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Research Notes on Certain Species of Alfalfa Insects at Manhattan (1904-1956) and at Fort Hays, Kansas (1948-1953)

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Opportunities in Entomology

Entomology deals with the study of insects and their near relatives. In Kansas, as in most other states and countries, insects are the most important, destructive group of animals affecting man's health and welfare. There are more species of insects than all other species of animals combined. About 16,000 different species of insects occur in Kansas and 80,000 are known from the United States and Canada; and more than 700,000 are known in the world. This does not include the closely related spiders, mites, and ticks that also are included in entomological work.

About 4,500 professional entomologists are employed in the United States. Approximately 25 per cent work for the U.S. Department of Agriculture primarily doing research and animal and plant inspection; 10 per cent for other Federal agencies such as the U.S. Public Health Service, Army, Navy and Forest Service; and about 15 per cent for State colleges, universities, and agricultural experiment stations, doing primarily teaching, research and extension work. Other employers are insecticide manufacturers, commercial pest control firms, privately endowed colleges and universities, museums, and private research foundations.

Entomologists may specialize in (1) "applied" entomology, which stresses insects' relation to plants and animals, including man; and/or (2) "basic" entomology, which involves fundamental studies of behavior, classification, physiology, toxicology, and various other studies in which insects are the animals under study.

Four hundred million dollars is spent annually to combat insect pests. Over 3 billion dollars in insect damage is reported annually in the United States alone. Insects are known to transmit many virus, bacterial, and fungus diseases of plants and animals, including many diseases of man.

There are also beneficial insects, such as honeybees, which pollinate plants as well as produce honey and beeswax. Other beneficial insects are those that kill harmful insects.

Students with a Bachelor's degree generally go into commercial pest control, sales and development work with insecticides, high school teaching, give technical assistance in research work, or do inspection work.

Students with M.S. and Ph.D. degrees become professional entomologists who supervise various entomological activities and teach or do research in colleges and universities.

There are about 100 full-time entomologists in Kansas who are engaged exclusively in studying insects and/or in insect control work. Several hundred others are engaged in work which is partly concerned with insects and their control.

Many youth who know that they cannot become farmers would like to hear of the many opportunities in entomology. You would do them, your profession, and your country a favor by making them aware of the opportunities-both in the United States and abroad.

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INTRODUCTION

This paper summarizes biological notes on certain alfalfa insects and results of chemical control tests. Because both authors have completed service in Kansas, it seems appropriate to record these notes for use by other investigators. More publications of Kansas workers are included than are recent papers by workers outside Kansas. No attempt has been made to summarize recent investigations by other workers.

The data presented here, sometimes fragmentary or based on small numbers, are presented to aid future investigators or to supplement their findings. Results from chemical tests and control methods are included for historical reasons, though some controls such as the hopper dozer are now largely obsolete and some of the chemicals tested are not approved for insect control on alfalfa.

Doyle (1916) included all that is known of the early history, development, and growing of alfalfa in Kansas to 1916. The crop apparently was first grown in Kansas at Marion, 1868-1869. More recent agronomic aspects of alfalfa culture in Kansas were given by Throckmorton and Salmon (1927) and Grandfield (1951).

Alfalfa diseases were described by Melchers, 1915, Doyle, 1916, and damage by mammals by Nabours, 1915 and Doyle 1916.

The first comprehensive summaries of the insect pests of alfalfa in Kansas were given by Dean, 1916, Doyle, 1916, and revised by Dean and Smith (1935). More recent published accounts of the culture of alfalfa in the United States were made by Tysdal and Westover (1945, 1949).

GRASSHOPPERS

Formal studies in Kansas of the life history, food habits, natural, and artificial control of economic species of grasshoppers in relation to alfalfa began with Agricultural Experiment Station Project No. 75 in 1910.

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1 Contribution No. 789, Department of Entomology and No.162, Fort Hays Branch, Kansas Agricultural Experiment Station. This report includes results obtained from work on Agricultural Experiment Station Projects No. 75 (1904-1910), No. 115 (1916-1953), No. 409 (1953-1956) at Manhattan and on Project No. 263 (1948-1953) at Hays, Kansas.

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The more important crop destroying species of grasshoppers in Kansas were listed by Smith et al. (1943) and Smith (1954). The "migratory grasshopper" (Melanoplus bilituratus) was the most plentiful species annually in alfalfa fields at Manhattan and Hays then. This species reaches a peak in early September when as many as 88% of the sweepings have been of this species. The "two striped" (M. bivittatus (Say)) and "differential" (M. differentialis (Thos.)) species reached peaks of 45% and 7% of collections, respectively, about mid-August. The peak of the "Carolina grasshopper" (Dissosteira carolina (L.)) was reached in October when up to 10% was this species.

Milling Flights

There were no great flights comparable to those of 1873-75 during these studies, only occasional "milling flights" or flights with hoppers flying in circles, 50 to several hundred feet high, then alighting near the starting point. Rarely, they alighted in another field; when they did, the distance traveled was limited possibly to a mile.

Five flights of the "red-winged grasshopper," Paradoloahora haldemanii, Sand., which winters in grassland as adults but occurs in alfalfa, were observed during 1935, under ecological conditions given in Table 1: 80° F. or above with 70% humidity and little or no breeze. The hoppers often hit the sidewalk so hard that they were stunned. The females were devoid of developing eggs, indicating that oviposition had taken place before the flights began.

Table 1. Weather conditions during observed "milling" flights of red-winged grasshoppers attracted to lights at Manhattan, Kansas, 1935.

Date	Time of day	Temperature °F	Relative humidity (%)	Wind velocity
June 25	9:00-10:00 P.M.	83	80	calm
June 27	8:30 P.M.	80	76	calm
July 3	9:45-10:00 P.M.	80	77	light
July 5	10:00 P.M.	88	72	--
July 8	9: 00-10:00 P.M.	98	46	--

Comparative measurements of swarming and nonswarming migratory grasshoppers are given in Table 2. Swarmers had wings more than 3 mm. longer than nonswarmers. Measurements of the swarmers agree with measurements of the Rocky Mountain locust, M. sptetus (Walsh). Milling flights were common in local areas of Kansas during the 30's. These flights, high above the ground, continued for as many as four hours.

Migratory grasshoppers were reported in swarms at Minneapolis, Kansas, in late September, 1935. Thirteen specimens from a flight had an average wing length of 21.7 mm. (range 20-24 mm.) and average total body lengths of 30.5 mm. (range 26-32 mm.) while 12 ordinary, field-collected specimens from Manhattan had an average wing length of 18.25 mm. (range 17-20 mm.) and an average total body length of 24.5 mm. (range 22-26 mm.).

Table 2. Comparative average lengths of the wings and bodies of swarming and field-collected migratory grasshoppers, October 3, 1935.

	Length of wings, mm.		Length of bodies mm.	
	Males	Females	Males	Females
Swarming grasshoppers	20.8	22.1	26.7	27.8
Field-collected grasshoppers	18.1	18.4	24	25.6

A field collection revealed up to five times as many males as females; at other times, females predominated. A summary of the sex ratio of seven species obtained from 1925 to 1933 is given in Table 3. Collections indicated a predominance of females in alfalfa fields and along roadsides near alfalfa fields where eggs are often deposited. Males slightly predominated in cage rearings of the three common crop-destroying species.

Table 3. Sex ratios in seven species of grasshoppers in sample net collections and rearings. Manhattan, Kansas. 1925-1933.

Species	Males	Females	Nymphs
Melanoplus			
bilituratus	33	67	17
differentialis	39	49	23
bivittatus	27	39	5
femurrubrum	158	133	0
Svrbula			
admirabilis	46	14	3
Chortophaqa			
viridifasciata	49	0	6
Hippiscus sp.	13	2	0
TOTAL	316	356	54

Life Histories

Eggs begin to hatch in southern Kansas March 15 to April 1. Frequent newspaper accounts of early large-sized nymphs or adults appearing in March and April, presaging a grasshopper outbreak; are based upon seeing the green meadow locust, *C. viridifasciata* (DeG.) or red-winged grasshoppers which normally winter as large nymphs or adults in pastures. Neither species has been observed to cause economic losses to crops.

First appearance of adults was found to be June 10 to 20 at Hays and Manhattan. First adults in field collections at Manhattan for four common species follows:

1. Migratory: June 12, 1927; June 3, 1936; June 2, 1938; June 10, 1939; June 26, 1940.

2. Two striped: June 30, 1934; June 23, 1936; June 18, 1937; June 23, 1938; June 27, 1940.

3. Differential: July 5, 1936; July 9, 1937.

4. Red-legged: May 31, 1934; June 2, 1938.

Eggs laid by the differential, migratory, and two-striped species as early as July 1, July 6, and July 7, overwintered. Neither, green nor red-winged species, which winter as nymphs or adults, deposited eggs, even in large cages set in good stands of succulent alfalfa.

Second generations. As early as 1878 (Thomas, 1880) the Rocky Mountain grasshopper, now believed to be the long-winged phase of the migratory grasshopper, was reported to produce two generations a year. Bruner (1901) stated that usually there is a single generation, but sometimes there are two. Herrick and Hadley (1916) found the species essentially single-brooded, with a tendency toward two broods.

In 1922 cage rearings, young migratory nymphs found in alfalfa in August suggested a second generation. First adults placed in large cages of alfalfa proved conclusively that the migratory species had a sizeable second generation (1924). Adults caged during the latter part of June, 1924, deposited eggs between July 1 and 12. Nymphs, plentiful in early August, reached maturity in early September. It was proved without knowledge of prior evidence that two generations may occur. Two generations seem to be the usual cycle, since adults were plentiful late in June most years during this study. Some field observations suggested that a partial third generation occurs occasionally. Nymphs commonly found in October indicate that a few individuals could complete the third generation before late killing frosts. A second generation was proved for the red-legged species also.

Two-striped grasshoppers also may have a second generation. Adults regularly occur in early June. Caged rearings in 1924 showed that second generation nymphs were one to three weeks old July 31 and observations indicated a second generation in 1931 to 1933 also. So far as known, this observation has not been included in published papers. Second generation nymphs one to three weeks old were plentiful July 31, 1934. This proved a second generation for this species.

Some significant observations on food preferences and feeding habits. Field surveys July 25, 1927, and later showed that most nymphs occurred in old alfalfa fields with considerable grass and weeds. Such fields provided excellent conditions for oviposition.

In certain cases, differential grasshoppers fed on annual weeds and young sunflowers in preference to alfalfa, In contrast, the two-striped grasshopper attacked alfalfa buds and flowers and reduced seed yields. During the serious grasshopper year of 1956, both species were exceedingly abundant in alfalfa and seriously inhibited flower development. The 1956 season was so dry that long rooted alfalfa plants were the only green vegetation available.

In 1948 at Hays, Kansas, when a wet July followed a dry spring, the differential grasshoppers defoliated Mexican firewood (Kochis scoparia (L.)) and pig weeds and avoided adjacent alfalfa fields. The two-striped grasshopper, at the same time, was abundant in alfalfa. In 1936 and 1956, the grasshoppers obviously preferred legumes. Weeds were second choice and corn third. Sorghum varieties, even when adjacent to badly damaged corn, were scarcely affected.

Food preferences were demonstrated July, 1939, in cages 3 x 3 x 3 feet in which young sweet corn, alfalfa, grass, and castor beans had been planted and stocked with as many as 100 grasshoppers of each species. The two-"striped and differential species attacked the corn first and most severely. Alfalfa was next most severely eaten, and grasses last. They nibbled on the castor bean leaves at first, but fed on them only after other plants no longer served for food. In no case were castor beans and grasses preferred to corn or alfalfa (Smith, 1940). Many grasshoppers died when forced to feed only on castor bean foliage.

The migratory species showed a slight preference for alfalfa but all species studied fed first on young, tender, succulent growth. The crop-destroying species attacked the young flowers, thereby reducing seed production. Grasshoppers fed on curing alfalfa saved for seed. Five grasshoppers placed over a clump of alfalfa containing 246 seed pods and 330 leaves reduced both in 40 hours to 130 seed pods and 105 leaves. In another cage, 150 seed pods, of'which 50 were dry, and 380 leaves were reduced in 48 hours to 99 seed pods and 188 leaves.

It has been stated that migratory grasshoppers fed on alfalfa produced smaller bodies and shorter wings than those fed on lettuce, hedge, mustard, and a mixed diet. These studies support the mixed diet preference, especially succulent annual weeds as described by Scharff (1954).

Parasites, Predators and Diseases

Commonest parasite of grasshoppers observed during these studies was the sarcophagid fly, Sarcophaga kellyi, the "grasshopper maggot", first observed in abnormal numbers in alfalfa in mid-August, 1924. Percentage of parasitism at various times during this study varied from 0 to 35%. Dissections revealed only one maggot per grasshopper. They measured 6.4 mm. in length. Before the maggot emerged, the hosts showed no symptoms of parasitism.

At least three generations of S. Kellyi were observed during 1936. The first or overwintering generation became adults eariy in June; the second generation adults appeared late in June or early in July; and third generation adults appeared late in July and during August. July 17, was the peak of the second generation adults.

Adult sarcophagids were plentiful in early June, 1936, and were noted until about July, when they ceased activity. In June, the shrill buzz of the flies could be heard as they darted toward the flying grasshoppers. This familiar buzz ceased as the drought continued. The flies began activities as soon as the rains came in late August. These parasites constituted an effective natural control during June and in the late summer, when the larvae were plentiful.

Sarcophaga flies were so plentiful during July, 1938, near Manhattan, that they took nearly all available nectar, so there were almost no bees of any kind present. Since flies do not trip alfalfa flowers, this condition was unfavorable to seed set. The flies were seen chasing grasshoppers in flight August 3.

The grasshopper mite (Eutrombidium trigonum (Hermann)). This well-known wing mite was present every year in this study. It was unusually abundant during some- seasons (Table 4). As many as-25 to 35 mites were found on one host.

Table 4. Summary numbers of wing mites on sample collections of grasshoppers from alfalfa fields at Manhattan.

Species of grass-hopper	Date	Number with wing mites	Number without wing mites	Total mites	Grasshopper Males No.	Grasshopper Males Mites	Grasshopper Females No.	Grasshopper Females Mites
Various	7-2-36	33	27	96	-	-	-	-
Various	7-31-37	15	13	47	5	10	10	37
Two-striped	7-31-37	15	16	126	7	39	8	56[1]
Differen-tial	7-31-37	4	-	19	3	14	1	5
Migratory	7-31-37							
Two- striped	8-3-38	19	-	158				

[1] Five mites occurred on the bodies of two females.

Severin (1944) described the life cycle, stages, and habits of this mite in detail. He indicated that the species wintered both as nymphs and adults in the soil. He noted them feeding on grasshopper eggs. The female mite laid approximately 4,700 eggs which hatched in 15-28 days. There was a complete and a partial generation in South Dakota. Observations made during the Kansas studies confirmed and enlarged Severin's discussion slightly.

Wing mites were attached primarily, but not wholly, on the hind wing. The point of fusion of cross veins with the longitudinal veins was a frequent point of attachment. They attached also to the tegmina and on the thorax, generally near the base of the wings. They were frequent under the pronotum. An occasional one was found posteriorly on the abdominal area around the ovipositor or claspers.

Mites on the wings were believed to result in breaking and fraying of the membrane wings, thus impairing flight.

The mites dropped off their hosts in cages, entered the soil, and molted to adults. They were bright red on the wings but they became pale pink in the soil. The molt occurred most commonly 10-14 days after dropping from the wings. For example, mites dropping to the soil August 27, 1939, changed to adults September 9. The bright, velvety-red adult mites overwinter in gardens and fields and are commonly seen in the spring. Eggs were readily deposited when the mites were confined with a moist blotter. While the eggs adhered in masses, making a count difficult, one mite, May 1, 1937, deposited some 1,416 eggs in seven. masses. The eggs were spherical, bright red, quite small, and glued to the glass or substratum. On slides, they resembled red smut spores. The adults were fed on grasshopper eggs. When wing mites were put in a salve box of soil with 25 grasshopper eggs August 10, 1939, they fed on the eggs, causing them to collapse slowly.

Wing mites were found in crevices, cracks, and tunnels in the soil of alfalfa fields as deep as 4 inches. Earthworm tunnels, where and when they occurred, were appropriated by the mites. Egg clusters were found in the soil, but rearing attempts on grasshopper eggs or adults were unsuccessful.

The so-called mite pupae were readily found in the grasshopper cages on the surface of the ground or barely covered by debris. Occasionally, the pupae were found as much as 3 inches below the soil surface. Some were found next to corn roots and resembled nodules on the roots. It was thought that the mites followed the roots below ground.

Mites dropped in one to three days after confining the hosts. They transformed to the pupal stage in 2 to 14 days, and adults emerged in 54 cases in 7 to 20 days, average 12.6 days. The sex of 25 of the mites reared was determined as 18 male and 7 female. Also there were more males than females in field collections.

Mites appeared to reduce the number of eggs laid by grasshoppers. Two series of female two-lined grasshoppers were confined in separate cages. One series had an average of 21 mites on their wings or bodies (range 6 to 26) while the other series was free of mites. The four ovipositing hoppers without mites deposited 497 eggs or an average of 124 each, while the 17 ovipositing hoppers with mites deposited 1,467 eggs or an average of 86 eggs each.

Nematode parasites. Merrill and Ford (1916) stated that *Diplogaster aerivora* Cobb. was "found feeding on grasshopper eggs after the eggs had been deposited in the ground." This nematode infested grasshopper egg capsules in Kansas.

Christie (1936, 1937) discussed *Agamermis decaudata* Cobb, family Mermithidae, which is a parasite of grasshoppers and occasionally in some other insects and *Meris subnigrescens* Cobb, which is strictly a parasite of grasshoppers.

A nematode nearly a foot long emerged from one of several grasshoppers collected at Salina, Kansas, while another was 11 1/4 inches long. A female two-striped grasshopper contained a nematode worm about six inches long. This host had a considerable number of eggs about ready to deposit so the nematode appeared not to have injured or reduced the number of eggs.

Nematodes were exceptionally plentiful during early August, 1938, both in cages and in the field, and clumps were frequently found on the surface of the soil in cages where grasshoppers had been confined for observation.

During the fall and spring of several years, clumps of nematodes were found in small cells in plowed soil. Following the plow was the best way to collect them. Apparently, they emerged from their hosts during the late summer, crawled into cracks in the soil, and either made a small ceil or located a small cavity where they spent the winter.

Grasshopper diseases. The results of investigations on the bacterial, polyhedral, and fungus disease of grasshoppers were published by Smith (1933 and 1954). The effort to introduce a new grasshopper disease caused by *Coccobacillus acridiorum* also was described in a l00-year summary (Smith, 1954).

Host plant resistance. An attempt was made in 1925 to determine if any variety or strain of alfalfa then under test carried any resistance to grasshoppers. The variety Argentine had the fewest feeding grasshoppers, 68 in a plot. Other varieties on comparable plots showing low populations were Grimm - 75, Cossack - 79, Kansas Common - 79, Kansas 435 - 87, and Dakota 12 - 89. The greatest population occurred in the Cape Lucerne variety - 352.

Chemical control. During virtually the entire period covered by this summary, sowing poisoned bran mash or other bait mixtures was the main control method for grasshoppers. Consequently, a great deal of effort over some 25 years was given to testing various bait formulae to increase the kills and to find the ecological conditions which favored good kills by baits.

Kansas exerted considerable influence from 1900 to 1920 and demonstrated effective control on a county-wide basis. The well-known formula known as “Kansas Bait” made with bran, white arsenic, ground oranges or lemons, molasses, and enough water to make the mash moist was used as a check in testing all other formulas..

The first account of grasshopper control in Kansas was a short article by Popenoe (1905) in which a Paris green bran bait with sugar and saltpeter was recommended. The paper by Dean (1914) is epochal. It gave the Kansas bait formula, and, for the first time, described the organization and operation of county-wide bait-sowing campaigns for grasshopper control based on the first successful such campaign in 1913 in western Kansas. Hunter and Claassen (1914) reported good results with a modified formula. The use of the standard bait was described in all alfalfa and alfalfa insect control bulletins, leaflets, and extension releases from 1914 until about 1950. Dean et al. (1919) reported on the successful control campaign with baits and harrowing. Now insecticides have largely replaced the use of baits except on wheat in the fall and in gardens.

Chlordane. Small pockets of grasshoppers at Hays were controlled in 1948 by applying 1 pound of chlordane in 50 gallons of water per acre. Such a large volume of water frequently is out of the question for Kansas farmers. Only 15 gallons of water per acre were used in 1949 when three species of grasshoppers became abundant, largely striped and migratory with a few differential species. A series of four plots ranging from 1 to 3 acres were treated with chlordane at l/2, 3/4, and 1 pound per acre. Results showed that only 1 pound satisfactorily controlled adults (Table 5). The 15 gallons of water per acre was judged adequate for thorough distribution of insecticide under experimental conditions.

Satisfactory control was obtained by use of 8 ounces of wettable powder chlordane per acre in 1948 and 1952. Other insecticides and rates of treatment which gave good control were aldrin, 4 ounces wettable powder, 98% control; endrin, 8 ounces emulsifiable concentrate, 96%; and endrin, 4 ounces emulsifiable concentrate, 95%. The treatments were a single application at the bud stage of development.

There was little difference in control when 24 ounces of toxaphene were applied in 5 gallons of water per acre or in higher gallonages. All treatments gave excellent control.

PLANT BUGS, FAMILY MIRIDAE

Three common species of plant bugs infest alfalfa in Kansas. They are, in order of abundance, the “tarnished plant bug” including its varities - (*Lygus lineolaris* (P. deB.)), the "rapid plant bug" (*Adelphorcoris) rapidus* (Say)) and the "alfalfa plant bug" (*Adelphocoris lineolatus* (Goeze).

Numerically, plant bugs rank among the most plentiful group of insects in alfalfa the year around.

The Tarnished Plant Bug

The first account of this species in Kansas was published by Dean and Peairs (1913) as a pest of fruit trees. Dean and Smith (1935) included both tarnished and field plant bugs in discussion of alfalfa insects. Sorensen (1932) reported that only one fourth of 25,000 alfalfa flowers observed formed pods. This species was responsible for 9 per cent of the so-called “stripping”; the “superb” species (*Adelohocoris superbus* (Uhl.)), for 13.7 per cent. Sorensen found that 75 per cent of alfalfa flowers dropped without forming seed pods. Stitt (1940) reported that seed yields were reduced in proportion to the number of plant bugs in fields. The flower fall varied from 52.5 to 78 per cent. Difference of seed yield between a plot with seven plant bugs to a sweep and one with an average of

Table 5. Experimental grasshopper control tests on alfalfa with a single spraying or dusting at the bud stage of growth, Manhattan and Hays, Kansas, 1948-1953. The emulsifiable concentrate formulation was used unless WP (wettable powder) or dust is indicated.

Insecticide and form	Rate, ounces per acre	Per cent control obtained in comparison with the check plots						Average of percentage control
		1948	1949	1950	1951	1952	1953	
Aldrin	8	98(4 oz WP)	88	78	92	83	95	39
BHC-all forms	1.6 to 4	32-49			51(4 oz)			41
Chlordane-all	8,12,16	66-100	86	73	79	92		31
DDT-all	16,32	47,48	9,48	25,50	35,54	20,45	69,61	32,51
Dieldrin	8		91	68	100	83	95	87
Endrin	4,8					96	89	93
EPN	8,16					83,83	89	86
Heptachlor	8					83	89	86
Isodrin	4,8					88,83		35
Metacide	4,8				83	83	79	32
Methoxychlor	32				54	54		54
Parathion-all	4,8,16	98-33	91	78	75		95	69
Systox	8					79	89	84
TEP	8			46	46			46
Toxaphehe	24		93	78	88	75	95	86
DDT + BHC, dust	16+0.9	73-94	12-30					55
DDT + Toxaphene	16+12			60-69	56-58	3-67	79-84	62

0.23 bug per sweep was 371 pounds. Carlson (1946) obtained 66 pounds of seed per acre where plant bugs were a factor and 175 pounds where they were controlled by insecticides.

Population peaks October 25, 1927, counts were made in alfalfa to determine numbers of tarnished plant bugs at the Agronomy Farm, Manhattan. In 30 sweeps 442 bugs, l7.4 average per sweep, were obtained. The bugs seemed to have migrated from dead or dying vegetation. In 1935, in a series of 25 sweeps on old stands every few days from mid-April to October, the largest numbers of adult and nymphal plant bugs were taken May 21-30, June 15-18, June 29 to July 4, August 11 to 18, September 10, and October 12-17, and November 12. In new stands, the peaks were June 15-22, July 6-10, July 22 to August 6, and September 14. In old stands in 1936, peak collections occurred on April 14-29, June 30, July 2l, September 14, and October 18. In new stands (seeded 1935) peaks occurred May 4 to June 6 when it was cut, June 30, July 21, and August 9.

Eggs and oviposition. June 20, 1927, a plant bug was observed ovipositing on an alfalfa plant in a chimney cage. Before oviposition, she walked nervously over the plant with her beak ready for insertion. She tested several places with her beak, moved on, and finally inserted her beak, as if testing the tissue, in the tender opening leaf bud. She then inserted her ovipositor. After 20 seconds, the ovipositor was withdrawn and the bug walked away. Bugs readily oviposited in cage studies in 1927. Twenty-seven eggs were deposited in one night by one female, 28 and 20 by two others. Others laid 1, 2, 7, 9, and 11 eggs,

They oviposit in the tenderest bxanches, the petioles, or parts of flowers. They may remain with the ovipositor inserted for hours; some trying to oviposit in hard stems die unable to withdraw the ovipositor. Apparently, they make cavities in the soft tissue with the ovipositor, then push the eggs in. As much as half an egg may protrude from small stems, or an egg may be pushed entirely through the stem. The egg may cause a marked swelling on a slender twig.

The females prefer the softest and tenderest tissue for feeding. Buds and flowers suffer most, both from feeding and ovipositing punctures. Drops of sap often exude at these punctures.

August 8, 1927, a tarnished plant bug was caged over an alfalfa plant. Two days later two leaves were wilted. The injury appeared to be caused by oviposition. In the crotch where the stem separated to form the leaves, at least 18 eggs were located with three or four in the stem below the crotch. The leaf bud at the crotch apparently was dead.

Instars. Instar measurements are given in Table 6. Time required for the egg stage in rearings varied from 5 to 9 days with 5 commonest. The time from hatching to adult varied from 16 to 35 days with 25 commonest. Eggs deposited per female in rearings varied from 0 to 33.

Table 6. Width of head length of five individuals and time interval for each of the five nymphal instar stages of development of the tarnished plant bug.

Measurements in mm.	Instars 1	2	3	4	5'
Width across head					
Widest	0.35	0.50	0.70	0.85	1.00
Narrowest	0.35	0.45	0.60	0.80	0.90
Average	0.35	0.47	0.64	0.82	0.97
Length of body					
Widest	1.4	1.65	2.25	3.	4.9
Shortest	0.9	1.3	1.15	2.15	2.75
Average	1.13	1.54	1.88	2.73	3.53
Average days in instar	5.0	3.6	4.0	5.5	6.2

Hatching. Eggs ready to hatch are smoky gray, with red eyes of the embryo showing through the chorion clearly. The nymph pushes upward, bursting open the upper end of the egg, and rises slowly from the egg shell. As soon as the legs are free it moves about feebly. The entire process requires only a minute or two. In a surprisingly short time, the pale, translucent, red-eyed nymph runs about. The distal segments of the antennae are smoky black.

In the first two instars the nymph is yellowish green and may be mistaken for a green aphid. It may be distinguished from the aphid by its dorsal, blackish, abdominal stink-gland, and by the absence of cornicles. In the third instar a pair of dark spots which become more conspicuous in the fourth and fifth instars is distinguishable on each of the first two thoracic segments. Distinct wing pads are present in the fourth and fifth instars and distinctive markings of adults begin to form. The nymphs first appear on alfalfa at Manhattan, Kansas, in late April or early May.

Adults' coloring varies from light yellowish-brown with dusky blotches to dark brown with dark blotches. In most cases, females are lighter than the males, especially on the under side.

Seasonal cycle. The first generation reaches maturity early in June. The adults of the next generation begin to appear about mid-July. The third generation matures in late August and early September. There is time for a fourth brood but none has been observed for certain. Some writers state that nymphs overwinter, but they have never been taken in alfalfa in mid-winter or early spring in Kansas. Adults have been taken from alfalfa clumps every month during the winter and are among the first alfalfa insects to become active in the spring in the Hays region. Overwintering individuals were darker than those found later.

Table 7. Generations of the tarnished plant bug at Manhattan, Kansas, approximated from collections and rearings.

First generation (overwintering) adults	March 1 to April 10
First generation nymphs	April 10 to May 20
Second generation adults	May 10 to June 10
Second generation nymphs	May 20 to June 10
Third generation adults	June 10 to July 15
Third generation nymphs	June 20 to July 20
Fourth generation adults	July 20 to August 20
Fourth generation nymphs	July 25 to September 20
Fifth generation adults	August 25 and overwintering
Fifth generation nymphs	September 25 to November 15
Sixth generation adults	September 10 to overwintering

Other host plants. Daisy fleabane (*Erigeron ramosus*) was found to be a favorite host plant for plant bugs. A plant bug was observed feeding in the yellow portion of an Erigeron blossom. It appeared to be pushing apart the disc flowers and sinking its proboscis into the tender base portion. Another specimen farther down in the middle region of the stem fed near the base of a leaf.

April 3, 1931, adults were found clustered on young wild mustard plants (Cruciferae) and *Rorippa* sp. The former is a fine-leafed plant, the latter coarse-leafed. There was no evidence of injury to mustard plants. One plant bug was found May 29, 1927, on a daisy and another on a cabbage head August 3.

Effect of cutting alfalfa on plant bug numbers. July 22, 1927, the third generation of adults occurred in enormous numbers in alfalfa being cut for hay. After cutting, a decrease of at least 80 per cent occurred, with only a few adults and nymphs to be found in the windrows. There was no evidence of any migration.

The effect of cutting alfalfa on the population was also ascertained June 5, 1936. There were 126 in three sweeps the day before the alfalfa was mowed; the day it was cut but not raked, 22 in three sweeps; three-days later only one bug was found.

Overwintering. It is common to find tarnished plant bugs more numerous in alfalfa fields in the fall than any other insects.

Forbes (1884) stated that the older nymphs also survive the winter under the leaves of mullein plants. Wier (1872) and others stated that only the females overwinter, that males die in the fall after copulation. Crosby and Leonard (1914) said they had found males and females about equally abundant in hibernation.

March 7, 1927, a female plant bug was found in hibernation in bunch grass in the sand dunes south of Manhattan. When placed on an alfalfa plant in a lantern chimney cage, it laid two eggs by March 10.

A few adults were found in alfalfa clumps. From collecting in mullein all through the spring, it was concluded that the plant bugs overwintered as adults in this plant and emerged with moderate weather to oviposit on mustard. Nymphs in the later instars of this generation moved from a patch of mustard to alfalfa when it was more succulent than the mustard. As many as 50 per cent of bugs from mullein plants collected February 13 and 17, 1916, were dead. Of nine adults whose sex was determined, six were males and three females.

