THE BIOLOGY AND CONTROL OF THE ALFALFA SEED CHALCID, *BRUCHOPHAGUS RODDI* GUSS.

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THE BIOLOGY AND CONTROL OF THE ALFALFA SEED

CHALCID, *BRUCHOPHAGUS RODDI* GUSS.

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PREFACE

In Oklahoma, very little attention was given to research on the alfalfa seed chalcid *Bruchophagus roddi* Guss., for a very long time. The larvae of this Eurytomid infest many species of *Medicago*, and cause great seed losses to the growers. Infestations of *B. roddi* are common in alfalfa seed throughout western Oklahoma and in some years and areas, chalcids are the most injurious insect on this crop. Therefore, a plan was made to find out the seasonal distribution and the chemical control of this insect, under the supervision of Dr. R. R. Walton, Professor of Entomology, Oklahoma State University.

The author wishes to express his appreciation and regard to his major adviser, Dr. R. R. Walton, for advice, helpful assistance and guidance throughout this study and preparation of this manuscript. Also sincere thanks are expressed to Drs. D. E. Howell, Professor and Head, Department of Entomology, W. A. Drew, Raymond D. Eikenbary and Jerry H. Young, Professors of Entomology, for their helpful suggestions and criticism in the preparation of this manuscript. Grateful recognition is expressed to Dr. Frank E. Strong, Professor of Entomology, University of California, Davis, Dr. J. G. Watts, Head Department of Entomology, New Mexico State University and Dr. Herbert Knutson, Head, Department of Entomology, Kansas State University for their valuable information on the seed chalcid. Sincere thanks are given to Enrique Jimenez, Richard E. Kinzer, Hossam A. Negm, graduate students in Entomology and Jerry L. Hayes and Kenneth Stanton for their help and suggestions. Special thanks are due to Mrs. Clara Yeck, for her careful typing and precision.

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CHAPTER I

INTRODUCTION

Alfalfa is very important in the United States, being used as hay, silage, pasture, and as a soil-building crop. It serves as an excellent source of carotene, riboflavin, protein and calcium. It derives its name alfalfa from the Arabic language meaning "best fodder". According to Tysdal (1937) its original home is considered to be southwestern Asia, from Mesopotamia northward across Persia and Turkestan to Siberia. It has been found wild in Persia, Afghanistan, Baluchistan and in Kashmir. It was introduced into United States in the early 16th century by the Spanish Explorers. Catholic missionaries are also supposed to have brought alfalfa from Mexico into Southern California, New Mexico and Arizona. By 1900, it became an important crop all over the United States. The total area devoted in 1965 for hay production was 68 million acres, out of which alfalfa occupied about 30 million acres.

In Oklahoma the same year about ½ million acres were allocated for alfalfa hay production, besides another 75,000 acres for seed production. Oklahoma ranked 7th among the states, producing 12,750,000 lbs. cleaned seeds, representing a gross value of $2,741,250 (U. S. D. A. Agricultural Statistics 1966). The per acre yield of seeds and income in Oklahoma are comparatively lower than that of the western states. The reasons for the low seed production per acre may be regarded as lack of irrigation facilities, improper cultural methods, lack of pollination, diseases and damage by destructive insects.

A small jet-black wasp, known as the Alfalfa Seed Chalcid, is a very serious pest and destroys 5-83% of the seed crop in western United States (Strong 1962). Because of this insect a greater dislocation of the seed production has occurred in the western states and also in Oklahoma. Viable seed production is significantly reduced, thus, increasing seed cost. In addition, it is difficult to obtain chalcid-free seed since infested seeds, prior to adult emergence, are difficult to separate from clean seeds.

In the past, several cultural methods have been adopted along with the use of some insecticides for its control. In 1947, systemic insecticides were synthesized which opened a new era for insect pest control.

This study was made to assess chalcid damage levels, record seasonal development and to test systemic insecticides as chalcid control agents.

CHAPTER II

REVIEW OF LITERATURE

Taxanomic Data and Host Plants

The alfalfa seed chalcid belongs to the Order Hymenoptera, Super Family Chalcidoidae and family Eurytomidae.

This insect was described in 1836 as Eurytoma gibba by a Scandinavian worker Boheman. Howard (1880) called it Eurytoma funebris, but Ashmead (1894) described a separate genus Bruchophagus and included Eurytoma funebris in it. Girault (1916) redescribed it as Bruchophagus funebris Howard. The subsequent workers followed this name until in 1933, Rodd and Gussakovskii from Russia, reported a new chalcid reared from alfalfa and they named it as Bruchophagus roddi Guss. From 1933 till 1952, the alfalfa seed chalcid Bruchophagus roddi Guss. was regarded as synonymous with B. gibbus (Boh.) and was called the clover seed chalcid. Kolobova (1950) studied the morphology and host specificity and produced sufficient data to prove that B. gibbus is a complex of three species: B. gibbus, infesting red clover; B. roddi, infesting alfalfa, and B. kolobovae, restricted to the genus Lotus and none of them would infest any of the sweet clovers (Melilatus species).

