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Parasites and Predators of Grasshoppers in Missouri

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Parasites and Predators of Grasshoppers in Missouri

J. L. HUGGANS AND C. C. BLICKENSTAFF*

INTRODUCTION

A study of the parasites and predators affecting grasshoppers in Missouri was initiated in 1959. This report summarizes the data obtained in 1959 and 1960 on the occurrence of nematodes, dipterous parasites, and the ectoparasitic phase of the grasshopper mite, *Eutrombidium locustarum* (Walsh). These represent only the biological factors readily observed by collecting and rearing nymphal and adult grasshoppers. Diseases and factors such as pure predation operating only in the field were not studied although they may play a very important role in natural control.

We included in the study all species of the Order Orthoptera that were collected by sweep net in the field. Four of these are generally considered of major economic importance: the differential grasshopper [*Melanoplus differentialis* (Thomas)], the two-striped grasshopper [*M. bivitattus* (Say)], the migratory grasshopper, [*M. sanguinipes* (F.)], and the red-legged grasshopper [*M. femurrubrum* (DeGeer)]. These species, singly or in combination, caused serious damage to a wide variety of crops in Missouri in one out of every three years from 1818, when records were first kept, to 1938 (Jones, 1939).

Much effort has been directed toward insecticidal control of grasshoppers, but relatively little is known about the biological factors affecting grasshoppers in spite of the fact that they occasionally, but dramatically, reduce outbreaks of grasshoppers to insignificance.

REVIEW OF LITERATURE

Sweetman (1958) assembled the world literature on biological control agents. Most of the important references to the parasites and predators included in our

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* The mite portion of this paper is based on a thesis submitted by Huggans to the graduate faculty of the University of Missouri in partial fulfillment of the requirements for an M.S. degree. Co-author Blickenstaff is with the Entomology Research Division, Agr. Res. Serv., U.S.D.A. The bulletin is a report on Department of Entomology research project 369.

study may be found in his publication. Spencer (1958a) presented a very comprehensive discussion of the natural control complex affecting all stages of grasshoppers in British Columbia. Parker and Wakeland (1957) reported the percentages of grasshopper egg pods of the economic species of *Melanoplus* destroyed by predators, as determined by egg surveys in the United States from 1936 to 1950. Smith (1958) summarized available information on parasites of grasshopper nymphs and adults in western Canada from 1938 to 1953.

Although nematodes of the family Mermithidae are common and widespread internal parasites of nymphal and adult grasshoppers, the only detailed study was made by Christie (1936, 1937) on the two species *Agamermis decaudata* Cobb, Steiner and Christie, and *Mermis subnigrescens* Cobb in Virginia and Massachusetts.

York and Prescott (1952) reviewed literature on nemestrinid parasites (Diptera:Nemestrinidae) of nymphal and adult grasshoppers and reported on the occurrence, life history, and habits of these parasites in Montana. Additional work on these parasites in Montana was reported by Prescott (1955) and York (1955). Spencer (1958b) reported on the host preferences of *Neorhynchocephalus sackenii* (Williston) and *Trichopsidea clausa* (Osten Sacken) in British Columbia.

Other dipterous parasites (Sarcophagidae and Tachinidae) were reported by Spencer (1958a) in British Columbia, Treherne and Buckell (1924) in British Columbia, Morgan (1901) in Mississippi, and Newton (1954) in Montana.

The biology of the very common and widspread ectoparasitic grasshopper mite, *Eutrombidium locustarum,* has been treated in detail by only two workers in this country: Howard (1918) in Minnesota, and Severin (1944) in North Dakota.

Scattered reports of the occurrence of grasshopper parasites in Missouri were given by Riley (1875), Jones (1939), Parker and Wakeland (1957), Shotwell (1960), and Blickenstaff and Sharifullah (1962).

METHODS AND PROCEDURES

In 1959, grasshoppers were collected at monthly intervals in 17 counties representing the major soil types and type of farming areas (Collier, 1955) in the State, and at weekly intervals in four habitats in Boone County. Figure 1 shows major State areas with the numbers collected in each county. The four Boone County habitats were located from north to south and are numbered to compare with 1960 sites, as follows:

1. Putnam-Mexico soil; margins of cultivated fields on upland prairie; crops included clover, corn, soybeans, and small grain. South Farm, University of Missouri.
2. No comparable site in 1959.
3. Weldon-Union soil; woodland, woods margin, and roadside in the river hills near Pierpont.
4. Winfield and Menfro soils; permanent pastureland in the river hills near Sapp.

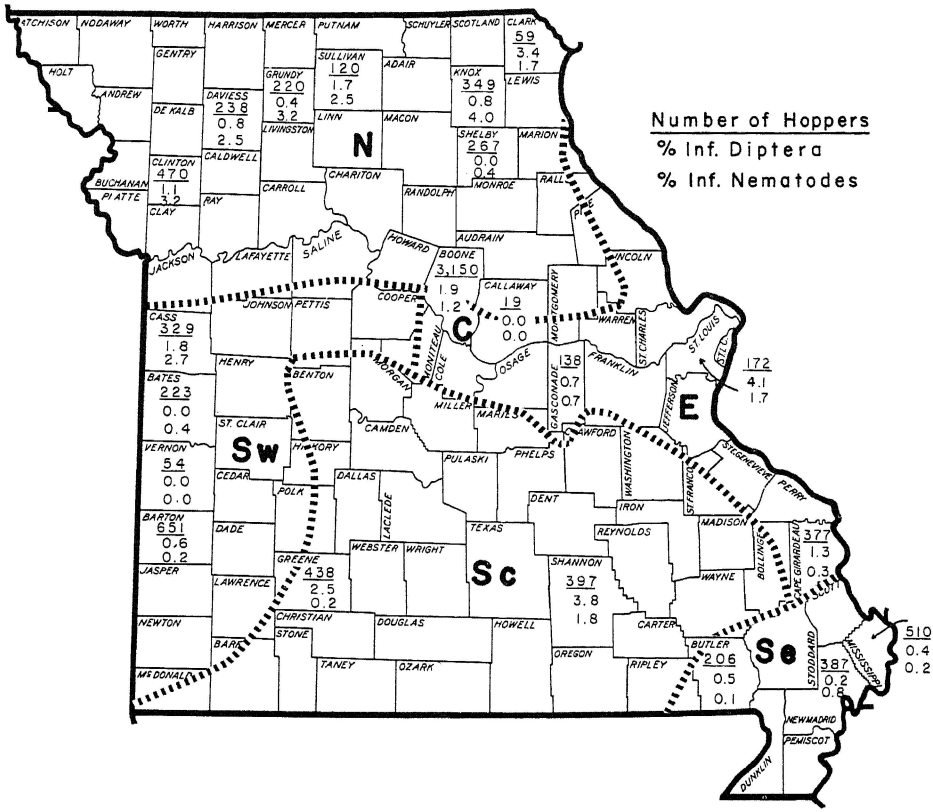

Fig. 1—Number of Orthoptera collected by county and percent parasitized by Diptera and nematodes, 1959.

5. Missouri River bottomland; crops included alfalfa, corn, soybeans, and small grain near Easley.

From one to five soil samples were also taken at each habitat each week. These were 1 foot square and 3 inches deep and were later processed in Berlese funnels for mite recovery.

In 1960 weekly grasshopper collections were confined to Boone County. The number of habitats was expanded to five representative of the major soil types and the type of vegetative cover each supported (Scrivner and Frieze, 1951). These were duplicated on two survey lines, line *A* being on the eastern side and line *B* on the western side of the County. The sites were numbered 1 to 5, from north to south, as illustrated in Figure 2, and are described as follows:

1. Putnam-Mexico soil; primarily cropland, rather intensively cultivated.
2. Lindley-Hatton soil; primarily pastureland, some white oak and cultivated areas.

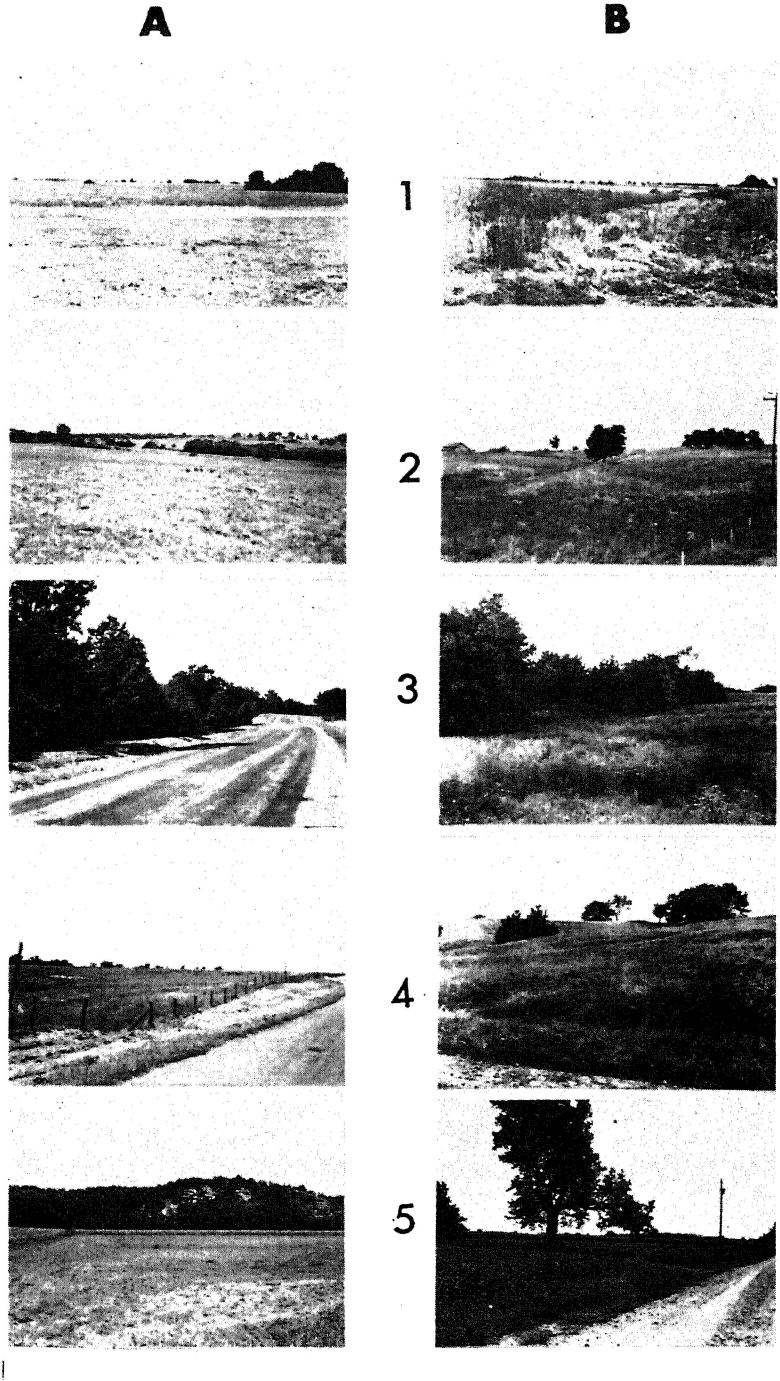

Fig. 2—Grasshopper collection sites in Boone County, 1960.

3. Weldon-Union soil; woodland, pasture, and level areas cultivated.
4. Winfield and Menfro soils; primarily pasture and woodland.
5. Missouri River bottom; intensively cultivated.

Grasshoppers were collected by net sweeping and each sample consisted of at least 50 specimens when possible. Each collection was transported in screen cages to the laboratory, where the grasshoppers were anesthetized with carbon dioxide and sorted to genus or species. Those found infested with mites in 1959 were isolated individually (Figure 3), but in 1960 they were held in groups in rearing cages for completion of mite engorgement. The remainder were held in rearing cages for nematode and fly parasite emergence. Survivors were dissected at varying intervals after they became adult for further parasite recovery.