Six hundred adult tarnished plant bugs were collected November 5, 1927, and placed in overwintering cages; 300 in one cage, 200 in another, and 100 in a third cage. The 200 cage was taken up January 7, 1928, and 58 live bugs and 31 dead ones were found. On January 9, 51 live adults were taken from the overwintering cage in which 300 had been placed. Twenty were males and 31 females. The 100 cage was left for generation rearings.

Charles Curtiss, February 6, 1939, found overwintering eggs of tarnished plant bugs (and of the rapid plant bug, Adelphocorus rapidus Say) by clipping off standing alfalfa stems. He found six eggs of the rapid plant bug in four stems and four of the tarnished species in another stem. The eggs did not hatch in a greenhouse insectary at temperatures of 59 to 88° F., 80 per cent humidity. January 7, he found eggs in a stem which contained Proctotrupid parasites. None has been reported in the literature; perhaps these were an unreported species.

Apparently viable tarnished plant bug eggs were found in alfalfa stems in the field, so the species may overwinter in egg stage in addition to the adult stage.

Damage. Injury is usually not so apparent on alfalfa as on other plants because feeding is distributed to all parts of the plant above ground and because alfalfa, during a good growing season, grows so rapidly that the injury is largely overcome. It was found that at the end of from seven to ten days potted plants in cages containing the tarnished plant bugs were entirely killed while the checks were growing vigorously. Infested plants tended to stool while noninfested plants did not. In the field, 25 plant bugs were put on an alfalfa clump within a screen cage and another clump used as a check. Although the infested plant was not killed, it was badly dwarfed and tended to stool.

To determine whether injury was caused by feeding or oviposition, potted plants with only females and only males were compared but no difference was found despite eggs being deposited by the females. Several eggs inserted near the same place in an alfalfa stem cause it and leaves above it to wilt and eventually die. When an egg is inserted through a leaf bud, it frequently punctures all three leaves; then when the leaves emerge from the bud, holes appear. These holes get much larger and may permit disease organisms to enter. Such injury has been found in the field.

Effect of feeding and oviposition on alfalfa seed production and yields. Observations indicate that tarnished plant bugs injure alfalfa in the three ways, viz., (1) mechanical injury by lacerating the tissues by the stylets; (2) carrying bacteria and injecting them along with salivary juices; and (3) injecting either a salivary secretion or regurgitation with a virulent toxic effect.

Plant bugs are one of the causes of crinkly, mishapen leaves and some irregularities in stems on alfalfa plants.

Special emphasis was given to the effect of plant bugs on seed set in 1939. Eleven cages containing 1, 5, or 10 bugs each were placed over the alfalfa (Table 8).

Table 8. The effects of tarnished plant bugs on seed set of alfalfa, Manhattan, June 26, 1939. When any plant bugs died, they were replaced by living specimens from the field.

Cage No.	No. in cage	Re-place-ments	Blossoms: No. in exp. cage	Blossoms: No. in ck. cage	Seed pods: No. in exp. cage.	Seed pods: No. in ck.cage
I	10	34	60	45	4	66*
II	10	19	60	75	0	35
III	10	27	110	15	0	65*
IV	10	29	70	35	8	13
V	5	10	70	35	0	17
VI	5	12	50	35	0	22
VII	5	12	80	85	2	28
VIII	1	2	50	50	0	0
IX	1	2	70	90	8	31
X	1	3	80	100	0	0
XI	1	1	21	13	0	16

* In Cages I and III, blossoms developed after they were counted, thus accounting for the large number of seed pods present.

In 7 of the 11 cages, no pods formed. In the other four, 11 per cent was the highest seed development. Percentage of increased pod development in check cages ranged from 30 to 100 per cent over the infested plants.

In seed set cage tests August, 1938, five seed pods were produced in a cage with 35 plant bugs placed there a month earlier, compared with 45 pods in the check Cage.

Halves of one clump of budding alfalfa were placed in two screen cages, one containing 125 tarnished plant bug nymphs. There were no seed pods in that cage a month later but 30 developed in the check cage.

In a cage with 231 alfalfa blooms or buds, tarnished plant bugs destroyed all the blooms but two, and there was no seed set.

Plant bugs cause the following damage to alfalfa producing seed:

1. Greyish or white blasted buds that do not open.
2. Bare stems after buds, flowers, and small seed pods drop.
3. Brown and shrivelled seeds.

Any of the above conditions can result from other causes also. Thrips can cause the greyish or whitish buds. Frost damage will cause buds and flowers to drop. Lack of bees to trip flowers may result in large numbers of flowers falling from the stems. Other insects such as grasshoppers and blister beetles feed on and destroy flowers and seed pods, leaving bare stems. Where plant bugs are present in numbers, all of the above conditions are certain to be evident as a result of the insect piercing the plant tissue, sucking the plant juices, and injecting toxic saliva into the plant.

Natural control. Stitt (1940) reported no parasites of the adult, nymph, or egg of plant bugs. Such predators as nabids (Nabis), Geocoris, an ant (Formica) and two species of spiders fed on them.

There are few natural enemies to check effectively plant bug increase. Birds do not prey upon them because of their offensive odor (Forbes (1884). Crosby and Leonard (1914) mentioned a minute mymarid parasite, Anagrus ramosus Crosby and Leonard, as destroying bug eggs to a slight extent.

Two species of spiders, a small black ant, and a tree cricket were observed feeding on the nymphs of tarnished plant bugs in field sweepings. Chrysopids fed on the nymphs in the field. This insect, even in the nymphal stages, is too active to be easy prey for ordinary insect predators.

The eggs and nymphs were attacked by the same common predators that attack pea aphids in alfalfa, but with less success. No fungous, bacterial diseases, or parasites were reared.

A spider was seen July 21, 1927, feeding on a tarnished plant bug in the field. In a net of sweepings from alfalfa, a small black ant was observed feeding on tarnished plant bug nymphs July 2, 1929.

Chemical control.[1] Tables 9, and 57 to 67 give results of chemical control tests.

With the advent of the new insecticides, mirid control in alfalfa has been accomplished generally by insecticidal application, at or before the bud stage of plant growth.

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[1] The alfalfa insect control summary tables, numbers 9, 15, 23, 29, 32, 44, and 52 have been condensed for this report. Large detailed tables are on file in the Department of Entomology at Kansas State University, Manhattan.

Table 9. Condensed table of control results for the tarnished plant bug in various alfalfa experimental plots at Manhattan and Hays, Kansas, 1947-1953. All treatments consisted of a single application on the second cutting near the bud stage except where indicated otherwise, EC = emulsifiable concentrate; WP = wettable powder; D = dust; All = previous three.

Insecticide	Rate ounces per acre	Formulation	No. of tests	Percentage control: Range Low and high	Percentage control: Average 1 to 7 years
Aldrin	8	EC	6	71, 97	82
BHC	1,1.6, 1.9,4	All	6	48 (1.9, WP), 64 (1.9, WP)	55
Chlordane	16	"	7	44, 91	63
DTT	16	"	8	47, 86	65
"	32	"	8	56, 96	74
Dieldrin	8	EC	5	62, 97	79
Endrin	4, 8	"	2	79 (4 oz.) 96 (8 oz.)	88
EPN	16	"	2	80, 98	89
Heptachlor	8	"	2	81, 100	90
Isodrin	4, 8	"	2	69 (4 oz.)	80
Metacide	4	"	1	60, 97	80
Methoxy-chlor	32	"	2	59, 69	64
Parathion	4, 8	All	7	38 (8 D,) 95 (4 oz. EC)	71
Systox	8	"	2	80, 98	89
TEPP	8	"	2	24, 57	40
Toxaphene	24	"	5	73, 99	82
DDT (16) + BHC (0.9) D			7	16, 97	70(1)
DDT (16) + Toxaphene (12) EC			20	0, 98	41(2)

(1) Insecticide applied at 4-6 inches growth.
(2) Insecticide applied at first and third growths. Second growth used as check.

Alfalfa seed yields were greatly increased by a single spraying with DDT and Toxaphene during these studies. Double and triple yields over unsprayed checks were obtained in a few instances. Typical results were recorded by Franklin (1951) and Grandfield and Franklin (1952).

Some 31 rates in three formulations of 15 insecticides and 8 combination treatments were included in control experiments 1947-1953 (Table 9). Percentage control varied considerably for some treatments from year to year. The 16-ounce rate of emulsifiable chlordane was 60% in 1948, 91% in 1949, and 44% in 1950. Two treatments, one when the plants reached 4 to 6 inches high and another at the bud stage of development usually gave better control than a single application. However, the reduction in the numbers of plant bugs for two applications seldom was sufficiently great to be practical.

The Rapid Plant Bug, Adelphocoris rapidus (Say)

The rapid plant bug was first described by Say in 1831 as Capsus rapidus. Glover (1856) next called attention to the presence and feeding of this insect on cotton. Uhler (1872) reported it from Colorado and in 1878 reported it as common throughout states east of the Mississippi River and into Canada and British America. Forbes (1884) wrote that it occurred from the Atlantic to San Francisco. It was extremely numerous throughout Illinois but less abundant than the tarnished plant bug.

Recorded information about the life history, habits, and importance of the rapid plant bug is based largely on observations on cotton by Ewing (1929), Ewing and McGarr (1933), and Gaines (1933).

Forbes (1905) listed both red clover and alfalfa as food plants. Dean and Smith (1935) listed it as one of the commonest insects in alfalfa fields, and stated it had a part in reducing seed production by feeding on blossoms.

This species belongs in that category of economic insect pests whose damage, though undoubtedly real, is usually not severe, concentrated, nor spectacular enough to attract much attention. It is common in alfalfa and clover fields, in meadows, and among roadside herbs. Ecologically and in general habits, it closely resembles the more abundant tarnished plant bug.

Lack of recognition of the injury attributable to these and similar species is due largely to: (1) scattered injury; (2) lack of complete destruction or defoliation; and (3) not associating damage with the species.

Among cultivated hosts are cotton, potatoes, beans, clover, alfalfa, strawberries, and corn. Wild hosts include many composites, lambsquarter, and Euphorbia.

Egg. Webster and Stoner (1914) described the egg. The writers supplement their descriptions with minor differences;

The egg is elongate, slightly curved, and subcylindrical, being somewhat compressed in the region of the operculum, or cap, varying from 1.15 to 1.3 mm long and up to 0.3 mm wide. A fresh egg is milky white, with a greenish or a yellowish tinge, except for the cap, which is darker, often appearing somewhat reddish-brown. The outer face of the operculum is concave and, under high magnification, appears to be sculptured. No definite pattern has been observed. There is some evidence of light sculpturing on the chorion just below the cap. At the edge of the operculum, and distal to the concave longitudinal curve of the egg, an elongate fasciculoid process is characteristic. To the naked eye or under low magnification, it appears spine-like. Under high magnification, it is seen to consist of many slender, sharp-tipped units, rather loosely united and slightly spreading distally. The function of the fasciculoid process, if it has any, is obscure. The process varies in length in different eggs, and frequently is absent. It is sometimes straight, sometimes curved inward.

Webster and Stoner (1914) obtained eggs easily from an insectary where they were deposited in potato stalks, most commonly where the smaller stems joined the main stalk, in leaf axils, and along the main stalk. They found the eggs were usually placed singly, but sometimes in close proximity, even adjacent. Our observations, using alfalfa instead of potato, were confirmatory.

In alfalfa, eggs are most commonly inserted within a few inches of the growing tip, where the tissues are relatively tender. Leaf axils are favored spots. Eggs may be found loosely inserted in flowers or flower bud clusters.

Eggs were inserted in the stems of alfalfa in lamp chimney cages in rearing tests. The plant had been cut back, and the eggs inserted at one puncture. The eggs closely resembled those of the tarnished plant bug though they were a little longer.

The maximum number of eggs deposited has not been determined. It has been easy to obtain eggs from females taken in the field and caged, but in no case have eggs been secured from a female reared through the immature stages in the insectary. The maximum number secured from a field collected female was 51.

Time elapsing between oviposition and hatching varied from 9 to 16 days (Table 10). The developmental period usually required 10-12 days.

Table 10. Developmental period of the rapid plant bug egg.

Days from oviposition to hatch	Number of egg represented
9	7
10	25
11	9
12	25
13	17
14	9
15	4
16	3
Total	99

This approximates Webster's (1915) finding 11 to 13 days for hatching.

On one occasion, a nymph was discovered in the later stage of emerging from the egg. The operculum had been pushed outward, and the nymph had extended two thirds of its body from the egg. To facilitate the process, the nymph repeatedly bent backward, then straightened. This movement, together with the fact that the long beak and legs were lying back close against the body, imparted to the emerging nymph a somewhat worm-like appearance. After a few minutes it loosened its forelegs and brought them into play, after which it was soon free. The last parts to be removed from the egg shell were the dark ends of the long antennae. The entire body was considerably lighter than nymphs even a few hours old.

Nymphs. Nymphs of the rapid plant bug, at all stages, are active, running about with great rapidity when disturbed. On various occasions they have been observed to leap several times the length of the body.

First instars, if given an opportunity, will begin feeding almost as soon as they emerge from eggs. When several nymphs hatched in a test tube and were left for several hours without plant food, one was discovered with its beak inserted in the body of another, from which most of the fluid had been withdrawn.

Duration of stages. A careful determination of the duration of each of the five nymphal stages was attempted, but was only moderately successful, because of the difficulty of rearing nymphs under observation. Data obtained are shown in Table 11. The duration of stages IV and V, especially, is quite variable, depending apparently on such factors as temperature and food.

Table 11. Duration of the nymphal stages of the rapid plant bug.

Nymphal stage	Number of individuals represented	Number of days required: Minimum	Number of days required: Maximum
I	5	5	6
II	3	4	5
III	8	3	4
IV	12	3	8
V	11	5	9

Of four individuals reared from egg to adult, one required 23 days, two 24 days, and one 25 days. The time from oviposition to adult is, therefore, about 35 days. However, variation is indicated by the record of one nymph that hatched September 9 from an egg deposited August 28. Molting first occurred September 15, and again September 20, September 23, and October 1. The nymph became inactive about October 9, and died two days later, still a fifth instar. The total period from oviposition to death was 44 days.

Description of nymphs. In all nymphal stages, the head and prothorax are reddish-brown. This provides an easy way to distinguish nymphs of this species from those of the tarnished plant bug, which are entirely greenish.

First and second instars are most difficult to distinguish. Webster and Stoner (1914) described the abdomen of the first instar as yellowish dorsally without the red patch covering most of the dorsal surface of the abdomen of the second instar. But in some cases, the abdominal dorsum of the first instar is reddish. In both first and second instars, the fourth antenna1 segment is the only one conspicuously darkened being deep red except for a whitish tip and a short proximal whitish area. The first, second, and third antennal segments are usually light greenish-yellow, but in advanced second instars, the third antenna1 segment may be somewhat reddish distally.

The distal one third to one half of the third antenna1 segment of the <u>third instar</u> is deep red. The other antennal segments are approximately as in the preceding stage, except that occasionally the tip of the second may be tinged with red. This is most commonly seen within a day or two of molting to enter the <u>fourth instar.</u> Nearly all nymphs of this stage have a conspicuous dorsal red spot on the abdomen, varying from about one half to two thirds the total dorsal abdominal area. Only the caudal tip and a larger anterior portion are green. Usually this red spot is without very definite shape, but occasionally it may resemble a rough triangle, with the apex directed forward. In this instar the wing pad development is first definitely evidenced, though not yet conspicuous.

The tip of the second antennal segment of the fourth instar is characteristically moderately deep red. The fourth antenna1 segment is essentially the same as in the third instar with one third to one half of the distal portion of the segment dark. A reddish-orange, much lighter than the head capsule, characterizes the first segment. The dorsal red on the abdomen is often quite conspicuous, but not infrequently suffuse. In nearly all cases, it approximates the shape of a triangle, with apex forward. About half of the dorsal surface of the abdomen is occupied by this spot, leaving a small green area at the tip, and a larger green area anteriorly. The wing pads are definite in appearance, and extend a short distance back over the abdomen. They are essentially greenish, though the tips maybe yellowish, especially toward the end of the stage.

The first antenna1 segment of the <u>fifth instar</u> is reddish, sometimes as dark as the head capsule. The distal one fourth to one half of the second antennal segment is quite dark, with a short, conspicuously red band just proximal to the darker area, the relative length of which increases during the stage. Third and fourth antenna1 segments are essentially the same in appearance as in the preceding stage.

There is usually a rather well-defined reddish triangle situated dorsally on the abdomen, with the apex reaching to a point slightly to the rear of the wing pad tips in a nymph with moderately distended abdomen. If the abdomen is shrunken, the apex of the triangle may lie between the tips of the wing pads. The reddish triangle occupies a smaller percentage of the dorsal area of the abdomen than in earlier stages. In some cases the reddishness is quite suffuse.

The wing pads are quite conspicuous in the fifth instar, extending far back over the abdomen. The tips are dark, often appearing black; the remainder of each pad is usually yellowish early in the stage. As the insect advances through this stage, there is a tendency for the duskiness of the tips to extend along the mesal margins of the wing pads, and for the rest of each pad to become olivaceous.

Adults. The blackish coloration on the posterior portion of the pronotum is extremely variable (Parshley, 1915). Commonly, there are two more or less elliptical dark spots lying transverse to the longitudinal axis of the insect. This pattern varies, however, from two relatively small, widely separated spots, to a condition in which there is a single, wide transverse band, usually with at least a slight concavity anteriorly. When the pronotal spots are divided, they may be approximately circular rather than elliptical.

In sweeps July 6, 1937, 11 male and 6 female rapid plant bugs were taken.

The adult bug seems to be a less hardy insect than the tarnished plant bug and dies more readily under experimental conditions. Observations have shown that in securing the bugs by sweepings, it is relatively easy to kill them. It may be that this lack of hardiness is at least in part responsible for their being normally less abundant than the tarnished plant bug.

Generations. Evidence indicates the normal occurrence of three full overlapping generations and perhaps a partial fourth in Kansas. Sweepings were taken at various intervals during 1939. Until the latter part of June, neither nymphs nor adults were abundant in an alfalfa plot which was swept periodically, and the majority of nymphs taken were in advanced stages. July 3, sweeping of the same plot revealed continued scarcity of adults, but nymphs were common, the greater part of them being early instars. Hatching of the second brood apparently occurred toward the end of June. These should have relative abundance about July 20.

Throughout August, nymphs were found in all stages, and were more abundant than adults which were common. Adults were relatively abundant through September at Manhattan but not at Hays. As late as September 28 all nymphal stages except the first were found in alfalfa on bottomland. The fifth instars were taken October 15.

It appeared that the first generation reached the adult stage toward the end of May, and began depositing eggs about mid-June. The first and second generations were fairly distinct. The second generation appeared in nymphal form in late June and early July, and from then until the end of the season there was so much overlapping of broods that it was impossible to draw any accurate lines of distinction. In general, however, it seemed that there were three full generations. The late nymphs mentioned above could have been either later members of the third generation or representative of a partial fourth.

August and September are the high population months. Variations from year to year are normal as indicated in Table 12. Variations also occur among varieties and strains of alfalfa. Kansas Common appeared to be more acceptable to the rapid plant bug than any other variety tested (Table 13). Italian and Argentine were least acceptable.

Table 12. Weekly collections of rapid plant bugs in sweeps, illustrating the seasonal occurrence of adults, April 1 to October 20, 1938 to 1942, at Hays, Kansas.

Week starting April 1	1938	1939	1940	1941	1942	Week total
April						
1-7	-	0	-	-	-	0
8-14	-	-	-	0	-	0
15-21	-	-	-	-	6	6
22-28	-	-	-	0	14	14
29-May 5	-	0	-	0	17	17
6-12	0	0	0	0	13	13
13-19	-	-	0	3	10	13
20-26	0	-	4	1	12	17
27-June 2	0	0	16	0	23	39
3-9	0	0	3	5	9	17
17-23	2	0	0	10	11	23
24-30	0	0	0	11	13	24
July 1-7	-	2	0	-	9	11
8-14	2	1	0	-	-	3
15-21	5	1	0	-	-	6
22-28	0	4	0	-	5	9
29-Aug. 4	0	4	-	7	62	73
5-11	0	6	-	5	361	372
12-18	1	0	-	6	268	275
19-25	1	21	-	1	19	42
26-Sept.1	0	0	-	-	-	0
2-8	0	-	-	-	-	0
9-15	1	0	0	-	-	1
16-22	-	0	0	-	-	0
23-29	-	-	-	-	-	0
30-Oct. 6	2	-	-	-	-	2
7-13	-	-	-	-	-	-
14-20	1	2	-	-	-	3
Year Total	17	41	23	54	858	993

Table 13. Number of rapid plant bugs in 15 sweeps in alfalfa variety plots, Manhattan, Kansas.

Variety or strain	April 10	June 5	June 19	July 8	July 24	Aug. 27	Variety total
Argentine	0	0	0	0	1	7	8
Cape Lucern	0	0	0	1	9	0	10
Cossack	0	0	0	1	3	7	11
Dakota Common	0	1	1	3	5	8	18
Dakota #12	0	1	1	6	5	6	19
Grimm	0	2	0	2	4	9	17
Italian	0	0	0	1	5	0	6
Kansas Common	0	2	0	7	6	12	27
Kansas 435	0	0	1	0	3	6	10
Ladak	0	0	0	0	4	7	11
Provence	0	0	0	3	10	5	18
Spanish	0	1	0	6	2	4	13
Sunflower	0	0	0	3	3	4	10
Turkestan	0	0	0	3	7	3	13
Utah	0	0	0	1	5	6	12
Date total	0	7	3	37	72	84	203

Hibernation. Although he did not mention,hibernating stages, Forbes (1884) reported taking adults in March, which indicates overwintering in that stage. Weigel and Sasscer (1923) stated that the insect wintered as an adult. Watson (1928) found that it overwinters in the egg stage, in plant stems.

In rearing experiments in the insectary during the fall of 1937, no eggs laid after September 1 hatched, although oviposition continued until October, indicating a diapause.

In 1939, alfalfa sweepings and light-trap collections were begun about March 15 to find the bug as soon as it appeared, and to ascertain the stage first appearing. The first individuals taken were two first or second instar nymphs, May 6. Thereafter, nymphs were taken at almost every sweeping and in progressively advanced stages. From fifth instars swept from the field May 16, two adults, one male and one female, became adults May 19 in the insectary. First adults were taken two days later. During the night of June 2-3, an adult was taken in the light trap.

Records strongly indicate that overwintering occurs in the egg stage in the vicinity of Manhattan. Also of 201 adult specimens in the Kansas State University collections taken at various times during the past 50 years, the earliest recorded date of collection was May 12, the latest November 2.

Injury to alfalfa. Dean and Smith (1935) reported that it fed on alfalfa blossoms and caused them to drop. Similar injury had been attributed to a closely related species, *Adelphocoris superbus* (Uhl.) by Sorenson (1932).

To test the effect of an infestation on flowering alfalfa, a series of experiments in which adult rapid plant bugs were caged on alfalfa blossoms and buds were conducted in 1939. Whenever possible, the control in each case consisted of another flower cluster on the same plant, screened to exclude insects. Some of the plants used were growing naturally in the field; the majority were potted plants placed in a large screened cage out of doors.

From one to eight bugs were caged with each flower cluster infested, the clusters varying in number of flowers and buds from about six to some 25 or 30. In every case, from two to five days after being infested, the flowers either wilted or fell. Sometimes the entire peduncle wilted a short distance below the cluster, causing the cluster to droop.

In some cases only female bugs were used, in other cases only males. It was hoped in this way to discover whether the entire injury resulted from feeding or whether oviposition punctures might also be a contributing factor. As nearly as could be determined oviposition made no difference.

Similar flower and bud cluster infestations, in which nymphs were substituted for adults, were made. Five to ten nymphs of various stages were caged on each cluster varying as indicated above. Results differed in no essential respects from those involving adult bugs.

In no case did a flower belonging to an infested cluster form a seed pod, with just one or several bugs present. Normal seed pods were regularly obtained from the check plants.

A series of experiments was begun August 23, 1939, to determine the result of infestation on young alfalfa seed pods. Nine clusters of apparently healthy young pods on growing plants were selected in the field and cages placed about them. Ten rapid plant bug nymphs of various stages were placed in each of four cages. The other five were used as controls. Observations were continued five weeks to allow development of the pods, although the bugs in the infested cages died within a few days. Then the plants were cut and the pods examined. Results are shown in Table 14. No pods were found on Plant I, although a few very small pods had been present at infestation. Plants II and IV had shrivelled pods. Plant III had one pod, in fairly good condition. The pods appeared normal on the control plants. Of the 37 seeds obtained from Plant VIII, all but four were found to contain clover seed chalcids, but they were classed with the plump seeds because there was no evidence of the shrivelling typical of seeds in the stocked cages. Of the seeds obtained from the control plants, approximately 88 per cent were plump, compared with 17 per cent from infested plants. Seeds produced and percentage of good seeds both were greatly reduced. Similar effects are caused by both the tarnished plant bug and the alfalfa plant

Table 14. Rapid plant bug injury to young alfalfa seed pods.

	Plant number	Plump seeds	Slightly shrunken seeds	Badly shrivelled seeds	Total seeds obtained
Infested plants	I	0	0	0	0
	II	0	5	0	5
	III	4	0	1	5
	IV	0	0	13	13
Totals for infested plants		4	5	14	23
Control plants	V	12	3	1	16
	VI	7	1	1	9
	VII	3	0	0	3
	VIII	35	2	0	37
	IX	5	0	0	5
Totals for control plants		62	6	2	70

Effect of feeding punctures on alfalfa plant tissue. To observe the histological effect of feeding punctures on alfalfa stems, cross-sections were secured and mounted for study. Apparently the bug does not feed exclusively on one type of plant tissue. Relatively large stylets enter the stem more or less at random. Result is a general collapse of cells of all types in the vicinity of the puncture. Whether a toxic substance is secreted was not established.

Control. Control did not become possible until synthetic organic insecticides after World War II. Control with most of the chemicals tested gave good results (Tables 15 and 67). Parathion and DDT gave best results. TEPP, having little residual activity was not satisfactory. Percentage control varied as much as 40% from year to year as in the case of aldrin. Control was somewhat higher on the first than on the second or third cutting. DDT reduced numbers 58 to 91%. Average on all 17 plots for all forms of DDT was 73%; parathion averaged 83.7% on 7 plots.

Table 15. Condensed table of control results for the rapid plant bug in various alfalfa experimental plots at Manhattan and Hays, Kansas, 1947-1953. All treatments consisted of a single application as a dust or in 15 gallons of water per acre near the bud stage of development on the second cutting of alfalfa except where indicated otherwise. EC = Emulsifiable concentrate; WP = Wettable powder; D = Dust.(1)

Insecticide	Rate ounces per acre	Formulation	No. of tests	Percentage Control: Range Low and high	Percentage Control: Average 1 to 7 years
Aldrin	8	EC	6	60, 100	81
BHC	1.0 - 4	EC,WP,D	7	61 (1 oz.WP), 88 (4 oz. EC)	77
Chlordane	16	"	7	52 (EC), 92(D)	71
DDT	16,24,32	"	17	49(D), 100(EC)	73
Dieldrin	8	EC	5	71, 85	79
Endrin	4, 8	"	2	76(8), 85(4)	80
EPN	16	"	2	72, 88	80
Heptachlor	8	"	2	48, 73	60
Isodrin	4, 8	"	2	56(8), 65(4)	60
Metacide	4, 8	"	3	64(4), 81(8)	74
Methoxychlor	32	"	2	46, 52	49
Parathion	4, 8	EC,WP,D	7	64(4,EC), 95(8,D)	83
Systox	8	EC	2	65, 72	68
TEPP	8	"	2	0, 20	10
	24	"	5	77, 88	84
DDT (16) & BHC	0. 9	D	7	41,99	70(2)
DDT (16) & Toxaphene	12	EC	20	0, 93	51(2)
DDT (5) & Toxaphene	10,20, 25,30	"	10	0	0(2)

(1) The detailed insecticide control test tables from which Table 15 control tests have been made are on file at the Department of Entomology, Manhattan, Kansas.

(2) Alfalfa growth 4-6 inches high or at bud stage of the first or third cuttings.

The Alfalfa Plant Bug, *Adelohocoris lineolatus* (Goeze)

The alfalfa plant bug was first reported in the United States by Knight (1930) and in Kansas by Curtiss (1941); however, a few specimens had been taken in alfalfa fields in Kansas each of the two seasons previous.

The life history, habits, and other aspects of the alfalfa plant bug in Minnesota were well presented by Hughes (1943). Field-collected females readily oviposited in stems of red clover, timothy, soybeans, hedge, bindweed, pigweed, and alfalfa. The largest number of eggs deposited by one female was 56. They hatched in 11 to 17 days, depending on temperatures. The mean length of the nymphal period was 27 days. The species wintered in the egg stage, and there were two generations a year at St. Paul.

The plant bug's larger size results in greater damage than from other plant bugs frequenting alfalfa.

Injury, like that of the tarnished plant bug, is usually not so apparent on alfalfa as on some other plants because feeding is distributed to all parts of the plant above ground and because alfalfa, during a good growing season, grows so rapidly that the injury is overcome.

Natural control. Few species of destructive insects seem so free from natural checks on their increase as this species and the other mirids. Birds do not prey upon plant bugs because of their offensive odor. The eggs and nymphs were attacked by the same common predators as attack the pea aphid in alfalfa, but fewer are destroyed because the nymphs are so active. No fungous or bacterial diseases nor parasites were reared.

Control with chemicals. (Tables 16, 23, 57 to 67). Mirid control in alfalfa has been accomplished generally by insecticidal application at or before the bud stage of plant growth. Table 16 gives the results of insecticide tests. Alfalfa seed yields were greatly increased, sometimes doubled or tripled, by a single spraying with DDT and/or toxaphene. Typical results were recorded by Franklin (1951) and Grandfield and Franklin (1952).

Only BHC and chlordane of the 16 insecticides used 1947-1953 failed to give satisfactory control (Tables 16 and 67). Parathion, DDT, dieldrin, and EPN gave good control. Since these insects fly into fields somewhat later in the year than tarnished plant bugs do, treating at the bud stage on the first cutting did not give satisfactory control. When second growth alfalfa was treated at the bud stage, control lasted longer. The third cutting alfalfa 1950-1953 was the only alfalfa left for seed in the plots for the bugs to feed on; therefore migrations into the area were great. There was no increase in control when more than 15 gallons of solution was used per acre. Five or 10 gallons of solution per acre were as good as 15 gallons.

Control of the alfalfa plant bug is usually accomplished when insecticides are used to control the other plant bugs. When bugs are numerous, it is well to cut the alfalfa for hay instead of trying to obtain a seed crop if insecticides are not going to be applied at the early bud stage.