Hansen (1955) showed that the Eurytomids reared from alfalfa would not infest species of Trifolium. Strong (1961) studied the female genitilia of B. gibbus, B. roddi and B. kolobovae, and separated them. Strong (1962) also studied the biology and host specificity under laboratory conditions. About the host plants of the chalcid, he wrote to the author,

> I have observed B. roddi in several species of Medicago such as M. sativa (alfalfa), M. hispida (bur clover) and M. falcata. Bruchophagus gibbus is restricted to the genus Trifolium. I have never observed B. gibbus to feed on other species of Trifolium than pratense, (red clover). As far as I know it will not infest T. repens (white clover). Also I do not believe it will infest alsike (Trifolium hybirdum). B. kolobovae is restricted to the genus Lotus. The only species I have examined is Lotus corniculatus (birdsfoot trefoil). None of the species of Bruchophagus will infest any of the sweet clovers (Melilatus species).

Biology

The original description of the clover seed chalcid was given by Howard in 1879. He described this insect as a new species of the genus Eurytoma from "clover-heads". He recorded the male as black with dark brown eyes, body length of 1.7mm, wing span of 2.5mm, antennae with 11 joints and with whorls of hairs. The female was light brown, 1.9mm long, wing span 2.7mm, short antennae with no whorls, and abdomen longer than thorax with an extruded ovipositor.

Rufus reported damage by this species in Michigan in 1899. Titus (1904) collected the chalcids in California from "clover-heads", and Headlee (1908) reported that it destroyed about 50% of the alfalfa seed crop in Kansas. He described it as a tiny four-winged black "fly" whose grubs feed singly upon the forming tissue of the seed, transformed into adults, emerged through little round holes in the seed coats. Folsom (1909) in Illinois, studied the detailed morphology, distribution, nature of injury, life history, and the natural enemies of this insect from alfalfa and clover. He observed that the adults laid the eggs in May and June, and the adults reared from these eggs appeared in July and August. The July and August adults lay their eggs, and some of the adults appear during the same season; rest not until the following year. The adults have two times of greatest abundance, falling near June 12 and August 12. He noticed as many as three generations per year and thought there was the probability of a fourth.

Urbahans (1914) recorded that the "chalcis-fly" hibernates in the larval stage within alfalfa seeds on neglected fields, and along fence lines and ditch banks. He observed that oviposition usually took place when the pods were about half grown. The time required for the eggs to hatch varied greatly. Under favorable temperatures feeding began about a week after the eggs were deposited. When there was sufficient moisture in the seeds, the larvae transformed to the pupal stage, which lasted from 10-40 days, before emerging as adults.

Carter et al.,(1925) mentioned that in Minnesota when frost came, emerged adult chalcids were killed but the brood which was still in the seeds lived through the winter and emerged in the spring. These early spring chalcids sought early blooming "clover" and alfalfa, which was usually by roadsides.

Sorensen (1926) studied the life history and the habits of the seed chalcid in alfalfa in Utah. He noticed it as being a gnat-like insect about 1/12 inch long, having elliptical eggs 0.2mm in length. They overwintered in the larval stage within the seed coats.

Wildermuth (1931) stated that the seasonal emergence of the chalcid in alfalfa varies greatly because of the climatic differences in various parts of the country. In the western and southwestern states, the adults emerge from hibernation as early as March. The generations follow one another every 30-40 days throughout the season and sometimes continue until late in November. In the mid-western states and in the colder northern areas the adults may not emerge until early June. There may be one or two generations during the season. In southern Arizona, where the mean temperature for the season is above 80° F as many as six generations have been observed.

Tysdal (1941) in Nebraska and Underhill (1946) in Virginia studied its biology and found that eggs were laid in the seeds about the time the pods are half grown.

Dickason and Every (1955) described it as wasp-like but without wing-veins. They found 2-3 generations in a year in Oregon.

Rodd and Gussakovskii (1933) worked on the morphology, bionomics and distribution and gave the name Bruchophagus roddi Guss. for the chalcid reared from alfalfa. Fedoseeva (1954-58) in Russia studied wing venetion, antennal characters, length and height of thorax and the shape of the abdomen to separate B. roddi from B. gibbus and B. kolobovae.

Strong (1962) worked out the details of its biology under laboratory conditions with special reference to diapause and effect of age of seed and temperature on oviposition. He observed that the diapause-ending process was hastened by exposure to lower or higher temperature, and seeds 8-10 days old were most favorable for oviposition. By measuring the lengths of the mandibles, he concluded that there are 4 larval stages. He also measured the lengths of the female genetilia of the B. gibbus complex and separated them into B. gibbus, B. roddi, and B. kolobovae. Hansen (1955) and Neunzig et al.,(1958) studied the host relationship and Harvey (1960) in Kansas, studied a device to serve as a "means of screening alfalfa for chalcid resistance and ultimately to find resistant plants". He found that adults emerged more rapidly at

90° F than at 75° F., that 9-day old adults were able to infest seeds, and that seeds from 6-11 days of age were subject to infestation.

