of nymphs in 1979, but the nymphs of M. differentialis and M. femurrubrum were first collected on 22 May and 30 May 1980, respectively.

In 1980, significantly fewer acridids were collected in acephate sprayed borders of tobacco plots than in adjacent, untreated

vegetation. However, significantly less tobacco was yielded in plots with unmowed borders than with mowed borders; competition for such requirements as light and water was suspected.

Tobacco plot damage by grasshoppers was not induced by cutting surrounding vegetation. Damage was caused in a nonrelated test (tobacco) site after cutting of an alfalfa field downhill from that site in 1979.

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## APPENDIXES

## APPENDIX 1

TABLE A-1. Vegetation Identified from the Main Sample Site,  
Greene County, Tennessee, 1980

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|                                                           |
|-----------------------------------------------------------|
| <u>Plantago major</u> L.- Broadleaf Plantain              |
| <u>Setaria viridis</u> (L.)- Green Foxtail                |
| <u>Trifolium pratense</u> L.- Red Clover                  |
| <u>Festuca arundinacea</u> Schreb.- Tall Fescue           |
| <u>Xanthium pensylvanicum</u> Wallr.- Cocklebur           |
| <u>Chenopodium album</u> L.- Lambsquarter                 |
| <u>Amaranthus retroflexus</u> L.- Redroot Pigweed         |
| <u>Rumex crispus</u> L.- Curley Dock                      |
| <u>Taraxacum officinale</u> Weber.- Dandelion             |
| <u>Ambrosia artemisiifolia</u> L.- Ragweed                |
| <u>Galinsoga parviflora</u> Cav.- Galinsoga               |
| <u>Digitaria sanguinalis</u> (L.) Scop.- Large Crabgrass  |
| <u>Cynodon dactylon</u> (L.) Pers.- Bermudagrass          |
| <u>Portulaca oleracea</u> L.- Common Purslane             |
| <u>Solidago altissima</u> L.- Goldenrod                   |
| <u>Trifolium repens</u> L.- White Clover                  |
| <u>Solanum carolinense</u> L.- Horsenettle                |
| <u>Cyperus esculentus</u> L.- Yellow Nutsedge             |
| <u>Echinochloa crus-galli</u> (L.) Beauv.- Barnyard Grass |
| <u>Eleusine indica</u> (L.) Gaertn.- Goosegrass           |
| <u>Erigeron canadensis</u> L.- Horseweed                  |
| <u>Erigeron annuus</u> (L.) Pers.- Annual Fleabane        |
| <u>Chenopodium ambrosioides</u> L.- Mexicantea            |

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## APPENDIX 2

TABLE A-2. Climatological Data, Greene County, Tennessee, 1979 and 1980  
(NOAA 1979-1980)

| Climatological<br>Factor | Year | Months |      |      |        |           |
|--------------------------|------|--------|------|------|--------|-----------|
|                          |      | May    | June | July | August | September |
| Precipitation (cm)       | 1979 | 9.2    | 16.1 | 16.7 | 8.1    | 14.0      |
|                          | 1980 | 9.7    | 4.4  | 11.0 | 10.8   | 11.6      |
| Temperature (°C)         | 1979 | 17.6   | 20.9 | 22.7 | 23.3   | 20.4      |
|                          | 1980 | 17.7   | 21.8 | 25.4 | 25.1   | 21.9      |

# APPENDIX 3

TABLE A-3. Seasonal Occurrence of Adults of Selected Acridids and Tettigoniids, Greene County, Tennessee, 1979

| Species                           | Week No. | Sample Weeks |       |       |      |       |      |
|-----------------------------------|----------|--------------|-------|-------|------|-------|------|
|                                   |          | July         |       | Aug.  |      | Sept. |      |
|                                   |          | 10-16        | 17-23 | 24-30 | 7-13 | 21-27 | 4-10 |
|                                   |          | 10           | 11    | 12    | 14   | 16    | 18   |
| <b>Acrididae</b>                  |          |              |       |       |      |       |      |
| <u>Melanoplus femurrubrum</u>     |          |              |       |       | X    | X     | X    |
| <u>Dichromorpha viridis</u>       |          |              | X     | X     | X    |       |      |
| <u>Melanoplus differentialis</u>  |          |              |       |       | X    | X     |      |
| <u>Chortophaga viridifasciata</u> |          |              | X     |       |      |       | X    |
| <b>Tettigoniidae</b>              |          |              |       |       |      |       |      |
| <u>Orchelimum pulchellum</u>      |          |              |       |       | X    | X     | X    |
| <u>Conocephalus brevipennis</u>   |          |              |       |       |      | X     | X    |
| <u>Conocephalus fasciatus</u>     |          | X            | X     | X     | X    |       | X    |
| <u>Conocephalus strictus</u>      |          |              |       |       |      | X     | X    |