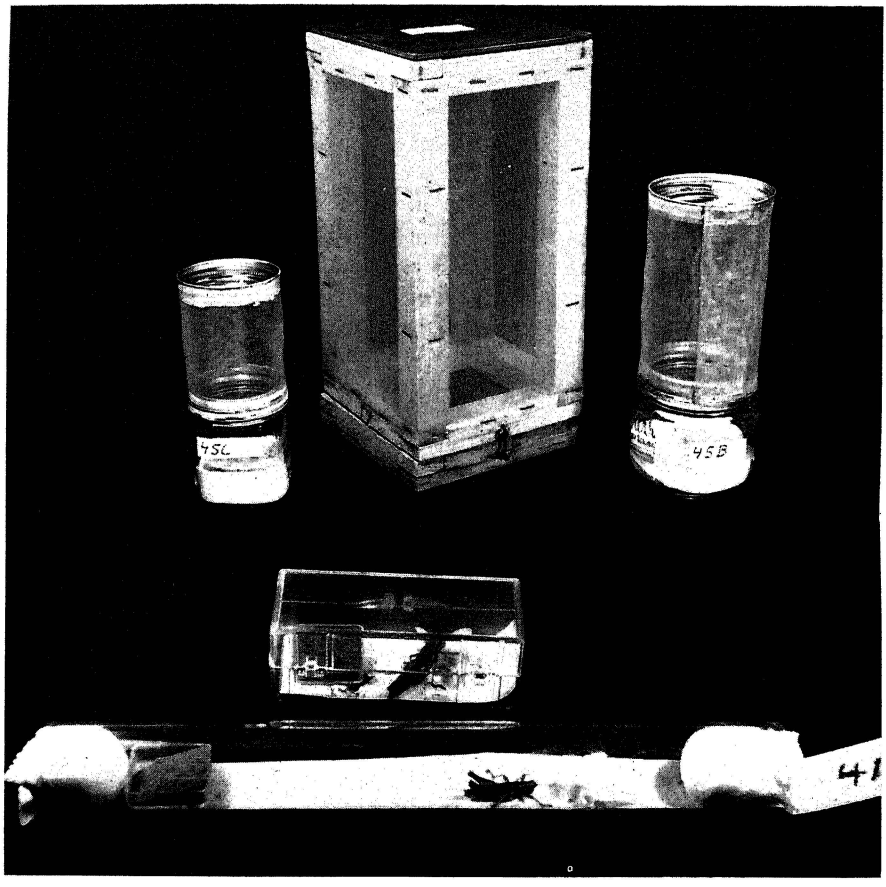

Fig. 3—Cages used to rear groups of grasshoppers in 1960 (upper) and containers used for isolating individual mite-infested grasshoppers in 1959 (lower).

Several types of holding and rearing containers were used: these included lamp chimneys set in petri dishes containing moist sand or filter paper; pint and quart glass fruit jars with cheesecloth tops; half-pint, pint, and quart glass fruit jars containing sand and topped with elongated cylinders of 32-mesh Saran[R] screen; and 6 x 6 x 12-inch screen cages with detachable solid tops and hardware cloth bottoms (Figure 3). Moist white sand in or under the cages provided a moist environment for grasshopper development and a suitable place into which engorged mites could burrow. Food for the grasshoppers consisted of Cerophyl[R] (a dried, ground mixture of young cereal plants) and fresh head lettuce changed daily. Parasites were removed at the time of feeding.

Dipterous parasites were usually held on moist sand in plastic boxes for pupation and adult emergence. Larvae failing to pupate were preserved in 80 percent ethyl alcohol. Pupae and adults were pinned. C. W. Sabrosky, U. S. Department of Agriculture, identified tachinids and sarcophagids. B. D. Burks, also of the U.S. Department of Agriculture, identified their hymenopterous hyperparasites. Nemestrinids were not identified to species.

Attempts to hold nematodes for maturation on sand were unsuccessful. Some remained alive in clay cells in tin boxes for several months, but all were eventually preserved in formaldehyde. H. E. Welsh, Canada Department of Agriculture, tentatively identified them.

Representative mites were preserved on slides in Hoyer's mounting medium and identified by Marc André, Paris, France. Representatives of all the grasshoppers collected were pinned, used as a reference collection, and identified by A. B. Gurney, U. S. Department of Agriculture. Specimens identified and preserved in this study are stored for further use in the University of Missouri Entomology Museum.

ORTHOPTERA COLLECTED

We collected 8,711 specimens of Orthoptera in 1959 and 13,531 in 1960. The difficulty of positively identifying the early nymphal stages and some adults of closely related species quite likely introduced errors in the parasite infestation rates for some species.

The Orthoptera collected in this study are listed systematically in Table 1. Also presented in this table are the numbers of each species taken by year, the seasonal occurrence of each species by year, the State distribution, and parasite occurrence.

TABLE 1--ORTHOPTERA COLLECTED IN MISSOURI, 1959 AND 1960

Family & Species	Number Collected 1959	Number Collected 1960	Seasonal Occurrence	State Distribution	Parasite Occurrence
Mantidae	0	28		C	
Phasmatidae					
Diapheromera blatchleyi (Caudell)	0	14		C	
Tetrigidae (5 species)	139	43		Statewide	
Acrididae					
Acridinae					
Syrbula admirabilis (Uhler)	181	278		Statewide	M D
Eritettix simplex (Scudder)	0	1		C	
Orphulella speciosa (Scudder)	55	481		N, C, Sw, S, Se	M N D
Dichromorpha viridis (Scudder)	230	185		Statewide	M N D
Chloealtis conspersa (Harris)	0	7		C	
Agenotettix deorum (Scudder)	16	34		N, C	M
Undetermined	17	226			
Oedipodinae					
Arphia (3 or 4 species)	91	131		Statewide	M N
Chortophaga viridifasciata (DeGeer)	418	295		Statewide	M N D
Encoptolophus sordidus (Burmeister)	37	52		N, C, E	D
Hippiscus rugosus (Scudder)	15	95		N, C, Sc	M D
Pardalophora (2 species)	8	29		N, C, Sc, E	
Dissosteira carolina (Linnaeus)	49	90		Statewide	M D
Spharagemon (2 species)	6	14		C, Sc	

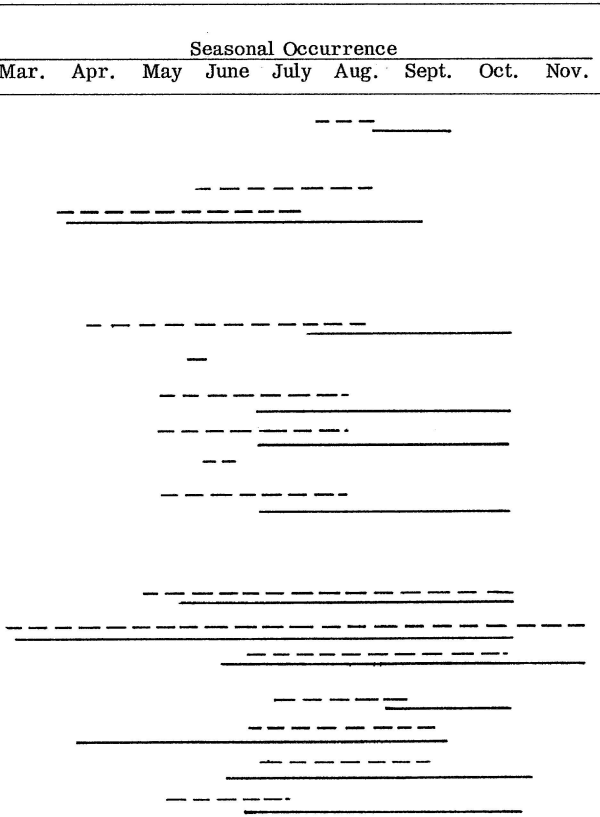

TABLE 1 (cont'd) ORTHOPTERA COLLECTED IN MISSOURI, 1959 AND 1960

Family & Species	Number Collected 1959	Number Collected 1960	Seasonal Occurrence Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	State Distribution	Parasite Occurrence
Hadrotettix trifasciatus (Say)	0	23										C	
Trimerotropus citrina Scudder	31	19										C	
Trachyrhachys kiowa (Thomas)	3	32										N, C	
Undetermined	17	0											
Cytacanthacridinae													
Schistocerca (3 species)	76	109										N, C, E, Sw, Sc, Se	M N
Campylacantha olivacea (Scudder)	41	132										N, C, Sw, Sc, Se	M N D
Hesperotettix viridis pratensis (Scudder)	8	3										C, E	M
Melanoplus sanguinipes (Fabricius)	1253	2046 1/										Statewide	M N D
M. femurrubrum (DeGeer)	1000	2072										Statewide	M N D
M. confusus Scudder	46	447										N, C, Sw	M N D
M. differentialis (Thomas)	1206	621										Statewide	M N D
M. bivittatus (Say)	537	297										Statewide	M N D
M. (8 short winged species)	106	157 2/										C, Sw, Sc, Se	M N D
M. species undetermined	69	1154											M N D
Paratylotropidia brunneri Scudder	2	13										C	
Undetermined	8	0											
Undetermined Acrididae	9	0											

TABLE 1 (cont'd) ORTHOPTERA COLLECTED IN MISSOURI, 1959 AND 1960

Family & Species	Number Collected 1959	Number Collected 1960	Seasonal Occurrence Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	State Distribution	Parasite Occurrence
Tettigoniidae													
Phaneropterinae													
Scudderia, Amblycorypha, and Microcentrum	137	262										Statewide	
Copiphorinae													
Neoconocephalus sp.	50	12										N, C, Sw, Sc, Se	
Conocephalinae													
Orchelimum spp. primarily O. vulgare (Harris)	600	1546										Statewide	M N D
Conocephalus fasciatus (DeGeer)	928	346										Statewide	M N
C. nemoralis (Scudder)	2	2										C, Sw	
C. strictus (Scudder)	380	1201										Statewide	M N
Undetermined O. or C.	519	431											N D
Gryllidae													
Gryllinae													
Acheta assimilis (Fabricius)	2	2										C, Sw	
Nemobiinae													
Nemobius fasciatus (DeGeer)	269	55										Statewide	M N D
Oecanthinae													
Oecanthus nigricornis Walker	152	642										Statewide	N D
Trigonidiinae													
Anaxia exigua (Say)	1	0										C	

TABLE 1 (cont'd) ORTHOPTERA COLLECTED IN MISSOURI, 1959 AND 1960

Family & Species	Number Collected 1959	Number Collected 1960	Seasonal Occurrence Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	State Distribution	Parasite Occurrence
Eneopterinae													
Hapithus agitator Uhler	0	2										C	
Totals	8,711	13,531											

— — — — Nymphs
———— Adults

C = Central
N = North
E = East
S = South
W = West

M = Mites
N = Nematodes
D = Diptera

1/ Numbers for the five named Melanoplus species were adjusted to allocate unidentifiable nymphs on the basis of a nymph-adult ratio of 1.63:1.

2/ Melanoplus ponderosus (Thomas), M. viridipes group, M. scudderi group, M. gracilis (Bruner), M. walshii Scudder, M. beameri Hebard, M. fasciatus (Walker), and the long wing M. foedus fluviatilis Bruner.

Eutrombidium locustarum (Walsh) the Grasshopper Mite

Taxonomy.

The taxonomy of the trombidiid mites that infest grasshoppers is at this writing unresolved. E. W. Baker, Agr. Res. Serv., Entomology Research Division, U.S.D.A. (personal correspondence, 1960), who examined the specimens collected in this study, said: "There probably are several species in this complex and a very thorough study should be made of the mites from different areas and different grasshoppers before decisions can be made."

In South Dakota, Severin (1944) considered *E. trigonum* (Hermann) as the valid name. This is the common grasshopper mite in Europe, but Berlese (1912) and André (personal correspondence, 1960) do not consider *E. trigonum* and the common new world grasshopper mite, *E. locustarum* (Walsh), as being the same, since definite morphological characters separate the two.

Baker tentatively identified the preparations of the larval, nymphal, and adult mites taken in this study as Eutrombidium sp. Baker and Wharton (1952) consider *E. trigonum* synonymous with *E. rostratus* Scopoli, 1783. André then identified these same preparations and concluded:

> (Translated) "These E. do not seem to be *rostratum* (Scopoli) if one considers that this species is identical to *trigonum* (Hermann) but must belong rather to the species described by Walsh (1866) under the name of *locustarum.* This would correspond to the morphological characteristics shown by the larva. Indeed, your larvae resemble the *trigonum* (Hermann) (1804), which is, according to Oudemans, identical to *Astoma locustarum,* described by Walsh in 1866. Your preparations do present, however, some characteristics which differentiate them from the figure given by Oudemans (1912) (p. 108, fig. D 1). In fact, I consider your specimens of *E.* to be larvae, nymphs, and adults of *locustarum* (Walsh)."