McAllister and Rowely et. al.,(1962) worked on the seasonal abundance of the chalcid in alfalfa in Utah, and found two generations in a year.

Behavior

In recent times considerable study has been made of the behavior of the chalcid and its responses to various stimuli. The experiments in Idaho have shown that the female chalcid spends almost 10 times as much time on floral parts of the plant as the male. At temperature ranges of 74-84° F males are more active and do not stay at a location for more than 30 seconds (Klostermeyer 1965). Hale and Fronk (1966) in Wyoming found the chalcids reacted most strongly to the light near the ultraviolet range, but were blind to the red.

Sampling technique for the estimation of the chalcid damage were worked out by Strong in 1960. He found the "strip" method to yield 3 times more information than the "scoop" method. Watts, Coleman and Glover (1966) described a colorimetric test for the detection of chalcid infestation. They crushed the unthreshed seeds in a paper jacket, against a paper towel impregnated with arsenophosphotungstic (APTA) acid to react with uric acid within the infested seeds. A blue spot developed at the point of the infested seed, when this towel was placed in an ammonia atmosphere. The sample size was determined by counting the seed impressions in the paper jacket.

Distribution

Titus (1904) reported that he found alfalfa seed chalcids in California, Colorado, District of Columbia, Illinois, Indiana, Kansas, Michigan, New York, Oregon, Rhode Island, Vermont, Virginia and Washington.

Urbahns (1920) found the distribution of this insect to extend from the Gulf coast to the northern limits of the United States, as well as in the southwestern states. His earliest record for other states were as follows: Nebraska and Ohio 1905, New Mexico 1908, Arizona and Texas 1909, Utah and Tennessee 1910, Idaho 1911, South Dakota and Oklahoma 1913, Missouri 1914, Iowa, Maryland, Massachusetts, New Hampshire and Pennsylvania 1915, and Nevada 1917.

Sorensen (1930) mentioned that this insect has a world-wide distribution and was reported from Siberia 1906, Turkey 1907, Chile 1908, South Africa 1910, and Germany 1913. The Russian workers mentioned its presence in most parts of the country (Rodd et.al. 1933, Chernova 1961, Arabadshiev 1960). Ahlberg (1945) in Stockholm reported it as the new pest of the legume seeds and estimated 10% seed loss due to its damage.

Guppy (1954) undertook the insect survey of clover, alfalfa, and birdsfoot trefoil in eastern Ontario, Canada, and found _B. roddi_ to be most abundant. Manninger (1958) noticed this insect in Hungary and found that it was responsible for 36% of the seed losses in alfalfa.

Doull (1961) in Australia found it most destructive in alfalfa, in the northern parts of the country. Wadhi (1965) in India, noted its existence from alfalfa samples collected at Indian Agricultural Research Institute Farm, and from Remount Depot Farm Hapur. This, according to him, is the first record of this species in India.

Nature of Injury

According to Ashmead, A. D. Hopkins of Virginia was the first to report that the larvae of this insect ate inside of the seeds. Hopkins stated that the female layed her eggs in immature seeds and the larvae fed upon the semi-fluid albumen of the cotylydons of the seeds, leaving only a thin shell. The seeds became dull brown, misshapen and a little undersized. The adult cut a little hole in the seed and emerged. Urbahns (1914) observed that the seed crop maturing late in the season suffered a greater loss than those crops maturing early. Several samples examined by him showed 85% seed infestation.

Sorensen (1926) found that the infested seeds weighed only 54.63% as much as uninfested seeds.

Records from different parts of the country indicate losses from 5-83%.

According to Strong (1960) the estimated loss in 1959 in Fresno County, California was $1.5 million.

Control

The early attempts to control alfalfa seed chalcid consisted mostly of cultural practices including cultivation, destruction of debris from threshing and screenings, and destruction of volunteer alfalfa and weeds (Folsom 1909, Urbahns 1914, Sorensen 1926). Shull and Fisher (1940) recommended cultivation to cover chaff and to kill the chalcids. Tysdal (1941) and Dickason and Every (1955) recommended control by sanitation methods.

Dobson (1953) suggested foliar applications of 10% DDT dust, 20% Toxaphene or 2% Parathion, when the adults first appeared.

Bacon and Riley (1963) used several insecticides and attained significant control with dimethoate and telodrin. The "Phosphorus-containing compounds" Parathion, Zinophos, and Guthion on the basis of their LD50, were "highly toxic" to the adult chalcids.

Bacon et al.,(1964) noted that parathion application to the soil in moist conditions was more effective in controlling overwintering population than in dry conditions of the soil. Insecticides when applied during bloom were not effective and were toxic to most pollinating bees.