Table 16. Control of alfalfa plant bugs in various alfalfa experimental plots at Manhattan and Hays, Kansas, 1947 to 1953. All treatments consisted of a single application as a dust or in 15 gallons of water per acre near the bud stage of development on the second cutting of alfalfa except where indicated otherwise. EC = Emulsifiable concentrate; WP = Wettable powder; D = Dust; All = previous three forms.

Insecticide	Rate ounces per acre	Formulation	No. of tests	Percentage control	
				Range Low and high	Average 1 to 7 yrs.
Aldrin	8	EC	6	86, 93	90
BHC	1, 1.6, 1.9, 4	All	6	62 (All), 95	71
Chlordane	16	"	6	60 (WP), 95(EC)	74
DDT	16,24,32	"	17	66 (D), 100 (16, 32, EC, WP	70
Dieldrin	8	EC	5	94, 100	96
Endrin	4, 8	"	2	78 (8), 97 (4)	83
EPN	8	"	2	93, 100	96
Heptachlor	8	"	2	95,97	96
Isodrin	4, 8	"	2	71 (4), 95(8)	83
Metacide	4, 8	"	2	82(8), 89 (4)	86
Methoxychlor	32	"	2	78, 86	82
Parathion	4, 8	All	7	66 (8,WP), 100 (All)	86
Pestox	16	EC	1	98	98
Systox	8	"	2	93, 95	94
TEPP	8	"	2	73, 82	78
Toxaphene	24	"	5	75, 96	88
DDT (16) + BHC (0.9)		D	5	45, 100	85(1)
DDT (16) + Toxaphene (12)		EC	20	0, l00	50(1)
DDT (16) t Toxaphene (12) 5, 10, 20, 25, 30 gals./Acre			10	0 All plots compared with 15 gals. per Acre.	

(1) Alfalfa growth 4-6 inches high or at bud stage of the first or third cuttings.

NABIDS IN CONTROL OF ALFALFA INSECTS

Three species of Nabids -- Nabis ferus (Linn.), N. rufusculus (Reut.) and N. subcoleoptratus (Kirby) -- have been among the many common insects in alfalfa fields. These "damsel" bugs are highly beneficial predators. They do not feed on plants ordinarily but on all kinds of small insects.

Harris (1928) included a general account of the life cycle of N. ferus, seasonal cycle, and habits from studies at Ames, Iowa. At this latitude, the species hibernates as adults. Eggs are deposited in the stems of grasses the following spring. They hatch in about eight days, producing extremely active nymphs. The nymphs pass through five molts three to seven days apart. The nymphs are protectively colored and shaped. Both the nymphs and adults of these species feed upon aphids, leafhoppers, and caterpillars. The nymphs characteristically fall to the ground when disturbed or in danger. Harris also included a key for determining the species and varieties of Nabis.

It has been stated that this species was an effective predator on the beet leafhopper. It was said to be a more effective check than Geocoris decoratus. Nabis feeds on any species of leafhopper, holding the leafhoppers by its own legs and puncturing them on the ventral side. One damsel bug required 20 minutes and another 30 minutes to exhaust the body fluids of its prey. N. ferus also feeds on the pea aphid as does N. alternata which is similar to N. ferus.

Nymphs and adults during these studies were seen feeding on many insects, especially thrips, aphids, leafhoppers, and small caterpillars. They were present, sometimes plentiful, from June to October each year in the Manhattan region and occasionally as early as May in the protected bottom land alfalfa fields in the Hays region. The seasonal distribution from 1938 to 1942 is given in Table 17. Earliest observed nabids occurred during the second week of April and the latest during the third week of October. Greatest numbers appeared just before the first cutting the first half of June and the second peak, near the second cutting the last of July.

Up to 15 nabids were taken in 25 sweeps of a net in late May and June, 1940. A maximum of 35 nymphs and adults was taken in 25 sweeps of alfalfa in June, 1936. In the Hays area Nabids were most prevalent on the second alfalfa cutting in June and July.

While Harris (1928) stated that eggs were deposited in the stems of grasses, all of the eggs in these rearings were found in alfalfa stems. Eggs were noted in a green wheat stem on one occasion. The eggs hatched in about eight days. The nymphs underwent five molts, the first four instars requiring an average of three days each while the last instar required about six days.

In alfalfa, the younger nymphs wandered about on the ground where their color and shape blended remarkably well with dead and dying blades and seeds. Older nymphs ventured to climb the higher grass stems but, on the least disturbance, they loosened their holds and fell to the bases of the plants. It was not common to take nymphs of N. ferus in sweepings.

Nymphal Stages

First instars of N. ferus are light tan. There are no wing pads, and the dorsal vessel is not visible. There is a dark ridge running along the sides of the thorax. The thorax is also a dark brown above, but some lack this dark on top. The antenna has four segments, and the proboscis three.

Newly hatched first instar nymphs are white or rather colorless, have several “bubbles” within them, a long jointed proboscis, long legs, and brown eyes, The length of the body is 1.45 mm; the head, 0.35 mm; and the antenna, 2.15 mm. Measurements of the head and body are given in Table 18. The abdomen is small compared with the rest of the body.

Table 17. Seasonal distribution of nabids in alfalfa fields near Manhattan, Kansas, 1938-1942, 25 sweeps of an insect net.

Week starting April 1	1938	1939	1940	1941	1942	total
April 1-7	-	-	-	-	-	-
8-14	-	-	-	6	-	6
15-21	-	-	-	-	2	2
22-28	-	-	-	5	22	27
29-May 5	-	1	-	8	9	18
6-12	2	5	4	17	2	30
13-19	-	-	4	17	2	23
20-26	12	-	8	-	2	22
27-June 2	11	1	3	-	29	44
2-9	4	5	21	21	3	54
10-16	16	23	14	27	17	97
17-23	19	3	8	6	5	41
24-30	6	7	14	7	5	39
July l-7	-	3	8	7	6	24
8-14	0	2	19	4	-	25
15-21	2	1	0	17	-	20
22-28	1	12	13	13	6	45
29-Aug. 4	2	3	-	14	55	74
5-11	0	9	-	15	34	58
12-18	1	7	-	8	46	62
19-25	2	14	-	10	8	34
26-Sept. 1	1	7	-	-	-	8
2-8	1	-	-	-	-	1
9-15	0	0	0	-	-	0
16-22	-	5	1	-	-	6
23-29	-	-	9	-	-	9
30-Oct. 6	0	-	-	-	-	0
7-13	-	-	-	-	-	-
14-20	4	-	-	-	-	4
Year Total	84	108	126	196	258	773

Table 18. Measurements (mm) of the different instars of *Nabis ferus*.

Instar	Head		Body width	Total length
	width	length		
First	0.3	0.4	0.5	2.0
Second	0.35	0.5	0.65	2.5
Third	0.45	0.65	1.1	3.25
Fourth	0.5	6.75	1.25	5.5
Fifth	0.65	1.25	1.5	6.0
Adult	0.85	1.25	2.25	7.5

There are still no wing pads in the <u>second instar.</u> The dark ridge running along the side is much more easily seen. The heart line can be seen running down the middle of the back.

The <u>third instar</u> resembles the second except it is larger.

The wing pads appear in the <u>fourth instar</u> with the second pad extending 1/2 mm. back from the tip of the first. It is still light tan with the region of dark color running along each side, beginning at the base of the antenna and continuing back to the tip of the wing pads. A heart line can be seen from the back of the head to the posterior end of the body.

In the <u>fifth instar,</u> a heart line can be seen distinctly running from the base of the antenna to the tip of the abdomen. It is still light to dark tan with a dark line running down each side of the body beginning at the base of each antenna. Wing pads are now much more distinct, being 1/2 mm. wide but only one set of pads can be seen. The origin can be easily located as the buds are one mm. long.

In this stage, some hair-like structures or setae can be seen. There are two pairs on the head--one pair is between the eyes and the other appears on the segment behind the eyes. The next segment has none but there is a pair between it and the next segment.

In molting, the nabid crawls up the alfalfa stem and turns head downward. The hind legs are extended as far back as they will reach and are fastened securely. The other two pairs of legs are extended backward at an angle of about 45^o. The skin bursts at the anterior region and the nabid works its way out.

Table 19. Summary of days spent in the instars of <u>Nabis ferus</u> from rearings.

Stage	Days
Egg stage	3 to 8
First instar	3
Second instar	3
Third instar	2 to 4
Fourth instar	3 to 7
Fifth	5 to 8
Length of life from egg to adult	29 to 30
Length of life of adult	1 to 30 in summer

The seasonal cycle of Nabis ferus at Manhattan has been recorded as follows:

First generation adults	overwintered; until June 1
First generation nymphs	May 15 to June 30
Second generation adults	June 10 to July 15
Second generation nymphs	June 12 to July 30
Third generation adults	July 1 to August 30
Third generation nymphs	July 5 to September 10
Fourth generation adults	August 1 to overwinter

One female N. ferus was observed during oviposition. She crawled up a stem to a tender point, placed her hind pair of legs behind her and lowered the abdomen. With her saw-tooth ovipositor she worked at making a hole in the alfalfa stem. She apparently was selective, testing the stem to determine how tough it was before making a hole with her ovipositor. When the stem was too tough, she merely paused, lowered her ovipositor to the stem, pierced it, and moved on to a tenderer spot. While making the hole, her abdomen was contracting and expanding mainly from the ovipositor back to the tip. This also occurred while placing the egg in the stem. It took almost a minute to make the hole in the stem. The ovipositor was inserted for ten seconds and she continued to contract and expand the abdomen. The ovipositor was removed, after a step forward, and another egg deposited. It took 15 minutes to deposit ten eggs. The external cap on the eggs was 0.25 mm. by 0.15 mm.

Nabids laid from 9 to 14 eggs each in rearings, but dessication when the stems dried prevented the eggs from hatching. Four eggs were found June 9, 1928, inserted in an alfalfa stem and the hole covered over by a white membranous substance. Two of the eggs hatched in 12 days. The stem was kept fresh by keeping it in water until the eggs hatched.

Feeding Habits

All the young and old nabids observed feeding held the potato leafhopper lengthwise underneath them, and were using the two fore pairs of legs to hold them while they fed. There was less of a tendency for them to hold on with their feet after their proboscis was inserted. They then turned the leafhopper with the two fore pairs of legs and inserted the proboscis in its abdomen. Periodically it rolled the leafhopper and inserted the proboscis again.

To induce hunger, some nabids were allowed to go without feeding for some time after being caught. A stem of alfalfa containing a leaf was placed in each vial to determine if they would feed on an alfalfa stem or leaf. The nabid moved up and down the stem, feeling and inserting its proboscis and feeding on the sap from the leaf. Others pierced the younger and tenderer parts of the stem. Sucking the plant juices occurred much more often when they had not fed on leafhoppers, aphids, or other insects for some time. One nabid lived 21 days on an alfalfa stem with no leafhoppers or aphids, but the abdomen became badly shrunken. When some leafhoppers were placed with it, it began feeding on them at once. When fed pea aphids, it approached them and inserted its proboscis without holding the aphids with its legs.

One second instar held the leafhopper perpendicular to its body with the first and second pairs of legs while the proboscis was inserted. Another inserted its proboscis in the gena of a leafhopper and fed for five minutes.

One nabid had no food except alfalfa stems for six days. These stems were old and tough and bore seed pods. The abdomen of the nabid became shrunken. When a drop of water was placed in the bottom of the vial, it immediately placed its proboscis in the drop and drew water for about three seconds.

Two nabids lived 17 days without being fed anything but alfalfa stems, This shows that the nabids can live, if necessary, without other food. One nabid was found dead after the alfalfa had dessicated so that the insect was unable to get any plant juice.

Near Manhattan, May 21, 1926, a nymph of N. ferus bit the senior author on the arm. The bite was similar to the sting of a solitary bee. It pained sharply at first, but caused no swelling. This species was plentiful at that time usually feeding on pea aphids and tarnished plant bugs.

Parasite

Some of the collected N. ferus had greatly enlarged abdomens, from which emerged cream-colored larvae of a dipterous parasite. Each larva measured 2 mm long by 1 mm in diameter. After spending a day in the larval stage after emerging, they continiued in the pupal stage 6 to 9 days before emerging as adults. June 19, 1947, dissection indicated that 60 per cent were parasitized.

An adult dipterous parasite emerged from a pupa June 22, 1941. The parasite was in the larval stage June 16; pupal stage, June 17; and an adult, June 23.

Nabids from which parasites emerged died the day of the emergence. Only four of 21 reared for parasites were parasitized.

H. J. Reinhard in an August 29, 1941, letter reported on parasite flies reared from nabids. "The two reared specimens apparently are Leucostoma atra Townsend (Family Tachinidae). Members of this genus parasitize, various species of plant bugs. No previous record of any rearing of this fly from Nabis ferus has been seen. The two remaining specimens in the shipment are not Muscoids."

Swezey (1933) listed Leucostoma atterrima as a parasitic fly. Modern texts do not list this genus but Leucostoma (Family Tachinidae) is a common genus.

The number of nabids in 15 strains of alfalfa in 1925 is given in Table 20.

Table 20. Number of nabids in 15 sweeps in the alfalfa variety test. Manhattan, Kansas. 1925.

Variety or strain	April 10	June 6	June 19	July 8	July 24	Aug. 27	Variety total
Argentine	3	5	4	3	8	9	32
Cape Lucern	3	10	4	11	5	7	40
Cossack	6	6	3	4	8	4	31
Dakota Common	10	12	11	14	12	7	66
Dakota #12	12	9	9	9	20	9	68
Grimm	12	8	7	13	8	2	50
Italian	2	7	8	10	3	8	38
Kansas Common	7	10	5	11	5	10	48
Kansas 435	6	7	8	8	5	12	46
Ladak	2	11	6	12	8	12	51
Provence	2	6	7	12	17	14	58
Spanish	9	13	2	17	7	12	60
Sunflower	19	7	1	13	12	7	59
Turkestan	0	11	6	1	17	10	45
Utah	12	3	7	4	11	11	48
							740
Date total	105	125	88	142	146	134	

The destruction of nabids in various insect control experiments from 1948 to 1953 is given in Tables 21 and 67. Many insecticides almost eliminated nabids. DDT and parathion were particularly destructive.

THE POTATO LEAFHOPPER, EMPOASCA FABAE (HARRIS)

Fifty or more kinds of leafhoppers have been collected in alfalfa fields in Kansas. The following were the commoner species during these studies: Empoasca fabae (Harris), the potato leafhopper; Aceratagallia sanquinolenta (Prov.), the clover leafhopper; Exitianus exitiosus (Uhler); Draeculacephala mollipes (Say); Gyponana octolineata (Say.); Macrosteles fascifrons (Stal.), six-spotted leafhopper; Endria inimica (Say), painted-leafhopper; Paraphlepsius irroratus (Say). Of these, at least the first three occurred in near outbreak numbers. Plants in small areas or borders of fields, may be seriously injured by leafhoppers when they are numerous. In these studies, leafhoppers were sorted by superficial appearances. Varieties or species of leafhoppers, closely resembling potato leafhoppers may have been involved in some of the collections and observations. The potato leafhopper is the most abundant and most thoroughly studied.

Sweep net counts showed this leafhopper present in alfalfa from early spring until late fall. Leafhopper occurrence during 1938, 1939, 1941, and 1942 is summarized in Table 22. Leafhoppers appeared late in 1939 and 1942 and early in 1941. Some areas with high populations occurred adjacent to other areas with below normal populations. Following its general appearance in Kansas in early May, the leafhopper can increase to enormous numbers within a short time. There are several generations

Table 21. Condensed table of destruction of Nabids in various experimental plots by various insecticides at Manhattan and Hays, Kansas, 1948-1953. All treatments consisted of a single application of an insecticide in 15 gallons of water per acre near the bud stage of development on the second cutting of alfalfa unless otherwise indicated. EC = Emulsifieble concentrate; WP = Wettable powder; D = Dust; All = previous three forms.

Insecticide	Rate ounces per acre	Formulation	No. of tests	Percentage reduction Range Low and high	Percentage reduction Average 1 to 7 yrs.
Aldrin	8	EC	5	74, 100	82
BHC	1, 1.6, 1.9, 4	All	6	40(WP,1.9) 94(1.9 WP)	78
Chlordane	16	"	6	65(EC), lOO(WP, D)	81
DM	16, 32	"	14	45(EC,16), 100(16,32, WP, D)	80
Dieldrin	8	EC	5	81, 91	88
Endrin	4, 8	"	2	70(4), 78(8)	74
EPN	8	"	2	84, 92	88
Heptachlor	8	"	2	65, 72	68
Isodrin	4, 8	"	2	66, 79	73
Metacide	4, 8	"	3	75, 94	82
Methoxychlor	32	"	2	56, 71	64
Parathion	4, 8	All	7	76(EC,8), lOO(EC 4) (8 D, WP,)	92
Pestox	16	EC	1	60	60
Systox	8	"	3	60	68
TEPP	8	"	2	62, 93	78
Toxaphene	24	"	5	73, 85	81
DDT (16) + BHC (0.09)		D	4	44, 100	66(1)
DDT (16) + Toxaphene (12)		EC	20	0, 100	57(2)
DDT (16) + Toxaphene (12) 5, 10, 20, 25, 30 gals. to acre compared with 15 gals. per acre.		"	10	0 (8 plots, 24)	3

(1) Applied when growth was 4 to 6 inches high.
(2) Bud stage, first and third cuttings.

a year, but the generations overlap and cannot be definitely distinguished. A Regional Technical Committee (NCR-24) has shown that the potato leafhopper migrates northward from the Gulf States early in the spring.

In 1940, 25 sweeps taken July 7 in an alfalfa field and 25 in a potato plot revealed 6 E. fabae in alfalfa and 34 in the potato plot. July 15, results were similar, 49 on alfalfa and 125 on potatoes. July 27, there were 234 on potatoes and 97 on alfalfa. The alfalfa was cut August 7 when there were 281 on potatoes to 62 in alfalfa.

Since World War II, potatoes have ceased to be an important crop in Kansas. The area now grows alfalfa for dehydration mills.

Table 22. Seasonal occurrence of potato leafhopper in alfalfa fields. Manhattan, Kansas.

Date	Number of leafhoppers per 25 sweeps			
	1938	1939	1941	1942
April l-10	0	0	5	0
April 11-20	0	0	31	0
April 21-30	0	0	21	0
May l-10	2	0	25	0
May 11-20	0	0	0*	0
May 21-31	22*	0*	46	0
June l-10	56	0*	78	0*
June 11-20	140	0	221	0
June 21-30	105	0	139*	196
July 1-10	1*	50	309	55
July 11-20	46	52*	618	0*
July 21-31	72	88	379	6000
Aug. l-10	39	95	174	8525
Aug. 11-20	39*	195	0*	3500
Aug. 21-31	10	65	0	46
Sept. l-10	28	82	0	0*
Sept. 11-20	0*	20*	0	0
Sept. 21-30	0	0	0	0
Oct. l-10	0	0	0	0
Oct. 11-20	0	0	0	0
Oct. 21-31	0	0	0	0

* Alfalfa cut for hay.

Injury

Poos (1952) stated that the potato leafhopper is a serious pest of alfalfa in the entire eastern half of the United States. It pierces the leaves and petioles and sucks juices, causing a yellowing and dwarfing of the foliage and, in heavy attacks, severe wilting. Various shades of pink, red and purple beginning at the midrib of the leaf indicate leafhopper injury. Some types of yellowing caused by diseases or by nutritional deficiencies are difficult to distinguish from advanced stages of potato leafhopper injury but such symptoms usually start at leaf margins. Injury to young stands permits weeds and grasses to crowd out alfalfa. Leafhopper-damaged alfalfa may be so weakened that it fails to survive the winter or is not healthy the next year. Usually the second crop is injured more severely during July, but the third crop may be damaged in August and September. Poos said an average of one potato leafhopper per sweep is sufficient to damage a crop within three weeks.

Jones and Granovsky (1926) produced "yellows" in alfalfa in Wisconsin with E. fabae. When leafhoppers were caged on healthy alfalfa plants, the stunting, discoloring symptoms were manifested in about a week.

The first recognized indications of "yellows" in Kansas occurred in 1928. A patch of alfalfa 20 feet square had been cut at a different from normal time to get some new tender alfalfa for rearings. Yellowing was noted August 1 when the new growth was 4 or 5 inches high. The older leaves turned reddish-purple by August 11 and the edges of the leaves turned up slightly. This growth was tough and stunted, not over 8 inches high.

An effort was made to repeat Jones and Granovsky's experiments on the production of "yellows" by E. fabae in Kansas. August 16, 1928, an area about 10 feet square of two-year-old alfalfa was cut very close and all the weeds and grass pulled out. The plot was sprayed to kill any insects present. Immediately following this spraying, two screen cages 3' x 3', covered with cloth, were placed 6 inches apart over this plot. August 29, 100 E. fabae (mostly adults) were added to one cage. In both cages, the leaf borders curled a little and were yellow from the spray. No effects of leafhoppers were noted August 30, when some 325 more leafhoppers (mostly adults) were added. Later 600 more presumably potato leafhoppers (mostly adults) were added. Thirty-five plants were in the infested cage, and 33 plants in the uninfested cage. October 1, many leaves in the leafhopper cage were wilted and had dropped off. Only two wilted leaves were found in the check, and these were very close to the edge where the cage was buried Leaves remaining on the plants in the infested cage had a purplish tinge, many a mottled mosaic. The distal parts of leaves were dead and dry. September 12, nymphs began emerging in the infested cage. September 19, it was determined that the change in foliage in the cage with leafhoppers had been progressive. No live green leaves could be seen on half of the plants. Plants with live leaves had mottled leaves, mostly bright reddish-purple, especially on the underside. From all indications, all the alfalfa plants in the infested cage were dead in mid-December. No "yellows" were discerned in the leafhopper cage in this test, or in later tests. Alfalfa yellows is apparently not common in Kansas.

Severe alfalfa injury (in cages) appeared as whitish blotches and occurred around the feeding punctures where air had entered. It was similar to thrips injury. The puncture healed imperfectly and later turned brown. Leafhoppers preferred to feed around the margin of leaves and when the punctures were numerous enough, the entire area withered. Plants fed on by numbers of leafhoppers and showing this type of injury appeared yellowish, sickly, and stunted and growth was slow.

In the field where leafhopper feeding is widely scattered on many vigorous plants, injury may not be noticed. Slow, reduced growth with consequent reduction in hay yield was the only clearly defined damage at Manhattan. The reduction in plant vigor and hay yield is in proportion to the number of leafhoppers present and lack of moisture.

July 6, 1940, an alfalfa field appeared as if killed by drought. Leafhoppers were virtually the only insects present. The plants were stunted and greenish-yellow. However, a few in the midst of the stunted ones were twice as tall and healthy looking. But after 22 days, a healthy caged plant heavily infested with leafhoppers appeared stunted, the leaves being one half as large as healthy uninfested plants and the tips of the leaves a creamy yellow. A healthy caged plant, with leafhoppers excluded, was 10 inches higher, greener, and the leaves were normal.

Wilson et al. (1955) found that'leafhoppers damaged alfalfa considerably more on nonirrigated than on irrigated land. E. fabae, in two weeks, reduced alfalfa growth 28 per cent more on land receiving less than normal rainfall than on irrigated land Ranger alfalfa was the most tolerant of leafhoppers. Buffalo had low yields when infested with leafhoppers. Following cutting and control of leafhoppers, nine varieties averaged 48 per cent more growth than Buffalo two weeks after cutting. Spring growth was more rapid when leafhoppers were controlled in the fall. Nine varieties averaged 18 per cent more growth.

Insecticidal Control Tests
(See Tables 23, 58, 61 and 67)

Table 23 gives the results of insecticide control experiments from 1947 through 1955. Seven insecticides attained maximum controls of 90 per cent or more during some years. Aldrin in 1948 gave 96 per cent control, but only 23 per cent in 1949. DDT which usually gives excellent control of leafhoppers at much lower dosage rates than with many other insects varied from 60 to 99 per cent control.

THE PEA APHID

Most of the results of studies by the authors on the pea aphid (Macrosiphum pisi (Harris)) as an alfalfa pest in Kansas have been published. Smith and Davis, 1926; Dean and Smith, 1935; Smith, 1932; Franklin, 1953; and in the 18 Annual Insect Population Summaries of Kansas. The notes given here are unpublished details, control test results, and some corroborative observations.

Table 23. Results of insecticide control tests for leafhoppers, mainly potato leafhoppers, at Manhattan and Hays, Kansas, 1947-1953. Single applications of the insecticides were made near the bud stage of development on the second cutting of alfalfa unless stated otherwise. EC = Emulsifiable concentrate; WP = Wettable powder; D = Dust.

Insecticide	Rate ounces per acre	Formu- lation	Per cent control - results: Range Low and high	Per cent control - results: Average 1 to 7 yrs.
Aldrin	8	EC	17, 96	56
BHC	1, 1.6, 1.9, 4	EC, WP, D	37 (4 oz. EC) 96 (1.9,WP)	62
Chlordane	16	" " "	0 (EC), 83 (EC)	40
DDT	16, 24, 32	" " "	60 (16 EC), 99 (24 D)	86
Dieldrin	8	EC	10, 71	33
Endrin	4	"	80, 89	84
EPN	16	"	70, 93	82
Heptachlor	8	"	74, 82	78
Isodrin	4, 8	"	64 (4 oz.), 89 (8 oz.)	77
Metacide	4	"	74, 94	84
Methoxychlor	32	"	89, 90	90
Parathion	4, 8	EC, D, WP	82 (4 EC), 94 (8D)	87
Systox	8	EC	72, 82	77
TEPP	8	"	51, 82	66
Tax aphene	24	"	28, 89	65
DDT (16) + BHC (0.9)		D	17, 90	69(1)
DDT (16) + Toxaphene (12)		EC	0, 99	57(2)

(l) Applied on growth 4-6” high.

(2) As above and on bud stage of first and third cuttings.

Notes from Non-Kansas Literature

Davis (1915) stated that this aphid occurred periodically as a pest of red and crimson clovers, vetch, alfalfa, and field and garden peas. It first appeared in destructive numbers in America in 1899, but the species was reported first by Cyrus Thomas in 1878. In 1915, alfalfa was not commonly attacked. Davis pointed out that there was no true alternation of hosts. In two series, 7 and 17 generations were reared. He reported 13 generations a year as the average. The reproductive period varied from 2 to 68 days with an average of 3.7 young produced per day and an average total of 68.3. The maximum production of young was 147 for one female.

Folsom (1922) said pea aphids were introduced into the United States with peas and clover and were injurious in 21 states. The following plants were reported as hosts: field and sweet peas, vetches, red and crimson clovers, beet, lettuce, shepherd’s purse, nettle, but “alfalfa seems to be immune to attack.”

Wadley (1923) concluded that nutrition, parentage (inheritance), and temperature showed definite relations to the percentage of wing development in aphid progeny.

Seasonal History

This aphid is always present in most alfalfa fields in Kansas in May and June and in some fields in the fall (Table 24). The species overwinters in Kansas almost exclusively as an apterous, viviparous female in alfalfa, surviving best in the low areas and more protected portions of fields, probably because there is a larger growth there in the fall which protects them somewhat against the cold of winter.

E. G. Kelly said (in conversations) that eggs were obtained at Urbana, Illinois, and Wellington, Kansas, and that pea aphids had overwintered in the egg stage. Eggs were found only a few times during these studies. The question arose whether this species aestivated in the egg stage, or whether fall populations flew in or were carried in by winds.

Nineteen generations were reared with peas as the host plant and 21 generations with alfalfa as a host plant. The average days for these rearings are given in Table 25.

The rearing results recorded in Table 25 show that, other conditions being equal, the pea aphid reproduced longer, had more young, and lived longer on alfalfa than on peas. However, during the summer or at high temperatures in the greenhouse, it was somewhat easier to carry on an unbroken series with peas as the host plant. This confirms field observations. After the spring outbreak in alfalfa fields, the aphids occurred on both garden pea varieties and sweet peas.

During 1926, special effort was made to carry an unbroken line through the season and to follow the aphid in the field. Stem mothers were found early in March and separate lines established on young alfalfa plants in lamp chimney cages on the shelves of the field insectary. One line reached the 17th generation by late October when the aphids died. In another series, the 16th was attained, and still another 15 generations in a somewhat shorter period. They were either rare or absent during most of the summer season in the fields so that the insect could not be followed. They persisted, however, in one galvanized wire cage over alfalfa plants. Enemies were kept out of the cage, and the temperature was lower than in the open field because of shade.

In 1940, not a single pea aphid was seen after about July 28. All experiments started with the aphids were unsuccessful after the fourth generation due to high temperatures. Only once that summer did the aphids get so numerous that they had to be counted in cc's in 25 sweeps. The alfalfa was cut June 28, and no aphids were observed up to August 3.

A few pea aphids were found February 14, 1934, in all fields visited, with the greatest numbers on young stands. This followed an exceptionally dry, mild winter. Many of the aphids were winged. Several small nymphs were found which indicated that reproduction had begun, an early record here.

Table 24. Number of pea aphids obtained in 25 sweeps in alfalfa fields near Manhattan, Kansas, 1937-1942.

Week starting April 1	1937	1938	1939	1940	1941	1942	Week total
April 1-7	-	-	-	-	-	-	-
8-14	-	-	-	-	50	-	50
15-21	-	-	-	-	-	5,056	5,056
22-28	-	-	-	-	0	13,904	13,904
29-May 5	300	-	190	-	25	24,648	25,163
6-12	927	2,907	2,750	50	9,480	33,496	49,610
13-19	320	-	-	15	2,944	8,848	12,127
20-26	290	15	-	223	-	3,160	3,688
27-June 2	1,440	16	0	53	-	2,528	4,037
3-9	15	85	170	113	82	1,264	1,729
10-16	65	984	155	180	65	1,264	2,713
17-23	52	3,539	50	213	179	660	4,693
24-30	10	4	10	318	221	188	751
July 1-7	2	-	120	5,056	0	632	5,810
8-14	4	0	5	93	12	-	114
15-21	6	0	10	11	47	-	74
22-29	0	0	0	10	23	3	36
29-Aug. 4	0	0	0	-	1	0	1
5-11	-	0	0	-	0	0	0
12-18	-	0	0	-	0	0	0
19-25	-	0	0	-	0	0	0
26-Sept. 1	-	0	0	-	-	-	0
2-8	-	0	-	-	-	-	0
9-15	-	0	0	0	-	-	0
16-22	-	-	0	0	-	-	0
23-29	-	-	-	0	-	-	0
30-Oct. 6	-	0	-	0	-	-	0
7-13	-	0	-	-	-	-	0
14-20	-	0	-	-	-	-	0
21-28	-	-	-	-	-	-	-
29-Nov. 4	-	-	-	4	-	-	4
Year totals	3,431	7,540	3,460	6,339	13,129	95,651	129,550

Table 25. Rearing data from the pea aphid on alfalfa and garden peas as host plants.

Average	Number of days when young fed on Alfalfa	Peas
Age of female when first young produced	9.3	8.9
Length of reproduction period	10.8	5.4
Number of young produced	41.0	19.7
Length of life	23.3	14.5

During most of June and July, 1934, not a single pea aphid could be found because of hot, dry weather.