This identification has been accepted for this study and the following is considered to be the synonomy of *E. locustarum:*

Astoma locustarum Walsh. 1866.
Atoma gryllaria LeBarron. 1872.
Astoma gryllaria (LeBaron) Riley. 1875.
Trombidium locustarum Riley. 1878.
Ottonia locustarum (Riley) Banks, 1894.
Microtrombidium locustarum Ewing. 1909.
Eutrombidium locustarum (Walsh) Berlese. 1912.

Say's description of a mite (1821) under the name *Trombidium sericeum* is too brief for positive identification as the grasshopper mite, though it was referred to under this name by Riley (1875, p. 175).

The description of the life stages of the grasshopper mite in South Dakota given by Severin (1944) seems to be an extension of Howard's work in Minne-

sota (1918). Howard also gives a key to the larvae, nymphs, and adults of the grasshopper mite in Minnesota and other closely related species found there.

General Life Cycle of the Mite.

The successive stages of development during the life cycle of the grasshopper mite were outlined by Severin, as follows:

1. Adult mite unengorged—feeds extensively on hopper eggs.
2. Adult mite engorged
3. Egg
4. Active larva recently hatched—parasitic on grasshopper nymphs and adults.
5. Inactive engorged larva—no longer on grasshoppers
6. Prenymphal pupa
7. Active nymph—feeds extensively on grasshopper eggs
8. Inactive engorged nymph
9. Preimaginal pupa
10. Adult mite unengorged

Severin states that one complete and a partial second generation occur each year in South Dakota. Our field data show continuous larval mite activity from late May to early October with no clear indication of multiple generations (Figures 4, 5, 7, and 8). However, 2 or more broadly overlapping generations could have occurred.

Mite Rearing and Laboratory Studies.

Engorged larval mites were recovered from field-collected grasshoppers and held in plastic boxes or petri dishes that contained moist sand, a sand and dirt mixture, or a plaster of paris-charcoal mix. In 1959, the mites from individual grasshoppers were held separately until the number of boxes became excessive. Colonies of mites were then established by host genus or species. For rearing purposes, nymphal and adult mites were fed exclusively on grasshopper eggs. Howard (1918) stated that grasshopper eggs were the preferred food of nymphs, but he had obtained partial engorgement on earthworms. His nymphs also attempted to feed on fly larvae *(Musca domestica)* "but they . . . proved too active." As for the adult mites, he stated that most of those in breeding cages refused to eat and went at once into hibernation. Severin also used grasshopper eggs as food but listed earthworms, pieces of earthworms, recently emerged grasshoppers, eggs removed from the ovaries of grasshoppers, and cow and horse dung, all of which he stated were readily fed upon. The dung contained fly larvae and other species of mites, which he suspected as being the material the nymphs fed upon rather than the dung itself.

We conducted a feeding test with unengorged adult mites collected in March, 1960, isolating 11 groups of 10 mites each in plastic boxes containing a plaster of paris-charcoal mixture. Each group of mites was offered food other than grasshopper eggs, as follows: Collembola, alive, dead, and eggs; Dermapter-

eggs; ground dog food, moistened; raw hamburger; earthworms, washed and unwashed; cow dung, sterilized and unsterilized; cerambycid larvae; termite workers; sow bugs or pill-bugs (Isopoda); an assortment of millipedes and centipedes; and yeast, wet and dry. As a check about 250 additional adult mites from the same collection were held on plaster of paris-charcoal in petri dishes and fed grasshopper eggs. Feeding in this colony was voracious and we collected about 200,000 mite eggs during the following 2 months.

Of the 11 foods offered the test mites, only the unwashed earthworms gave visible evidence of mite feeding. Seven of the ten mites placed in the container with the worms attempted to feed within 1 hour. All of those attempting to feed became entangled in the slime covering the worms and were rendered completely helpless for 1 to 2 hours, with the death of one mite resulting from the encounter. No attempts to feed on the washed worms were observed. None of the 110 adults used in the test laid eggs. Visible engorgement was not observed, though it is believed that the mites obtained water from the plaster and possibly from the cow dung. All test adults ultimately died, apparently from starvation.

An attempt was made to get larval mites to feed on *Acheta domesticus L.*, *Periplaneta americana* (L.), dermestid larvae, and human citrated blood, without success.

Our attempts to heavily infest adult grasshoppers with larvae to determine their effect on the host also failed.

Results of Field Surveys.

Grasshopper mite abundance and host relationship are presented in terms of hosts found infested by attached larvae. As noted above, the nymphal and adult stages of the mite are known to feed extensively on grasshopper eggs in the soil, and the soil sampling procedure used in 1959 was intended to show nymphal and adult mite abundance per unit area. From the 196 soil samples examined only one adult and two larvae taken on September 7 were identified as *E. locustarum.* However, several species not known to be parasitic on grasshoppers were collected. Representatives of 73 specimens were identified by Dr. André as *Microthrombidium columbianum* Berlese. These were compared by the senior author with the description of *M. magnitarse* Ewing given by Howard (1918) and found to agree. Other specimens taken that closely resemble the grasshopper mite included *Allothrombidium pulvinum* Ewing and a specimen identified by Dr. André as being "near *Thrombidium mediterraneum.*"

The larval mite infestation is summarized by host family, subfamily, genera, and species in Table 2. Mite infestation for the 1959 Statewide collections is presented by species only in Table 2 and is given by region and date for subfamilies in Table 3. Unless specifically noted, the remaining results pertain to 1959 and 1960 collections in Boone County. The general progression of mite infestation by selected host subfamilies is given in Figs. 4 and 5 for 1959 and 1960. Fig. 4 also shows the general lifespans of the economic species of *Melanoplus* and of

TABLE 2--ORTHOPTERA PARASITIZED BY EUTROMBIDIUM LOCUSTARUM (WALSH) IN MISSOURI, 1959 & 1960

Host Species	1959 Statewide 1/ Total Hoppers Collected	1959 Statewide 1/ % Para	1959 Statewide 1/ 95% Confidence Limits	1959 Boone County Total Hoppers Collected	1959 Boone County % Para	1959 Boone County 95% Confidence Limits	1960 Boone County Total Hoppers Collected	1960 Boone County % Para	1960 Boone County 95% Confidence Limits
Acrididae									
Acridinae									
Syrbula admirabilis	105	21.0	13.7-30.0	76	48.7	37.0-60.4	273	37.7	31.2-42.4
Orphulella speciosa	49	8.2	2.3-19.6	6	0.0	0-45.9	476	0	0- 0.7
Dichromorpha viridis	44	31.8	18.6-47.6	186	1.6	0.4- 4.8	185	0	0- 1.8
Oedipodinae									
Arphia (3 species)	49	2.0	0.1-10.8	42	7.1	1.5-19.5	131	9.2	4.9-15.6
Chortophaga viridifasciata	270	0	0- 1.2	148	0.7	0- 3.7	295	7.8	4.9-11.3
Hippiscus rugosus	10	0	0-30.8	5	40.0	5.3-85.3	95	34.7	25.2-45.2
Dissosteira carolina	25	8.0	1.0-26.0	24	4.2	0.1-21.1	90	1.1	0- 6.0
Cyrtacanthacridinae									
Schistocerca (3 species)	43	2.3	0.1-12.3	33	9.1	1.9-24.3	109	1.8	0.2- 6.4
Campylacantha olivacea	3	0	0-70.8	3	33.3	0.8-90.6	132	1.5	0.2- 5.5
Hesperotettix viridis pratensis	4	75.0	19.4-99.4	4	75.0	19.4-99.4	3	0	0-70.8
Melanoplus differentialis	602	8.3	6.2-10.4	604	11.2	9.2-14.5	621 2/	18.5	15.3-21.7
M. bivitattus	300	24.7	19.9-30.0	237	51.0	45.6-58.3	297	51.2	44.2-55.8
M. sanguinipes	625	13.1	10.7-16.3	628	12.6	10.7-16.3	2046	13.1	11.6-14.6
M. femurrubrum	741	14.8	12.6-17.7	259	5.8	3.1- 9.2	2070	8.7	7.6- 9.9
M. confusus	38	5.3	0.6-17.8	8	37.5	8.5-75.5	447	18.3	14.7-21.7
M. spp. (short wings) 3/	39	7.7	1.6-20.9	60	11.7	4.8-22.6	157	7.6	3.9-12.8

TABLE 2 (cont'd) ORTHOPTERA PARASITIZED BY EUTROMBIDIUM LOCUSTARUM (WALSH) IN MISSOURI, 1959 & 1960

Host Species	1959 Statewide 1/ Total Hoppers Collected	1959 Statewide 1/ % Para	1959 Statewide 1/ 95% Confidence Limits	1959 Boone County Total Hoppers Collected	1959 Boone County % Para	1959 Boone County 95% Confidence Limits	1960 Boone County Total Hoppers Collected	1960 Boone County % Para	1960 Boone County 95% Confidence Limits
M. spp. undet.	60	0	0- 6.0	9	0	0-33.6	1134 4/	0.2	0- 0.7
Paratylotropidia brunneri	0			2	0	0-84.2	13	23.1	5.0-53.8
Tettigoniidae									
Conocephalinae									
Orchelimum vulgare	443	2.9	1.6- 5.2	334	17.2	13.9-21.6	1538	2.3	1.6- 3.0
Conocephalus fasciatus	781	0	0- 0.5	147	0.7	0- 3.7	349	0.3	0- 1.8
C. strictus	291	1.4	0.4- 3.4	89	2.2	0.3- 7.9	1201	0.8	0.3- 1.6
C. spp. undet.	110	0	0- 3.3	107	0.9	0- 5.2	0	-	-
Conocephalinae undet.	94	2.1	0.3- 7.5	18	11.1	1.4-34.7	431	0.7	0.2- 2.2
Gryllidae									
Nemobiinae									
Nemobius fasciatus	213	0.5	0.0- 2.8	56	0	0- 6.4	57	0	0- 6.3

1/ State collections without Boone County.

2/ Rate of parasitism and host numbers adjusted as in Table 1 for the five major Melanoplus species.

3/ Of the 8 species of short winged Melanoplus collected only M. beameri (1 adult collected) had no mites.

4/ Primarily 1st and 2nd instar nymphs that failed to reach an identifiable stage.

TABLE 3--PERCENT MITE INFESTATION IN 1959 BY REGION AND DATE FOR HOST SUBFAMILIES

Region 1/ & Date 2/	Cyrtacanthacridinae			Acridinae			Oedipodinae			Conocephalinae		
	No. Coll.	% Infested	95% Confidence Limits	No. Coll.	% Infested	95% Confidence Limits	No. Coll.	% Infested	95% Confidence Limits	No. Coll.	% Infested	95% Confidence Limits
Central (Boone Co.)	253	24.1	18.9-29.8	47	46.8	32.1-61.9	16	6.2	0.2-30.2	162	2.4	0.7- 6.7
North	763	11.5	9.2-14.0	113	5.3	2.0-11.6	37	5.4	0.7-18.2	324	1.2	0.4- 3.4
East	266	8.6	5.7-12.4	20	45.0	23.1-68.5	57	0.0	0.0- 6.3	190	0.0	0.0- 1.9
Southeast	411	15.0	11.6-18.9	47	36.1	22.7-51.5	23	4.3	0.1-22.0	485	0.0	0.0- 0.7
South central	540	7.0	4.9- 9.6	28	17.8	6.3-38.1	96	0.0	0.0- 3.8	272	0.4	0.0- 2.2
Southwest	406	23.2	18.5-26.9	86	11.6	5.7-20.4	74	0.0	0.0- 4.9	632	2.2	1.2- 3.7
State Total	2639	13.9		341	20.6		303	1.3		2065	1.1	
May 10-16	211	0.0	0.0- 1.8	0	-	-	30	0.0	0.0-11.6	547	0.0	0.0- 0.7
June 14-20	667	16.1	14.0-20.0	53	3.3	0.5-13.0	46	2.1	0.1-11.5	456	0.4	0.0- 0.9
July 12-18	546	11.1	8.3-16.3	144	20.8	14.5-28.1	88	2.2	0.3- 8.0	319	6.5	4.1-10.1
Aug. 16-18	477	19.7	16.6-23.8	86	27.9	18.8-38.6	31	0.0	0.0-11.2	343	0.0	0.0- 1.2
Sept. 13-19	738	14.3	11.8-17.1	58	24.1	13.9-37.2	108	0.9	0.0- 5.0	400	0.0	0.0- 0.9

1/ Regional percents for five dates combined.