Strong (1962a) studied the reactions of 40 alfalfa varieties in 1960, and 25 in 1961 for resistance to the seed chalcid. He did not find any variety having "light" (10%) infestation, but he believed that further studies on resistance should be made.

Wingfield and Fronk (1967) in a test of 95 chemicals on chalcid adults, found 38 to be attractive, 9 were repellent, and 48 produced no response. Beta carotene was most attractive and Butyric acid highly repellent.

In New Mexico, alfalfa selection 58-53-0 produced chalcid free seed in 1963 and 1965. A total of 31 clones have been identified which had no chalcid infestation for at least two years (Klostermeyer 1965).

Nielson (1967) in Arizona screened "thousands" of alfalfa plants for resistance to the chalcid. He discarded plants that averaged one or more chalcid larvae per raceme, and those with less than one were given a second test. The data indicate that many of the progeny did not inherit chalcid resistance.

Parasites and predators have been observed on alfalfa seed chalcid since 1905. Folsom (1909) described, "there emerged frequently, in our jars of 'clover heads' a second black chalcid, which might casually be mistaken for the first species though belong to another genus - Tetrastichus. This species was named by Ashmead as Tetrastichus bruchophagi."

Urbahns (1914) reared T. bruchophagi from chalcids collected at Tulare, California. It was found later in Arizona, Oregon, Virginia, Indiana, Michigan and Minnesota. This parasite was of considerable importance in California, where it destroyed about 52% of the chalcid larvae in 1913. Other parasites described by Urbahns were Habrocytus medicaginisis, Liodontomerus perplexus, L. secundus, Eutelus bruchophagi and Trimeromicrus maculatus.

Habrocytus was distributed throughout the alfalfa seed growing states, but the rate of parasitism was not high. Hansen (1955) in California found that at least 8 species of parasitic Hymenoptera attacked the alfalfa seed chalcid, and in some areas the rate of parasitism was important in control. Neunzig and Gyrisco (1958) in New York reported H. medicaginisis as the dominant parasite and Amblymerus bruchophagi as second in number. Other parasites associated with alfalfa seed chalcid were: Tetrastichus bruchophagi, Eutelus atropupareus, E. microzonus, Eupelmella vesicularis, Liodontomerus longfellowi and Trimeromicrus maculatus.

CHAPTER III

SEASONAL DISTRIBUTION

Methods and Materials

The seasonal distribution of the alfalfa seed chalcid was determined by taking sweeps of the six alfalfa plots allotted for this purpose on the Experiment Station at Perkins. The sweepings were taken on alternate days with a standard 15 inch diameter net. The sweepings were then transferred carefully into a ½ gallon ice cream carton. The cartons were brought to the laboratory, kept in a freezer to kill the chalcids, and were later counted for population. The plots selected were located at such an area where there was very rare use of the chemicals. The data on seasonal distribution are presented as mean number of the chalcids for 100 sweeps at approximately weekly intervals. The temperature and humidity of the area were also recorded.

Results and Discussion

Under Oklahoma field conditions, the alfalfa seed chalcid appeared to have three generations.

Folsom (1909) in Illinois, Dickason and Every (1955) in Oregon, McAllister and Rowley (1962) in Utah, found 2-3 generations in a year. Wildermuth (1931) observed as many as 6 generations in Arizona to 1-2 in northern areas.

Alfalfa generally produces 2-3 sets of blooms during its growth.

The first bloom starts about June 1-10 and is complete by June 15-20. The second bloom begins about July 4-10 and is in full flower by July 20. The third continues to bloom from August 20 till early September. The chalcid emergence seemed to be in direct relation with the blooming habits of alfalfa. The first spring brood of chalcid comes from the seeds infested previous year, which are generally scattered on the ground during threshing. This small number of overwintering population, however, finds some green seeds along the borders of alfalfa fields, fence lines and ditches to oviposit. The eggs become larvae within 3-4 days and change to pupae within 10-12 days. In Oklahoma the chalcid developmental cycle was completed within 24-30 days. This cycle was repeated as long as temperature and alfalfa bloom conditions were suitable. With the approach of the colder season, the life cycle was not completed and the chalcids overwintered as larvae within the seeds.

The seasonal distribution of the alfalfa seed chalcid shown in Fig. 1 may be described as follows:

May 14 to June 14: The lesser number of adult chalcids (0 to 3 per 100 sweeps) probably came from overwintering population derived from the seeds infested previous year, or may have come from migration from another area.