The approximate pea aphid generations as determined by cage rearings. supplemented by field observations in 1926 is given in Table 26.

Table 26. Generations of pea aphids at Manhattan, Kansas, as determined by cage rearings and supplemented by field observations. 1926.

Generation number	Date and life forms of the generation
1	Overwintering eggs and wingless agamic females February 20 to March 23
2	March 15 to April 10
3	April 1 to April 30
4	April 20 to May 25
5	May 10 to May 25
6	May 20 to June 10
7	June 5 to June 15
8	June 10 to June 25
9	June 20 to July 5
10	July 1 to July 12
11	July 10 to July 25
12	July 20 to August 1
13	July 25 to August 10
14	August 1 to August 25
15	August 20 to September 15
16	September 10 to October 15
17	October 10 to October 30
18	October 15 to November 15 - Eggs or overwintering females

There was a difference in populations in the 15 varieties of alfalfa checked in 1925 (Table 27). Provence, Turkestan and Ladak (Table 28) had the fewest aphids while Dakota #12 and Spanish had the most. The pea aphids were twice as numerous in April as on either June date.

Injury to Yields

The increase in yield of alfalfa in plots treated with certain insecticides was 2 to 2.5 times that of the check plot.

Table 27. Number of pea aphid in 15 sweeps in the alfalfa variety test. Manhattan, Kansas. 1925.

Variety or strain	April 10	June 6	June 19	July 8	July 24	Aug. 27	Variety total
Argentine	28	10	11	4	0	2	55
Cape Lucern	6	33	5	4	1	0	49
Cossack	31	5	0	4	0	0	40
Dakota Common	61	24	22	4	0	0	111
Dakota #12	60	33	36	5	0	0	134
Grimm	76	5	26	7	0	0	114
Italian	14	12	56	9	3	0	94
Kansas Common	44	11	7	9	0	0	71
Kansas 435	34	7	14	6	0	0	61
Ladak	8	11	13	4	0	0	36
Provence	4	5	6	3	0	0	18
Spanish	69	29	13	5	1	0	127
Sunflower	60	19	4	5	2	0	80
Turkestan	8	9	2	5	0	0	24
Utah	49	10	39	4	4	0	106
Date total	552	223	254	78	11	2	1,120

Table 28. Pea aphid injury to three varieties of alfalfa. McPherson, Kansas. May 10, 1934.

Variety	% damage	Number of lady beetle larvae	Condition of plant
Utah	70-90	few	wilted, yellow, stunted with a few dead clumps
Grimm	50	few	wilted, leaves mostly pale green but some yellow, short, no dead clumps
Ladak	10	many	poor stand, plants scarcely wilted, green color , no dead clumps

Natural Control - Predators

Predators, especially lady beetles, were observed from the first outbreak to be powerful checks on aphids. Lady beetles were generally present in large numbers during these studies when pea aphids were plentiful. In May, 1926, they aided in stopping an outbreak near Manhattan. Predators on the spotted alfalfa aphid in Kansas have been evaluated by Simpson and Burkhardt (1960).

Nabis ferus was one of the commonest and most effective predators of the pea aphids. Sometimes it was quite plentiful. May 12, 1924, a Nabis ferus was observed feeding on pea aphids and the serpentine leaf miner, Agromyza pusilla.

Published records indicate that the main predatory insects and mites were in the following families:

Gryllidae	Chrysopidae	Coccinellidae	Braconidae
Pentatomidae	Syrphidae	Lampyridae	Chalcidae
Acanthiidae	Ichneumonidae	Cecidomyiidae	Acarina

In sampling sweepings in mid-May, 1926, lady beetles in alfalfa were Hippodamia convergens - 194 larvae, 44 adults; Ceratomegilla fuscilabris - 3 adults; and Hippodamia 13-punctata - 3 adults, 3 unidentified larvae.

Hippodamia convergens, especially, were always plentiful during pea aphid outbreaks. Larvae and adults were as potent in controlling the pea aphid as all other insects combined. These insects, however, reach effective numbers too late to prevent early injury. As many as 100 larvae and adults occurred per square foot in very small areas, but, in outbreak areas, the aphids were even more numerous.

Other Coccinellids present in aphid outbreaks in the order of their importance were Hippodamia parenthesis (Say), Cycloneda munda (Say), and Olla abdominalis (Say).

The Hymenopterous parasite of Ceratomegilla fuscilabris was fairly common during these studies. The parasite larva spins a brown silken cocoon under the dead lady beetle and the wasp emerges by cutting off the end of the pupae case. A brief description of the wasp follows:

Head light reddish brown except eyes, which are black. Antenna longer than body. Thorax black, and legs brownish black. Coxa of legs large and bulb-like, especially pairs 2 and 3. Black spot in anterior margin of forewing. Ovipositor sheath rather large and pubescent. Thorax appears pitted. Abdomen curved, very dark brown on dorsal side and light brown or tan on ventral. Pupa clear white and sparsely ciliated with long white hair. Legs not compact against body but stick out on either side.

Hippodamia convergens was especially numerous May 5, 1934. All stages were present, but pupae were scarce. Many of the larvae were in the pre-pupal stage and were just beginning to attach themselves to leaves and stems. An attempt was made to count the larvae on a square foot, but they were too numerous and too active. The same difficulties were encountered in trying to count the adults. On several occasions larvae and adults were found eating larvae and pupae of their own species, when aphids and other possible prey were scarce and beetle numbers great. A conservative estimate of beetles and larvae per square foot in certain places was from 75 to 200. This figure did not represent the average per square foot. There was considerable migration of the beetles out of these plots.

Ceratomegilla maculata adults were taken in considerable numbers in alfalfa March 20, 1922, where they presumably overwintered.

Lady beetles did not occur in peaks as shown by the 25-sweep surveys. They were, however, most numerous during April and May each year. They declined during June; then from the last of June to fall they were scarce.

During the outbreak near Great Bend, April 29, 1931, lady beetles were abundant. All stages were in evidence. Convergens was by far the most plentiful. Chrysopid adults were also plentiful with C. plorabunda the most abundant. Franklin gulls were observed eating aphids. No parasites were seen.

The pea aphid was almost entirely controlled in the Manhattan area May 5, 1934, by lady beetles. The aphids were almost as scarce as the lady beetles had been two months earlier. In sweepings few aphids were taken.

The Chrysopids, chiefly Chrysopa plorabunda and C. oculata, were often effective natural controls near the end of outbreaks, but they did not become numerous in alfalfa fields until late April or early May. The same was true for Hemerobiids, Pentatomids, Reduviids, Nabids, and other forms which prey on them. Birds, chiefly robins, English sparrows, grackles, and domestic fowls have been observed in numbers feeding on the aphids.

Chrysopid adults and larvae were noticeably numerous in alfalfa June 2, 1922, feeding on pea aphids. An occasional C. oculata was taken in an alfalfa field near Manhattan May 19, 1924 -- perhaps 10 in 100 sweeps. There was a very large number of adult C. oculata around a cage over infested alfalfa. Grown larvae of C. plorabunda were collected May 16, 1927. The alfalfa was knee high, and growing rapidly. The lower leaves were dead. There were many aphid molted skins on the ground. Chrysopid adults located a heavy infestation in a cage, presumably by the sense of smell, and congregated to feed and to oviposit. Sight probably played little, if any, part.

Bird enemies of aphids on alfalfa. Robins and English sparrows were unusually abundant in an alfalfa field during the outbreak in April, 1921. Both helped hold aphids in check. Grackles also were seen to feed presumably on aphids in fields.

Syrphid enemies. Practically all of the Syrphids which emerged up to May 31, 1927, were Syrphus americana. They were in the puparium from May 19, to May 30. A large number of puparia were gathered from the aphid dozer sweepings. Alfalfa swept May 16, 1927, at the field insectary was heavily infested with aphids, and a few sweeps yielded a handful of Syrphid larvae.

Pea aphid parasites. The commonest parasite was a small Braconid, Praon simulans (Prov.), which spun a cocoon under the aphid. Parasitized aphids could be detected in the early stages by their yellowish color and the faint outline of the parasitic larva in the abdomen of the aphid. After about eight days, the aphid died and the parasite left it to spin a pyramidal, brownish cocoon under it. The dead body of the aphid turned brown and appeared swollen. Schlinger and Hall (1960) provided considerable information about Praon palitans Mues., a closely related species.

In June, 1928, pea aphids known to be parasite-free were placed in chimney cages and exposed to Praon adults for 24 hours. Parasites were seen ovipositing. One aphid was dissected and the larvae found. It was 0.27 mm. wide at the widest place and 0.675 mm. long.

The parasites were observed ovipositing in aphids at 11:00 a.m. May 2, 1928. These little parasites walked hurriedly around over the leaves, scanning every bit of the surface for the host, often covering both surfaces of a leaf two or three times before leaving it. When an aphid was found, the abdomen was quickly curved under and forward and the ovipositor thrust into the body of the aphid, while the legs were used to hold the victim. Generally, on being disturbed, the aphid turned loose and dropped. The parasite either held onto the host until oviposition was finished or rode the unlucky aphid to the ground, where it finished the job. Each aphid secreted a little honeydew and ran around and kicked as if much disturbed when attacked. No choice as to size of aphids attacked was exhibited as those just recently born were seen with an egg deposited within.

A great many aphids were observed to have been parasitized in April, 1928. Counts of the largest aphids showed that one sixth were parasitized. There were two sorts of hymenopterous parasites present in every case. They were different in size, one having a shiny black abdomen which is short and the other having a long, rather slender abdomen. When caged, many of them died and turned brown. It appeared that in piercing these smaller aphids to oviposit, the sting of the little parasite killed many of them. The black parasites, with the short shiny black abdomens, Aphidius pisi, are apparently hyperparasites also of some pea aphid parasite.

Several hours before the pea aphid dies, due to the ravages of this little hymenopterous parasite within, it is easy to discover the parasitized aphids. They lose their true color, turn a greenish-yellow, and become restless. They crawl around slowly. Often the observer can see a dark spot through the body wall. This is the larval parasite. The body of the aphid then turns lighter greenish-yellow and quickly after death turns greyish-tan, which it remains or turns a little lighter as the tissues dry out.

Before the aphid dies, the body is full of liquid. The parasitic larva turns round and round within the body and tears all the inside tissue loose within the aphid. This makes one cavity within the entire body of the aphid. The liquid remaining is taken by the parasite larva. After this but while the aphid body is still moist and pliable, the turning of the parasite larva becomes more vigorous and finally the underside of the aphid's skin splits. A mere split is not enough, so the larva turns and pushes until a good-sized opening is made. At times, the larva seems to rest on the edge of the torn tissue and push. During all this time, the aphid clings to the alfalfa plant where it dies.

One of the first things done by the larva after tearing the hole is to string a few threads of silk from the leaf or object upon which the aphid is resting to the aphid's body which prevents the aphid from falling.

the dead aphid. The first threads are strung from the very edges of the aphid's torn tissue. After the first dozen or more threads are fastened, the larva reaches out farther and makes a line of threads. The threads of this second circle (outer ones) are almost half the length of the larva. When enough threads (three to four dozen) are completed on the outer circle to hold the aphid well, the larva gradually comes entirely out of the aphid's body and works while lying on the torn edges of the aphid. The first threads spun (inner ring) are torn loose now and pushed out against the outer ring. After threads are fairly thick, the larva just rubs the tip of its anterior end back and forth many times, leaving a thread cemented to the other threads it crosses. This is done until the threads are close together. The larva turns to the opposite direction and crosses threads the other way. After almost a solid sheet of threads is formed, the larva evidently gets tired of lying on the edge of the hole in the torn aphid, so threads are spun across the hole until it is closed. Every time a new thread crosses another, the two are cemented together, since the soft, new material is adhesive. Instead of looking like a mass of threads, they appear as a cone-shaped sheet extending from the aphid to the leaf. This spinning started at 8:30 a.m. and at 12:30 p.m., the larva finished the outer ring and began the inner ring which is about the size of the hole in the aphid. Measurements were:

Outer ring - 2.75 mm. to 3.25 mm., and
Inner ring - 1.5 mm.

This second line or spun arch is gradually woven so that it forms an almost round cell wherein the parasite larva pupates. The spinning is resumed until even the leaf surface to which the little cocoon is attached is covered with silk.

Fungus disease of pea aphids. The well-known fungus disease which develops under humid conditions and which has been reported frequently as being the most important natural control of this aphid has been much less important during these outbreaks than predacious insects have been. It was seldom found at Manhattan, but it occurred during the rainy April of 1941. Diseased aphids were grayish. Fungus sometimes developed in masses or piles of aphids and in collections sent in for identification. Healthy aphids changed from green to light green, yellowish green, yellowish, and then grayish. Eventually they turned hard and brittle.

Davis (1915) stated that *Empusa aphidis* was the most important natural check. It develops after a few days of warm, rainy weather. The disease is highly contagious and may eradicate the aphids. They first turn brownish; later they are covered with fungus threads. During rains and hot dry weather, the fungus destroys or hinders increase of pea aphids.

In Kansas this fungus disease has been, during the period covered by this summary, one of the least effective of the natural controls.

Mechanical Control

Much of the experimenting through the years with the former standard aphicidal dusts and sprays and with such mechanical means as brush dragging, aphid-dozer, suction cleaner, harrowing and rolling is now of historical interest only. Consequently, the few notes here give only limited evidence of the great effort that was made to find a suitable, satisfactory control for this major alfalfa pest.

Davis (1915) gave cutting of infested clover and spring pasturing as artificial control measures. Dean and Smith (1935) described harrowing with a spike-toothed harrow, the chain drag, cyanogas, the use of resistant varieties such as Ladak, and the value of vigorous stands to aid in recovery and survival.

Smith (1932) summarized results obtained by the various control measures for pea aphids up to that time, and described a chain drag which gave distinctly better results than harrowing. The idea of a chain drag was original, but later advertisements of chain drags of various designs were seen in the Implement and Machinery Review of England; as for example in Vol. 60, No. 716, December 1, 1934. Some have a design of triangles, others Y's, zigzag, diamonds, and square patterns. They were not used for aphid control in England.

Many plot and field tests of control measures for pea aphids were attempted. The tests involved harrowing with various kinds of harrows; use of cultopacker and roller; brush drags of various kinds.

A glorified vacuum cleaner or suction machine to collect aphids was made and tested in May, 1935. It was suggested by the suction harvester which is used successfully in western Kansas to harvest buffalo grass seed. This machine was designed and assembled by the Department of Agricultural Engineering in May, 1935. It was a large vacuum cleaner consisting of a two-foot grain blower mounted on a two-wheeled trailer. The fan operated from the power take-off of a tractor at 1500 to 1800 r.p.m. using an automobile transmission case. There was a 5-foot nozzle connecting it to a flexible pipe with a cone at the center of the fan. The nozzle-dragged flat on the alfalfa. The front part of the nozzle jarred the aphids down. The nozzle was large enough to allow the alfalfa to straighten up partly. The nozzle dragged over the alfalfa by two chains attached to runners at the outsides. The aphids were sucked up with dust, sand, and field trash and were blown out at one side. It was hoped that such a machine might be useful not only for pea aphid control but for control of clover leaf weevils, young grasshoppers, chinch bugs, and perhaps other insects.

Nine plots of alfalfa which were cleaned by the suction machine three days before revealed an average of 22 pea aphids in 25 sweeps with a range of 6 to 64. Six check or uncleaned plots of the same size revealed an average of 47 aphids per 25 sweeps. This gave only 53 per cent control on the fourth day after vacuum cleaning. The range in numbers of aphids on the check plots was 17 to 97 aphids.

Sweeping with a net before cleaning with the machine resulted in 100 to 116 plant lice in 25 sweeps. A half hour after sweeping, only two to four aphids were taken, or 96 to 98 per cent control.

Similar counts on May 11, 5 days after cleaning, showed a reduction of 88 per cent in the numbers of aphids in the cleaned area, and on May 16, 10 days after cleaning, the reduction was 84 per cent.

In another alfalfa field where considerable dust had lodged from recent dust storms and the surface of the soil was loose and dry, the machine blew a cloud of black soil in the air. Removal of the dust from the alfalfa cleaned it, and it appeared lighter green.

A net full and three shoe boxes nearly full of dust was caught from the blower and examined thoroughly for live insects. Not a single living insect was found. Only one mangled and dead grasshopper could be recognized. It is believed that all insects going through the blower were destroyed. This included lady beetles and other beneficial species.

While the machine appeared to be promising for the control of all non-flying insects in alfalfa, the cost of the suction machine and the power cost made it impractical, particularly as low cost insecticides became available.

Burning the Old Dead Growth in the Spring

Burning off alfalfa fields was advocated as a pea aphid control in California, but it proved completely unsuccessful in Kansas, by delaying spring growth, which was undesirable (Smith, 1922).

Chemical Control (See Tables 29, 58, and 61)

Insecticides tested for pea aphid control included nicotine sulphate dust and spray, tobacco dust, derris, cube, rotenone, soap, oil emulsions, and such trade preparations as Agicide Nicodust. Two per cent nicotine dust did not control the pea aphids in tests early in these studies, but 4 per cent would ordinarily give good results. About 95 per cent control was necessary to check the aphids, Otherwise their rapid reproduction soon restored original numbers.

In various control experiments undertaken from 1948-1953 (Table 29), pea aphids were most readily controlled by parathion. Systox and metacide gave good control while DDT and endrin of the chlorinated hydrocarbon insecticides gave the best control. Little or no additional control was obtained by applying an insecticide twice or by using more than 15 gallons of solution per acre.

Resistance in Alfalfa to the Pea Aphid

Painter and Grandfield (1935), Dahms and Painter (1940) and Emery (1946) have studied resistance in alfalfa to the pea aphid in Kansas. Resistance by Ladak has been mentioned. The combining of resistance to aphids in alfalfa with other desirable characters has been accomplished by selection and crossing of strains.

Table 29. Insecticide control results for pea aphids in alfalfa plots at Manhattan and Hays, Kansas, 1948 to 1953. All tests consisted of a single application of the insecticide in 15 gallons of solution per acre or as a dust in alfalfa near the bud stage of growth unless indicated otherwise. EC = Emulsifiable concentrate; WP= Wettable powder; D = Dust.

Insecticide	Rate ounces per acre	Formulation	No. of tests.	Per cent control Range Low and high	Average 1 to 6 yrs.
Aldrin	8	EC	3	33, 50	40
BHC	1, 1.6, 1.9, 4	All	5	24 (4 oz. EC) 85 (1.6 oz. D)	66
Chlordane	16	"	6	0 (EC), 63 (EC)	23
DDT	16, 32, 64	"	11	22 (16 oz. D), 97 (64; EC)	66
Dieldrin	8	"	3	44, 69	53
Endrin	2, 4, 8	EC	5	55 (8 oz.), 95 (4 and 8)	83
EPN	4, 8, 16	All	4	46 (4 oz.), 93 (16oz)	77
Heptachlor	8	EC	1	42	42
Isodrin	4, 8	"	2	42 (8 oz.), 54 (4 oz.)	48
Metacide	2, 4, 8	"	6	59 (4 oz.), 98 (4 and 8)	88
Methoxychlor	32	"	2	54, 62	58
Parathion	2, 4, 8	All	10	75 (4 oz. EC), 98 (4.8 oz.)	94
Sulphenone	16	WP	1	32	32
Systox	8, 16, 32	EC	7	68 98 (16, 32)	81
TEPP	8	"	1	69	69
Toxaphene	24	"	3	35, 64	51
DDT (16) + BHC (12)		D	1	90	90
DDT (16) + Toxaphene (12)		EC	17	0, 90	12(1)
DDT (16) + Toxaphene (12)		EC		0 (5,20,25 g.), 42 (10 g.)	6(2)

(1) Applied on 4” - 6” plant growth, or bud stage of first and third cuttings.
(2) Mixture applied at rate of 5, 10, 20, 25, or 30 gallons per acre compared with 15 gals. per acre.

BLISTER BEETLES

In “Insects in Kansas" (Smith et al., 1943) eight common species of blister beetles, all occurring in alfalfa, are listed and described briefly. A summary of unpublished notes shows that the following species in alfalfa were studied chiefly during the period of this report.

Macrobasis immaculata (Say). The large yellow or "immaculate blister beetle. June to August.

M. unicolor (Kirby). Small gray blister beetle. May to June.

M. segmentata (Say). "White segmented' or large black blister beetle. June and July.

Epicauta lemniscata (Fab.). "Three-striped blister beetle." Most abundant and destructive species. July to September.

E. vittata (Fab.) "Striped blister beetle." July and August.

E. cinerea (Forst). "The clematis blister beetle', a large, gray species. July and August.

E. cinerea var. marginata (Fab.). Medium, gray spotted blister beetle.

E. maculata (Say). "Spotted blister beetle." June to August.

E. puncticollis (Mann.). June to October.

E. pennsylvanica (DeG). "Black blister beetle". Small.

E. marginata (Say). June to August.

E. unicolor (Kirby). June to October.

Milliken (1921) published a foundation paper on blister beetles in Kansas stressing their damage to alfalfa. His key is useful for identifying 15 common species. Since the larvae feed upon grasshopper eggs, the fluctuations in numbers of the two groups were studied. The beetles devour not only the petals and pollen of alfalfa flowers but severe defoliation of crops also occurs. Strong to double regular strengths of paris green, zinc arsenate and lead arsenate gave control.

Gilbertson and Horsfall (1940) gave the life histories, descriptions, damage done, and control of blister beetles common to South Dakota, particularly of the immaculate blister beetle, a striped blister beetle, the spotted blister beetle, ash-gray blister beetle, shiny black blister beetle (M. murina Lec.), squash blister beetle (Henous confertus (Say)), white-segmented blister beetle, and sunflower blister beetle (E. callosa Lec.). Many of the approximately 35 species found in Kansas have a wide variety of host plants and are often scattered more or less uniformly over whole sections, while others are limited or have preferred hosts and therefore are concentrated or localized.

Horsfall (1941), describing the biology of the black blister beetle, reported that it may have either a normal complete metamorphosis or a hypermetamorphosis, and that in either event there were five feeding larval instars that are merphologically similar. Following, there may be two supernumerary instars which do not feed. The sixth instar of coarctate larva is the only one of the seven which does not resemble the others closely. Therefore, there are one or two larval forms, and there are five or seven larval instars. The whole larval period usually required about 10 months in the field, but in the laboratory the period may be completed within an average of 28 days. In the field, the greater part of the period may be spent as an egg, a first-instar larva, or as a sixth instar larva. Adults of this species emerge in late summer and may be collected until mid-November in northwestern Arkansas. They feed on goldenrod and aster pollen and not on foliage. Eggs are deposited in masses of about 165 at the bottom of tubular cavities in the soil. They hatch in about 15 days under favorable conditions, or after several months during unfavorable temperatures.

Horsfall (1943) published a detailed life history of seven species and the methods of control.

Blister beetles occur particularly in the central and western parts of Kansas in restricted localities practically every year. The infestations are confined, around Manhattan at least, to small areas in fields. Adults of four species begin to, emerge early in June, and outbreaks in alfalfa are reported during July and early August. The striped beetles are gregarious and cluster on alfalfa in spots sometimes in enormous numbers. Infested areas are conspicuous from distances both because of the color of the beetles and the damage done. The beetles attack chiefly the upper leaves and flowers of alfalfa plants. They may completely destroy the bloom and severely injure the foliage. They spread as they feed, the damaged area enlarging daily in a somewhat irregular outline. When one approaches a patch of infested alfalfa plants, the beetles drop and soon practically all are on the ground hurrying to escape. Small infestations and newly infested areas have been discovered by hearing the peculiar noise of their dropping to the ground. All species occurring in alfalfa are exceedingly active. They run or fly away on the slightest disturbance. Their appetites are enormous. They can defoliate a small area of alfalfa overnight when present in outbreak numbers.

Other species occur generally scattered over the alfalfa fields. At both Manhattan and Hays these species were obtained in nearly all sets of sampling using a sweep net. There numbers were few and usually consisted of several species. The percentage of each of the blister beetle species observed in the four year period (1950-1953) at Hays, Kansas, is given in Table 30.

Table 30. Percentages of the various blister beetle species collected in alfalfa fields at Hays, Kansas. 1950-53.

Blister beetle species	Percentages collected				Four year percentage
	1950	1951	1952	1953	
M. unicolor	85	47	73	96	75
E. pennsylvanica	4	22	0	0	7
E. lemniscata	1	17	9	1	7
E. cinerea var. marginata	2	1	10	1	3
E. cinerea	5	1	4	1	2
E. sericans	2	4	1	1	2
M. segmenta	0	6	1	0	2
M. immaculata	1	0	2	0	1
E. maculata	0	2	0	0	1

Life Histories

Only Macrobasis segmentata Say, Epicauta cinera, and E. maculata were reared. They overwintered as coarcata larvae or prepupae and pupated in early May. The first generation of M. segmentata matured the latter part of June. In 1925, for example, the adults were taken in numbers while they were digging egg tubes and ovipositing near Manhattan. The elongated, slender, yellow eggs were deposited in clumps or masses similar to grasshopper eggs. The eggs were smaller and not enclosed in a definite pod and lacked a viscous frothy covering. They are deposited in little cylindrical burrows about 1 inch deep and about 3/16 inch in diameter. These burrows may extend vertically or at an angle. The female digs them, working energetically for a half hour or more. After oviposition, she fills the burrow with fine soil particles. These egg tubes were generally dug between plants in bare areas. The little piles of freshly worked soil gave an unmistakable clue to their presence.

In 13 days the eggs hatched to exceedingly active, triungulin larvae, as reported by Milliken (1921) and others. However, the entire period of incubation was somewhat longer. Triungulins were plentiful in the field from June 19 for about two weeks. The first generation of the migratory grasshopper had begun to mature a few days previously and was ovipositing. These little larvae were ceaseless in their search for grasshopper eggs but most of them must have perished. When placed in boxes with grasshopper eggs, they were slow to discover them. They crept in all crevices in the field, under clods, and under trash. Occasionally they started to burrow but did not go far. They grow rapidly and pass through the hypermetamorphic larval stages in about a month.

All reared larvae stopped in the coarctate stage and wintered, resulting in only one generation a year. In the field, however, adults were observed again plentiful in late August and early September. There are, therefore, two generations of this and other small species. There is unquestionably only one generation of the larger species of blister beetles.

Small black (E. pennsylvanica), gray (M. unicolor), and spotted-gray species (E. cinerea var. marginata) were laying eggs at wheat harvest time so that two generations are probable. The gray species was reared through one generation during July and August. One large gray adult was taken September 2.

Two blister beetle coarctate larvae were put in a salve box in the cave for overwintesing and taken out March 9, 1926. They had molted by April 28, and the large larvae squirmed around, apparently wanting food. This species evidently overwintered as partly grown larvae.

Gray blister beetles (M. unicolor) and little black blister beetles (E. pennsylvanica) were common in mid-June, 1920. They were plentiful again June 2, 1922, in alfalfa.

Some beetles were taken at Manhattan August 5, 1927, and placed on alfalfa growing in pots. The black spotted species and the gray species ate into the leaves from the border, leaving the ribs extending beyond the eaten portion. Sometimes only one side of the leaf was eaten and sometimes feeding was fairly uniform around the leaf. These leaves were fairly old and small and the plant was not making any growth. They might eat the ribs with the leaf on young, succulent growth. However, similar conditions were observed in the field at Hays during drought periods.

In mid-September, 1935, a gravid female blister beetle was seen attempting to make a burrow for her eggs. She was placed in a cage constructed thus: sifted damp earth in a jar and tamped firm, holes made in the soil with the handle of a dissecting needle. The female was then introduced, and the jar covered. The egg mass obtained by this method had no definite shape, and was longer than-wide, with the eggs mostly pointing in same direction. Eggs were oval and hatched in rearings in August, in 19 days.

A gray blister beetle kept in a cage June 1, 1932, with alfalfa foliage ate little. When given alfalfa blossoms, it ate them readily, apparently preferring the petals to the foliage.

The gray blister beetle was present in alfalfa fields, June 2, 1938, in large numbers. The large populations of grasshoppers the preceding years enabled this species to attain a large population. It is the first to appear as adults at Manhattan.

A blister beetle was found August 9, 1919, with two eggs thought to have been Tachinid eggs. One was laid on, the soft wing cover midway between the ends and the other on the dorsal side of the next to the last segment of the abdomen.

Small, cylindrical holes filled with loose soil, about 5 mm. in diameter were found June 19, 1925, about 1 inch below ground surface. They resembled those made by grasshoppers in ovipositing, with approximately two dozen elongate, yellow blister beetle eggs. These were found in open, bare spots in the field where the alfalfa was thin. One triungulin larva, probably of this species, was seen running around on the ground, indicating that the eggs were hatching,

A small patch of alfalfa at Manhattan was heavily infested with the three-striped blister beetles by July 6, 1925. Apparently they had started feeding into the field from a road. The. patch was conspicuous by absence of bloom. The beetles had eaten practically all of the blossoms and many of the ripening seeds but the foliage was not damaged. Beetles in numbers were clustered on the leaves and stems of alfalfa in the border. On slight disturbance they all would become active, drop to the ground, and scatter. No excrement, often described as being so plentiful in alfalfa, was seen.

The three-striped blister beetles occurred in numbers at Manhattan July 9, 1933; July 27, 1934; August 19, 1932; July 21, 1923; and July 19, 1924.

An adult of E. vittata and an adult of the smaller spotted, yellowish one (E. cinerea var. marginata emerged from the pupal stage June 4, 1937. Adults of the latter species were appearing in the field at that time.

An outbreak of the immaculate blister beetle, around Hill City and Hays, Kansas, was investigated during July 13-16, 1928. This is the most common species in north-central and western Kansas, though at Hays quite a few of the spotted blister beetles occurred that year. These beetles came from the pasture land and wheat fields in early July and concentrated on potatoes which they quickly defoliated. Later they went to tomatoes and alfalfa, which likewise suffered foliage injury. They ate rapidly, and often entirely defoliated a patch before they were discovered. Their well-known resistance to arsenicals rendered their control difficult except by mashing or jarring them from the plants into a bucket containing kerosene.

The first blister beetle noted in 1928 was M. unicolor. It was taken May 22 by sweeping alfalfa. There was a heavy population of this species in alfalfa fields at Manhattan June 1, 1937, eating buds and bloom. The injured buds did not bloom.

Some half dozen adults were reared from larvae taken in grasshopper egg pods. They emerged from rearings at the same time others were becoming plentiful in the fields.

Many triungulin larva were seen June 25, 1925, running about and looking for grasshopper egg pods. They seemed to be well fitted for digging into the loose earth. They entered cracks in the soil and searched under trash. None was seen on plants. A female was observed very actively digging a burrow for eggs.

Triungulins have the following color markings: upper surface of head and thorax dark reddish brown; 1st and 2nd abdominal segments tan or light brown; 3rd, 4th, and 5th, dark; 6th and 7th light; 8th medium or light; 9th and 10th dark; 11th light. The head is dark on both surfaces, but the thorax on the under side along with the abdomen is very light--almost white.