2/ Date percents for all state locations combined.

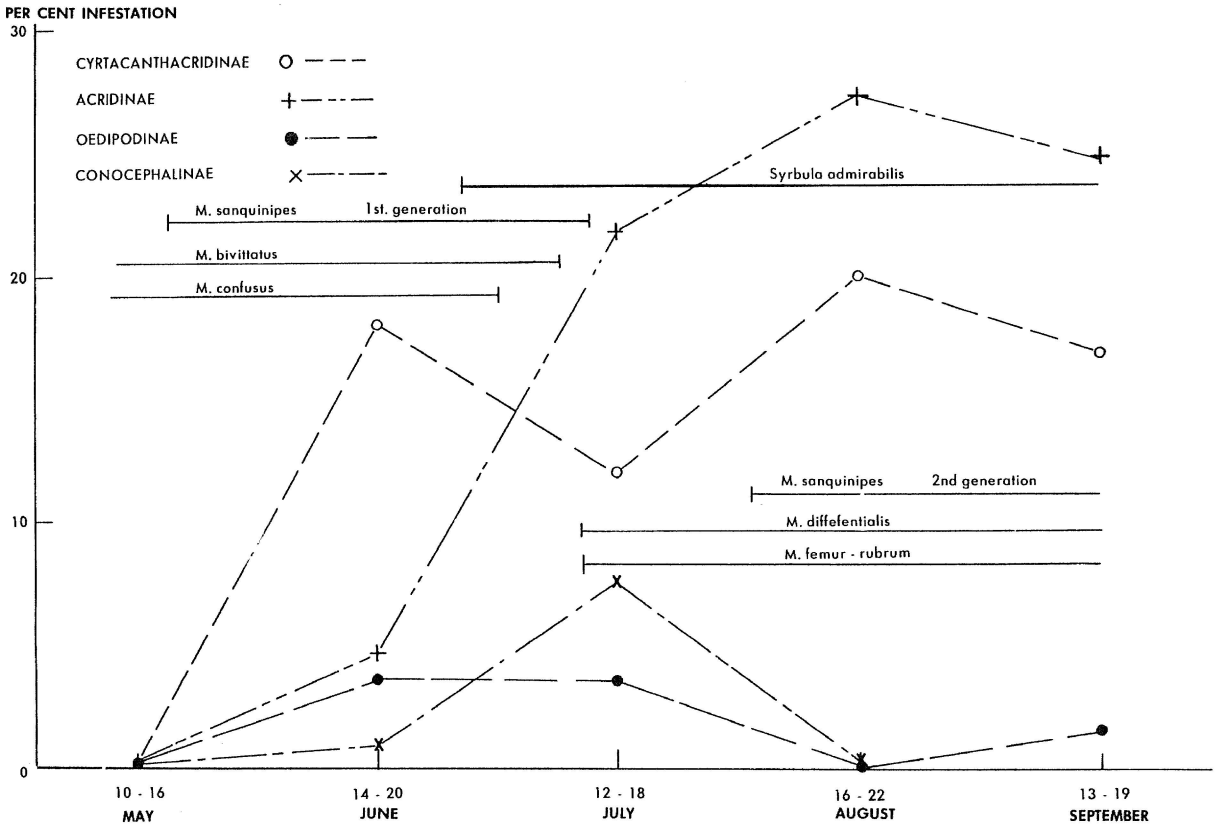

Fig. 4—Statewide mite infestation in 1959 by collection date and subfamily, and six host life spans.

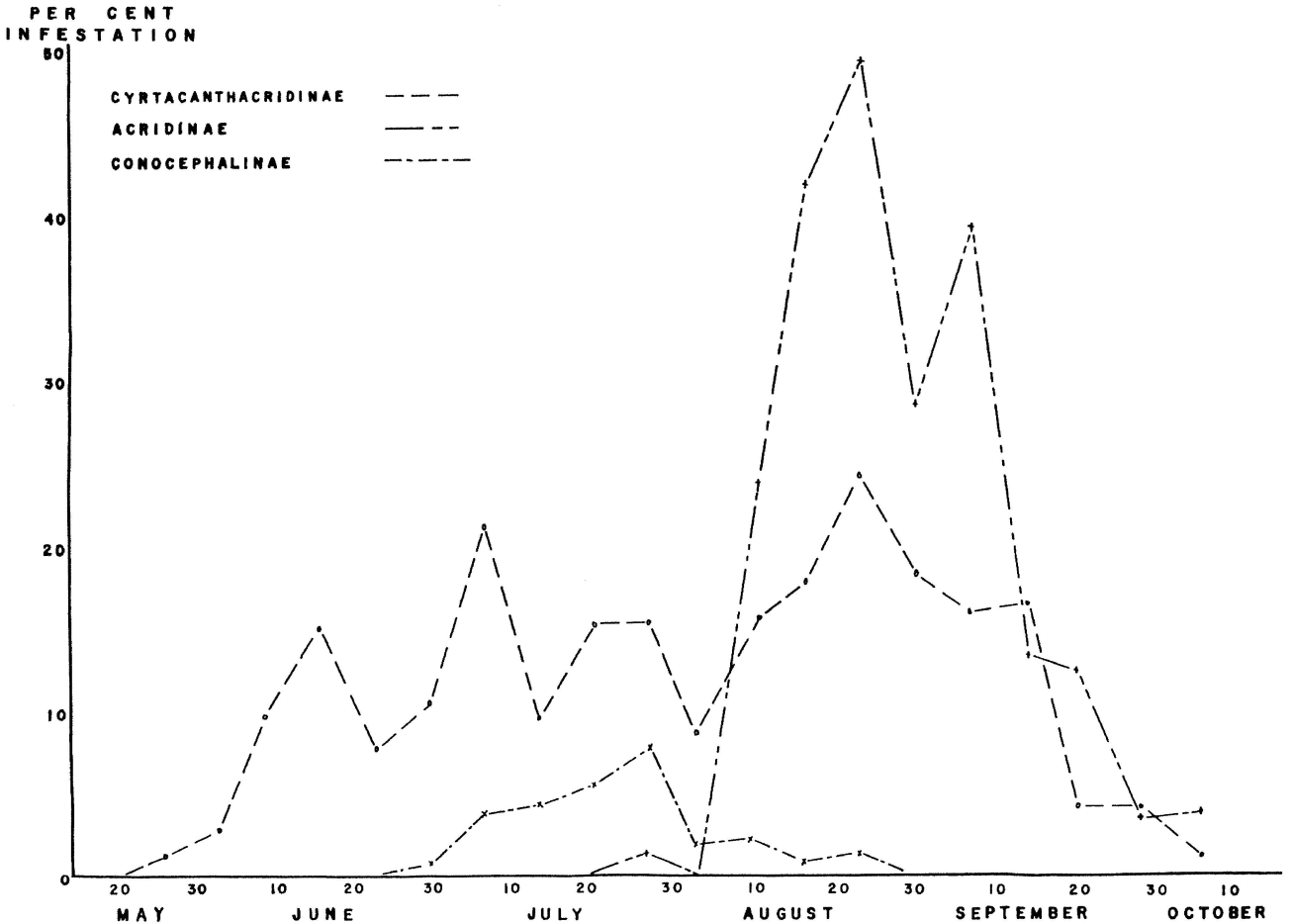

Fig. 5—Mite infestation by date and subfamily in Boone County, 1960.

Syrbula admirabilis (Uhler) which served as hosts for most of the mites. A fifth species, *M. confusus* Scudder, must be considered with the four economic ones, because of our inability to distinguish between the females and nymphs of *M. confusus* and first generation *M. sanguinipes.* This combination was called *sanguinipes* in 1959 for the most part, but additional separation was made in 1960, as will be noted later. However, this further separation did not alter the mite infestation picture except to strengthen an indicated preference for the genus.

In general, mites were most common on the Cyrtacanthacridinae of the Acrididae, though some members of the Acridinae and Oedipodinae were infested at various times. Of the three subfamilies of Tettigoniidae collected, only the Conocephalinae served as host. The Gryllidae were uninfested with the exception of one larva found *in association* with an adult *Nemobius fasciatus* (DeGeer). No mites were found on the Mantidae, Phasmatidae, or Tetrigidae. Of the 33 infested species (the short winged *Melanoplus* are here considered as a group) listed in Table 2, ten contained 95.6 percent of the infested hoppers in 1959 (92.0% of the Statewide collections) and 96.5 percent in 1960. The 10 species represented 64 percent of the total hoppers collected in 1959 (Boone County and Statewide) and 58 percent of those taken in 1960. The 10 species with their respective percentages of infestations for the two years are listed in Fig. 6. The correlation between the percentage of these species infested in 1959 and that in 1960 was 0.855, statistically significant at the 1 percent level.

Mite infestations in 1960 on the two survey lines were compared by correlation between percentages infested on line A and line B of eight of the 10 hosts shown in Figure 6 (*Chortophaga* and the short winged *Melanoplus* group were omitted). The highly significant value of 0.886 showed that percentage of mite infestation was similar on the two lines. Correlations between percentages infested at comparable sites on the survey lines for five host species on which sufficient data were available were computed. The results were:

Species	Correlation Coefficient
M. sanguinipes	0.953**
M. bivitattus	0.950**
Syrbula admirabilis	0.657 n.s.
M. femurrubrum	0.328 n.s.
M. differentialis	0.177 n.s.

** Statistically significant at the 1% level

n.s. not significant

Having shown that the mite infestations on the two lines were similar for the two species, *M. sanguinipes* and *M. bivitattus,* the data were then subjected to an analysis of variance to test, within each species, the mean infestations encountered on the lines and at the sites. For these analyses, the percentages were

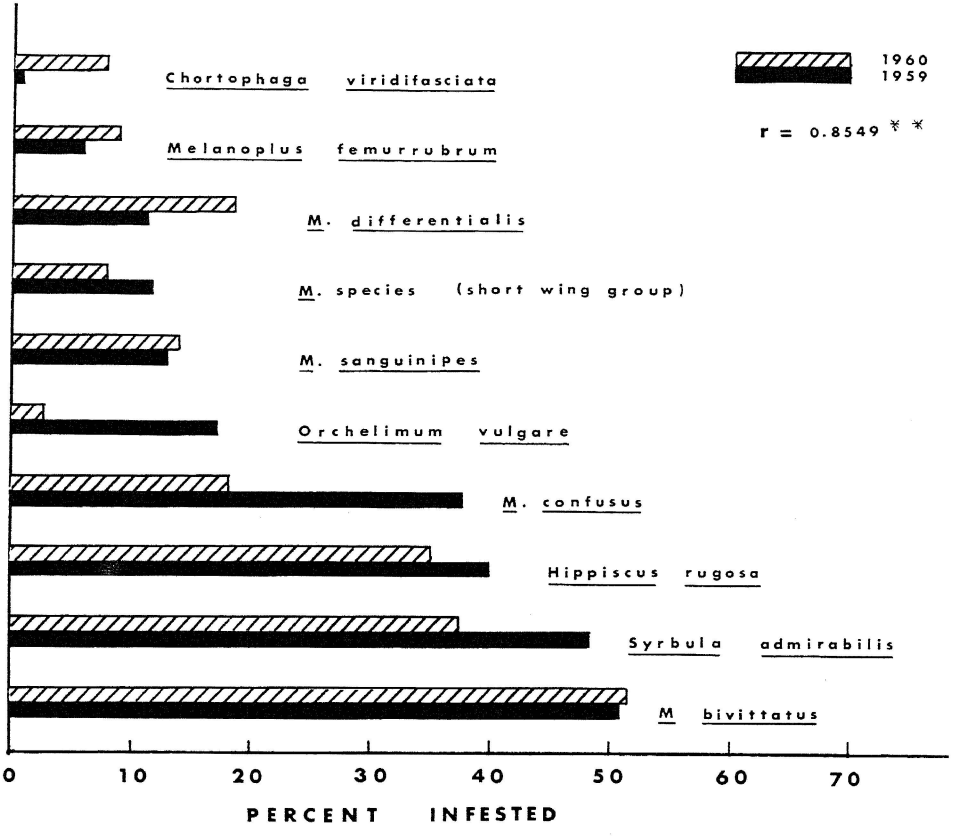

Fig. 6—Comparison of mite infestation on ten species for two years in Boone County.

transformed to angles (Snedecor, 1946). The analyses showed that mite infestations were significantly different (1% level) at the different sites but that the two means for lines were about the same. Site means as angles were separated by means of Duncan's multiple range test (LeClerg, 1957). Actual means are given below for each species. Those followed by the same letter are not significantly different at the 5% level of significance.