In the western and southwestern states the overwintering population emerges as early as March, where the average temperature for that month ranges from 85°to 95°F. Perkins, Oklahoma, recorded the highest temperature as 104°F. for the season, whereas the highest for California was 123°F. in 1967. Therefore, the overwintering chalcid emergence in Oklahoma was delayed, compared to these states. But in Utah, the overwintering generation started emerging during June, almost a month later

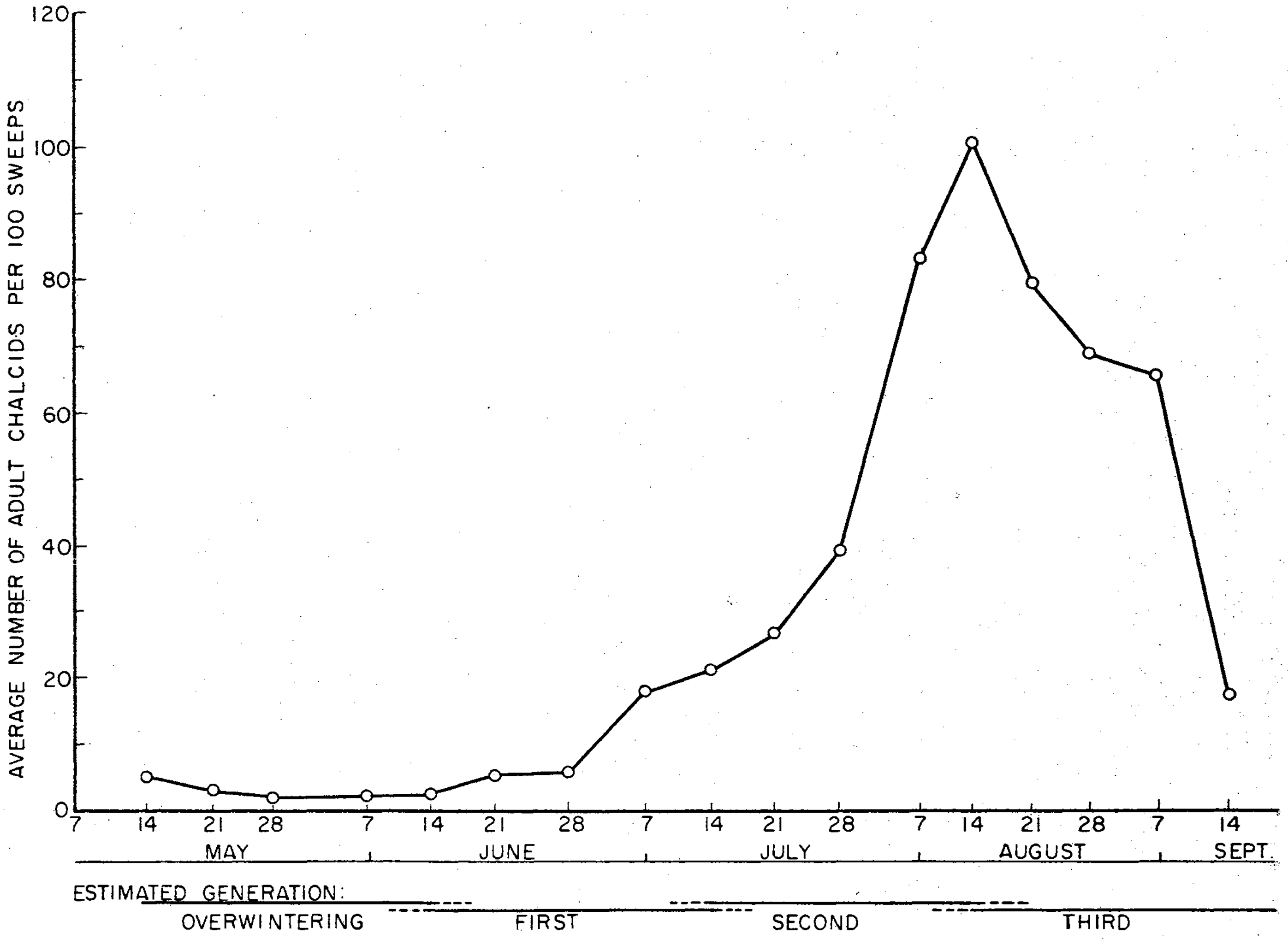

Figure 1. Seasonal distribution of the alfalfa seed chalcid during summer 1967.

than in Oklahoma, as Utah has comparatively milder temperatures during the summer. Table I gives the temperature record of five states from March to July for 3 years.

June 14 to July 14: The increase in chalcids (3 to 22 per 100 sweeps) came from the first generation chalcids of the study area. At this time of the season the alfalfa was in full bloom and the weather conditions were also favorable for the increased oviposition.

July 14 to August 14: The remarkable increase in chalcid number (22 to 101 per 100 sweeps) represents some migration from the first and the chalcids of the second generation, which had the ample supply of the second seed crop. At the same time the climatic conditions were also congenial, with the mean temperature reaching about 87° F and a little rainfall of 1.94 inches for that period. The chalcids were more active and a "major peak" of emergence was obtained between first and second week of August.

August 14 to August 21: This decline in chalcid number (101 to 68 per 100 sweeps) may seem to correspond to the gap between second and third bloom periods. As indicated earlier, the third bloom in alfalfa starts late with the last week of August and continues up to first week of September. As Strong (1962) observed LT 50 for adult chalcid at 90° F to be 1.4 days without food, it can be inferred that a greater number of chalcids must have died at this time, reducing the high chalcid number.