# APPENDIX 4

TABLE A-4. Seasonal Occurrence of Adults of Selected Acridids and Tettigoniids, Greene County, Tennessee, 1980

| Species                           | Week No. | Sample Weeks |       |      |      |       |       |      |     |        |       |       |      |      |       |       |  |
|-----------------------------------|----------|--------------|-------|------|------|-------|-------|------|-----|--------|-------|-------|------|------|-------|-------|--|
|                                   |          | May          |       | June |      | July  |       |      |     | August |       |       |      |      |       |       |  |
|                                   |          | 8-14         | 22-28 | 29-4 | 5-11 | 12-18 | 19-25 | 26-2 | 3-9 | 10-16  | 17-23 | 24-30 | 31-6 | 7-13 | 14-20 | 21-27 |  |
|                                   |          | 1            | 3     | 4    | 5    | 6     | 7     | 8    | 9   | 10     | 11    | 12    | 13   | 14   | 15    | 16    |  |
| Acrididae                         |          |              |       |      |      |       |       |      |     |        |       |       |      |      |       |       |  |
| <u>Melanoplus femurrubrum</u>     |          |              |       |      |      |       |       |      |     |        | X     | X     | X    | X    | X     | X     |  |
| <u>Dichromorpha viridis</u>       |          |              |       |      |      |       |       |      |     |        | X     | X     | X    | X    | X     |       |  |
| <u>Melanoplus differentialis</u>  |          |              |       |      |      |       |       |      |     |        | X     | X     | X    | X    | X     | X     |  |
| <u>Chortophaga viridifasciata</u> |          |              |       |      |      |       |       |      |     | X      |       | X     |      | X    | X     | X     |  |
| Tettigoniidae                     |          |              |       |      |      |       |       |      |     |        |       |       |      |      |       |       |  |
| <u>Orchelimum pulchellum</u>      |          |              |       |      |      |       |       |      |     |        | X     | X     | X    | X    | X     | X     |  |
| <u>Conocephalus brevipennis</u>   |          |              |       |      |      |       |       |      |     |        |       | X     | X    | X    | X     | X     |  |
| <u>Conocephalus fasciatus</u>     |          |              |       |      |      | X     | X     | X    | X   | X      | X     | X     | X    | X    | X     | X     |  |
| <u>Conocephalus strictus</u>      |          |              |       |      |      |       |       |      |     |        |       |       | X    | X    | X     | X     |  |

# APPENDIX 5

TABLE A-5. Relative Abundance of Adult Tettigoniids Collected, Greene County, Tennessee, 1979 and 1980

| Species                                              | 1979 | 1980 | Total |     |
|------------------------------------------------------|------|------|-------|-----|
|                                                      | %    | %    | %     | No. |
| <u>Orchelimum pulchellum</u> <sup>1</sup>            | 52.7 | 52.3 | 52.4  | 173 |
| <u>Conocephalus brevipennis</u>                      | 14.5 | 23.6 | 20.6  | 68  |
| <u>Conocephalus fasciatus fasciatus</u> <sup>2</sup> | 18.2 | 14.1 | 15.4  | 51  |
| <u>Conocephalus strictus</u>                         | 14.5 | 8.2  | 10.3  | 34  |
| <u>Orchelimum vulgare</u>                            | —    | 0.9  | 0.6   | 2   |
| <u>Neoconocephalus retusus</u>                       | —    | 0.4  | 0.3   | 1   |
| <u>Scudderia furcata</u>                             | —    | 0.4  | 0.3   | 1   |

<sup>1</sup>Not previously recorded in Tennessee.

<sup>2</sup>Adults collected before quantified sampling in 1980 (13 June through 8 July) were not included.

APPENDIX 6

TABLE A-6. Identified Orthoptera, other than Acridids, Greene County, Tennessee, 1979 and 1980

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Tetrigidae

Tetriginae

Tetrix arenosa angusta (Hancock)

Batrachideinae

Tettigidea lateralis (Say)

Tettigoniidae

Conocephalinae

Conocephalus brevipennis (Scudder)

Conocephalus fasciatus fasciatus (De Geer)

Conocephalus strictus (Scudder)

Orchelimum pulchellum Davis

Orchelimum vulgare (Harris)

Copiphorinae

Neoconocephalus retusus (Scudder)

Phaneropterinae

Scudderia furcata Brunner von Wattenwyl

Gryllidae

Oecanthinae

Neoxabea bipunctata (De Geer)