The average length of 15 blister beetle eggs of E. maculata was 1.43 mm.; range, from 1.25 mm. to 1.5 mm. Diameter range was 0.4 mm. to 0.55.

The average length of 12 triungulins coming from the eggs was 1.74 mm.; range, 1.5 to 1.95. The average width at the widest place in the body was 0.45 mm.

Damage

Eight blister beetles of assorted species were put on an alfalfa plant and another plant left as a check. Later the check was in excellent condition with flower and seed pods in abundance. In the test cage, the blister beetles were dead but flowers on the upper part of the plant had been totally destroyed. However, on the lower part of the plant, flowers and developing seed pods apparently had appeared after the blister beetles died.

At Manhattan, July 18, 1938, ash gray blister beetles had completely stripped a bean patch. Black blister beetles were completely defoliating rows of beets, while corners of the field had a heavy infestation of the striped blister beetles.

The effect of ash gray blister beetles on seed production was studied July and August, 1938, by placing them in cages over half of large alfalfa flowering clumps. All old and imperfect flowers were removed at the start of the tests, and the flowers were tripped in both cages with a camel's hair brush. Beetles were added to maintain up to 6 in cages as they were reduced by death. One seed pod formed in one infested cage compared with 38 pods in the check cage; no pods formed in the other two beetle infested cages compared with 48 and 208 pods in the check cages.

Control

Various alfalfa strains and varieties showed considerable variation in resistance to attacks of black blister and gray blister beetles (Table 31). The gray blister beetle was not found in the rows of Argentine, Cape Lucern, Cossack, Dakota Common, Dakota #12, Italian, Ladak, Provence, Sunflower, or Utah. The most gray blister beetles were found in Kansas Common. Black blister beetles were most numerous in Dakota Common, Spanish, and Grimm. Argentine and Ladak were free of both species.

A small local outbreak of striped blister beetles July 28, 1926, in a small patch, perhaps 20 x 30 feet, at Manhattan provided an early opportunity to try calcium cyanide for control. The field was in full bloom, but in the infested area practically all flowers and most of the foliage had been eaten, making the spot conspicuous. This small patch was dusted rather heavily with calcium cyanide "dust" with remarkable results. Practically a 100 per cent kill was effected in a few minutes. Daily observations showed that no appreciable number revived and the alfalfa was not injured by the dust. After three or four days, the alfalfa field was cut and used for hay. Because of wind, calcium cyanide was somewhat less successful for the larger blister beetles in western Kansas. The larger species also appeared to be somewhat more resistant.

During the 1926 outbreak, various other materials were tried in cages to control several species on potatoes and alfalfa. Conclusions follow:

1. Paris green, 2 lbs. to 50 gallons of water + 2 lbs. of hydrated lime gave a good but not complete kill. Results were apparent at the end of'24 hours and complete at 48.

2. Paris green, 1 lb. to 50 gallons of water + 2 lbs. of lead arsenate gave about the same results as the above.

3. Calcium fluosilicate dusted on heavily with a mechanical duster and a homemade pepper box and also as a spray gave poor results. Not over 5 per cent of the dust lodged on the nearly defoliated plant, partly because of high winds prevailing. No kill was noted in cage tests in 24 hours, and only a slight one at 48 hours. The experiment was repeated, dusting the plants until they were white. A 100 per cent kill was obtained in 72 hours.

Table 31. Number of the black blister and the gray blister beetles in 15 sweeps in an alfalfa variety test, Manhattan, Kansas, 1925. Black blister beetle numbers are given with variety names. Gray blister beetle numbers, when present, are indicated.

Variety or strain	April 10	June 6	June 19	July 8	July 24	Aug. 27	Variety totals
Argentine	0	0	0	0	0	0	0
Cape Lucern	0	0	0	0	2	0	2
Cossack	0	0	2	0	1	1	4
Dakota Common	0	1	1	0	1	7	10
Dakota #12	0	0	1	0	3	0	4
Grimm	0	2	0	0	0	5	7
gray	0	0	1	0	0	0	1
Italian	0	0	0	0	1	2	3
Kansas Common	0	1	0	0	0	2	3
gray	0	0	0	1	4	0	5
Kansas 435	0	1	0	0	0	1	2
gray	0	1	0	0	0	0	1
Ladak	0	0	0	0	0	0	0
Provence	0	0	1	1	0	0	2
Spanish	0	0	1	0	0	7	8
gray	0	1	0	0	0	0	1
Sunflower	0	0	0	0	1	2	3
Turkestan	0	0	1	1	2	1	5
gray	0	0	1	0	1	0	2
Utah	0	0	0	0	1	1	2
Date totals							
black	0	5	7	2	12	29	45
gray	0	2	2	1	5	0	10

4. Calcium cyanide dusted heavily on the plants in the open gave only about 50 per cent control at best. To eliminate the effects of wind, a "fumigator" of sheet metal to cover the plants and retain the chemical in a tray was devised. Five minutes or more was necessary to get a killing concentration of gas, but the time was reduced when the material was blown in with a duster. This equipment was believed to be useful and effective only in gardens. In alfalfa, the wind was less of a factor because plants tended to hold the dust and perhaps the fumes.

5. Calcyanide, 100 per cent grade, gave the same results as calcium cyanide except it acted more quickly. Complete kills under the fumigator were obtained in two minutes when the dust was blown in.

6. Sodium fluosilicate dusted heavily on plants gave a 100 per cent kill in cages in 24-48 hours.

In another test with 15 ash gray blister beetles in each of three test cages, the following results were obtained:

Cage No. 1. Dusted with sodium fluosilicate. After 33 hours, 13 of 15 dead, 2 escaped.

Cage No 2. Dusted with Dutax (barium fluosilicate). After 30 hours, all 15 beetles dead.

Check Cage. No chemicals; 13 alive, 1 dead, 1 not recovered.

No difference in effectiveness was indicated in tests between sodium fluosilicate and Dutox at the end of 48 hours.

Cyanogas calcium cyanide "dust" at 160 lbs. an acre gave 85 per cent control of large black blister beetles. They could run 40 feet over a granule barrier and not be killed.

Striped blister beetles were numerous August 14, 1939. In 7 sweeps, 33 beetles were collected. An area of 150 sq. ft. was dusted at 4 p.m. with Pyrocide, 1 quart being used for medim dusting. Six hours later, all the Pyrocide was washed off the plants by rain. Several minutes after the dusting, the beetles were all on the ground on their backs but moving their legs; very few were left feeding on the leaves. Next morning, beetles were again feeding in the tops with many also still crawling on the ground. About half of them recovered. In 7 sweeps, 7 blister beetles were taken.

Striped blister beetles were dusted in a 5 x 5 foot plot August 15, 1939, with Pyrocide. The results were better than in the previous test. Beetles were quite numberous over the ground, but two days later all were dead.

Potatoes and tomatoes were dusted with sodium fluosilicate 50 per cent by weight and 50 per cent of lime July 14, 1938. Next day the blister beetles were gone. No dead beetles were found, Control results using some 15 of the chemicals either singly or in combination (Table 32) indicate that the rate and timing of the insecticide is much more important than the insecticide used. Only in 1947 when BHC dust gave 100 per cent control was it necessary to apply control measures primarily for blister beetles. In this alfalfa seed field, the damage to the flowers was so extensive that the only parts of the field worth harvesting were those where blister beetles were controlled. Table 32 also indicates that it is easier to control blister beetles in the second cutting alfalfa seed crop than in the first or third cutting (information above and below line). Ten gallons of emulsion were as effective as 15, 20, 25 gallons per acre.

Four general alfalfa insect control experiments were in operation at Hays, Kansas during the four year period 1950-1953 without change. These included (1) a comparison of the more promising insecticides for insect control, (2) the rate of insecticide needed for control, (3) the time of obtaining the seed crop, and (4) the number of insecticide applications required for the most economical control of alfalfa insects. The results are included in Table 32. Differences among experiments and years were not significant. The differences in numbers among M. unicolor and the other eight species in the control plots were marked. The difference between E. lemniscata and M. immaculata was just barely significant.

Beginning in 1953, two pounds of actual toxaphene per acre or one pound of chlordane was used with excellent results. When the blister beetles flew in and attacked alfalfa in the bud stage, the usual two pounds of DDT for plant bug control gave satisfactory control.

THE GREEN CLOVERWORM

The green cloverworm, Plathypena scabra (Fabr.), is one of the commonest insects in alfalfa in Kansas. Though serious injuries have not been reported from their feeding, their constant presence and occasional large numbers make them a potentially important pest. This insect frequently was the most abundant lepidopterous insect in alfalfa.

Grote (1872) redescribed Hypena scabra Fabricius and stated that the species was very common throughout the Atlantic "district." Lintner (1873) mentioned this species briefly under the name Hypena scabra (Fabr.) and noted that all specimens in his cabinet were males. He made H. erechtalis a synonym because the specimens before him were all females.

Coquillet (1880) described the larva of this species. Comstock (1880) gave a good general account and described the full grown larva and pupa. Coquillet (1881) described the life history, stages, and gave clover as its food plant. Riley (1885) gave a somewhat more detailed account, drawing on the literature on the species, and mentioned rearing the parasite, Euplectrus platyhypenae How. from the larva. He reared Euplectrus in 1882. Hill (1918) published a fine account and much of this summary report is confirmatory from studies in Kansas to this detailed discussion of all aspects of the species. Sherman (1920) discussed the natural enemies such as a bacterial disease which had killed many larvae, and Trichogamma pretiosa, an egg parasite. Other parasites of the green cloverworm reported were Phorocera claripennis, Exorista boarmiae, Frontina aletiae, Euphorocera floridensis, Sarcophaga cimbicis, Anthrax lateralis and eight new, unreported parasites.

Table 32. Summary of control tests of blister beetles in various alfalfa experimental plots. All treatments consisted of a single application of insecticide in 15 gallons of solution per acre near the bud stage of development on the second cutting of alfalfa unless otherwise indicated. Manhattan and Hays, Kansas, 1947-1953. EC = Emulsifiable concentrate; D = Dust; WP = Wettable powder.

Insecticide	Rate ounces per acre	Formulation	No. of tests	Per cent control Range Low and high	Average 1 to 7 yrs.
Aldrin	8	EC	4	75, 100	85
BHC	1, 1.6	WP,D	2	100	100
Chlordane	16	EC	3	73, 94	86
DDT	16, 32	"	8	57 (16 oz.), 100 (32 oz.)	81
Dieldrin	8	"	4	90, 94	92
Endrin	4, 8	"	2	88 (4 oz.), 100 (8 oz.)	94
EPN	8, 16	"	2	44 (8 oz.) 91 (16 oz.)	68
Heptachlor	8	"	2	62, 82	72
Isodrin	4, 8	"	2	56, 82	69
Metacide	4, 8	"	3	56 (4 oz.), 95(8 oz.)	78
Methoxychlor	32	"	2	73, 86	80
Parathion	4, 8	EC,WP	5	75 (4 oz. EC) 100 (8 oz. WP)	91
Pestox	16	EC	1	100	100
Systox	8	"	2	56, 91	74
TEPP	8	"	2	56, 60	58
Toxaphene	24	"	4	62, 95	84
DDT (16) + Toxaphene (12)		EC	20	0, 100	44(1)
Same but 5, 10, 20, 25 or 30 gallons per acre		EC	10	0 (All, 10,20,25) 25 (5 and 30)	3(2)

(1) Insecticide applied on alfalfa growth 4".6" high and in bud stage of the first and third cuttings.

(2) Compared with 15 gallons per acre.

Table 33. Average number of blister beetles per year per experiment in Buffalo alfalfa insect control plots, Fort Hays Branch, Kansas Agricultural Experiment Station. 1950-1953.

Species of blister beetles	Average number
<u>M. unicolor</u>	28.88
<u>E. lemniscata</u>	2.18
<u>E. pennsylvanica</u>	1.12
<u>E. cinera</u> var. <u>marginata</u>	0.88
<u>E. cinera</u>	0.81
<u>E. sericans</u>	0.75
<u>E. maculata</u>	0.69
<u>M. segmentata</u>	0.56
<u>M. immaculata</u>	0.25

The taxonomic history and synonomy was given by Smith (1895). It has apparently been known to be present in the United States for a long time but no historical account has been published. Hill (1918, 1925) gave the distribution as including all of the United States from central Kansas eastward. Spelling of the generic name varies in the literature.

Damage

First instar larvae eat only the epidermis of the alfalfa leaves, usually the lower side of the leaf. Second instar larvae begin to eat entirely through the leaves, but they prefer to eat at the margins. Infested alfalfa shows slight or severe eating at the margins of the leaves, depending on the infestation. Severely damaged alfalfa as occurred repeatedly in rearing cages, may have the leaves more or less completely destroyed, only the stems and midribs remaining in worst defoliations. In the field, complete defoliations have never been observed nor reported, but slight injury occurs almost annually.

Life History

The general habits of the larvae have been rather fully described and there is little to add. The length of time between molts and the number of molts have not been recorded. Tables 34 and 36 give these data and the measurements for instar recognition are given in Table 35.

The average length, of the life histories, of 20 green cloverworms from laying of egg to emergence of adults was 38.8 days. Hill (1925) gave 38.81 days as the average in his rearings. The average of 13 life histories during June and July was 33.3 days, the extremes being 27 and 39 days.

The average period in the cocoon of 20 rearings was 24 days. This was rather long. The weather became quite cool during the latter part of these rearings. The average length of the prepupal period in 113 life histories during the summer was 10.8 days.

Seasonal History

Some difference of opinion exists concerning the manner of overwintering of this insect. Most writers state that it overwinters as an adult. Riley (1885) and Hill (1918), working in eastern U. S., stated that it may overwinter as a pupa. Hill (1925) stated that this species hibernated in both the pupa and adult stages. The data on this point are not perfect, but it has been impossible to carry through adults at Manhattan, although pupae were successfully wintered several times. Pupae also survived a month's refrigeration in an ordinary household refrigerator, and the adults emerged. There is considerable overlapping of broods in the field, such that the generations are not as clearcut as this account might indicate. In general, however, the generations appear to be influenced by the time and frequency of cutting the alfalfa.

The earlier appearing moths in the spring probably overwintered as adults; the later appearing ones constituting the bulk of the spring emergence overwinter as pupae. These pupae are most commonly found in an earthen cell below the surface of the soil up to a depth of 3 inches.

The seasonal history in Kansas is given in Table 36. It is not known whether the overwintering moths come from the third or fourth generation pupae. It was noted that, as the summer advances, an increasingly longer time is spent in the cocoon extending to 28 days when not overwintering. There is a prepupal period of 1 to 5 days, as pointed out by Sherman (1920). This period increases as the season advances, but an average of 49 life histories gave 1.9+ days for this period.

The moths appear early in the spring (March 28, 1922; March 23, 1925) at Manhattan. The earliest moth was taken in a home near a light. It was thought that those captured indoors, far removed in all cases from alfalfa fields or gardens, indicated that they might have overwintered as adults. Since pupae have passed through the winter successfully, it is believed that the species may winter either as adults or pupae.

The instar measurements (Table 35) average a little higher than those given by Hill (1925), and the time occupied by each instar is a little shorter. These differences may result from food and temperature conditions.

In rearings, there was a slight excess of female moths over males. In one series, 22 males and 31 females were obtained. In the field collections, the sexes were about equal in number or a slight excess of males.

Table 34. Length of time occupied by 5 male and 11 female green cloverworm life histories during the summer at the field laboratory, Manhattan, Kansas, 1925.

Period under observation	Days - range of time required: Minimum	Maximum	Average of 16 cloverworms
Egg deposition to hatching	3	6	4.5
First instar	1	4	1.8
Second instar	2	4	2.1
Third instar	2	4	2.2
Fourth instar	2	4	2.2
Fifth instar	1	3	2.5
Sixth instar	3	10	4.3
Prepupal period	1	3	1.5
Pupal period	20	25	22
Egg stage	3	6	4.5
Larval stage	18	25	21.5
Prepupal stage	1	3	1.5
Pupal stage	10	13	11.0
Adult stage	1	19	9.0
Egg to adult	28	34	31

Table 35. Instar measurements of 20 green cloverworms reared in the field insectary.

Larval instar stage	Dimension	Maximum mm	Minimum mm	Average mm
First	Length	4.0	1.5	2.98
	Width of head	0.25	0.23	0.23
Second	Length	6.0	3.5	4.53
	Width of head	0.4	0.35	0.37
Third	Length	11.0	4.0	7.54
	Width of head	0.65	0.5	0.54
Fourth	Length	18.0	8.0	12.76
	Width of head	1.1	0.8	0.96
Fifth	Length	24.0	14.0	17.7
	Width of head	1.75	1.25	1.5
Sixth	Length	31.0	18.0	25.7
	Width of head	2.15	1.85	2.04

The seasonal history and span for each generation as indicated by field collections in 1922 to 1925 are given in Table 36.

Table 36. Life span for the four generations of green cloverworm observed at Manhattan, Kansas from 1922 to 1925.

Number of generation	Stage	Date observed in field earliest	latest
First generation	Adults from over-wintering pupae	March 23	June 5
First generation	Larvae	April 12	June 8
Second generation	Adults	May 30	June 24
	Larvae	June 4	July 20
Third generation	Adults	July 9	August 14
	Larvae	June 24	August 8
Fourth generation	Larvae	August 22	October 17
	Pupae	Sept. 24	Overwinter

The eggs were described by Coquillet (1881), Balduf (1923), Britton (1920), Chittenden (1901), Hill (1918, 1925), and were illustrated by Riley (1885)

Four moths deposited, 237, 254, 216, and. 213 eggs each. A female moth was dissected and 353 eggs and ovules were counted. Hill obtained 670 eggs from one moth, but in all other cases that he reported the numbers varied from 60 to 300 eggs. There is a preoviposition period of about 10 days.

The flight of these moths is distinctive. They fly up ahead a short distance and alight low on the plants, as a person walks through alfalfa. They align themselves longitudinally with the substratum; and rest with the outer ends of the wings flat and the head slightly tilted. They are attracted to lights and to certain chemical substances. Among those tried were amyl acetate, sugar water, and sorghum molasses diluted with water. They were not caught in numbers to suggest trapping moths as a control measure. Copulation was never seen nor has it been described.

Natural Control

Lavae are rather heavily parasitized at times, although at no time have parasites been dominating factors. Lists of parasites and predators were given by Chittenden (1901) and Hawley (1922).

During these studies, the following parasites were reared: Winthemia quadripustulata Wide., the commonest larval parasite; Phorocera claripennis McQ. , also larval and Rogas nolaphanae Ash. (Det. Gahan) which was reared many times from May to August. The latter species parasitizes and kills larvae in about the third instar. The old host skin shrinks to form a cocoon from which the adult parasite emerges through a small, round hole eaten by the parasite. Euplectrus platyhypenae Howard, which was originally described from specimens reared from this species, was first taken during 1926 at Manhattan (Smith, 1927), and Apanteles scitulus Riley, a hymenopterous parasite of the larva which was not common.

An unidentified parasite larva emerged June 16, 1924, from a green cloverworm larva and pupated. This parasite pupa was l/2 inch long and dark except for a large light green stripe running down its back, and two small, light green stripes, one on each side of the large stripe. This pupa was on the underside of an alfalfa leaf and was enclosed in a finely netted silken case. The adult parasite emerged June 21. It had a moth-like insect body about 3/8 inch long, and slender yellowish-white stripe on its back which divided and extended back on each wing.

Another unidentified species of parasite came out of a green cloverworm June 16, 1924. It burst out of the larva and pupated. It lay crosswise of the host larva and had one end outside the larval skin but the other end remained within. It was about 3/16 inch long and l/16 inch in diameter or about the same diameter, as the host larva was w hen it died. The parasite had two setal projections at each end of the body. This parasite was quite unlike any other obtained from any other green cloverworm.

Some larvae were parasitized by a large, unknown Hymenopterous parasite that pupated within the larval skin which turned brown. Another parasite spun a brown, wrinkled cocoon resembling a grain of wheat. The cocoon often was attached to the lid of the box. It was one of the small Hymenopterous parasites.

The large fly parasite (W. quadripustulata) of green cloverworms required 7 to 26 days in the pupal stage (6-13 to 7-9-24). This is the fly with the light colored abdomen. But one fly, pupating July 16, emerged (July 23).

In a rearing series from green cloverworms collected in the field May 30 to September 17, 1921, consisting of 279 larvae, 15 were parasitized by either Dipterous or Hymenopterous parasites and the host larvae died; 68 moths emerged; 34 died as pupae; 22 died as prepupae; 82 died as larvae; and 58 were killed during rearing, escaped, or were transferred to other series.

Green cloverworms with a black mass about 1 mm. in diameter, with presumably Euplectrus eggs on them, were not always killed by the parasites. A larva collected August 8, 1923, molted on August 10, pupated August 14, and the moth emerged August 24.

Of the predators, Sinea diadema, Orius (Triphleps) insidiosus, and Chrysopid larvae, especially Chrysopa plorabunda Fitch and Chrysopa oculata Say, are important.

The larvae were attacked both in the field and in rearings by a bacterial wilt. It contributed to natural control, but varied in abundance in different seasons, being practically absent some years.

September 9, 1924, a digger wasp was seen dragging a green cloverworm to its burrow. The wasp opened the burrow and put the larva inside. It then covered the hole. The burrow was about 11/2 inches deep and had a cavity at the bottom. Another green cloverworm and a forage looper were in the cavity. The green cloverworm had an egg attached to its side. The egg was white, about 1/8 of an inch long, and about as thick in diameter as a common pin. It was pointed at each end and was attached to the larva by one end. The larvae were all paralyzed but not dead.

Artificial Control

The control measure suggested by Hill (1918), viz., cutting the alfalfa when the larvae were abundant, was satisfactory during these studies. Repeated unsuccessful efforts were made to follow individual larvae when the alfalfa was being cut. Certain birds, such as grackles, robins, and several varieties of sparrows were commonly seen at alfalfa-cutting time walking over the newly mown hay or stubble and eating larvae. Grown larvae promptly make a pupal cell, others wander about and eventually succumb to exposure to high temperatures sometimes prevailing at cutting time (Smith, 1956). Thermometers on the ground in the sun, exposed to the direct rays of the sun and radiation, registered from 105^{o} F. to 133^{o} F. on hot, summer days. Air temperature in the shade of alfalfa plants at the time of the latter temperature was 108^{o} F. Such temperatures, while not immediately fatal, may result in eventual death of larvae.

It appeared from a study of alfalfa varieties in 1925 (Table 37) that Utah and Ladak were least preferred by the green cloverworm while Provence and Italian were the most preferred. This table also shows the large August population mentioned earlier.

Table 37. Number of the green cloverwormsin 15 sweeps in the alfalfa variety trials. Manhattan, Kansas. 1925.

Variety or strain	April 10	June 6	June 19	July 8	July 24	Aug. 27	Variety totals
Argentine	0	0	0	1	0	2	3
Cape Lucern	0	0	0	0	1	1	2
Cossack	0	0	3	0	0	7	10
Dakota Common	0	0	1	1	0	0	2
Dakota #12	0	0	2	1	0	8	11
Grimm	0	0	1	1	0	7	9
Italian	0	0	0	0	0	21	21
Kansas Common	0	0	1	1	0	3	5
Kansas 435	0	0	0	2	0	2	4
Ladak	0	0	0	1	0	0	1
Provence	0	0	0	0	1	22	23
Spanish	0	0	0	1	0	1	2
Sunflower	0	0	0	0	2	8	10
Turkestan	0	0	0	4	3	4	11
Utah	0	0	0	0	0	0	0
Date total	0	0	8	13	7	86	114

Chemical control (Tables 38 and 61). Endrin, DDT, chlordane and toxaphene, when applied for leafhoppers, grasshoppers, and webworms in field tests, gave a high degree of control of green cloverworms.

In the December 1, 1937, number of the Bureau of Entomology newsletter, it was reported that sulphur dust alone gave good protection from the green cloverworm attacking beans. The work was done at the Norfolk, Va., laboratory. Sulphur dusted alone and in combination with pyrethrum, rotenone, and cube and sprays of wettable sulphur were used. The dry dusts were said to be better than sprays, and sulphur gave as good protection as the combination dusts. These materials were used on alfalfa during these studies, but results against this insect were not recorded.

Control experiments 1950 to 1953 at Hays, Kansas (Table 38) showed fair to good results from all chemicals at the indicated rates. Endrin, parathion, DDT, and toxaphene gave excellent control. Best results were obtained when the insecticides were applied at the budstaqe of development on the seed crop. Applying the insecticide twice improved the rate of control. There was little difference in control with the insecticides on the three cuttings of alfalfa.

GARDEN WEBWORM

Results of studies on the garden webworm, *Loxostege similalis* (Guen.) were rather completely summarized in the authors' recent joint paper (Smith and Franklin, 1954). This account is intended to supplement, and in some cases corroborate, observations and results reported in that paper, in the report by Dean and Smith (1935) and in the annual insect population summaries for 1930 to 1948 inclusive.

Notes from the Early Literature

Most of the early writings on webworms deal with these pests on plants other than alfalfa such as the first account by Riley (1885). Forbes (1900) gave a good general account of the garden webworm, but did not mention alfalfa. He said it lived largely on pigweed (*Amaranthus*) and purslane but that it attacked cultivated crops, such as beets, soybeans, buckwheat, corn, and cotton.

Popenoe (1905) stated that there was much complaint in June of garden webworm damage to alfalfa in the middle and eastern sections of Kansas. Sanderson (1906) wrote at length about the garden webworm as a cotton pest.

Sanderson (1906) said this pest made its first appearance in 1873. He described the life history, stages, habits, food plants and control in detail much of which agrees with subsequent findings.

Observations on Host Plants

In 1947, a field of sesame plants located adjacent to alfalfa at Manhattan was severely damaged. The alfalfa seed crop was completely destroyed by the insects. Having no place else to go, they moved over into the

Table 38. Summary of control results for the green cloverworm in the various alfalfa experimental plots. All treatments consisted of a single application of insecticide at the bud stage of the second cutting of alfalfa unless otherwise indicated. Manhattan and Hays, Kansas 1947-1953. EC = Emulsifiable concentrate; WP = Wettable powder; D = Dust.

Insecticide	Rate ounces per acre	Formu- lation	No. of tests	Per cent control Range Low and high	Average 1 to 7 yrs.
Aldrin	8	EC	4	80, 100	89
BHC	4	"	1	75	75
Chlordane	16	"	3	80, 87	84
DDT	32	"	4	85, 100	94
Dieldrin	8	"	4	40, 95	80
Endrin	4, 8	"	2	100 (4 and 8)	100
EPN	8, 16	"	2	60 (8), 93 (16)	77
Heptachlor	9	"	2	80	80
Isodrin	4, 8	"	2	80(8), 100 (4)	90
Metacide	4	"	2	80, 87	84
Methoxychlor	32	"	2	67, 90	78
Parathion	4, 8	"	4	80 (8), 100 (4, 8)	93
Systox	8	"	2	40, 93	66
TEPP	8	"	2	75, 80	78
Toxaphene	24	"	4	80, 100	93
DDT (16) + Toxaphene (12)		EC	20	0, 100	55(1)

(1) Insecticide applied in 5 plots when alfalfa plants were 4-6 inches high or at the bud stage, on the first or third cuttings.

sesame field. Soybeans near by were also severely damaged. It was clear in 1923 that Amaranthus or “red root” was the favorite food plant of these larvae. Everywhere this plant was infested and most of them defoliated. Keeping these weeds down so that the first generation could not feed on them might be an important control measure. A little patch of these weeds showed prolonged infestation and was completely defoliated.

Wherever observations were made in late July 1923, Amaranthus was infested and injured. A field of perhaps five acres of alfalfa had been riddled and was cut though it was only about 10 inches high. The larvae migrated from this field and entered the truck gardens around it. Many tomatoes and cantaloupes in an adjoining field were eaten. Some larvae bored directly through the tomatoes. Others were nibbled at the surface. No damage was done to the foliage of tomatoes. The owner had put bran mash around each plant but no control resulted. The larvae severely injured the melon leaves and many of the nearly ripe melons. The leaves were webbed and eaten similarly to that of alfalfa and other crops. The larvae nibbled at the surface, sometimes eating considerable and less commonly bored into the melons. In either case, the melons were rendered unsalable and most spoiled before ripening. The larvae had been crossing a road and entering a sweet potato field. The sweet potato leaves were webbed together and were being rapidly defoliated. Peppers, eggplant, cabbage and melons also were being destroyed. Both foliage and fruits of cucumbers were injured exactly as were cantaloupes. Corn was little injured but pigweeds in the corn were again heavily infested. Melons to- the south were severely injured along the alfalfa field. The foliage was the chief object of attack. Farther along, watermelon vines showed the same general injury. All pigweeds in the patch were defoliated and heavily infested. Many of the larvae were apparently so hungry when they reached these plants that they made no web and fed on the surface of the leaves, eating holes in a manner not quite typical. The gardener had dusted the plants with lead arsenate without control.

The night of July 27, 1923 a 11/4-inch rain largely cleaned alfalfa and other plants of webs. Fields after being almost ruined by the webworms soon looked green again. Without larvae, the plants put out new foliage and while the leaves were small, the foliage was in good condition. The stems were rather tough for hay, but the hay was better in a few days to a week than it would have been the previous week. Several striking things were noted during this outbreak of July 1923. First, no pupae were seen. The surface of the soil under which they are supposed to occur was examined many times as was the trash at base of the plants, but not one was found. Second, only one parasitized larva with a Tachinid egg was seen. Perhaps many were parasitized by Ichneumonids but they showed no evidence of it. Ordinarily the third or next brood would be exceedingly large but it was smaller.

Life History and Habits

This pest has been studied by many entomologists over the years. Kelly and Wilson (1918) described in detail the distribution and history of the garden webworm, the life history, seasonal history, natural and artificial control. Poos (1951) gave basic ecological and biological information. Smith and Franklin (1954) gave a summary of the biology, seasonal history, life history, life stages with instar measurements, and a summary of natural and artificial controls.

First brood larvae begin to appear in the alfalfa fields in May, and are mature late in the month, the moths appearing early in June. Second generation moths appear the last of June and continue to mid-July. Second generation larvae attack the second or third (usually the second) cuttings of alfalfa in July and do more or less serious injury, depending on numbers. Larvae pupate the first of June and throughout July. Third generation adults begin to appear late in July, and continue throughout August. Very few eggs are deposited by this rather large brood of moths. There is a light third brood of larvae which appears during September and October. Adults occur at all times during these months and up to killing frosts. There are, therefore, three complete generations each year in Kansas, the second generation commonly being the injurious one. Forbes (1900) suggested four generations per year and a possible fifth.

The number of eggs deposited by individual moths is summarized in Table 39. A female obtained June 20, 1925 produced egg clusters ranging from 7 to

37 each. A moth obtained July 11, 1924, deposited 15, 18, 21, 29, and 32 eggs per cluster.