August 21 to September 14: A little increase in number (68 to 79 per 100 sweeps) may account for the chalcids from third generation plus a little carry-over of the second generation chalcids. This generation seemed to have developed on the third seed crop bloom. However, this number was small because of lack of adequate blooms and pods and the

TABLE I

MONTH-WISE MAXIMUM TEMPERATURES FOR 5 STATES FROM 1965-1967 (DEGREES FARENHEIT)

State	Year	March	April	May	June	July
Arizona	1967	94	92	112	118	121
California		94	90	115	122	123
New Mexico		95	95	102	105	107
Oklahoma		98	98	106	109	110
Utah		83	81	103	107	112
Arizona	1966	99	101	110	118	117
California		104	108	110	119	119
New Mexico		90	94	104	107	107
Oklahoma		95	94	108	109	111
Utah		88	90	102	107	110
Arizona	1965	91	104	107	111	120
California		89	104	107	112	118
New Mexico		85	102	101	105	109
Oklahoma		83	98	96	102	110
Utah		82	89	93	99	104

cooler temperatures. Besides, Perkins had a rainfall of 4.33 inches during this period, which increased the vegetative development in alfalfa.

The results obtained here can be compared with the rate of chalcid infestation in the seeds collected at different periods. It was 2.82, 3.6, and 3.9 on August 15, 28 and September 7. The harvests of August 28 and September 7 must have had a larger number of ovipositing chalcids than on the seeds collected on August 15. Apparently, at the time of fertilization of these seeds, a larger number of chalcid population was present. The increase in infestation level may then be regarded as logical.

Chalcid Development Stages

Results

The eggs of the seed chalcid were very minute and could not be seen in the infested seeds under a low power magnifier. According to Strong (1962) the eggs are milky white when laid and the mean hatching time was 42.5 hours.

The larvae seemed to consist of 4 instars. Though no effort was made to actually measure each instar, yet the observations showed the first-instar to be slightly greenish and with limited movement. The second and third instars were white with brown mandibles and with distinct movement. The fourth instars were short, thickened, without movement, and varied from 1.5 to 2mm in length. The larvae fed on the entire albumen of the seed, cut a small hole in the seed coat (Fig. 2) for the adults to emerge and leave a hollow shell behind (Fig. 3).

The early pupa was white which gradually changed to black body

Figure 2. Emergence hole of the alfalfa seed chalcid in seed pod

Figure 3. Empty shell of an alfalfa seed after chalcid emergence

color and had brown eyes. The wings, legs and antennae were folded closely to the body which was en-cased in a thin transparent pupal skin (Fig. 4).

The adult chalcids were black, with tarsi and tibiae of the legs yellowish brown. The male chalcid was slightly smaller than the female (Fig. 5), and the antennae had 11 joints with whorls of light hairs on the last 8 segments.

In the female the abdomen was larger and more pointed at the posterior end, which served as an ovipositor (Fig. 6). The female antennae consisted of 10 joints with very fine short hairs.

Figure 4. Mature alfalfa seed chalcid pupa in alfalfa seed

Figure 5. Male alfalfa seed chalcid

Figure 6. Female alfalfa seed chalcid showing pointed ovipositor

CHAPTER IV

CROP MATURITY AND CHALCID DAMAGE

Alfalfa is a very uncertain seed crop, and it is often difficult to estimate exactly as to which crop should be saved for seed. The dry climatic conditions in western Oklahoma makes it better adapted for the seed production than the more humid conditions of the central and eastern sections of the state. The supply of water and the weather conditions during the growing period largely determine which crop to harvest for seed. In the more humid years, alfalfa will not be allowed to go to seed until after two or more hay cuttings are made. In the drier years the second crop is usually permitted to go to seed. Most growers seem to prefer the third crop for seed, as it has the advantage of taking two hay crops.

Thus, farmers in western Oklahoma may mow alfalfa once in May to get seeds in August, or cut once in May and in June to take a seed crop late in August or some cut three times (May, June, and July) and harvest for seeds in September.

The object of this experiment was to learn the seasonal distribution of the alfalfa seed chalcid in Oklahoma in order to determine the potential infestation rate for crops setting seed during various periods during the summer.

Methods and Materials

The relative damage to seed crop by chalcids, during the season, was traced by determining the infestation level at different seeding dates. These studies were made on alfalfa grown on the Perkins Experiment Station. A plot of 93 x 272 ft. of standing Cody alfalfa was selected and was divided into 20 sub-plots of 21 x 52 ft. A 3 ft. wide alley was left in between the plots to serve as pathways for making observations. Each plot was marked with labelled 24-inch stakes.