Sites	M. sanguinipes	M. bivitattus
1	8.5 a	2.2 a
2	15.6 a	2.2 a
3	26.6 b	42.0 b
4	31.8 b	10.0 a
5	8.0 a	12.2 a
SE ($\bar{x}$)	1.79	3.03

Both species sustained significantly higher degrees of infestation at sites 3, the wooded areas. Both species tended to have significantly lower infestations at sites 1 and 5, which were cultivated areas. The two species differed, however, at sites 2 and 4, the pasture areas, *M. sanguinipes* being medium to heavily infested and *M. bivitattus* having light to medium infestation. These analyses indicated that percentage of infestation alone is not a good criterion for either host or habitat preference comparisons. Other factors obviously affecting this relationship are relative abundance of host and parasite per unit area, relative abundance of preferred host species, their stage of development, and seasonal availability of host species. When these factors are considered in addition to the percentage of infestation, further site distinctions and host parasite relationships emerge.

As indicated initially in Fig. 4, mite infestation progresses from a desirable host to a new desirable host as each appears during the season. To better illustrate how the mite population progresses from host to host throughout the season, we have shown the four species of *Melanoplus,* as well as *Syrbula admirabilis* and *Orchelimum vulgare* Harris, in Fig. 7 for 1959 according to the sequence of percentage of host adults taken by species and the total percentage of mite infestation for each species. Fig. 8 shows that the same progression from host to host that occurred in 1959 also occurred in 1960. It should be kept in mind that in 1959 we were not able to separate *M. sanguinipes* and *M. confusus* accurately and they are graphed together as *M. sanguinipes;* whereas, in 1960, the two species were better identified and are graphed separately. In 1959, *Orchelimum vulgare* was added to show its contribution as host between the generations of *M. sanguinipes* and until the preferred *Syrbula* and other *Melanoplus* species became available (Fig. 7). In 1960, *O vulgare* was too lightly infested to appear on the graph.

The seasonal infestation in relation to the percentage of adults present for a given species during its lifespan is shown in Fig. 9 for three *Melanoplus* species and *Syrbula.* The figure shows how the mite infestation increased as the number of available grasshopper adults increased.

In Fig. 10 the relationship of mite infestation, the numbers of mites per infested hopper, the numbers of hoppers collected, and a relative mite abundance index (number of hosts collected x number of mites collected ÷ 1000) are brought together for comparison by survey line and habitat (site) for the five species of *Melanoplus* combined. Using these criteria we determined, by analysis of variance, the statistical significance of the site and line comparisons. Data for the percentages of infestation were transformed to angles for analysis. Lines did not differ significantly for any of the comparisons, but significant differences (5%

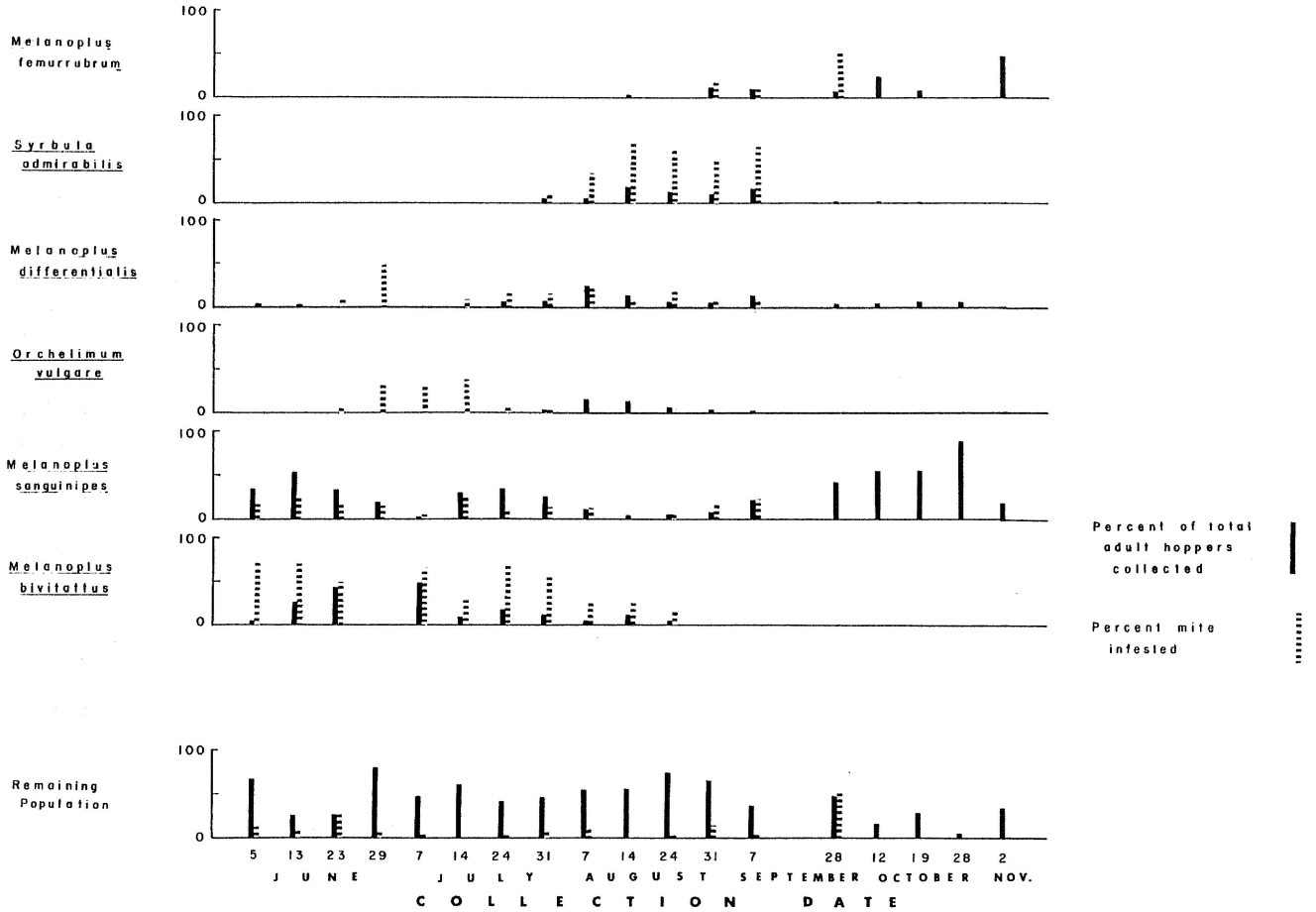

Fig. 7—Seasonal progression of mite infestation on six selected grasshopper species in Boone County, 1959.

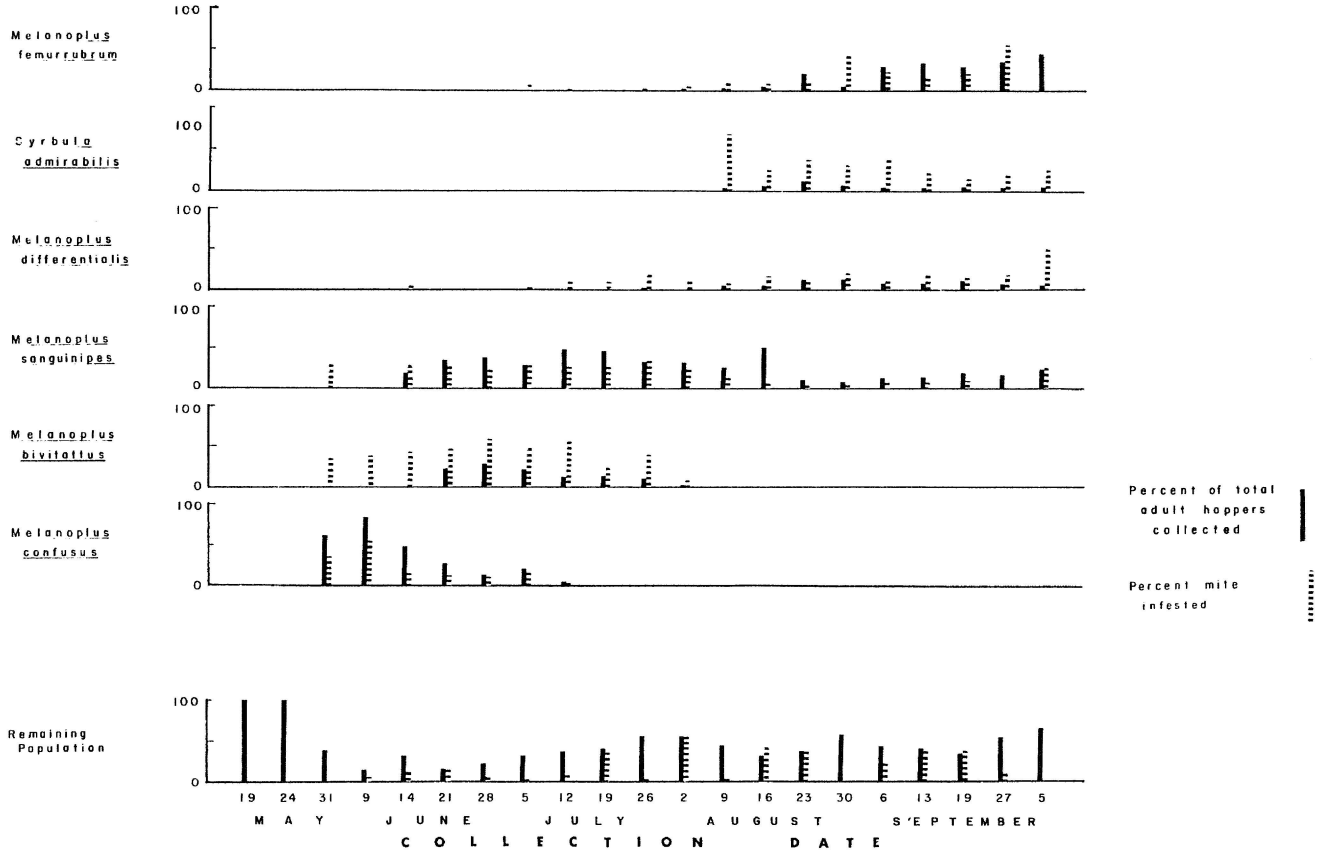

Fig. 8—Seasonal progression of mite infestation on six selected grasshopper species in Boone County, 1960.