Oecanthus quadripunctatus Beutenmuller

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# APPENDIX 7

TABLE A-7. Occurrence of the Most Abundantly Collected Species of Melanoplus, Greene County, Tennessee, 1979

| Species               |              | Percent of Total Collected/Sample Date |      |      |      |      |      |       |   |
|-----------------------|--------------|----------------------------------------|------|------|------|------|------|-------|---|
|                       |              | July                                   |      |      |      | Aug. |      | Sept. |   |
|                       |              | 13                                     | 23   | 30   | 6    | 13   | 24   | 7     |   |
| <u>Melanoplus</u>     |              |                                        |      |      |      |      |      |       |   |
| species               | <u>1</u>     | 0.3                                    | —    | —    | —    | —    | —    | —     | — |
| species               | <u>2</u>     | 41.6                                   | 21.3 | 12.4 | 0.9  | —    | 1.8  | 7.4   | — |
| <u>femurrubrum</u>    | <u>3</u>     | 52.5                                   | 62.7 | 53.5 | 20.7 | 3.7  | 1.8  | —     | — |
| <u>differentialis</u> | —            | 4.3                                    | 3.8  | 2.5  | 2.6  | —    | —    | —     | — |
| <u>femurrubrum</u>    | <u>4</u>     | 0.3                                    | 7.3  | 28.7 | 57.8 | 38.8 | 7.4  | —     | — |
| <u>differentialis</u> | —            | 1.1                                    | 3.8  | 1.5  | 0.9  | 1.5  | —    | —     | — |
| <u>femurrubrum</u>    | <u>5</u>     | —                                      | 0.5  | —    | 14.7 | 50.0 | 66.7 | 14.8  | — |
| <u>differentialis</u> | —            | —                                      | 0.8  | 1.5  | 2.6  | 2.2  | 1.8  | —     | — |
| <u>femurrubrum</u>    | <u>Adult</u> | —                                      | —    | —    | —    | 1.5  | 18.5 | 77.7  | — |
| <u>differentialis</u> | —            | —                                      | —    | —    | —    | 2.2  | 1.8  | —     | — |

# APPENDIX 8

TABLE A-8. Occurrence of the most Abundantly Collected Species of Melanoplus,  
Greene County, Tennessee, 1980

| Species               |              | Percent of Total Collected/Sample Date |      |      |      |      |      |      |  |
|-----------------------|--------------|----------------------------------------|------|------|------|------|------|------|--|
|                       |              | May                                    | June |      | July |      | Aug. |      |  |
|                       |              | 22                                     | 9    | 27   | 15   | 25   | 12   | 26   |  |
| <u>Melanoplus</u>     |              |                                        |      |      |      |      |      |      |  |
| species               | <u>1</u>     | 100.0                                  | 39.6 | —    | —    | —    | —    | —    |  |
| species               | <u>2</u>     | —                                      | 41.6 | 41.1 | 0.9  | —    | —    | 1.8  |  |
| <u>femurrubrum</u>    | <u>3</u>     | —                                      | 18.8 | 42.9 | 65.4 | 30.2 | 3.3  | —    |  |
| <u>differentialis</u> | —            | —                                      | —    | 12.5 | 4.7  | 6.2  | —    | 1.9  |  |
| <u>femurrubrum</u>    | <u>4</u>     | —                                      | —    | 3.6  | 20.6 | 52.1 | 26.2 | 5.4  |  |
| <u>differentialis</u> | —            | —                                      | —    | —    | 4.7  | 1.0  | —    | —    |  |
| <u>femurrubrum</u>    | <u>5</u>     | —                                      | —    | —    | 2.8  | 6.2  | 54.1 | 16.3 |  |
| <u>differentialis</u> | —            | —                                      | —    | —    | 0.9  | 1.0  | 1.6  | —    |  |
| <u>femurrubrum</u>    | <u>Adult</u> | —                                      | —    | —    | —    | 2.1  | 11.4 | 63.6 |  |
| <u>differentialis</u> | —            | —                                      | —    | —    | —    | 1.0  | 3.3  | 11.0 |  |

## VITA

Stuart Harris Stein was born in Chattanooga, Tennessee, on 6 July 1955, the son of Herbert and Gitta Stein. He graduated from Brainerd High School in 1973. While attending Brainerd High he was a member of the Beta Club. He graduated from The University of Tennessee, Chattanooga, in May 1978, with a Bachelor of Arts Degree in Biology. While at The University of Tennessee, Chattanooga, he was inducted into Tri Beta.

In the fall of 1979, he received an assistantship at The University of Tennessee, Knoxville, in the Department of Entomology and Plant Pathology. In June 1983, he received the M.S. degree with a major in Entomology.

He is a member of the Entomological Society of America and the Entomological Society of Pennsylvania.