To get a seed crop in August, 6 plots (A in Fig. 7) were left uncut during the summer 1967 and 3000 seeds from these 6 plots were collected in August and examined for chalcid damage. The crop was cut on June 21 in the remaining 14 plots and 2743 seeds from 7 plots (B in Fig. 7) were collected in late August and examined. The crop was given a second cut in the last 7 plots (C in Fig. 7) in the middle of July so as to get seeds in September. The seed samples were dried for 24 hours and seeds were removed by rubbing the pods on a rubber-surfaced board.

The seeds and chaff were separated and the remaining material cleaned in a South Dakota Seed Blower. The seed blower consists of a squirrel-caged fan, mounted on a table, which sends a blast of air into a seed cleaning tower. This tower is provided with air-setting valves at the top and a fine meshed screen at the bottom. The threshed seeds were placed on the screen, the valves were adjusted to a standard setting, and the air was blasted into the tower. The chaff was collected at the top of the tower and the cleaned seeds remained at the bottom. The sample was then divided in equal portions by passing the seeds through a Boerner Sampler (Fig. 8). The sampler primarily consists of a cone-shaped distributor which disperses the seeds to 32 channels. Sixteen alternate channels carry the seeds to aliquot no. 1 and the other 16 to aliquot no. 2. The process of passing the seed through the

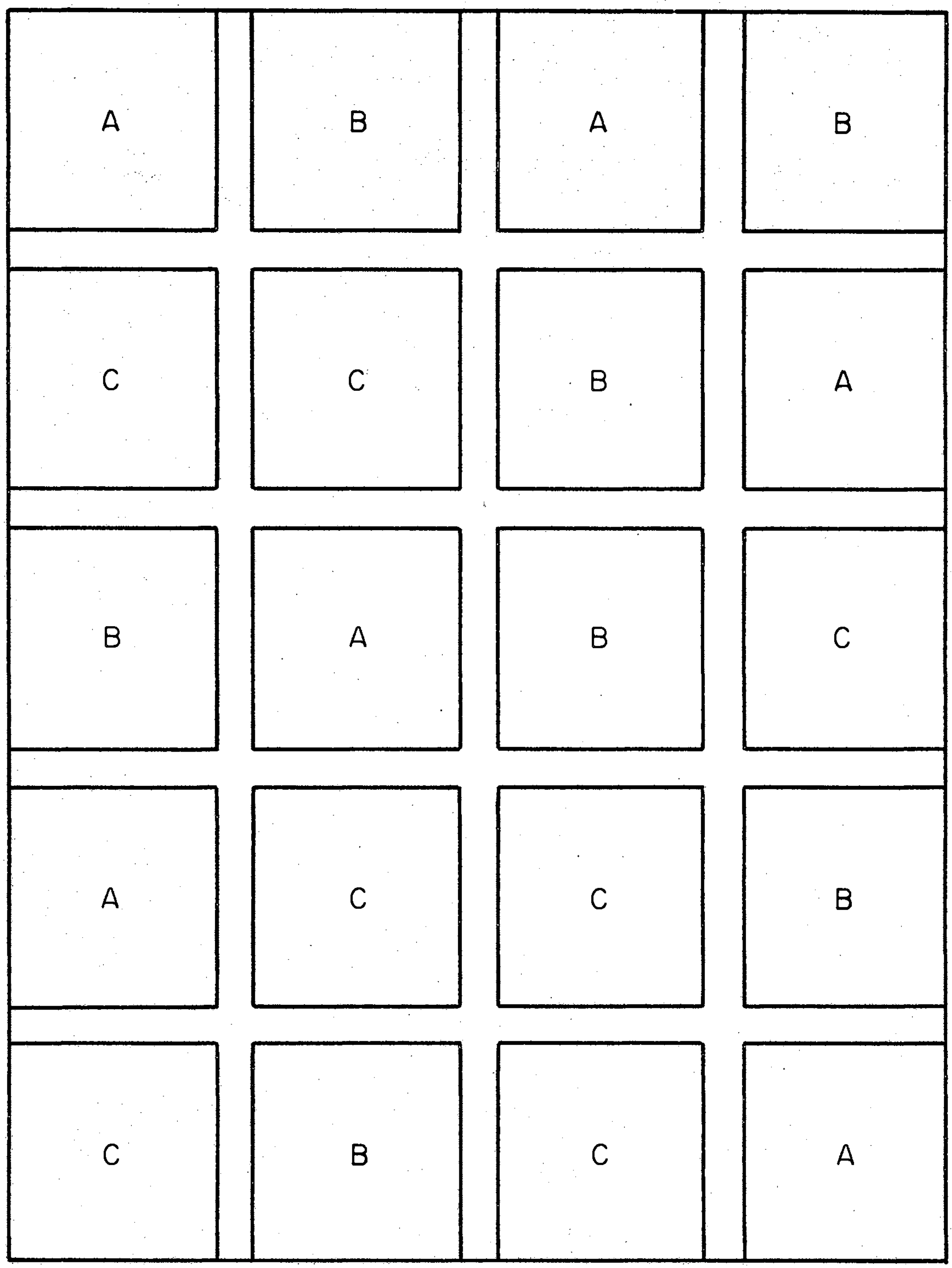

Figure 7. Plot arrangement in test of infestation rates of alfalfa mowed at different dates, Perkins, Oklahoma. A plots not cut during 1967, seed harvested 8-15-67. B plots cut 6-21-67, harvested 8-28-67. C plots cut 6-21-67 and 7-15-67, harvested 9-1-67.