Two female moths were collected September 1, 1925, and dissected for egg counts. The female has a somewhat tubular ovipositor which is drawn up. The egg calyxes appeared to consist of strings of eggs of varying size and stage of development. This species appeared to be atrophic. In one female 495 ovules were counted.

Table 39. Number of eggs deposited by individual garden webworm moths. Manhattan, Kansas. 1924-1926.

Date female collected	Number of egg clusters	Total eggs deposited
July 11, 1924	5	115
June 20, 1925	5	99
June 20, 1925	8	60
June 20, 1925	11	170
July 10, 1925	?	115
July 13, 1925	16	180
May 22, 1926	?	157
Average	9.0	126.7

When the larvae hatch, they eat a small hole or break out of the flat egg shell at the border of the egg or they lift the scale-like egg. The shell is clear and glassy. There is a raised series of 4- and 5-sided figures over the egg. The enclosed areas are flat and glassy as is the remainder of the shell.

To determine if webworm moths laid eggs on the ground and on dry leaves where they did not hatch until the rains come, moths were caged and allowed to deposit eggs. Eggs were laid on dry leaves and grass, but no evidence was obtained of eggs laid on the ground. A number of egg masses were laid on two small alfalfa plants in pots, then the potted plants were put in an alfalfa field July 20, 1930. None was parasitized so parasites were not keeping down webworms.

There was a small outbreak July 7, 1925. In fields in bloom the moths were exceedingly abundant. They flew up in a cloud. The larvae were not numerous but moths were depositing eggs.

Eggs and young larvae were sought August 4, 1925, but none was found. Yet the moths were as plentiful as ever, primarily feeding on the alfalfa bloom. But the moths were also plentiful on bare stubble fields, in corn fields, and in wheat stubble fields, and were otherwise generally distributed. They were expected to lay eggs on weeds but no eggs or young larvae were found. Majority of the moths were males.

When larvae are ready to spin, the coloration becomes dull. They spin a tight, flat cocoon on the bottom of boxes, on lids and on blotting paper. The silk is quite tough. Inside the cocoon, the prepupa shortens to as much as 7 mm. across the dorsum of the thorax. At first the pupa is amber, but soon turns darker, being dark reddish-brown before the adult emerges, The end of the abdomen has two clumps of straight, short, stout spines of 3 each. The pupa is longer and more narrow than noctuid pupae.

There were a great many moths in the field July, 1930, but few larvae. Dissected moths were well filled with eggs but oviposition was limited probably because of the hot weather and because the alfalfa was not in the proper stage. While this is the season of heavy parasitism, it did not appear that this was limiting the population. A moth placed in a cage of alfalfa June 30, 1939, laid 368 eggs before she died.

To determine if they might overwinter as eggs, some eggs which had been deposited in confinement at the laboratory were put in a refrigerator at a temperature of 45° to 50° F. Most were freshly deposited, while others were partly developed. It was hoped to see if development would stop for a time from cold and if the eggs would hatch when removed. Many hundreds of eggs were placed in the refrigerator July 13 to August l, but none hatched when removed. This is evidence against overwintering in the egg stage.

Many larvae pupated in battery jars at the insectary in the fall of 1931. The soil was dry and hard when examined May 24, 1932; no living pupae were found nor did adults emerge. One cocoon containing a dead unemerged adult was found. Also, no adults emerged in cages where larvae had been placed the previous year.

Sanborn (1916) stated that pupation of the garden webworm occurred in the web on the food plant. It appears that either this species has a different habit in Oklahoma, which is unlikely, or some other species was confused with it. Haematopsis grataria is the one suspected as causing the confusion, for it pupates in that manner in Kansas, and the pupae resemble those of the garden webworm. Webworm pupae were never taken by sweeping during these studies. Quite a few garden webworm pupae were found close to the base of alfalfa plants and just below the surface of the soil August 1, 1923.

In July, 1924, it was thought that the garden webworm might overwinter in the adult stage, since adults appeared rather suddenly worn and battered in the early spring. It was difficult sometimes to identify these moths until eggs or larvae were obtained. Two moths taken April 10, 1925, at Manhattan were much rubbed as if they might have flown some distance. This was the earliest appearance date for these moths here. All attempts to carry them through the winter in any stage failed.

Three cages with inverted cone bottoms like those of the cone fly traps were set up July 28, 1923, to determine whether moths were attracted to various substances. Cages were placed in alfalfa fields about 6 inches above the alfalfa. In the little cup was placed various substances to test attractiveness, using water as a check. Moths were caught in all the cages two days, later. The water cage had three moths, banana oil two, and dilute molasses, one. When moved to another field, two days later the water cage had seven, banana oil, six, and dilute molasses, eight.

On July 25, 1925, it was observed that third generation moths were much more sluggish in their flight at night than in daytime. In former years, third generation moths deposited few eggs. But as late as September 28, an outbreak had completely destroyed fall-sown alfalfa at Yates Center and had badly damaged an old stand also. There were many small light-colored moths in flight. One farmer reported an entire field of 6 acres of fall-sown alfalfa 4 inches high destroyed in 2 days. Only stems remained. At this time no webworms were found around Manhattan.

The seasonal life history at Manhattan, Kansas, is summarized in Table 40. First generation moths and fourth generation larvae lived longest. The shortest duration for both moths and larvae was the second generation occurring in June to July on the early part of the second cutting of alfalfa.

Table 40. Seasonal life history of garden webworms. Manhattan, Kansas.

Generation	Life form	Earliest date	Latest date	Duration, days
First	Moths	April 5	June 1	58
First	Larvae	May 10	June 25	47
Second	Moths	June 10	July 1	22
Second	Larvae	June 20	July 15	26
Third	Moths	July 5	August 10	37
Third	Larvae	July 20	August 25	37
Fourth	Moths	August 20	October 1	43
Fourth	Larvae	September 1	October 20	50

Control

Forbes (1900) mentioned <u>Limneria</u> <u>eurycreontis</u> Ashm., <u>Agathia</u> <u>exoratus</u> Cr. and <u>Pachymenus</u> sp., and a Tachinid fly as parasites of the garden webworm. Sanderson (1906) stated that many larvae collected were parasitized by <u>Apanteles</u> <u>laphygmae</u> Ash., <u>Cardiochiles</u> <u>explorator</u> Say, <u>Mesochorus</u> <u>electilis</u> Cress., <u>Exorista</u> <u>hypenae</u> Coq. and <u>Phorocera</u> <u>parva</u> Prigot.

Eggs exposed in alfalfa fields were readily parasitized by <u>Trichogramma</u> sp. Very few larvae were parasitized July, 1923. Of hundreds examined, only one was seen with a Tachinid egg. Of 30 larvae collected in the field and reared during August, 1920, five were parasitized. More webworms were observed parasitized by <u>Euplectrus</u> <u>platyhypenae</u> in 1931 than any prior year. They were not controlling any species of larvae. This parasite has been taken repeatedly on the variegated cutworm, corn earworm, cotton cutworm and on the garden webworm. The latter was an unrecorded host for this parasite. Adults have been reared but so far as known oviposition was never obtained although attempted repeatedly.

A Tachinid, probably Winthemia, was reared from garden webworms beginning July, 1920. Of nine larvae collected August 7, 1920, 4 had Tachinid parasite eggs on their heads. The larvae were all nearly grown at the time of observation.

Differences were noted in the amount of injury in the different strains of alfalfa July 31, 1923. Kansas Common, Dakota, and Sunflower were the least injured alfalfas and Turkestan, Cape Lucern, Ladak and Grimm were most injured by the second brood of larvae. A week or two earlier, it appeared practically stripped but, following some regrowth, made fairly good hay.

Alfalfa varieties were checked several times for garden webworms during 1925. Kansas Common, Cossack, and Dakota Common were the most heavily infested. The first two were the least injured in 1923. Spanish alfalfa had no observed garden webworms while Argentine and Kansas 435 were only slightly infested.

Results of insecticides tested for garden webworm control are included in Tables 41, 42, 43, 44, 61, and 67. Toxaphene at the rate of 36 ounces to the acre, aldrin 8 ounces, parathion 8 ounces, DDT 32 ounces (Table 41) gave good control. A nearby field was left untreated as a check. Chlordane and aldrin had no appreciable effects on this pest at the dosages used.

Table 41. The degree of infestation, insecticides and amounts used for the control of <u>Loxostege similalis</u> Guen. on 5- to 7-acre plots at Manhattan, Kansas, 1949.

No. of acres	Material used	Ounces per acre	Degree of infestation before spraying on scale of 0 to 5	Control obtained
7	Toxaphene	36	2.28	good
5	Chlordane*	24	2.94	none
7	Aldrin*	8	2.22	none
5	Parathion	8	3.20	good
6	DDT	32	2.66	good

* Resprayed with Toxaphene 2 days later at 36 oz./acre with good control.

Another plot treated with DDT at 2 pounds per acre yielded 503 pounds of seed per acre while an untreated section yielded only 106 pounds per acre.

Accurate determination of the increase in seed following spraying in other treated plots could not be made because no portions were left untreated. If the same check plot is used as a check, the comparative yields were as shown in Table 42 though variables other than insects may have been involved.

Table 42. Alfalfa seed yields from plots treated with insecticides. Manhattan, Kansas. 1949.

Treatment	Pounds per acre	% increase
Toxaphene	139.1	30.5
Chlordane & Toxaphene	180.0	69.8
Aldrin 8 Toxaphene	144.5	36.3
DDT	331.5	118.4
Parathion	100.0	-5.7
Untreated	106.0	---

Results from a larger experiment at Hays are summarized in Tables 43 and 67. There was no seed increase in the toxaphene and chlordane plots. However, after garden webworms entered the pupation period, the alfalfa developed many secondary blooms. These flowers were tripped almost as soon as they appeared since there were more than five colonies of honeybees per acre adjacent to the plots and no other floral source of honey within 3 miles.

Table 43. Percentage control of the garden webworm and percentage of increase in yield in insecticide treated plots. Hays, Kansas. 1949.

Insecticide	Ounces per acre	Percentage garden webworm control	Seed yield, lbs. per acre*	Percent seed increase
Parathion	8	95	1,000	24
Toxaphene	24	85	642	-20
DDT	32	83	1,050	30
Aldrin	8	68	985	22
Dieldrin	8	60	853	6
BHC-gamma	0.35	51	1,073	33
Chlordane	16	47	595	-26
Check	--	--	806	--

* State average, 75 pounds per acre.

Smith and Franklin (1954) reported best control results with DDT, toxaphene, metacide, and parathion.

Table 44. Control of the garden webworm in various alfalfa experimental plots. All treatments consisted of a single application of insecticide as a dust or in 15 gallons of solution per acre near the bud stage of development and on the second cutting of alfalfa unless otherwise indicated. Manhattan and Hays, Kansas. 1947-1953. EC = Emulsifiable concentrate; D = Dust; WP = Wettable powder.

Insecticide	Rate ounces per acre	Formulation	No. of tests	Per cent control Range Low and high	Average 1 to 7 yrs.
Aldrin	8	EC	5	61, 74	72
BHC	1, 1.9	D, WP	7	49 (1.9 WP), 85 (1.9 WP)	67
Chlordane	16	D,WP,EC	8	47 (WP), 85 (D)	68
DDT	16, 24, 32	"	17	45 (16D, EC), 90 (32, D, WP)	73
Dieldrin	8	EC	5	65, 80	75
Endrin	4, 8	"	2	77 (8), 86 (4)	82
EPN	8	"	2	56, 88	72
Heptachlor	8	"	2	79, 98	89
Isodrin	4, 8	"	2	76 (4), 86 (8)	81
Metacide	4, 8	"	3	63 (4), 84 (8)	76
Methoxychlor	32	"	2	55, 56	56
Parathion	8	D,WP,EC	8	35 (WP), 95 (EC)	76
Pestox	16	EC	1	41	41
Systox	8	"	3	41, 76	65
TEPP	8	"	2	59, 75	67
Toxaphene	24	"	5	75, 84	75
DDT (16) + BHC (0.9)		D	5	28, 75	53(1)
DDT (16) + Toxaphene (12)		EC	20	0	51(2)
DDT (16) + Toxaphene (12)		"	10	0 (10), 29 (20)	8(3)

(1) Insecticide applied when growth was 4 to 6 inches high and in bud stage.
(2) Same, first and third cuttings.
(3) Insecticide applied 5, 10, 20, 25, or 30 gallons per acre compared with 15 gallons as a check.

A summary of the control obtained in various experiments from 1947-1953 is given in Table 44. Parathion gave good control in most experiments, especially where the webworm was plentiful. DM, endrin, heptachlor, isodrin, metacide, dieldrin, and toxaphene also gave good control. Spraying when the alfalfa was 4 to 6 inches high gave 11.8% better control than spraying at the bud stage. Spraying at the 4- to 6-inch growth atage arid also at the bud stage gave 5.5% better control than spraying only at the 4 to 6 inch stage and 17.3% better control than spraying only at the bud stage. Five gallons of spray per acre gave as good control as did 20 gallons and better control than 10, 25, or 30 gallons per acre. In all cases, treatments were made at 16 ounces of DDT and 12 ounces of toxaphene per acre.

THE ALFALFA CATERPILLAR

The alfalfa caterpillar, Colias eurytheme Bdv., is one of the commonest, most widespread and most constantly present Lepidopterous alfalfa insect in Kansas from early in the season to frost. It is occasionally abundant. It has all the qualifications of a serious alfalfa pest, and it might become so, especially in central and western Kansas. Considerable work has been done on this insect in Arizona because of its abundance in alfalfa. Observations in Kansas alfalfa fields started the spring of 1920.

The following forms and varieties of this species as determined at various times in the past by specialists, Drs. Forbes, Dyar., and Benjamin, from collections during these studies,

Eurymus (Colias) eurytheme form eurytheme (Bdv.) - The typical yellow fom; abundant.

Eurymus eurytheme form alba (Stkr.) - The so-called albino of the above occurs practically altogether in the female; a sex linked color replacement.

Eurymus eurytheme form amphidusa (Bdv.) - Similar to the typical form but with a distinct orange area in the disk of the wings. Common

Eurymus eurytheme form eriphyle (Edw.)- A rare form resembling philodice. In addition the following other pierids, as determined by the same authorities, also occur with the above in clover and alfalfa fields, and several at least have the same food habits.

Eurymus philodice form philodice (Godt.). The common sulphur. Chiefly a flower visitor, but it may occasionally breed in alfalfa.

Eurymus philodice form luteicincta (Wolc.). Much like the above but with orange coloration in the disk of the wings. Rare.

Eurymus philodice form pallidice (Scud.) - The albino of philodice, corresponding to alba above. Fairly common.

Eurymus philodice form miscidice (Scud.) – An abberation in which the smoky border extends over much of the front wing. Rare.

Ascia (Pieris) protodice form protodice (Bdv. and Lee) - Frequent vistor to alfalfa blossoms and probably larva feeds on alfalfa.

Ascia (Pieris) rapae (Linn.) - Frequent in alfalfa fields, but never reared on alfalfa. Chiefly a flower visitor. Cabbage butterfly.

Nathalis iole (Bdv.) Occasional. Larva feeds occasionally on alfalfa.

The best published accounts of the alfalfa caterpillar are those of Wildermuth (1914 and 1920) and Gerould. The only published accounts based on work here are Dean and Smith (1935) and the notes in the annual summaries. It is widely distributed over most of the United States and is especially injurious in the western and southwestern states. Wildermuth (1920) indicated that this insect occurred over the entire United States west of the Alleghenies.

Gerould (1911, 1916) stated that Eurydice crossed with other varieties and that the so-called albino form transmits this characteristic to its progeny. He cited examples of hybridization in this and other species which are sometimes fertile even in unlike strains. Evolution of color in yellow and orange butterflies of the genus Colias (Eurymus) involves white, which exists today in heterozygous conditions of certain females. If ancestors of Colias were white, as in Pierids generally, a mutation occurs in the male producing germ cells of the original white females such that white pigment is replaced by or transmitted into yellow. This makes all the males yellow, leaving all females white, which is true of certain arctic species. A similar mutation affecting the germ cells of white females, but introducing the factor for yellow into half of them, would produce the heterotygous condition found in C. philodice and C. eurytheme. Pure yellow strains may be bred readily from such mixed stock, and hence probably it has come about that 4/5ths or 9/10ths of the females of mutations from yellow to orange and reddish orange affected first the male, then the female. He stated that they have probably occurred in Colias in many parts of the world, especially in warmer climates. Climatic conditoins determine the amount of orange pigment in the cross between the orange eurytheme and the yellow philodice. This hybrid is larger and contains more orange when raised in summer than when bred in late fall and winter, C. philodice is a Mendelian recessive in this cross.

Gerould (1916) said, “Cold weather varieties of Colias eurytheme are produced in large part by arrested development of pigmentation. This is a most remarkable seasonal polymorphic butterfly. It is flamin orange in summer (eurytheme), paler orange-yellow in spring and autumn (called ariadne and keewaydin). These variations are also due to differences in the reaction to the environment of definite Mendelian factors. This is shown by crossing eurytheme and philodice. The yellow segregates clearly from the orange in the F2 generation as a recessive. Hybrids show seasonal polymorphism. F1 hybrids are dilute orange. Orange is, therefore, incompletely dominant. The heterozygote is an intermediate."

Wildermuth (1914, 1920) published basic accounts on the alfalfa caterpillar which were used as a guide in the early stages of the studies summarized here. These two papers were based on observations made in southwestern United States.

The form alba is a white sex-linked variation of the species eurytheme, and pallidice is the corresponding form of the species philodice. The yellow of the wing is replaced by white, the other color markings remaining the same. White males are known though exceedingly rare in the fields but, according to Gerould (1924), their genetical origin is very different from that of these females. A white male form of these two species was never taken during 25 years of observations.

Gerould (1927) concluded that wild, white female butterflies are heterozygous for white female coloration and that, when white ones are bred to normal yellow males, the white pattern is inherited in a three-to-one ratio. The common yellow type is recessive to the less common white form. He also found that eurytheme and philodice hybridize. So all these forms may cross in nature, the general life economy of all the forms being the same. This hybridization makes their identification difficult. Britton (1932) stated that the orange sulfur butterfly Colias (Eurymus) eurytheme Boisdv., was formerly prevalent in the southern Atlantic and middle western states. Color phases were discusbed by Hovanitz (1944) also.

The forms and varieties of the various Pierids from alfalfa have been determined by comparison with identified specimens. These results are shown in Table 45. A comparison of sexes in the various species in collections showed a much greater predominance of males than might be expected from rearings. Though the numbers are small, they are approximately equal in the rearings. Gerould also obtained a slight predominance of males in rearings.

It is not possible to demonstrate why there is this great excess of males in field collections. Gerould, 1941, pointed out that in the Lepidoptera, females require a slightly longer time to develop than males. Gerould (1911) proved this to be the case in these butterflies and, therefore, larvae destined to be females are exposed to the virus disease for a little longer and consequently more females die. Only a slight difference in the developmental period of the sexes was found in these studies. Gerould reported only a slight excess of males with larger numbers, ratios of 1.4 to 1.02.

Table 45. A summary of the collections of the various color forms by sex of the alfalfa caterpillar and related forms during 26 hours of collecting on 14 days from June to September, 1923, at Manhattan, Kansas.

Species or forms	Sex		Totals
	Male	Female	
E. eurytheme f. eurytheme	213	57	270
E. eurytheme f. amphidusa	82	37	119
E. eurytheme f. alba	0	38	38
E. philodice f. philodice	219	119	338
E. philodice f. pallida	0	31	31
Pieris protidice*	10	0	10
Pieris rapae*	6	12	18
Nathalis iole*	1	0	1

* Most of the collections of the last three species, were made by students, in some cases no effort was made to catch these three species. However, they were less abundant than the other species in alfalfa.

A comparison of sexes in collections and rearings at Manhattan, Kansas is given in Table 46.

Table 46. Comparison of sexes in the various species in collections and rearings. Manhattan, Kansas.

Species and forms	Collections		Rearings	
	Females	Males	Females	Males
E. eurytheme f. eurytheme	46	209	8	11
E. eurytheme f. amphidusa	34	74	0	4
E. eurytheme f. alba	48	0	1	0
E. eurytheme form and variety undetermined	134	500	19	21
E. philodice f. philodice	114	209	1	1
E. philodice f. pallida	28	0	0	0
E. philodice form and variety undetermined	28	24	0	0

It was thought that the stage of growth of the alfalfa might account for the presence of all males in a field and the absence of females. When a large number of males and a few females were taken, the alfalfa was in full bloom--attractive for feed and unattractive for oviposition. When all females were taken, the stage of growth was attractive for oviposition, but unattractive for food. There were a few blossoms here and there, probably enough for food for the females present. A person walking through the alfalfa would cause females to dart up out of the alfalfa. Collections at nearly all periods from early morning until late afternoon gave the same results.

There was a marked difference in the proportion of sexes from fields at different stages of growth. Females predominated in fields of young, succulent growth a week or two after cutting. The females oviposited on the young growth and were readily taken while ovipositing. But the question arises--if all of the fields in a community are of one kind or the other, where is the greater number of the male sex? These adults are quite closely confined to the clovers, alfalfa and vetch. They do not feed generally on weeds or other blossoms.

Another complicating factor is that in rearings the female caterpillars required a longer period to reach pupation than the males. This would tend to increase the number of female larvae killed by disease. Collections at certain times as of August 16, 1923, contained only one or two females out of a total of 100 adults.

Food Plants

Alfalfa is its preferred food plant. It has been taken during these studies and reared on crimson, white and sweet clover, prairie pea (Liatrus sp.), garden peas and vetch.

Method of Rearing

Rearings were largely unsuccessful because of the extreme prevalence of a virus disease which killed many larvae before pupation. Bright, new salve boxes or well-cleaned sun-sterilized boxes were usually used, but still fatalities were high. Holes punched in the lid gave no appreciable improvement. Confining larvae in separate semi-transparent peanut sacks, both with and without ventilating holes, tied over alfalfa branches was then tried. Many of the larvae died. Some gnawed holes in the sacks and escaped. The best results were obtained with separate lamp chimney cages over potted alfalfa in as dry a location as possible, but this did not provide for ready examination nor following individuals through their instars. Most of the life histories were obtained in salve box rearings, despite high fatality rates. Small cages similar to those described by Gerould (1911) were used for adults. Dr. Gerould informed the senior author in correspondence that alfalfa caterpillars sent from Kansas were more severely decimated by the virus disease than were those from any other part of the United States.

The larvae ordinarily molted four times. Table 47 gives a summary of the length of each instar from insectary rearings and Table 48 the usual measurements of each instar. The stages have been described by Scudder (1889). The larval stage averages 16.6 days from hatching to the prepupal stage. This allows for a generation a month during the summer. Larvae which have the wilt disease spend a somewhat longer period than the greatest listed in the table in the instar before death. The last instar is sometimes a little prolonged.

Larval coloration of the later instars differed materially from the normal. The blue-gray type reported by Gerould (1941) is fairly common at Manhattan. The deep leaf green is replaced by a lighter green which has a distinct bluish tinge. The body appears somewhat smoother also. Another type of coloration early commented upon by Doctor Gerould as being unusual is a variety of larva with an extra pair of sub-dorsal longitudinal stripes. Gerould (1927) pointed out another variation occurring in the late fall. This form has a pair of black spots dorso-laterally on practically all the segments of the body. They are sometimes faint, but generally are prominent in the middle of the body. None of these three variations in the coloration of the caterpillars could be correlated with any particular form coloration or sex of adults.

Table 47. Summary of the length of stages of the alfalfa butterfly in rearings. Manhattan, Kansas.

Life stage	Days spent	Commonest period during July, days
Egg stage	2 to 7	3
Larval stage	12 to 25	16
Prepupal	1 to 3	1
Pupal (chrysalis)	4 to 14	6
From egg deposition to adult	23 to 32	
Life length of caged butterflies	1 to 10	

Table 48. Alfalfa caterpillar larval instar measurements. Manhattan, Kansas.

Larval stage	Dimension	Maximum mm.	Minimum mm.	Most frequent mm.
First	length	3	1.8	3
First	width of head	0.47	0.3	0.46
Second	length	5	2.5	4
Second	width of head	0.8	0.5	0.7
Third	length	9	4	5
Third	width of head	1.3	1.0	1.2
Fourth	length	17	10	12
Fourth	width of head	2.4	1.4	2.0
Fifth	length	28	18	20
Fifth	width of head	3.3	2.1	3.2

When the hybridization of these forms and species is considered, the lack of greater variation in larval color patterns is surprising.

Seasonal History

The manner of overwintering was not definitely determined, as individuals could not be carried over winter alive regularly in any stage. Bits of evidence, however, indicate that it winters chiefly as small larvae and probably also as pupae in Kansas because adults appear as early as the last of March and early April. Gerould wintered small larvae in a wash boiler and a tub of beets and carrots in a rather dry cellar. It was impossible to carry any larvae through the winter at Manhattan following his method rather closely for three years. Scudder (1889) stated that this species wintered as hibernating caterpillars and adults in Nebraska and Illinois. It is altogether probable that the species hibernates in any stage except the egg, but the stage varies with the locality. Five larvae, one third to half grown, were found in alfalfa on the southern slope near Manhattan March 10, 1927. The growth of alfalfa was several weeks ahead of that in the open field. Since no adults were out prior to that date, the small larvae must have overwintered. Several half or nearly grown alfalfa caterpillars were found in alfalfa clumps April 15, 1931. This is circumstantial evidence of overwintering as larvae. Occasional yellow butterflies had been out in fields for several weeks. This is near positive proof of overwintering in the larval stage.

Adults are fairly plentiful in late April and early May. They deposit eggs from which the larvae mature from late May to late June in Kansas. The second generation adults begin to appear about June 1, but the majority of the adults appear about mid-August. Eggs are deposited for a third generation which may mature in October or November. All sizes of larvae could be taken during most of the season, and especially during the fall, so considerable overlapping of broods normally occurs. In regularly cut fields, a brood develops on each growth. There was a maximum of four full broods in Kansas or three full and a partial fourth, The seasonal activity of this species at Manhattan, Kansas, is summarized in Table 49.

Table 49. Seasonal sequence of generations of the alfalfa caterpillar, Manhattan, Kansas.

Generation	Life form	Dates
First	butterflies	March 20 to April 30
First	caterpillars	April 1 to May 10
Second	butterflies	May 1 to June 15
Second	caterpillars	May 15 to June 20
Third	butterflies	June 20 to July 20
Third	caterpillars	June 25 to August 10
Fourth	butterflies	July 25 to August 23
Fourth	caterpillars	August 10 to September 15
Fifth	butterflies	September 15 to October 30
Fifth	caterpillars and over-wintering chrysalids	September 20 to November 1

Life History and Stages

The upright, elongate white eggs are deposited singly on alfalfa foliage. The female bends the abdomen strongly forward and touches the leaf surface usually selecting the upper but occasionally the lower surface and in rare cases the stems. The egg appears immediately and is held for an instant with the base in contact with the leaf. The attachment hardens quickly, the abdomen is lifted to a horizontal position, and the egg is left standing stiffly upright. The female may then deposit another on the plant, but she usually flies a short distance to another plant, thus scattering eggs over the field. As many as 200 eggs may be deposited in one night. A total of about 400 are deposited, though counts from captive females rarely reached 300. Wildermuth (1920) stated that the female lays from 200 to 500 eggs during her brief life of about two weeks.

In a day or less, the eggs turn pink, then reddish. The period of embryonic development varies from three to ten days, the seasonal average being about six days. The larvae emerge from the eggs through a circular. hole chewed by them through the chorion. The egg shell is quite glassy and colorless after hatching.

The young larvae are dark with disproportionately large, black heads. They bear little resemblance to the green larval stage of later instars. The larvae, when grown, climb alfalfa and web together some of the upper leaves to form a shelter. Then the caudal end is spun fast. The little loop of silk is spun around the thorax. There is a thin and somewhat irregular mat of silk under the larva. It then bends inward and shortens. The prepupal molt occurs in a day or sometimes a little more. These little shelters can be fairly easily recognized in a field. The upper leaves are somewhat bent over, suggesting a wilting tip. There are, however, some pupae lower on the stem and parallel to the stem. A few pupae can be taken by sweeping.

The 164 pupae, in rearings during June and July, 1935-1941, required an average of 8.02 days for development, the range being 6 to 12 days.

Descriptions

The first instar alfalfa caterpillar has a jet black head with nine short, blunt-ended hyaline setae each side of the occipital suture which is of five parts; a narrow band on which there are four short, blunt setae each side; on the prothorax these extend forward. Behind this narrow segment are four sub-segments, quite narrow and set off by sutures. The chitin of these four small sub-segments is quite sculptured and reticulated. On the abdomen, there are but two pairs of the short hyaline blunt setae on the anterior sub-segment, but there are two more setae on the third of the small sub-segments posteriorly. These are wider apart than the first two. This scheme continues on the first seven segments of the abdomen. Beyond this, the segmentation and setal maps are different. There are four rows on each segment and one row of two each side of the dorsal vessel. Another row of the same number occurs laterally.

The larva appears quite dark. It feeds by eating the upper surface from the leaves. Each was found resting on the dorsum of the leaves along the mid-rib.

Measurements of head capsules and body lengths are summarized in Table 48.

The head capsule of the second instar larva is wholly green, hence molted larvae are readily recognized. It is lighter green and quite thickly covered with a great number of short, hyaline, knobbed setae both head and body. Each is attached to a small black papilla with a smooth circular area surrounding the base. These are in irregular, longitudinal rows. Between these smooth spaces, the cuticula is sculptured with black points or irregularities.

The head capsule of the second instar ready to molt, is brownish, appears quite small and is attached to the end of the larva like a cap. The prothorax is much elongated, broader than the head, and lighter green. The cuticula is visibly stretched. The crescent of eyes can be seen on either side of the prothorax. The larva remains motionless during molting.

The head and body of the third instar alfalfa caterpillar and body are light green, closely set with small hyaline setae which are expanded little, if any, at the tips. There setae are more or less in rows on the body and in fairly regular distribution on the head.

The head is large in proportion to the body, the papillae dark green to blackish, the head shining, light green, and the dorsal occipital suture deep and prominent.

The body is light green, divided into many small sub-segments. The pattern is by 6's--first a broader subsegment, followed by five quite narrow subsegments beset with one or two rows each of short hyaline setae. Over the prothorax and mesathorax there are four; over the metathorax, there are five. Over all of the abdomen there are six small subsegments, except the last two which appear to have but five each. The papillae are blackish surrounded by a light green, smooth, circular area. Between these areas, the surface is reticulated with a blackish pattern.

The fourth instar alfalfa caterpillar resembles the grown larva except for size. The head is wholly light green. The previous scattered short setae are present, and, in addition, many more shorter hyaline hairs are interspersed. The setae are on small brownish papillae. The spaces between the setae are filled with somewhat irregular, grayish-green or washed green spots making the head appear spotted when magnified. The eyes form a crescent, three are quite large and black, one is small and black, another is green.