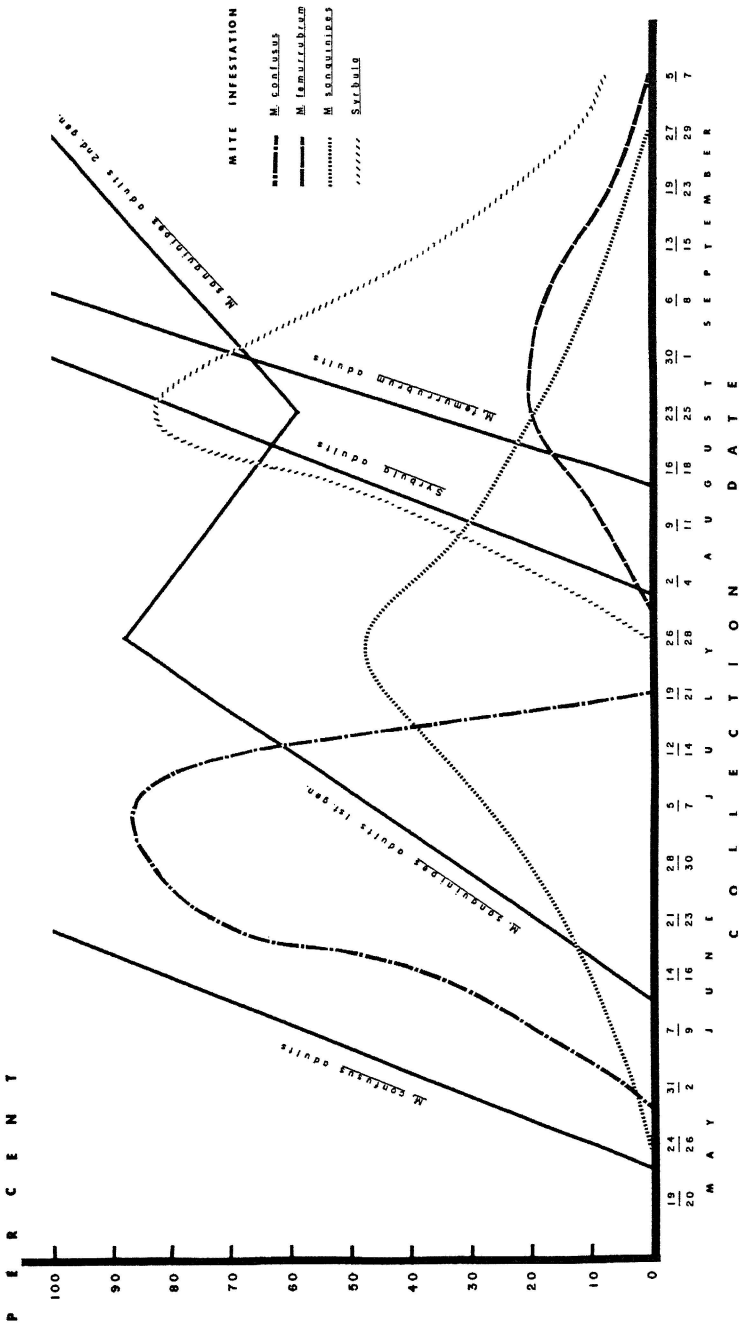

Fig. 9—Mite infestation in relation to development of four selected grasshopper hosts in 1960.

level) among sites were indicated for each comparison. Means for sites are given in Table 4.

Sites 5 and 1, cultivated areas, differ significantly only in number of host hoppers collected. Sites 2 and 4, pasture areas, do not differ significantly in host abundance or percentage of hosts infested, but do differ significantly in number of mites per infested hopper and relative mite abundance. Site 3, woods margin, had relatively few hoppers but a high percentage of hosts infested with large numbers of mites per host. The mite abundance index does not show true abundance because at sites where hosts were scarce, we searched for them more thoroughly.

Actual mite abundance could be obtained only by accurate measurements of host population per unit area. However, the index does reflect relative mite abundance more nearly than percentage infested since it includes a relative measure of host abundance as reflected by the number collected. On the basis of this determination, the areas did not differ significantly in actual mite abundance except for site 4.

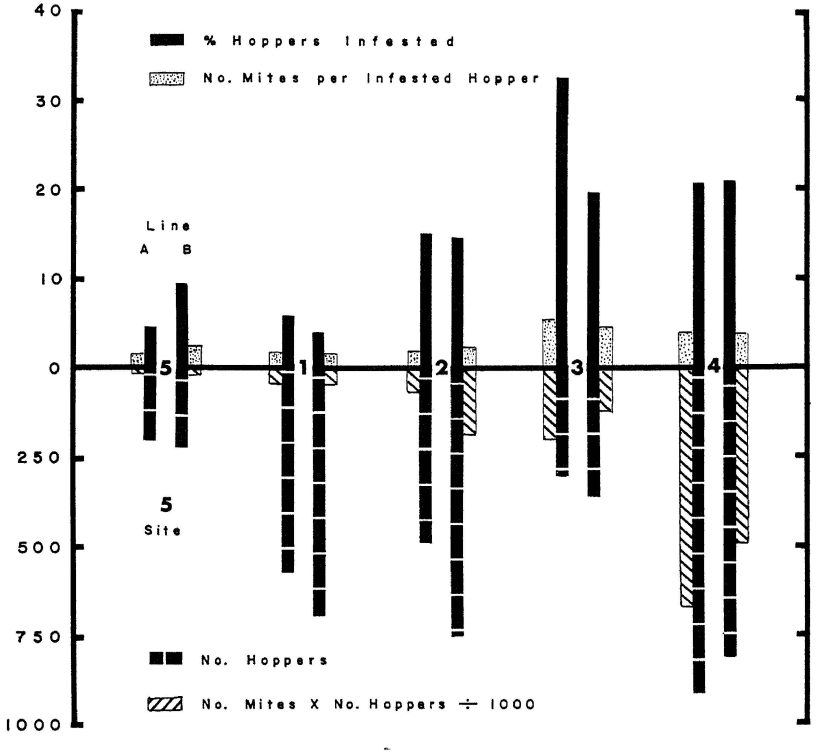

Fig. 10—Survey line and site comparisons in terms of host abundance, percent infestation, mites per hopper, and mite abundance index. Five economic Melanoplus combined, 1960.

TABLE 4--STATISTICAL COMPARISON OF HABITAT MEANS 1/ BY FIVE CRITERIA USING DUNCAN'S MULTIPLE RANGE TEST. BOONE COUNTY, 1960

Sites	Five Melanoplus species 2/		Mites		
	Number Collected	Percent Infested	Number Collected	Number Per Infested Hopper	Abundance 3/ Index
5	218.0 a	6.6 ab	29.5 a	1.90 a	6 a
1	633.5 b	4.8 a	53.0 a	1.75 a	33 a
2	616.5 b	14.6 bc	187.5 ab	2.05 a	122 a
3	331.5 a	25.7 c	461.0 bc	5.05 b	148 a
4	865.0 b	20.5 c	665.5 c	3.75 b	579 b

1/ Means followed by the same letter do not differ significantly at the 5% level.

2/ *Melanoplus confusus*, *M. differentialis*, *M. sanguinipes*, *M. femurrubrum*, *M. bivitattus*.

3/ Number of mites x numbers of hoppers divided by 1000.

NEMATODES

Positive identification of mermithid nematodes depends largely on adult characters. Most of those sent to Dr. Welsh were immature, the identification tentative, and thus, for the purpose of this study, are lumped together. Nematodes obtained from *Chortophaga,* almost entirely during late fall and early winter, were *Hexamermis* sp., probably new, and are reported elsewhere (Blickenstaff & Sharifullah, 1962). The remaining ones, determined by Dr. Welsh, were "mostly *Agamermis,* probably *decaudata,* but a few *Mermis* were also present, probably *subnigrescens.*"

The incidence of parasitism by nematodes was low, both in 1959 and 1960, and essentially the same hosts were involved, as shown in Table 5. At least 19 species were infested, most of them being acridids. Parasitism occurred in all areas of the State in 1959, as shown in Fig. 1. Parasitism of the major *Melanoplus* species averaged 2.5 percent from June 14 through Sept. in 1959, and about the same during 1960 with slightly higher parasitism occurring in June and July.

A marked seasonal progression from one host to another was noted and is shown for the five major *Melanoplus* species in 1960 in Fig. 11.

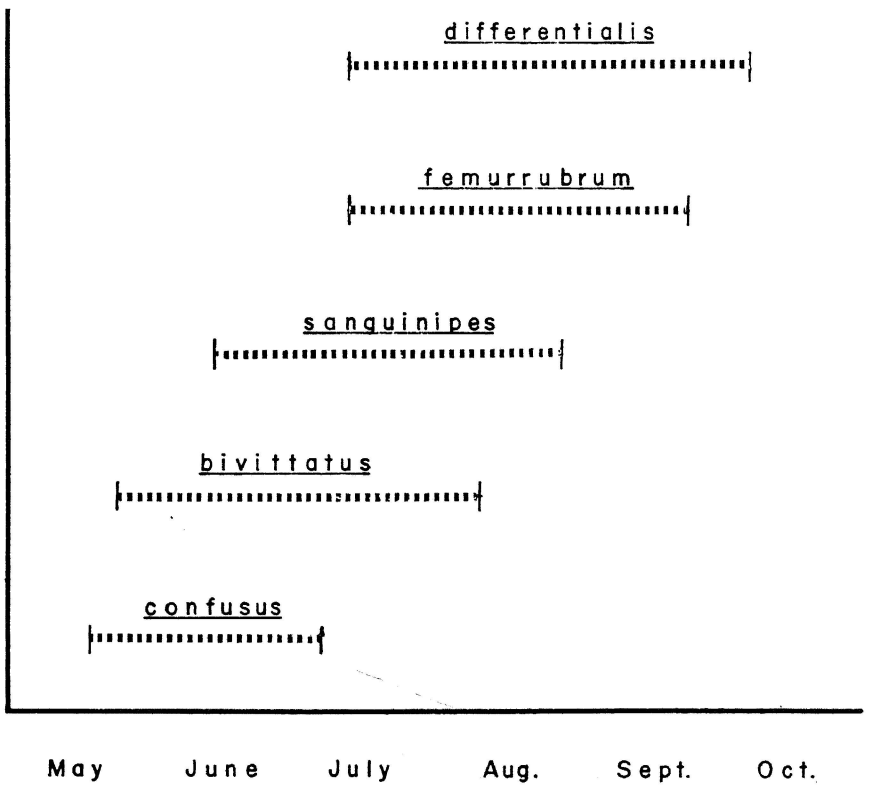

Fig. 11—Seasonal progression of nematode infestation in five Melanoplus species. Boone County, 1960.

TABLE 5--PARASITISM BY NEMATODES IN MISSOURI. 1959 AND 1960

Host	Statewide 1959				Boone Co. 1960 A-B			
	Number Hosts Collected	Percent Infested	95% Confidence Limits	Infestation Period	Number Hosts Collected	Percent Infested	95% Confidence Limits	Infestation Period
Acrididae								
Acridinae								
Orphulella speciosa	55	0	0- 6.5		476	0.6	0.1- 1.7	7/26-8/25
Dichromorpha viridis	230	1.7	0.6- 4.6	7/15-9/17	185	1.1	0.1- 3.6	8/11
Oedipodinae								
Arphia (3 spp.)	91	1.1	0- 6.0	7/15	131	0.8	0- 4.2	6/23
Chortophaga viridifasciata	418	2.6	1.2- 4.6	3/19-4/16 & 11/2	295	0.7	0.1- 2.4	6/23-7/7
Cyrtacanthacridinae								
Schistocerca (3 spp.)	76	1.3	0- 7.1	6/18	109	0	0- 3.3	
Campylacantha olivacea	41	0	0- 8.6		136	2.2	0.4- 6.1	8/16-9/8
Melanoplus confusus	46	2.2	0.1-11.5	5/20-8/15	351 1/	7.1	4.8-10.6	5/19-7/7
M. bivitattus	537	3.0	1.7- 4.9	6/4-8/20	1000	4.6	3.4- 6.1	5/24-8/11
M. sanguinipes	1253	1.4	0.8- 2.3	6/15-11/2	1516	1.6	0.9- 2.6	6/14-8/25
M. femurrubrum	1000	2.4	1.5- 3.6	7/15-11/2	1926	1.4	0.7- 2.3	7/12-9/23
M. differentialis	1206	1.2	0.6- 2.1	6/15-9/14	604	2.6	1.4- 4.1	7/12-10/7
M. viridipes group	10	20.0	2.5-44.5	6/4-6/23				
M. fasciatus					13	7.7	0.2-36.0	6/21
M. gracillis					79	6.3	2.1-14.2	7/12-9/1
Tettigoniidae								
Conocephalinae 2/	2427	0.9	0.4- 1.4	6/14-9/17	3600	1.1	0.7- 1.4	6/7-9/8

TABLE 5 (cont'd) PARASITISM BY NEMATODES IN MISSOURI. 1959 AND 1960

Host	Statewide 1959				Boone Co. 1960 A-B			
	Number Hosts Collected	Percent Infested	95% Confidence Limits	Infestation Period	Number Hosts Collected	Percent Infested	95% Confidence Limits	Infestation Period
Gryllidae								
Nemobinae								
Nemobius fasciatus	269	0.4	0- 1.8	9/14	55	0	0- 6.5	
Oecanthinae								
Oecanthus nignicornis	152	0.7	0- 3.7	6/29	642	0	0- 0.6	

1/ Numbers for 5 Melanoplus are unadjusted as in Tables 1 and 2. Percent parasitism with the figures adjusted are: M. confusus 5.6, M. bivitattus 15.5, M. sanguinipes 1.2, M. femurrubrum 1.4, and M. differentialis 2.6.

2/ Includes Conocephalus fasciatus, C. strictus, Orchelimum vulgare, and O. nigripes Scudder.

Parasitism by similar habitats in both years is shown for the five *Melanoplus* species combined in Fig. 12. Percentage parasitism of these combined species ranged from 0.0 to 8.6 at individual sites. No consistent site differences were found except for river bottom areas where percentage parasitism ranged from 0.0 to only 0.7. The average percentage of parasitism for the season is shown in Fig. 13 by individual *Melanoplus* species for 1959 and by the two survey lines for 1960. There appeared to be some host preference, *M. confusus* and *M. bivitattus* being more heavily parasitized on the average. As stated earlier, nymphs of *M. confusus* were confused with the other species in 1959 and actual parasitism was probably higher than shown. However, these two species appear early in the season and the higher degree of parasitism may be only a reflection of host availability.

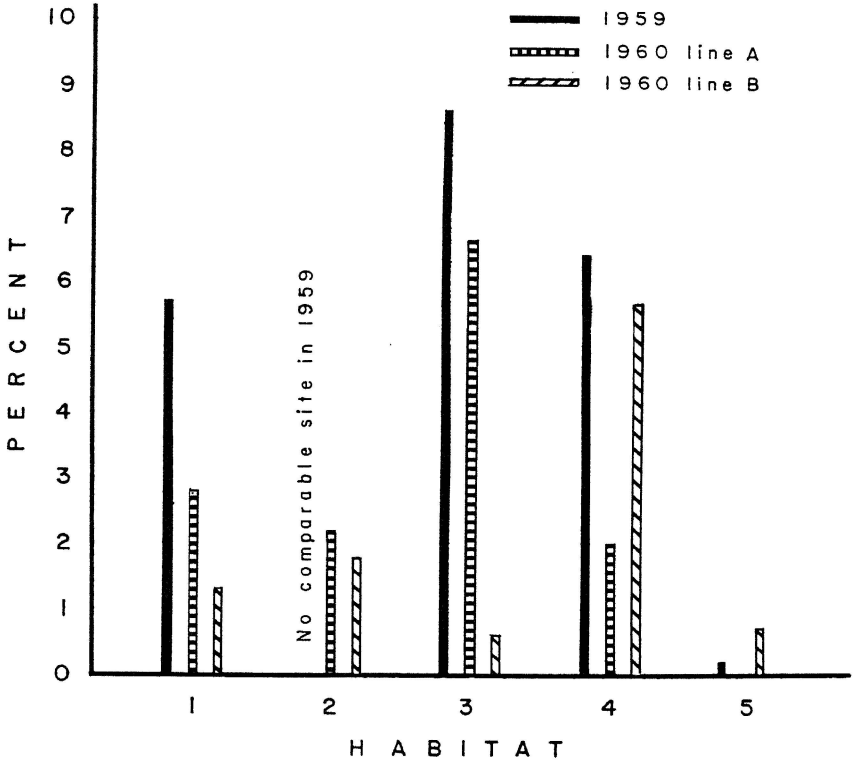

Fig. 12—Nematode infestation by habitat for five Melanoplus species combined. Boone County, 1959 and 1960.

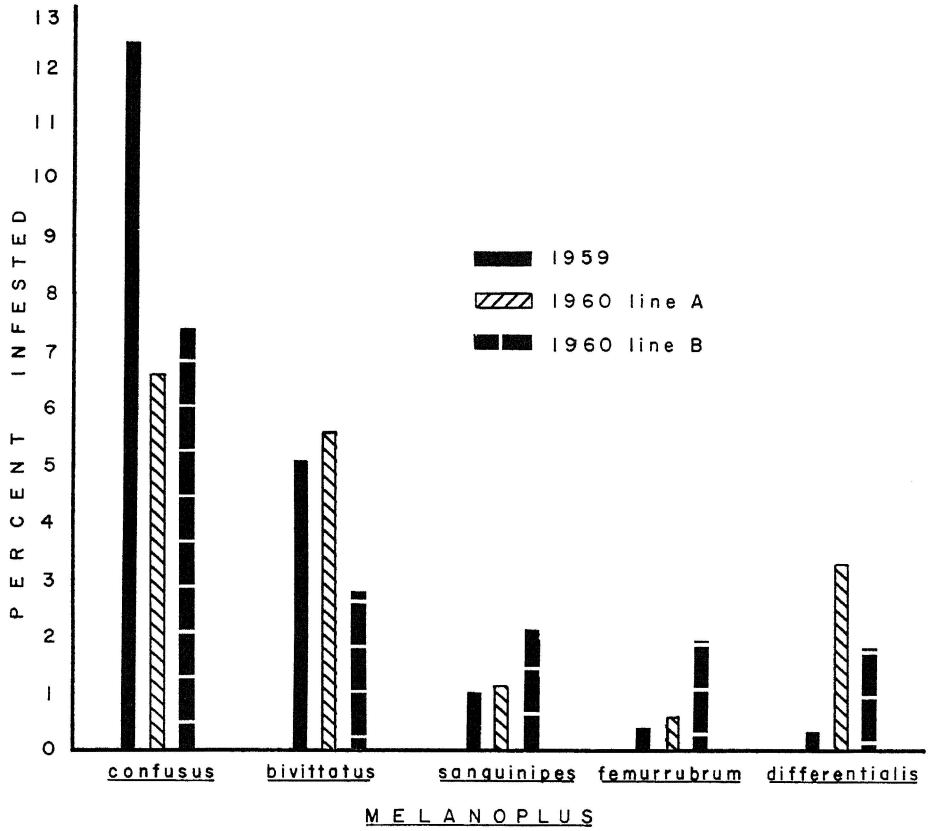

Fig. 13—Nematode infestation of Melanoplus species, habitats combined. Boone County, 1959 and 1960.

DIPTEROUS PARASITES

Tachinidae

Ceracia dentata (Coquillett), by far the most common dipterous parasite, was reared from grasshoppers collected in 13 of the 20 counties surveyed in 1959. During 1959 and 1960 it was reared from nymphs of *Chortophaga* collected as early as March 19 and as late as the first part of November and rather uniformly throughout the intervening period. In 1959 we observed that the incidence of parasitism progressed from host to host through the season as host nymphs became available. This progression was clearly evident in Boone County in 1960, as tabulated below by using the date when 50 percent of the selected host species had become adults as an index of their seasonal occurrence.

Species	Date 50% were Adult	Inclusive Dates of Parasitism
Chortophaga viridifasciata	May 1	March 29 - May 20
Melanoplus confusus	June 6	May 19 - June 2
M. bivitattus	July 12	May 19 - June 23
M. differentialis	Aug. 14	July 12 - Aug. 18
M. femurrubrum	Aug. 26	July 26 - Sept. 1

Ceracia dentata emerged almost exclusively from large nymphs or very young adult grasshoppers. Except for specimens found in very late collections, parasite larvae emerged from the host 0 to 20 days from the date of collection. Overwintering nymphs of *Chortophaga viridifasciata,* collected on November 2, 1959, were in diapause and parasite larvae emerged from two to four months later. This finding showed that the parasite overwintered at least partially in available nymphs. One overwintering nymph of *Syrbula admirabilis* also contained a parasite.

The number of parasites emerging per host in 1959 ranged from 1 to 11, with distribution as follows:

No. maggots per host	1	2	3	4	5	6	7	11
No. hoppers parasitized	56	13	3	1	1	2	1	1

Table 6 is a list of hosts with percentages of nymphs parasitized for the 1959 and 1960 seasons. During the two seasons, 144 out of 8,492 host nymphs, or 1.7 percent were parasitized. Host species were restricted to members of the family Acrididae with no evidence of marked preference for those species parasitized, although there appeared to be some preference for members of the subfamily Crytacanthacridinae.

A comparison of parasitism by site location in Boone County is given in Fig. 14. Sites in 1959 and 1960 were not strictly comparable, but grasshoppers

TABLE 6--ORTHOPTERA PARASITIZED BY CERACIA DENTATA (COQUILLETT)

Host	1959 Boone Co. No. Nymphs	1959 Boone Co. % Parasitized	1959 Remainder State No. Nymphs	1959 Remainder State % Parasitized	1960 Boone Co. No. Nymphs	1960 Boone Co. % Parasitized	Average % Parasitized
Acrididae							
Acridinae							
Syrbula admirabilis	11	0.0	56	1.8	122	0.0	0.5
Dichromorpha viridis	16	12.5	97	0.0	136	0.0	0.8
Oedipodinae							
Chortophaga viridifasciata	120	5.0	146	2.1	416	3.8	3.5
Cyrtacanthacridinae							
Campylacantha olivacea	2	0.0	26	0.0	101	2.0	1.6
Melanoplus sanguinipes	269	3.3	417	1.2	811	0.6	1.3
M. femurrubrum	140	0.7	322	2.2	1,138	0.6	0.9
M. confusus	6	0.0	36	0.0	181	1.6	1.3
M. differentialis	524	1.5	458	2.0	369	1.1	1.6
M. bivitattus	147	4.1	280	0.4	893	0.4	0.8
M. gracilis	2	50.0	0	-	41	0.0	2.3
M. spp. undetermined	8	0.0	59	0.0	1,134	0.0	0.0
Host unknown	0	-	8 (7) 1/		(30) 2/		
Totals & Averages	1,245	3.0	1,905	2.2	5,342	1.2	1.68

1/ Parasite larvae or pupae in field collection cages.

2/ Twenty-nine of these were taken from cage bottoms on 9/1/60 from sites A3 & A4; at this time they were being taken only from M. sanguinipes and M. femurrubrum. If these were distributed between the 2 hosts in proportion to numbers available (1:4) and at the average rate of 1.33 per host, their % parasitized would be 1.1 and 2.2, respectively.

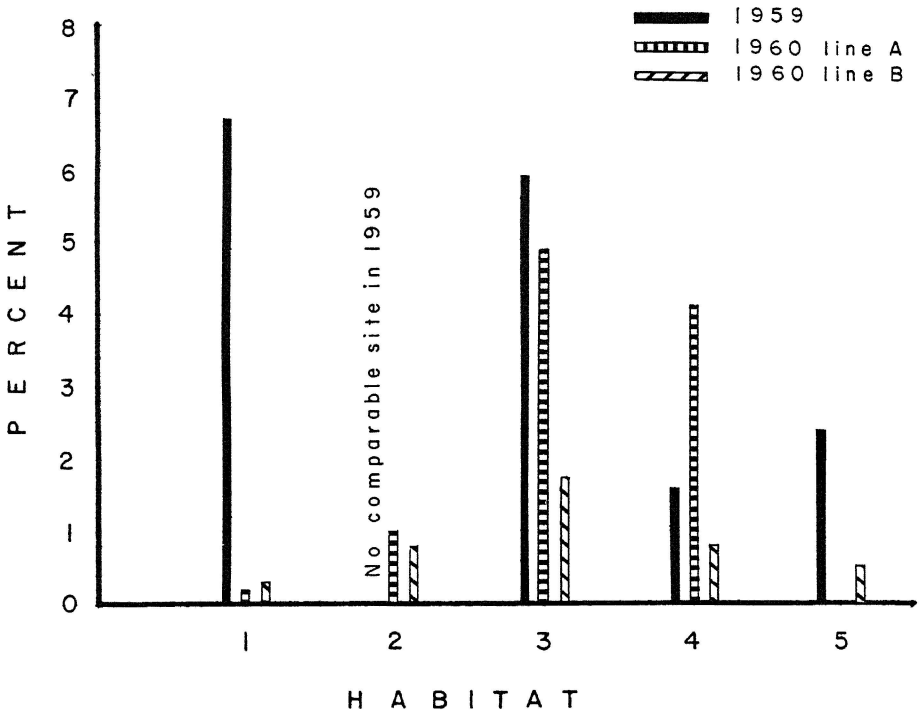

Fig. 14—Percent of host nymphs parasitized by Ceracia dentata in Boone County habitats in 1959 and 1960.

taken from woods margins were generally most heavily parasitized. In 1960, there was general agreement between comparable sites, with greatest incidence of parasitism at woods margins and least in the more intensely cultivated areas.