The body is deep green and the dorsum is subdivided into 4 to 6 sub-segments to each segment. Three sizes of setae appear in somewhat irregular rows on each segment. Each seta is on a papilla proportionate in size to the hair, which is lighter green and brownish at tips. On the side is an ivory-white stripe extending through the spiracles from head to the base of the anal proleg. Below the spiracles, the small segments unite into a single segment or rather the sutures or wrinkles dividing them disappear above the ivory band. At the posterior end of the body, the subsegments are broader and reduced in number to two or three. The spiracles are yellow, with amber brown rings. The venter is the same green as the dorsum and about as thickly set with setae and hairs. Recognition characters of instar--first appearance of lateral broad ivory-white line and spotted condition of head.

The fifth instar resembles the fourth instar closely and differs only as to size and increase in the number of setae on the sub-segments. The head, light green, grayish mottled, with many scattered but approximately equally spaced spinuli or setae and the areas between the setae are largely taken up with the yellowish-green or light green spots. The body is formed into many small subsegments as before, three to six subsegments to a body segment. The first one is broader than any other. Many small, colorless setae are scattered over the segments. Each seta arises from a small black papilla set in a light green, smooth circle. Between these areas, the surface of the cuticula is roughened or sculptured slightly. On the side of the body, extending through spiracles, is a broad silvery-white band in which there is a smaller and incomplete red band extending from the head to the anal proleg.

The abdomen has five pairs of prolegs including the anal prolegs; abdominal legs in groups--on segments 3 and 4, 5 and 6, and at end of abdomen. Venter is uniform green but lighter than dorsum. Thoracic legs are light green and extend forward.

The larva may spin a silk thread to drop itself to safety. The larva described was probably slightly beyond the middle of the instar.

The sixth instar, when it occurs, is light green much like the previous instar except the light green areas around the base of the setae are much less obscure and there is red or salmon pink in the lateral stripe.

The head is green, thickly beset with small, short, colorless setae with black papillae at bases. The light spots between the setae are obscure. Body is light green, divided into the sub-segments as before.

Each body segment consists of three to six sub-segments--six being the number on the abdomen--one broad segment and five smaller ones, all with many short black and few colorless setae on black papillae arranged about equidistance from each other. Around each papilla there is an obscure, lighter green, circular area. A shining white lateral stripe running through the spiracles is broad and conspicuous, with a complete and conspicuous salmon stripe slightly below the middle of the whiter stripe. Five pairs of abdominal prolegs are present including the anal prolegs. The venter is uniformly lighter green than the dorsum. The larva described was near the prepupal stage. It had spun some silk and was restless. The setae on the sub-segments occupied about four irregular equally spaced rows. Total time from hatching to pupation in July was 17 to 19 days, and from hatching to adult in July was 23 days.

Natural Control

Many larvae were eaten by predators, both birds and insects, but most succumbed from disease.

This species ranked third in number as to species in the third growth alfalfa left for seed September 8, 1921. Despite parasites, predators and disease, many go through to adults judging by the large number of yellow butterflies present. A nabid nymph was observed feeding on an alfalfa caterpillar. It was almost full grown and the caterpillar was about half grown. A coreid, Coriscus fuscous and Chrysopa plorabunda larvae were observed feeding on alfalfa caterpillars July, 1922.

English sparrows on several occasions hovered 2 or 3 feet above alfalfa then darted down and pulled off a larva in areas where alfalfa caterpillars and garden webworm larvae were abundant. The majority of the larvae caught were the latter, for the plant would sway as the larva let go. At other, times, it seemed as if the larvae were being pulled from a sort of nest. At least one larva was an alfalfa caterpillar. On August 11, 1922, a kingbird was observed flying out over the alfalfa, poised like a hawk; it than darted down and pulled a larva from the foliage and'fed it to one of the young birds. She quickly caught perhaps a half dozen larvae. Martins catch the yellow and white butterflies on the wing.

September 8, 1921, quite a few of the chrysalids of alfalfa caterpillars in the field had been partly eaten by corn earworms. Counts of the injured and uninjured pupae showed that, of 34 pupae, 11 had been more or less eaten by earworms. The remaining 23 were in perfect condition. Earworms begin to devour pupae by eating a small hole, usually near the anterior part of the abdomen. They may eat other holes and, in some cases, most of the pupa is devoured. No prepupae had been touched. The work of the earworms, while important, must nevertheless be only a small check on the pest a's the butterflies remained abundant.

Ants fed on and kiIled pupae in rearings.

Polyhedrosis. This insect is largely held in check by a disease Chapman and Glaser (1916) called a polyhedral disease. This disease is caused by an ultra-filterable virus which invades the bodies of the caterpillars, and the polyhedral bodies or "crystals" arise as a reaction against the invasion of the virus. These bodies arise within the nucleus of hypodermal, fat, tracheal, matrix and blood cells. The nuclei become swollen within them and finally disintegrate, allowing the crystals to mingle with the body fluids. They are, therefore, degenerative products of the disease or products of nuclear disintegration.

Steinhaus (1948) gave a history of this disease. It was first reported in 1888 and has been commonly called "wilt." The first published account was provided by Wildermuth (1911, 1914). Dean and Smith (1935) first correctly ascribed the disease to a polyhedral virus in a publication. Steinhaus calls the disease polyhedrosis of the alfalfa caterpillar.

Young larvae of the first two instars are rarely, if ever, affected. It commonly appears first in the third and fourth instars, though death may not result until the last two instars. Nearly grown larvae appear to be resistant to a greater extent than in the two or three previous instars. If larvae are kept free from the disease to the last instar, pupation may be expected and the adult will emerge. This is the only way any adults could be obtained in rearings. Larvae infected earlier may pupate, but the disease causes the contents of the pupa to liquefy. In rearings, only about 10 per cent of larvae started successfully emerged as adults. In many rearings, every larva was lost because of this disease. The percentage emerging in the field is probably 50 to 75, but there normally is a marked death rate in the field which varies with several factors. Dead larvae and pupae which show the usual characteristics of the disease can be found easily on alfalfa.

Larvae destined to die of this polyhedral disease first show symptoms with a slight "off color" appearance. Instead of the healthy uniform leaf-green coloration, they have a slightly yellowish tinge. This may include the coloration in general or there may be scattered spots of lighter green or yellowish green over the body. Otherwise, the caterpillar appears normal. The second day, the larva is distinctly spotted with yellowish-green, smoky green, or blackish spots. It also is somewhat less active then. The third day, the larva is smoky and fast becoming soft and flabby. Within the next 24 hours, the body contents become liquid, the body soft, the exterior smoky or black, and it is either dead or nearly so. Sometimes the disease begins posteriorly and goes forward. In such cases, the anterior end of the larva may exhibit movement while the posterior portion is dead and decaying. In the final stage, it turns brown, the body wall bursts, allowing the liquefied contents to escape. The brown deflated body dries on the plant and can be seen for several weeks. In rearing chambers, a very foul odor accompanies this disease.

Larvae were reared in temperature-moisture controlled cages. Results were inconclusive because larvae and food known to be free from the disease to serve as checks were not available. However, there was an indication that humidity is a more important factor than temperature in the prevalence and rate of development of this disease. A somewhat higher percentage of the larvae died when the humidity approached 100 per cent than when it was around 60 per cent with the temperature fairly constant. The disease progressed more rapidly in individuals at higher temperatures (90^{o} to 95^{o}F.)

than at lower temperatures (65^o to 75^o F.) with humidity not fluctuating widely, around 70 per cent.

These studies are not regarded as final, but field observations bear out the above indications. This disease is much worse in wet years than in dry years. It is apparently commoner in eastern Kansas than in central Kansas. It is less common in the dry, or even irrigated Southwest where this insect is a serious alfalfa pest, but the disease sometimes is an effective check according to Wildermuth.

The pathogen is apparently spread in many ways, by contact, wind, rain and on leaves. Newly hatched larvae from laboratory ovipositions, put in new boxes, developed the disease presumably from the alfalfa food. Adults may transmit the disease too. The pathogen may be spread by the dust from dried and dead larvae, larval contents, or excrement of infested larvae. These materials were practically certain to cause this or a similar disease to develop in other larvae of the same species or to a lesser extent to widely different species such as some of the Noctuid larvae studied. Disinfection with a 3 per cent solution of formalin, 2 per cent solution of mercuric chloride, or exposing to the hot sun for a day or more reduced mortality.

Parasitic enemies. Parasitic enemies have always been less of a natural check on alfalfa caterpillars than the above described disease. Several parasites, all previously reported, were reared: Phorocera claripennis Mcq. (Tachinidae was the commonest fly parasite; Archytus analis A. was reared several times. It required 8 to 11 days for the pupal stage; Pteromalus eurymi (Gahan.) (Braconidae) was reared from pupae several times. It overwintered as pupae in the alfalfa caterpillar chrysalis.

Large tachinid flies were abundant everywhere on sweet clover fields visited July 10, 1918. July 9, 1923, there was such a humming over alfalfa and sweet clover bloom that the flies sounded like honeybees. Archytas analis was the dominant species. The flies were plentiful over alfalfa stubble, apparently looking for host larvae, chiefly alfalfa caterpillars, green clover worms, and forage loopers.

Chalcis ovata is a parasite which emerges from the pupa of the alfalfa caterpillar. It may not be so important since the damage by the larvae is not prevented. The Chalcid apparently deposits its eggs in the larva. The larval host continues and pupates normally. However, instead of the normal green coloration with the developing butterfly within, the chrysalid turns a dull grayish-green and the body wall becomes hard. About the time for the emergence, 25 to 50 adult parasites emerge. The numbers of the two sexes appear to be equal. The males perch on the backs of the females as do the alfalfa seed chalcids, and stroke the antennae of the females, attempting to copulate.

Three alfalfa caterpillar chrysalids in a jar August 23, 1935, yielded parasitic wasps. Whether these all came from one chrysalid or from 2 or 3 was not known., All had the round emergence holes. Females generally are larger than males, antennae are largely black, the dorsum of the thorax is black or blue-black, and the tip of the abdomen has a small pointed projection.

The abdomen is blue-black. The ovipositor shows clearly on the venter. The smaller males have yellow antennae and coppery-black bodies. The genitalia are extruded at death.

A parasite of the eggs is Trichogramma minutum. Some eggs were collected August 20, 1928; eleven days later seven small wasps emerged from one egg. Having no other Eurymus eggs for hosts, two eggs of Danaus (milkweed butterfly) were obtained and put in with the parasites. In less than two minutes, the females were ovipositing. They oviposited in one place about 10 minutes. One female changed positions on one egg three times. The adults lived 52 hours (maximum). At each place where the female thrust the ovipositor through the egg shell, a black spot appeared. The adults did not feed on sweetened water nor crushed host eggs but they were very active. Seven days were spent in the pupal stage, June, 1924.

Alfalfa Varieties Related to Alfalfa Caterpillars

It was noted in 1925 that the populations differed among various strains (Table 50). Provence with 33, followed by Italian and Dakota Common, had the most larvae while Grimm with six followed by Argentine and Sunflower had the least.

Table 50. Number of alfalfa caterpillars per 15 sweeps in the alfalfa variety test, Manhattan, Kansas, 1925. None was taken in sweepings April 10 and June 6; 1 on June 19 on Cape Lucern.

Variety or strain	July 8	July 24	Aug. 27	Variety total
Argentine	2	4	5	11
Cape Lucern	2	3	14	20
Cossack	2	4	8	14
Dakota Common	1	2	19	22
Dakota #12	1	8		17
Grimm	0	1	5	6
Italian	3	6	15	24
Kansas Common	2	2	6	10
Kansas 435	3	4	8	15
Ladak	1	5	12	18
Provence	3	10	20	33
Spanish	2	2	16	20
Sunflower	1	3	9	13
Turkestan	4	6	9	19
Utah	0	3	13	16
Date total	27	63	167	268

Artificial Control

Smith and MacLeod (1943) stated that Colias eurytheme Bdv. was the most important alfalfa pest in the southwestern states, and in spite of the effectiveness of natural control by the wilt disease and by a parasite, larvae frequently caused serious damage. Hitherto, the authors stated that contact insecticides had proved ineffective or too expensive, and poisons offered a hazard to livestock. Trials indicated excellent results were obtained by treating 8-inch alfalfa with 325-mesh dusting sulfur at 75 lb. per acre without a residue problem. The sulfur did not affect either the parasite or wilt disease. They also speculated that it might be beneficial as a soil amendment.

Artificial control has never been necessary in Kansas. Experiments in alfalfa insect control where records of the alfalfa caterpillar were also included show that good control can be obtained by most of the newer insecticides (Table 51). Control was as effective on the second cutting as on the first or third cuttings. Also, 5 gallons of spray gave as good control as using 15 or even 30 gallons per acre.

Nearly all caterpillars perish or are destroyed following the cutting of the crop because a new generation of larvae must be reared from eggs deposited on the new growth. Frequently many pupae were found on the ground after the hay was cut and raked into windrows. Pupae from which adults were nearly ready to emerge produced perfect adults in cages, but in practically all other cases the adults had crumpled wings and were otherwise imperfect.

Hovanitz (1944) stated that physiological and genetical data on the alfalfa and clover butterflies (Colias = Eurymus) of North America have indicated several means of control now in progress and others by which it would be possible in some areas to disrupt the normal living conditions so populations would be reduced to the level of economic control.

The behavior of the female in laying eggs is primarily that of a transient--a single egg at one time and place. A great number of females must be available in the vicinity of a freshly cut field if enough eggs are laid at the right time to affect the crop disastrously. Great destruction of the pest would result from the cutting of fields in cooperation among ranchers, so that the fields of one could not produce adults for laying eggs on the fields of his neighbor. This procedure will wipe out almost any genesation of Colias in a region. Hovanitz reported the destructiveness of Colias is closely correlated with climatic conditions and the abundance of alfalfa fields.

July 21, 1923, quite a few chrysalids were found on the ground after cutting at the University agronomy farm whereas none was found on the ground before cutting. Only a small minority were on the stalks so low that they remained attached. Most were entirely free from visible disease symptoms or parasites. Some had been injured and killed by being trampled or pierced by stubble, but the great majority were not injured.

It was observed July 23, 1932, in a stubble field that quite a few butterflies with crumpled wings were fluttering around. Perhaps they had emerged from pupae on the ground following cutting and were injured by the high temperature. Perhaps lying on one side was not suitable for emergence. At any rate, they died prematurely. Some empty pupal skins and some partially devoured pupae were seen on the ground. It was surprising that any pupae would survive the extreme heat (Smith, 1956)

Sprays for practical control. (See Tables 51, 58, 61, 64, and 67). Spraying infested fields with a suspension of the polyhedral virus obtained from caterpillars killed by the disease has been tested for control of alfalfa caterpillars in California and Arizona. Clark (1955) said the microbial method of control with the virus has been known for 50 years, but its identity only about 10 years. The virus can be increased by spraying a field with a virus suspension, then collecting the dead and dying larvae after the incubation period of 4 to 7 days. The larvae are ground up and suspended in water. One pint of the suspension treats 50 acres. Application may be made by either ground rig or aircraft. The critical factor is proper timing of the treatment. Application must be made when the population is in the third instar but applications for the first, second, and early third instars gave good results. Applications for the later instars give control but did not prevent damage by the caterpillars.

Table 51. Summary of insecticidal control tests for the alfalfa caterpillar in the various alfalfa experimental plots. All treatments consisted of a single application of the insecticide at 15 gallons of solution per acre at the bud stage on the second cutting of alfalfa unless otherwise indicated. Manhattan and Hays, Kansas, 1947-1953. WC = Wettable powder; D = Dust; EC =Emulsifiable concentrate.

Insecticide	Rate ounces per acre	Formulation	No. of tests	Per cent control Range Low and high	Average 1 to 7 yrs.
Aldrin	8	EC	6	90, 100	94
BHC	1, 1.9, 4	All	6	55 (1.9, WP), 100 (4, EC)	84
Chlordane	16	"	6	85 (EC), 100 (EC)	81
DDT	16, 32	"	14	74 (16, EC), 100 (16, 32, All)	91
Dieldrin	8	EC	5	60, 100	92
Endrin	4	"	1	100	100
EPN	8	"	1	75	75
Isodrin	8	"	1	92	92
Heptachlor	8	"	1	100	100
Metacide	4, 8	"	3	75 (8), 100 (4)	84
Methoxychlor	32	"	3	100	100
Parathion	4, 8	All	5	90 (8,EC), 100(All)	99
Systox	8	EC	2	100	100
TEPP	8	"	2	67, 85	76
Toxaphene	24	"	5	100	100
DDT (16) + BHC (0.9)		D	6	20, 100	75(1)
DDT (16) + Toxaphene (12)		EC	20	0, 100	55(2)
Same, 5, 10, 20, 25, 30 gals. applied. Check 15 gals.			15	100 (All)	100

(1) Insecticide applied on 4- to 6-inch growth.
(2) Same and in bud stage of first and third cuttings.

Adding Bacillus thuringrensis to the spray was said to make it more residual and help in the timing. This control method is practical and, economical.

THE CLOVER SEED CHALCID

The clover seed chalcid (Bruchophagus gibbus (Boh.)), also called alfalfa seed chalcid, ranks close to a major alfalfa pest in Kansas. It was somewhat prominent nearly every year of these studies. Many times it was so abundant in farmer-held seed in the spring that it was considered a stored grain pest. Since the chalcid does not propagate in dry seed, the damage is already done by the time the pods are developed.

This is a difficult insect to study because of its small size. Nevertheless, its importance makes more intensive study highly desirable. Kansas ranked first to third among all states in both acreage of alfalfa and in seed production up to 1957. Consequently, several years of favorable weather for seed production allows this species to reach damaging populations. Grandfield and Franklin (1952) gave infestation by this species as a reason why growers often harvest a small crop of seed when conditions otherwise favor a large seed crop. Its incidence was at least partially responsible for the low seed yields in Kansas which Glenn and Pallesen (1954) placed at only 76 pounds per acre for a 10-year average. This chalcid was abundant in 1921, 1926, and 1930. In 1921, as many as 78 per cent of the seed pods of alfalfa and burr clover had holes like these made in emerging. In 1926, damaged seed reached approximately 50 per cent.

Damage

Larvae feed within alfalfa and clover seeds, destroying them. There is usually nothing but the seed coat left. Black and shrivelled seed was thought to be caused, at least in part, by chalcids, but this could not be demonstrated experimentally.

About half of the alfalfa seed pods examined had more than one hole. Two holes are fairly common, while three and four were readily found when the insects were numerous. These small circular holes are clearly chewed out by the adults at emergence, and are somewhat jagged.

Both Dean (1916) and Dean and Smith (1935) included brief descriptions of the clover seed chalcid, its distribution, seasonal history, damage and control. The account of Urbahns (1920) was followed as a basis for these studies. The life history is included in that account and in the excellent earlier discussion by Folsom (1909).

Crosby and Leonard (1916) stated that this chalcid made seed production uncertain and at that time it was the worst enemy of seed production. They said the chalcids occurred in clover heads throughout the season.

Clover seed heads and alfalfa seed pods were gathered along the fence rows or ditches at Manhattan in August, 1921, and held in cloth-covered jars for emergence of the adults. The clover seed heads collected showed a high infestation by clover seed chalcids. Forty-one per cent of the heads collected August 9 and 88 per cent of the heads collected August 22 were infested with chalcids. In the latter case, 17 heads were observed. As many as five chalcids emerged from one head.

Chalcid adults were noticeably plentiful in sweepings June 29, 1921. Of 18 heads observed, 77 per cent were infested September 6. A summary of the extent of chalcid infested seed, 1917-1940, is given in Table 52.

Dr. E. G. Kelly, former extension entomologist, upon his return from the wheat train August 19, 1930, reported an outbreak of the clover seed chalcid in Kansas. Farmers had told him they had poor yields as most of their alfalfa seed was blown out with the trash when they threshed it because the seeds were hollowed by the chalcid.

Oviposition

August 14, 1933, between 9: 30 and 11:00 a.m., observations were made on oviposition in the field. Several females thrust their ovipositors for an instant into the pods which were in the right stage of development, and then moved to another place in the same pod or to another pod to repeat the process. Pods in which females apparently oviposited were immediately brought into the laboratory and placed in lamp chimney cages. August 21, no larvae were found and no injured seeds were apparent. It was noticed that the pods were drying and the seeds shrinking, which may have accounted for the absence of larvae. The seeds probably dried up before the eggs hatched or at least before the larvae developed to any extent. On the other hand, females may not have oviposited in the pods, but were merely testing the seeds in an attempt to find one at the proper stage for oviposition. This study was repeated several times, with the same results.

A heavy emergence of chalcids at Manhattan and an even heavier emergence at Hays occurred September 9, 1926. A number of adults were placed in a large bottle with a bouquet of alfalfa twigs, with both young and old seed pods, others with flowers or the petals just fallen. The chalcids soon copulated. The next morning, females were seen with ovipositors inserted in the green pods, presumably ovipositing. All were ovipositing in young green pods except one which was ovipositing in the ovary of a flower devoid of petals. Again, the chalcids could not be reared with this arrangement.

Pods had one to four emergence holes located in all surfaces of the pods. Most had some “frass” around the hole. Good seeds occurred in practically every pod whether infested or not. Most seeds were rather wrinkled and misshaped. As high as 42 per cent of the seed pods found August, 1926, showed present or past infestations.

Alfalfa seed pods June 18, 1931, yielded a large number of chalcids. Alfalfa blossoms were placed in a flask with a large number of adults but eggs were not deposited. They paid little attention to the heads. There were almost constant attempts at copulation. The adults are decidedly phototropic. This characteristic was used in getting them out of the vials. Ninety-one adults were collected September 12, 1934, in 25 sweeps of a net.

Green alfalfa seed pods were collected August 10, 1933, and larvae and pupae dissected from the discolored, pale green to brownish, seeds. Such

Table 52. A summary of chalcid infestations in Kansas as indicated by infested seed or emergence of adults from collected seed pods.

Date	Seeds examined	Infested seeds or emerged adults	Remarks
1917	100	33	First crop.
1917	100	47	Second crop.
1917	100	9	Third crop.
1926, August 3	750	143	
1930, August 30	125	10	
1931, August 13	427	8	
1933, August 1-10	3100	136	
1933, August 10	500	32	Dry pods collected.
1935, August 15	195	31	From 36 pods, 26 black seeds.
1935, August 16	74	54	13 seed pods, 16 seeds infested, 4 shrivelled.
1935, August 19	82	26	29 seeds shrivelled.
1935, August 30	21	3	1 shrivelled.
1936, August 18	397	29	From 85 pods, 15 seed heads, 26 infested pods.
1938, July 12, Aug. 3	806	3	
1940, Sept. 14	25 pods	16 pods	

* * * * *

By contrast, of 14,047 alfalfa seeds collected from October 21 to December 10, 1909, at Phoenix, Arizona, by G. F. Freeman, 10,422 were infested or damaged by chalcids, leaving only 3,625 good seeds.

seeds often appeared , also, shrunken or shrivelled when the included insect was well along towards maturity. The insect apparently did not pupate until the pod and seeds began to dry. When pupation began, there was nothing left of the seed but the brown seed coat.

The question often arises whether chalcids emerging from seed lay eggs in other seed in the sack and reduce it to powder as the bean weevil does beans. This point has not been stressed in accounts of the chalcids. Apparently this insect lays its eggs only on the green pods and the larvae feed only on the soft developing seed.

Urbahns (1920) stated that sweet clover seed was not attacked by the chalcid. This insect was not reared from sweet clover seed during these studies.

There were indications from collections that common crimson clover heads were preferred to alfalfa. Only stray plants or small patches of clover in out-of-the-way places were observed, but they were generally severely attacked. This condition was used to obtain adults quickly.

Seasonal History

The heaviest emergence of the first generation in Kansas occurs the latter part of June and continues through early July. Ordinarily the alfalfa for hay is cut before seed has formed so these observations have been made largely on alfalfa along roadsides, ditches, and fence rows. The second generation of adults began to emerge the middle of August. This is the time the preferred second cutting of alfalfa is flowering and setting seed. There is a third generation normally reared which either emerges the latter part of September or overwinters in the seeds. The adults from overwintering larvae emerge in April or May. There are, therefore, three full generations in Kansas. At Hays there was a slight but nonsignificant increase of infested seed in the second cutting over the first, and third cutting over the second (Table 53).

Table 53. Average number of clover seed chalcid infested seed per 100 seeds in the insecticide control plots at Hays, Kansas, 1950-1953. Insecticide applied at the bud stage of each cutting.

Cutting left for seed	Average number of infested seeds per 100 seeds
First[1]	2.39
Second	2.77
Third	3.72

1 Treatment, data, block, and treatment x date interaction L.S.D. 5% - N.S.

There is considerable overlapping of life cycles so that the broods are difficult to follow. Seed gathered almost any time after July 1 will produce adults in a week or ten days.

Natural Control

There were strong indications that the insect is more abundant during dry than wet summers. For example, the summer of 1926 was particularly dry, and these insects were abundant both at Manhattan and at Hays. Rains at the time of egg laying as the flowers are drying hinder oviposition, kill adults, and hasten the maturity of the seed. The western and drier parts of Kansas have grown the most alfalfa seed and usually had the most damage.

This species is heavily parasitized. This is thought to be largely responsible for the usual reduction in numbers in September and October.

Urbahns (1916) described the life history and stages of _Habrocytus medicaginis_ Gahan, a rare parasite on _B. gibbus._ His studies were made in Arizona, but he reported the parasite also from California, Oregon, Idaho, Utah, and Wellington, Kansas. It has emerged from both clover and alfalfa seeds. However, the rate of parasitism was found to be no higher than 4.9 per cent at Yuma, Ariz.

Urbahns (1917) gave a general account of the distribution, life history, and importance of _Tetrastichus bruchophagi_ Gahan, another parasite of the chalcid, in alfalfa seed. It was described from California, but it was also reared from infested seed from Oregon, Virginia, Indiana, Ohio, Nebraska, and some other states. There are two to four generations a year and it hibernates as a larva. It was said to be of considerable importance in controlling the chalcid on both clovers and alfalfa.

Artificial Control

Most commonly used for seed in Kansas are the second, third, and fourth cuttings. These occur during July, August, and September. Locally, the seed pods of uncut alfalfa in waste places have been examined to determine the degree of infestation before deciding whether a field should be left for seed or not. If the percentage of infestation is high, it appears advisable not to let an ordinary or poor crop go to seed. If the stand, however, is good, the bloom unusually heavy, and there is a low infestation of the chalcid and the midge _(Dasyneura leguminicola)_, seed prospects are likely to be good. Recent observations of tripping by bees introduces another factor.

Cutting the wild or volunteer alfalfa along fences and roadsides regularly, as is often recommended, is certainly an important though not an absolute control measure.

Carlson et al (1950) listed the following six practices recommended to aid in controlling chalcids: 1. All farmers in a seed area should harvest seed from the same crop, preferably the second. 2. Manage the seed crop to ripen as uniformly as possible. 3. Harvest the crop promptly. 4. Prevent volunteer alfalfa and bur, red, or crimson clovers from forming pods. 5. Eliminate chaff stacks before chalcids emerge in the spring. 6. Reclean all seed and destroy or feed all screenings.

Wildermuth (1931) suggested cultivating the alfalfa in the fall and winter to help control chalcids. It was thought that covering the seed with soil would cause the seed to decay, killing the larvae. Cultivation is not normally recommended in Kansas. However, the other cultural practices recommended by Wildermuth and also by Carlson help with control. But this requires community cooperation which is difficult to obtain since many farmers do not decide to cut for hay or leave for seed until too late to follow through on all of the recommended practices. Many times it is the pressure of other work, rather than a definite plan for a seed crop, that makes a farmer decide to let a particular cutting go for seed.

Insecticides. Chemical control of injurious insects was applied in a similar fashion from 1950 to lg.53 in four different sets of experiments. One of these has been given in Table 53. In all four experiments racemes were selected at random over the plot at the full bloom stage and the florets counted. Each raceme was tagged and let stand until just before harvest. Then they were collected, placed in separate manila envelopes and allowed to stay in a warm room for six months or more before examining. The number of seed pods and the number of good seed and hollow seed caused by chalcid infestation were recorded for each pod. From this method the number of clover seed chalcids per 100 seeds was determined. When left for seed, 16 ounces of DDT plus 12 ounces of toxaphene per acre was applied to the plots on each cutting at the bud stage. Thus there was a slight increase from cutting to cutting but no significant difference.

During 1950-53, five insecticides were used at the same rates each year (Table 54). The data for 1951 were eliminated since floods destroyed the seed crop. Only parathion, with an average of 12.3 chalcid infested seed per 100 seeds, gave significantly lower infestation than the other treated or check plots. This resulted apparently from the lack of chalcid control in 1950 when all treatments except parathion had almost 50% infestation.

In the other two years of lighter chalcid infestation, there was little difference among the treatments. All treatments reduced the population level by almost 50%. The difference in population levels between 1950 and 1952 was highly significant. The difference between population levels in 1952 and 1953 was almost significant.

During the same four years, there was no significant difference in chalcid population when DDT was used at the rate of 16 ounces or 32 ounces per acre (Table 55).

In the fourth separate experiment from 1950 to 1953 (Table 56), there was no difference in chalcid infestation when insecticides were applied when the plant growth, on the second cutting reached 4 to 6 inches high, at the bud stage of growth, or at both times. Also there was no difference in population levels in 1950 and 1951. There was a highly significant decrease in population levels from 1951 to 1952 and a further significant decrease from 1952 to 1953.

Table 54. Average number of chalcid infested alfalfa seeds per 100 seeds in the experiments comparing the effectiveness of several insecticides in insect control, Fort Hays Branch Experiment Station, Hays, Kansas. 1950-1953.

Insecticide used	Rate oz./acre	Average number of infested seed per 100 seeds: 1950	1952	1953	Treatment average
Original data					
Check	--	58.3	7.3	7.0	24.2
Parathion	4	12.0	3.3	0.0	5.1
DDT	32	51.0	3.7	0.7	18.4
Toxaphene	24	52.0	4.7	1.3	19.3
Dieldrin	8	59.0	3.0	1.0	20.9
Aldrin	8	58.0	4.0	0.7	20.9
Transformed data - log of (x t 1)					
Check2	--	51.7[1]	16.3	14.3	27.4
Parathion	4	19.0	12.0	6.0	12.3
DDT	32	46.3	12.3	7.3	22.0
Toxaphene	24	46.7	13.3	8.7	22.9
Dieldrin	8	50.7	11.0	8.0	23.2
Aldrin	8	50.7	12.7	7.3	23.6
Year Average		44.2	12.9	8.6	--
			Treatment L.S.D. 5%		7.7

1 Date L.S.D. 5% = 5.0

2 Treatment x date not significant.

Table 55. Average number of alfalfa seed infested by chalcids per 100 seeds in the rate of insecticide experiment. DDT, 16 or 32 ounces per acre used. Hays, Kansas. 1950-1953.