In 1959 we reared three species of hyperparasites from *C. dentata. Perilampus hyalinus* Say, the most common, accounted for 8.2 percent parasitism of its host. We took it from five counties representing all sections of the State. These occurred in almost equal numbers in the three most common species of *Melanoplus: differentialis, sanguinipes,* and *femurrubrum.* We reared *Brachymeria tegularis* (Cresson) from *C. dentata* in *M. sanguinipes* collected in St. Louis County, and *B. coloradensis* (Cresson) from *C. dentata* in an unknown host from Shannon County. All emerged in September with the exception of two *Perilampus,* which emerged in June.

Gilvella gilvipes (Coquillett) was reared only once from "crickets" (probably *Nemobius fasciatus*) collected in Boone County in July, 1959.

Hemithrixion oestriforme Brauer and Bergenstamm has been reported as parasitic on grasshoppers in Canada (Smith & Finlayson, 1950). We took it from

the bottom of a field collection cage containing several species of grasshoppers collected in Clinton County in July, 1959.

Sarcophagidae

Seven species of sarcophagids were taken from 10 known hosts as shown in Table 7. *Blaesoxipha reversa* (Aldrich), *B. hunteri* (Hough), *B. aculeata* (Aldrich), *B. opifera* (Coquillett), and *Helicobia rapax* (Walker) were reared exclusively on *Melanoplus* hosts, with *B. reversa* the most common. *B. spatulata* (Aldrich) was reared only from the Conocephalinae, and *B. uncata* (Wulp) only from *Dissosteira* in the Oedipodinae. The incidence of parasitism was less than 1 percent for the season for any species or all combined on any host.

B. reversa also transferred from host to host as they became available throughout the season. The progression of hosts in 1960 and the inclusive dates of parasitism were: *M. sanguinipes,* June 21-July 12; *M. bivitattus,* June 7-July 12; *M. differentialis,* July 7-21; and *M. femurrubrum,* August 16.

B. spatulata and *B. uncata* occurred only from late August to mid-October.

The occurrence of *B. reversa* by habitat, although inconclusive, was the reverse of *Ceracia dentata* in 1960. Of the 16 parasitized hosts, 12 were from cultivated sites in upland prairie, four from permanent pastures, and none from woods margins.

All of the sarcophagid species listed were taken in Boone County. In 1959, we also took *B. reversa* from seven scattered counties in the eastern half of the State, and *B. hunteri* from Shannon County.

Nemestrinidae

Nemestrinids were found only in 1960 in grasshoppers collected between August 23 and October 7. The seven hosts from which they were recovered, their number, and the percentage parasitism of each during the period were: *Hippiscus rugosus* (Scudder) (68) 16.2, *Encoptolophus sordidus* (Burmeister) (42) 4.8, *Chortophaga viridifasciata* (70) 1.4, *Orphulella speciosa* (Scudder) (87) 1.1, *M. sanguinipes* (442) 0.9, *M. femurrubrum* (997) 0.5, and *M. differentialis* (224) 0.4. The hosts during this period of collection were almost exclusively adults. Parasites appeared at all locations on both lines except the riverbottom sites, but 11 of the 26 parasites were taken from 49 *H. rugosa* at site B-4. This site included a stream running intermittently through a narrow rocky draw within a large pasture area.

Our attempts to rear 13 of the larvae after emergence were fruitless. They were placed on moist sand for two months, then transferred to loamy soil for five months, then to hard clay soil. They were held at room temperature except for three periods of two, three, and six weeks at 40° F. Six larvae were still alive in March, 1962, but died during the following summer.

TABLE 7--ORTHOPTERA PARASITIZED BY SARCOPHAGIDS IN MISSOURI IN 1959 AND 1960

Host	Parasites Recovered	Parasites 1/ by Key No.	Individuals Parasitized
	(Key No.)		(No.)
Dissosteira carolina	7	1. reversa	31
Chortophaga viridifasciata	8	2. hunteri	9
Melanoplus sanguinipes	1, 2, 3, 4, 8	3. aculeata	2
M. femurrubrum	1, 3, 5	4. rapax	2
M. bivitattus	1, 4	5. opifera	1
M. differentialis	1, 2, 8	6. spatulata	6
M. scudderi	1	7. uncata Wulp	1
M. spp.	1, 2, 8	8. spp. undet.	7
Conocephalus (fasciatus or strictus)	6		
Orchelimum vulgare	6		
Oecanthus spp.	8		
Unknown (probably M. spp.)	2, 8		

1/ Genus Blaesoxipha except for rapax in genus Helicobia

Prescott (personal correspondence) identified one specimen as *Trichopsidea clausa* (Osten Saken). He also stated that all previously known hosts of this species belonged to the band-wing locust group (Oedipodinae).

SUMMARY

A study of the parasites attacking nymphal and adult Orthoptera was conducted in Missouri. A total of 8,711 specimens of Orthoptera were collected from major soil and farming areas in 1959 and 13,531 from five representative habitat areas in Boone County in 1960. Parasites included the grasshopper mite, *Eutrombidium locustarum* (Walsh), 11 species of Diptera (3 Tachinidae; 7 Sarcophagidae; 1 Nemestrinidae), and probably three species of nematodes. Data on abundance, host preference, seasonal occurrence, state distribution, and habitat preference are presented. The five major *Melanoplus* species plus the meadow grasshoppers comprised the bulk of orthopterans collected. Except for the nemestrinids, the common parasites studied showed a preference for the *Melanoplus* group and, for the most part, detailed comparisons were restricted to it.

The degree of parasitism of *Melanoplus* species was essentially the same for both years. The grasshopper mite, the most common, infested about 14 percent of this group throughout the season, as compared with about 2 percent by dipterous parasites and about 2 percent by nematodes. Infestation by species of the Diptera or nematodes invariably resulted in death of the host. Attempts to determine the direct effect of mite infestation on the host were unsuccessful. The only known direct effect, that of egg predation by nymphal and adult mites, was not studied.

The more common parasites exhibited a marked seasonal progression of infestation from one host species to another closely related to host development and availability. This progression was clearly shown for the grasshopper mite, nematodes, *Ceracia dentata* (Coquillett) (Tachinidae), and *Blaesoxipha reversa* (Aldrich) (Sarcophagidae).

Comparison of habitats in Boone County showed that the grasshopper mite tended to be most abundant in the least disturbed areas. Nematode infestation was very low in intensively cultivated riverbottom areas, but showed no consistent site differences otherwise. *C. dentata,* in general, appeared to be most prevalent at habitats with woods margins and least prevalent in more intensely cultivated areas.

LITERATURE CITED

Banks, N. 1894. Some new American Acarina. Trans. Amer. Ent. Soc. 21:209-222.

Baker, E. W., and G. W. Wharton. 1952. An introduction to acarology. The MacMillan Co., New York. 465 pp.

Berlese, A. 1912. Trombidiidae. Prospetto dei genera. Redia 8:1-291.

Blickenstaff, C. C., and M. Sharifullah. 1962. Infestation of overwintering nymphs of *Chortophaga viridifasciata* by mermithids. J. Econ. Entomol. 55:268.

Christie, J. R. 1936. Life history of *Agamermis decaudata,* a nematode parasite of grasshoppers and other insects. U.S.D.A. J. Agr. Res. 52:161-98.

Christie, J. R. 1937. *Mermis subnigrescens,* a nematode parasite of grasshoppers. U.S. D.A., J. Agr. Res. 55:353-64.
Collier, J. E. 1955. Agricultural atlas of Missouri. Missouri Agr. Expt. Sta. Bull. 645. 75 pp.
Ewing, H. E. 1909. A systematic and biological study of the Acarina of Illinois. Bull. Univ. Ill. 7:1-120.
Howard, C. W. 1918. A preliminary report on the Trombidiidae of Minnesota. Minnesota State Entomol. Rept. 17:111-44.
Jones, G. D. 1939. Grasshopper outbreaks in Missouri. Missouri Ag. Expt. Sta. Bull. 406. 32 pp.
Le Clerg, E. L. 1957. Mean separation by the function analysis of variance and multiple comparisons. U.S.D.A., ARS-20-3. 33 pp.
Morgan, H. A. 1901. The differential grasshopper in the Mississippi Delta. U.S.D.A. Div. of Entmol., Bull. 30, New Series, pp. 7-33.
Newton, R. C. 1954. New records of dipterous parasites of grasshoppers. J. Econ. Entomol. 47:935-36.
LeBaron, W. 1872. Second Ann. Rept. on the Noxious Insects of Illinois. pp. 157-8.
Oudemans, A. C. 1912. Die bis jetzt bekannten larven von Thrombidiidae und Erythraeidae. Zool. Jahrb., Supp. 14:230 pp.
Parker, J. R. and C. Wakeland, 1957. Grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles. U.S.D.A. Tech. Bull. No. 1165.22 pp.
Prescott, H. W. 1955. *Neorhynchocephalus sackeni* and *Trichopsidea clausa,* nemestrinid parasites of grasshoppers. Ann. Entmol. Soc. Am. 48:392-402.
Riley, C. V. 1875. Seventh annual report on the noxious, beneficial, and other insects of the State of Missouri. Regan & Carter, Jefferson City, Missouri, 196 pp.
Riley, C. V. 1878. First Ann. Rept. U.S. Entomological Commission for the year 1877, relating to the Rocky Mountain Locust. U.S. Govt. Print. off., p.306.
Say, Thomas. 1821. An account of the Arachnides of the United States. J. Acad. Nat. Sci. Philadelphia. 2:69-70.
Scrivner, C. L. and J. A. Frieze. 1951. Soils of Boone County. Univ. Missouri, Coll. Agr., Dept. of Soils, Progress Rept. 14. 11 pp.
Severin, H. C. 1944. The grasshopper mite *Eutrombidium trigonum* (Hermann) an important enemy of grasshoppers. South Dakota Agr. Expt. Sta. Tech. Bull. 3, 36 pp.
Shotwell, R. L. 1960. Grasshopper control with sprays. Missouri Agr. Expt. Sta. Res. Bull. 751. 20 pp.
Smith, R. W., and T. U. Finlayson. 1950. Larvae of dipterous parasites of nymphal and adult grasshoppers. Canadian J. Res. Sect. D 28:81-117.
Smith, R. W. 1958. Parasites of nymphal and adult grasshoppers (Orthoptera; Acrididae) in Western Canada. Canadian J. Zool. 36:217-62.
Snedecor, G. W. 1946. Statistical methods. The Iowa State College Press, Ames, Iowa. 485 pp.
Spencer, G. J. 1958a. The natural control complex affecting grasshoppers in the dry belt of British Columbia. Internatl. Congr. Entomol., Proc., 10th, Montreal, 1956 (4):497-502.
Spencer, G. J. 1958b. On the Nemestrinidae of British Columbia dry range lands. Internatl. Cong. Entomol. Proc. 10th, Montreal, 1956 (4):503-09.
Sweetman, H. L. 1958. The principles of biological control. Wm. C. Brown Company, Dubuque, Iowa, 560 pp.
Treherne, R. C., and E. R. Buckell. 1924. Grasshoppers of British Columbia. Canada Dept. Agr. Bull. 39(ns), 40 pp.
Walsh, B. D. 1866. Practical Entomologist 1(12), p 126.
York, G. T. 1955. Notes on parasitization of grasshoppers by Nemestrinids. J. Econ. Entomol. 48:328.
York, G. T., and H. W. Prescott. 1952. Nemestrinid parasites of grasshoppers. J. Econ. Entomol. 45:5-10.