Year	Average number of clover seed chalcids oer 100 seeds: Original data	Transformed data[1,2]
1950	53.3	47.4
1951	2.2	1.0
1952	3.4	1.1
1953	1.4	0.9
	Date L.S.D. 5%	24.2
	1%	34.5

1 Transformed by log. (x + 1).

2 Treatment block, and treatment x date -- not significant.

Table 56. Average number of clover seed chalcid infested alfalfa seeds per 100 seeds in the time of insecticide application experiment plots, Hays, Kansas, 1950-1953. All treatments were 16 ounces DDT + 12 ounces toxaphene per acre.

Year of treatment	Average number chalcids per 100 seeds: Original data	Transformed data[1]
1950	53.4	47.4
1951	56.7	49.4
1952	7.8	16.2
1953	1.6	9.2
	Date L.S.D. - 5%	6.3
	1%	8.5

1 Transformation - log (x + 1).

INSECT CONTROL IN ALFALFA SEED FIELDS AS AFFECTED BY THE VOLUME OF SPRAY USED PER ACRE[1]

Water for spraying is a scarce item on many farms in the area near Hays. To haul sufficient quantities of water for the high pressure high gallonage spraying machines used to control cattle insects is uneconomical for alfalfa insect control if sufficient control can be obtained by using less water at higher concentrations. Hill (1933) used 100 gallons of spray per acre for tarnished plant bug control. Bissell and Ditman (1956) found that using heptachlor emulsion in the pea broadcast boom at 50 gallons of spray per acre reduced the pea aphid population significantly. When they reduced the pressure from 100 to 40 pounds per square inch and the water from 25 to 12.5 gallons per acre, they reduced the effectiveness of the treatment against both pea aphid and alfalfa weevil. Franklin (1951) also tried using a high pressure sprayer, reducing the pressure from 100 to 40 pounds per square inch and the gallonage from 100 to 30 gallons per acre. Control of most insects was judged to be satisfactory, especially at the higher rates of insecticide application.

The development of the low pressure, low volume sprayers following World War II, such as described by Franklin (1953) allowed a much lower gallonage of solution per acre. In controlling the spotted alfalfa aphid, Burkhardt and Gates (1956) recommended using a high gallonage of water, 10-20 gallons per acre, when using ground equipment. In Indiana, 10 to 15 gallons of DDT or DDT-Aldrin emulsion per acre and 10 gallons of toxaphene spray per acre were recommended to be applied by airplane. Petty and White (1952) and Poos (1953) recommended at least 10 gallons of solution per acre for spittlebug control. The lowest gallonage recommended for alfalfa insect

1 This paper, and the next two written by the junior author, Dr. Franklin, is based wholly on research conducted by him at Hays.

control using regular ground equipment was 5 to 6 gallons per acre (Daniels, 1956). Russell (1952) reported using four gallons per acre with an air blast sprayer but did not obtain control of stink bugs.

To maintain even distribution of insecticides over the experimental plots, tests set up to determine coverage showed that 15 gallons of spray per acre gave adequate coverage. This, however, is still higher than the gallonage used in most weed control work. Since most farmers that have sprayers for weed control do not have interchangeable tips or nozzles, it was decided to determine if lower gallonage of solution could be used and still obtain good insect control and high seed yields. If that is possible, one 55-gallon drum could carry l/2 to a full day's supply of water for the sprayer.

Methods and Materials

Replicated l- to 2-acre plots were established in a field of Buffalo alfalfa at Hays. Each plot was sprayed with the same quantity of DDT-toxaphene emulsion per acre. The desired rate was obtained by varying the nozzle sizes and pressure to obtain the given volume of solution. Since the sprayer was a gear-pump tractor mounted sprayer built in the machine shop of the Branch Experiment Station with a 30-gallon drum as the tank, the highest rate used was 30 gallons containing the required 16 ounces of active ingredient of toxaphene per acre. Other rates used were 5, 10, 15, 20, and 25 gallons of solution per acre. The amounts of insecticides needed were increased to maintain a constant rate per acre.

The population of insects in each plot was determined by using 25 sweeps of a 15-inch insect net in each plot. Sweeps were also taken on 1, 3, 7, 14, 21, and 28 days following application of the insecticide.

Seed yields were obtained by harvesting 10 square meter areas in each plot, placing the alfalfa in sacks, hanging it to dry, threshing the alfalfa on a drum plot thresher, and cleaning the seed with a power cleaner.

Racemes of alfalfa flowers were counted and tagged at the full bloom stage. At harvest time these racemes were collected and the seed pods examined for seed setting and the clover seed chalcid, *Bruchophagus gibbus* (Boh.).

Other insects observed included the alfalfa caterpillar, *Colias philodice eurytheme* (Bdv.), the alfalfa plant bug, *Adelphocoris lineolatus* (Gooze), the blister beetles, *Epicauta lemniscata* (F.), *E. pennsylvanica* *E. cinerea* (Forst.), *Macrobasis unicolor* (Kinley), the garden webworm, *Loxosteqe similalis* Gn., the green cloverworm, *Phathypena scabra* (Fabr.), nabids, *Nabis ferus* (L.), the pea aphid, *Macrosiphum pisis* Kalt., the potato leafhopper, *Emposca fabae* (Harris), the rapid plant bug, *Adelphocorus rapidus* (Say) and the tarnished plant bug *Lygus oblineatus* (Say).

Results

Control test results for the tarnished plant bug in 1953 are given in Table 57. Almost complete control was obtained in all plots 24 hours after spraying. It was only after 14 to 21 days that the population started to build up again. The same condition also existed in 1952. Nymphs were also found on the 21st day in 1952.

Control of all of the insects listed is given in Table 58. Control was as good with 10 gallons per acre as with any other rate. The five gallon rate was somewhat less effective with some of the insects observed. Even 20 gallons per acre was little better than five gallons of solution.

The average number of flowers, seed pods, and seeds produced per raceme and the percentage of flowers setting seed are given in Table 59. Two coincidental items that stand out clearly were noted in the average number of flowers per raceme and the percentage of chalcid infestation. Thirty-three per cent more flowers were produced per raceme in 1953 than in 1952. The plots of 1952 had more than four times as many chalcids as occurred in 1953. There were 25% more pods per raceme, 30% more seeds per raceme, and the average number of seeds per pod was 7% greater in 1953 than in 1952. The year 1952, on the other hand; had 1% more flowers setting seed pods and 1% more seeds produced per flower.

Table 57. Average number of the tarnished plant bugs per 25 sweeps of a 15-inch insect net in the rate of diluent experiment in Buffalo alfalfa field 203, Fort Hays Branch Experiment Station, Hays, Kansas. 1953.

Gals. spray solution used per acre	Average number of tarnished plant bugs: Before treatment June 26	days after application: 1	3	7	14	21	28	Total	Per cent control compared with 15 gal. rate
5	15.5	0.0	0.0	0.5	0.0	1.5	0.2	2.2	100
10	15.0	0.8	0.2	0.2	1.2	0.2	1.0	3.8	100
15	15.8	0.0	0.2	1.0	1.2	0.5	0.8	3.8	--
20	17.0	0.8	0.5	1.2	0.2	0.5	0.8	4.0	95
25	15.5	0.2	0.5	1.0	0.5	0.8	0.0	3.0	100
30	17.0	0.2	0.0	0.8	0.8	0.0	0.8	2.5	100

Table 58. Percentage of control obtained using 16 ounces of DDT and 12 ounces of toxaphene per acre in six different volumes of spray solution, Hays, Kansas, 1952-1953.

Insect	Year	Number of gallons of solution per acre 5	10	15	20	25	30
		Control percentages					
Alfalfa caterpillar	1952	100	100	--	100	100	100
	1953	100	100	--	100	100	100
Alfalfa plant bug	1952	100	100	--	100	100	100
	1953	100	100	--	--	100	100
Blister beetles	1952	50	100	--	100	--	100
	1953	100	100	--	100	100	100
Garden webworm	1952	92	100	--	92	100	100
	1953	100	100	--	68	100	100
Nabids*	1952	90	100	--	76	100	76
	1953	100	100	--	96	93	100
Pea aphid	1952	75	100	--	92	92	100
	1953	100	100	--	100	100	100
Potato leaf hopper	1952	100	100	--	100	100	100
	1953	100	100	--	100	100	100
Rapid plant bug	1952	50	100	--	100	100	100
	1953	100	100	--	--	100	100
Tarnished plant bug	1952	100	100	--	100	100	100
	1953	100	100	--	95	100	100

* Per cent reduction.

Table 59. Average number of flowers, seed pods, and seeds produced per alfalfa raceme and the percentage of flowers setting seed in the rate-of-diluent experiment for control of Chalcids on Buffalo alfalfa, Hays, Kansas, 1952-1953.

Volume of spray per acre	Year	Av. no. of flowers	Av. no. of seed pods	Av. no. of seed	Av. no. of seeds per pod	Av. no. of seeds per flower	Per cent of flowers setting seed	Per cent Chalcid infested seed
15	1952	11.61	2.10	10.12	4.82	0.87	18	7.3
	1953	16.29	3.54	10.47	2.98	0.64	22	1.8
5	1952	11.37	2.08	7.87	3.78	0.69	18	6.0
	1953	15.62	3.39	9.92	2.92	0.64	22	1.6
10	1952	11.97	3.25	10.06	3.10	0.84	27	5.3
	1953	16.14	3.19	9.37	2.91	0.59	20	1.7
20	1952	12.20	2.29	9.73	4.25	0.80	19	7.7
	1953	16.56	3.16	10.11	3.98	0.62	20	0.9
25	1952	12.53	3.29	7.98	2.43	0.64	26	6.8
	1953	16.14	3.00	10.24	3.42	0.64	19	1.6
30	1952	12.90	2.98	8.85	2.97	0.67	23	5.3
	1953	15.50	3.67	11.78	3.14	0.76	24	1.2
Average	1952	12.10	2.66	9.10	3.42	0.75	22	6.4
	1953	16.04	3.32	11.83	3.67	0.74	21	1.4

There was very little difference in seed yields in 1952 (Table 60). The yields ranged from 229.7 to 258.0 pounds per acre. Fluctuations around the fifteen gallons per acre rate varied from 10.6 pounds per acre or 4.4% less to 17.7 or 7.4% more than at the 15 gallon per acre rate. These differences were not significant at the 5% level of probability.

Table 60. Alfalfa seed yield in the rate of diluent experiment from Buffalo alfalfa, Hays, Kansas. 1952.

Gallons of spray solution per acre	Pounds of seed per acre				Per cent increase over the 15 gallon rates
	Block A*	Block B	Block C	Average	
15	248	235	238	240.3	
10	230	277	267	258.0	7.4
20	219	288	244	250.3	4.2
25	249	226	238	237.7	-1.1
5	217	272	223	237.3	-1.3
30	191	226	272	229.7	4 . 4
		LSD	5%	N.S.	

* Block LSD - 5% N. S.

Discussion

When plant growth is sparse and when regrowth is starting from the crown in the spring or after removal of a hay or seed crop, a lower volume of spray and pressure can be used. Good stands at the bud stage of development, on the other hand, require higher pressures and volumes of spray solution to give the same coverage and control of the insect. The 5 gallon rate appears to be the lowest volume to use in alfalfa insect control. The 10 gallon rate appeared to be better. Seed yield in 1952 indicated as good for the 10 gallon rate as for any higher rate. All yields were three times the Kansas average of 76 pounds per acre (Glenn and Pallesen, 1954).

INSECT CONTROL AND ALFALFA SEED PRODUCTION AS AFFECTED BY TIME OF HARVEST[1]

So many factors affect the seeding plant that only the most skillful producer is generally able to obtain a profitable seed crop. That many farmers try to produce seed is shown by the 10-year average Kansas acreage of 156,000 acres (Glenn and Pollesen, 1954). That only a few are really successful is shown by the low average yield of 76 pounds per acre.

1 The investigations summarized in this paper or section were conducted wholly by Dr. W. W. Franklin and this report was written by him.

Westgate (1908) stated that alfalfa requires a dry, hot season for the best development of seed. Therefore, only when there is a comparative moisture shortage will alfalfa set seed in paying quantities. TenEych and Freeman (1908) stated that alfalfa should be cut for hay if the weather has been wet because the alfalfa grows too rank for seed production. Westgate et al. (1912) found that sufficient soil moisture to enable the plant to mature its seed crop and yet not enough to induce crown shoots in advance of the maturation of the seed crop was needed. Aicher (1917) recommended those conditions but stated further that insufficient moisture caused the flowers to drop. Too much rainfall causes shattering, discoloration or premature sprouting of the seed. An annual rainfall of 18 inches properly distributed with relatively high temperatures were about the best climatic conditions for seed production. Brand and Westgate (1909) thought that the semi-arid portions of the Great Plains, the intermountain area, and the Palouse country of eastern Washington met those climatic conditions.

Soil types also affect alfalfa. Southworth (1928) found that heavy soils held sufficient moisture to cause new shoots to form during the seed crop, resulting in the production of many "thin, brown, underdeveloped" seed. Favorable for seed setting is a loamy soil with sandy soil in a "fine state of division". Tysdal (1946) stated that soils low in moisture produced only 0.92 seed per plant. Plants grown in soil with medium soil moisture had 1.64 seed per plant, while plants grown in high moisture soils had 2.23 seeds.

Thickness of the stand also affects seed production. Ten Eych and Freeman found that "a rather thin" stand of alfalfa with vigorous plants of average growth favored seed development. Westgate et al. (1912) stated that thin stands make greater yields more certain. Brand and Westgate (1908) recommended growing alfalfa in wide spaced rows to reduce the stand.

The timing of the cutting of the preceding crop has a direct effect on seed production. Grandfield (1945) stated that allowing the crop previous to the seed crop to go to the full-bloom stage before cutting permitted the plant to accumulate food reserves in the roots. Garber and Sprouge (1935) found that delaying the cutting of the previous crop allowed leafhoppers time to lay eggs. These eggs are destroyed with the hay crop and leafhopper damage to the seed crop eliminated. Jewett (1936) also stated that by delaying the cutting of the previous crop from the 10% bloom stage to the full-bloom stage, leafhopper damage can be confined to the hay crop and not to the seed crop. Carlson and Stewart (1931) reported that clipping of the first-growth alfalfa should not be delayed beyond the beginning of the bloom stage.

The "preceding crop" usually referred to is the first hay cutting in the spring. But it could well be that of the last cutting in the preceding year, TenEych and Freeman (1908) stated the second crop was the safer one to save for seed in Kansas. Brand and Westgate (1909) found that no crop later than the second will yieid returns that will be at all satisfactory in the area near Stockton, Kansas. For Kansas as a whole, Hallowell (1944) stated that the second crop developed during the hottest, driest part of the year and produced the most seed. However, the third crop should be used in southern Kansas and the first crop in the north. Grandfield and Franklin (1952) stated that the second cutting usually comes on when weather conditions are most likely to favor seed production. However, if conditions have been too unfavorable early in the year, it might be better to leave the third crop for seed. In this case the first cutting should be removed at the early bud stage and the second cutting allowed to go to the full bloom stage. In this way the third cutting seed crop can mature before frost. Each growth has its own special problems. The first cutting is plagued with pea aphids. But Franklin (1953) showed that they dan be controlled. The second cutting is plagued with plant bugs, leafhoppers, and garden webworms. Control for these insects has been demonstrated by Franklin (1949, 1951, 1952), Grandfield and Franklin (1952), and Smith and Franklin (1954).

Weather factors are probably the greatest problem to deal with. Weather drastically alters the plants' growing conditions, and the microclimate of both plants and insects. Judgment as to cutting the alfalfa for hay or letting it go for seed is best made in the field, taking into consideration past weather records, plant conditions, prospects of honeybees and other pollinating insects, the farm program, and the economics of the hay and seed business. Many farmers are anxious to have a definite answer as to which cutting to leave. Best observations in the past have been, that the second crop should, be left for seed. The present experiments were conducted 1950 to 1953 to find an answer to this problem.

Methods and Materials

Nine Buffalo alfalfa plots each l/4 to 1 acre in size were treated with 16 ounces of DDT and 12 ounces of toxaphene, applied at the bud stage on each of the three cuttings using a gear-pump tractor mounted sprayer. Injurious insects were determined by taking 25 sweeps with a 15-inch net in the plots before treatment and on 1, 3, 7, 14, 21, and 29 days after spraying. One colony of honeybees per acre was placed near the plots. Seed yields were obtained by hand harvesting, allowing the sacks of alfalfa to air dry, threshing on a drum thresher or with a small plot thresher, and cleaning with a small power cleaner.

Results

The percentage of control of nine of the injurious insects and the reduction of nabids is given in Table 61. Control, in this instance, should be compared with that obtained on the second cutting each year rather than with untreated plots. Thus the alfalfa pests were controlled as well on the first cutting in 1950, 1951, and 1952 as on the second cutting, but only 78% as well in 1953. On the third cutting, control was ineffective in 1952 but was as good as that obtained on the second cutting in l950, 1951, and 1953. Much better control of the potato leafhopper was obtained each year on the second cutting than on the first or third cutting. Alfalfa caterpillars and the green cloverworms were not numerous any year. Alfalfa plant bugs and blister beetles were somewhat plentiful. Garden webworms were present in large numbers in 1950, 1952, and 1953 but reached outbreak numbers in 1951. The pea aphid reached outbreak proportion on the first cutting in all four years. Pea aphids were not a problem on the third cuttings and were virtually nonexistent on the second cuttings.

Table 61. Percentage control obtained of alfalfa insects on the first and third cuttings of alfalfa in comparison with control obtained on the second cuttings. All plots in all cuttings were treated with the same rate of insecticides, Hays, Kansas. 1950-1953. In the computations, the base is the control obtained on the second cuttings which was considered at 100.

Insect species	Cutting	Per cent control Year 1950	1951	1952	1953	Average %
Alfalfa caterpillar	1	100	100	100	78	94
	3	100	100	0	100	75
Blister beetles	1	0	100	100	0	50
	3	100	87	100	100	97
Alfalfa plant bug	1	50	62	100	100	78
	3	14	60	0	100	44
Green cloverworm	1	0		50	100	56
	3	0		50	100	50
Nabids	1	52	82	79	56	67
	3	81	0	11	56	37
Tarnished plant bug	1	100	0	81	0	45
	3	100	0	100	36	59
Pea aphid	1	100	83	0	0	46
	3	0	0	44	100	36
Garden webworm	1	11	99	29	19	40
	3	60	97	0	0	39
Rapid plant bug	1	100	93	33	0	56
	3	0	30	0	0	8
Potato leafhopper	1	40	70	0	0	28
	3	50	74	0	0	31

The highest average number of flowers per raceme, 14.87, occurred on the first cutting (Table 62). Only in 1953 were there more flowers in both the second and third cuttings than on the first cutting. More flowers, 16.45 per raceme (the highest number observed) occurred on the third cutting in 1952 than on the first cutting. The first cutting also had the highest average number of seed pods, seed, seeds per pod, seeds per flower, and the highest percentage of flowers setting seed. The second cutting had a greater number of flowers per raceme and a higher average number of seeds per pod than the third cutting. But the third cutting had a higher average number of seeds per pod, seed per raceme, seed per flower, and percentage of flowers setting seed.

Table 62. Average number of flowers, seed pods, and seeds produced per raceme and the percentage of flowers setting seed, Hays, Kansas, 1950-1953.

Year	Average number per raceme: Flowers	Seed pods	Seed	Average seed per: Pod	Flower	Per cent of flowers setting seed
First cutting						
1950	15.83	3.33	11.23	3.39	0.71	21.04
1951	16.17	0.17	0.57	3.35	0.04	1.04
1952	14.95	3.28	17.52	5.34	1.17	21.67
1953	12.53	8.47	38.25	4.55	3.29	68.33
Average	14.87	3.81	16.89	4.16	1.30	28.02
Second cutting						
1950	13.80	0.37	0.43	1.16	0.03	2.63
1951	12.73	0.81	2.35	2.90	0.18	6.37
1952	11.28	2.93	11.48	3.92	1.02	26.67
1953	14.99	4.50	20.30	3.74	1.42	31.67
Average	13.20	2.15	8.64	3.68	0.66	16.84
Third cutting						
1950	0.00	0.00	0.00	0.00	0.00	0.00
1951	0.00	0.00	0.00	0.00	0.00	0.00
1952	16.45	3.92	14.61	3.73	0.89	23.67
1953	13.59	6.01	28.87	4.48	2.19	45.33
Average	7.51	2.48	10.87	2.05	0.77	17.25.

The first and second cuttings averaged 79.8 pounds of seed per acre over the four years (Table 63). The third cutting averaged only 30 pounds of seed per acre. Only in 1950 was the first cutting able to produce an excellent crop, 216.7 pounds per acre, the highest yield of any cutting during the four years. In 1950 the second and third cuttings were failures. All three cuttings failed in 1951. Normal yields occurred in 1952 with the second cutting highest followed by the third and first cuttings. Only the second cutting in 1953 produced good yields.

Discussion

The determination of which cutting to leave for seed as a “rule of thumb” could not be established during the four years 1950-1953 which included years of the record highest rainfall recorded and second lowest rainfall.

Insects were almost as well controlled on the first and third alfalfa cuttings as on the second cutting.

The first cutting had the highest average number of flowers, seed pods, and seeds per raceme, the highest average number of seeds per pods, and per flower, and the highest average percentage of flowers setting seed.

It would appear from the work of the four years that the farmer must still look at his alfalfa, consider the rainfall to date, rainfall prospects, root reserves, determine his over-all objective, and then make a decision each year.

Table 63. Alfalfa seed yields from indicated cuttings, Hays, Kansas, 1950-1953.

year	Block number	Number of cutting 1	2	3
		Pounds per acre		
1950	A	216.8	0.8	0.2
	B	189.9	2.1	0.3
	C	243.6	1.8	0.1
	Average	216.7	1.6	0.2
1951	A	19.1	9.4	0.0
	B	19.1	18.0	0.0
	C	14.6	8.6	0.0
	Average	17.6	12.0	0.0
1952	A	24.0	111.0	110.0
	B	98.0	179.0	33.0
	C	43.0	162.0	104.0
	Average	54.9	150.3	87.0
1953	A	36.6	140.4	36.7
	B	22.3	166.4	41.1
	C	30.4	157.5	34.7
	Average	29.8	154.8	37.5
4-year average		79.8	79.8	30.0

CONTROLLING INJURIOUS INSECTS IN ALFALFA SEED FIELDS WITH ORGANIC INSECTICIDE[1]

Excellent opportunities were provided to test the newer insecticides on the commoner insects in alfalfa at Hays from 1948 to 1953.

Methods and Materials

During 1948-1953 replicated plots of Buffalo alfalfa 1/4 to 2 acres were treated with six insecticides, preferably emulsions, but wettable powder or dust formulations were occasionally used.

1 The information given in this section was provided exclusively by Dr. W. W. Franklin. The senior author did minor editing only.

Insecticides in the later years were applied with a gear pump, tractor-mounted sprayer that was built in the machine shops of the Fort Hays Branch Experiment Station. This allowed use of low pressure, low volume spray application. In all cases, spray pressure was maintained at 30 pounds per square inch. Total volume applied was maintained at 15 gallons per acre. Since the plots were small, one tank was sufficient to treat all replications using one insecticide. In one year, a small trailer type piston pump sprayer was used. Gallonage applied was maintained at 50 per acre. In 1948, insecticides were applied, as dusts,, varying the rate to maintain the required amount of active ingredient of each insecticide.

Insect populations were obtained by use of 25 sweeps of a 15-inch insect net. Counts were made on the same days insecticides were applied but before they were applied, and on the lst, 3rd, 7th, 14th, 21st, and 28th days following.

The insecticides were applied at the bud stage only. Since one colony of honeybees per acre of alfalfa was placed in the alfalfa field, a second application of insecticides was ruled out. The honeybees and wild bees were too valuable as pollinators to risk losing. The native wild bee population was quite low before spraying.

When the alfalfa was in full bloom, 50 racemes were selected at random, the florets, buds, and later the number of seed pods on the racemes and the number of seeds per pod were counted. Average number of seeds per pod, average number of seeds per flower, and the percentage of flowers setting seed were computed.

Whenever possible, seed yields were obtained by hand harvesting 10 square meter quadrats. The harvest was placed in burlap bags and hung from nails in the machine shed to dry. Later the alfalfa was threshed on a drum thresher or in a small plot thresher. The seed was cleaned with a small power cleaner.

Only in 1951 were no seed yields taken. The low yields of 1950 showed. the futility even for research purposes of harvesting seed.from plants so rank that lodging occurred before bloom developed. In that year hay yields were obtained by use of a 39-inch cutter bar sent through, the middle of the plot for 30 feet. The green weight was taken immediately and a sample was oven dried and weighed again. The yield per acre was then computed for air dry hay containing 15% moisture.

Results

The results of the application of insecticides on insect control are given in Table 64. Control of the alfalfa caterpillar was the highest, 95.9%. The average control of the potato leafhopper was only 61.9%. Only DDT and parathion gave good control of this insect. Dieldrin gave poor potato leafhopper control. The beneficial nabids were easily killed, particularly by parathion. The best control of the alfalfa caterpillar was obtained with toxaphene but all gave excellent control. Toxaphene also gave the best control of the tarnished plant bug. Dieldrin gave the best control of the alfalfa plant bug. Good control was also given by the other insecticides.

Table 64. Percentages insect control with the indicated newer synthetic insecticides (data analyzed by Arcsin transformation), Hays, Kansas, 1948-1953.

Insect species	Insecticide and rate in ozs./100 gal. of water: Toxaphene	Aldrin	Parathion	DDT	Dieldrin	Chlordane	Species average
Alfalfa caterpillar	100.0	94.3[1]	98.3	96.3	93.3	93.3	95.9
Alfalfa plant bug	88.2	90.5	87.7	92.0	96.2	77.0	88.6
Nabids	70.3	81.8	90.7	82.3	88.0	76.7	83.1
Rapid plant bug	83.3	81.0	83.3	90.3	78.7	67.3	80.7
Garden webworm	78.5	71.7	82.2	82.7	75.2	67.8	76.3
Tarnished plant bug	91.5	70.3	78.8	62.0	71.8	74.8	74.9
Potato leafhopper	64.7	55.7	86.7	90.3	33.2	40.8	61.9
Insecticide average[2]	84.3	84.0	83.9	77.9	76.9	75.7	--
Species LSD 5%							0.64
1%							1.20

1 Interaction LSD 5% 3.8; 1% 6.6.

2 Insecticide LSD 5% 0.55; 1% 0.92.

Difference between species control was significant at the 1% level. Differences among the top three insecticides (toxaphene, aldrin, and parathion) were not signif icant. Differences between those three and DDT were highly significant as was the difference between DDT and dieldrin, and between dieldrin and chlordane.

First order interaction was present to a considerable degree. Complete control of 100% of any insect species with any insecticide occurred with toxaphene on the alfalfa caterpillar. This difference was highly significant at rank six and below and significant at rank four and below. Differences at both levels of probability existed in like manner between all treatments and the lowest ranking treatment (dieldrin against the potato leafhopper).

All of the treated plots had a higher average number of flowers per raceme and of seeds per flower than did the check plots. Except for the chlordane treated plots, all plots had a higher number of seed pods and seeds than untreated alfalfa plots did. All pods except those on plants treated with aldrin had a higher average number of seeds per pod than in the untreated alfalfa. Only the chlordane treated plot had a lower percentage of flowers setting seed than did the check plot. The aldrin plots had more than twice the percentage of flowers setting seed and the toxaphene plots more than 50% more flowers setting seed.

Hay and seed yields are given in Tables 65 and 66. The aldrin and dieldrin treated plots yielded 97% as much as the hay check plots. Increases in hay yields in treated over check plots were DDT 3%, toxaphene 16% and chlordane and parathion 19%.

All treated plots produced more seed than did check plots. The highest increase, 103%, was in dieldrin treated plots. The aldrin treated plots increased yields 90% Other increases were DDT 54%, toxaphene 45%, parathion 21%, and chlordane 10%.

Table 65. Average number of flowers, seed pods, and seeds produced per raceme and the percentage of flowers setting seed after treatment with the indicated synthetic insecticides in control of alfalfa insects, Hays, Kansas, 1948-1953.

Insecticide	Average number of Flowers	Average number of Seed pods	Average number of Seeds	Average number of Seeds per pod	Average number of Seeds per flower	Per cent of flowers setting seed
Check	13.35	1.83	6.04	3.30	0.45	14
Aldrin	13.72	4.24	8.54	2.01	0.62	31
Toxaphene	13.42	2.72	10.67	3.83	0.79	20
Dieldrin	14.15	2.40	8.68	3.62	0.61	17
Parathion	13.92	3.18	8.14	3.73	0.58	16
DDT	13.80	1.88	6.67	3.55	0.48	14
Chlordane	14.39	1.52	6.50	3.61	3.89	11

Table 66. Yields of alfalfa seed in the experiment comparing indicated insecticides in control of alfalfa insects, Hays, Kansas, 1948.1953.

Insecticide plot	Hay yield: tons/acre: 1951	Per cent seed increase	Pounds of seed per acre 1948	1949	1950	1952	1953	Year average	Per cent increase
Check	1.10	---	16.2	77.0	8.8	172.3	61.7	67.0	--
Dieldrin	1.07	103	52.9	79.0	11.7	312.0	125.3	136.2	103
Aldrin	1.07	90	137.5	82.0	8.8	290.3	116.6	127.0	90
DDT	1.13	54	39.8	73.0	13.5	274.7	100.2	102.2	54
Toxaphene	1.17	45	54.6	59.0	7.4	259.3	104.6	97.0	45
Parathion	1.20	21	43.0	56.0	8.4	209.7	87.4	80.9	21
Chlordane	1.20	10	28.0	66.0	12.0	193.7	67.4	73.4	10

Table 67. Percentage control of injurious insects or reduction of predatory insects in the DDT tests, Hays, Kansas, 1948-1953.

Insect species	Lbs. of DDT per acre	Per cent of control or reduction obtained: 1948	1949	1950	1951	1952	1953	Average
Alfalfa caterpillar	1	100	80	75	74	82	89	83.3
	2	100	100	78	100	100	100	96.3
Alfalfa plant bug	1	66	78	100	76	80	81	80.2
	2	67	100	91	89	92	96	89.2
Garden webworm	1	45	45	54	61	60	84	58.2
	2	90	83	88	83	71	84	83.2
Nabids	1	100	66	81	45	64	72	71.3
	2	100	82	90	67	65	90	82.3
Potato leaf-hopper	1	86	88	67	84	67	60	75.3
	2	90	96	84	93	86	90	89.8
Rapid plant bug	1	84	67	50	49	50	72	62.0
	2	85	94	100	82	90	90	89.8
Tarnished plant bug	1	52	70	55	68	67	86	66.3
	2	60	66	62	77	82	96	73.8

Source of variation1	Sum of squares	Degrees of freedom	Mean square
Rate	3,256	1	3,256.0*
Species	3,213	6	535.5
year	659	5	131.8
R X S	665	6	110.8
RXY	247	5	49.4
SXY	4,776	30	159.2
Error	1,847	30	615.7

* Rate difference-significant at 5% level of probability.

1 Arcsin transformation.

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