Figure 8. Boerner Aliquot Sampler used in obtaining a random sample of alfalfa seed

sampler was repeated until one aliquot contained as little as 150-200 seeds. These samples were placed in paper bags and labelled for plot number and name.

To determine the infestation rate, the seed were placed on a 16-inch strip of Scotch filament tape, 3/4 inch wide, with sticky surface up, which was fixed to a wooden slat 18 x 1 x ¼ inch (Fig. 9). The plot number and the fraction of the original sample was recorded on a small piece of paper, pinned at one end of each slot. All fertilized individual seeds were dissected under a low power magnifier to determine the number of infested seeds and the various stages of the chalcid in the sample. These different dates of seeding and the record of infestation indicated the period at which maximum damage is done.

Results and Discussion

Urbahns as early as 1914 mentioned that seed crops maturing late suffer greater loss than those crops maturing early. The results given in Table II and III indicate that the chalcid damage was maximum to the seed crop maturing late. The seeds harvested early on August 15 showed the chalcid infestations of 2.82 percent and the damage level increased to 3.6 and 3.9 percent, when the crop was allowed to mature late in August and in first week of September, respectively. This increase in the damage with the growing season seemed to correspond well with the time of abundance of the alfalfa seed chalcid. The early maturing crop had comparatively lower infestation because the number of chalcids emerging during the early parts of the season was not very high. The chalcids responsible for this damage should have come either from overwintering generation or from the first. Fig. 1 shows that the peak chalcid

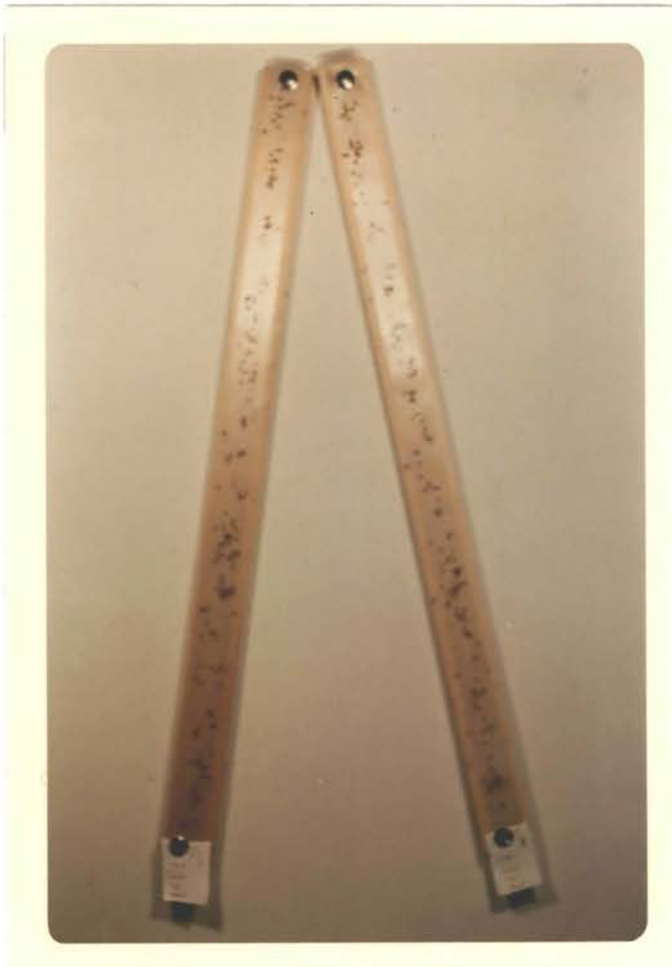

Figure 9. Wooden slats showing method of examining samples of alfalfa seed

TABLE II

SEED INFESTATION RATES OF ALFALFA MOWED AT DIFFERENT DATES

A. Not Cut Harvested 8-15-67		B. Cut 6-21-67 Harvested 8-28-67		C. Cut 6-21-67 and 7-15-67 Harvested 9-1-67	
No. Seeds		No. Seeds		No. Seeds	
Examined	Infested	Examined	Infested	Examined	Infested
181	5	196	4	118	6
153	1	176	11	120	7
147	2	190	8	197	6
180	4	180	12	153	6
185	2	197	10	190	7
203	10	179	8	210	8
195	18	180	6	189	7
186	2	194	3	175	4
130	2	185	2	160	7
177	7	187	6	110	4
174	2	150	7	157	7
195	6	190	6	139	5
200	4	195	7	188	8
190	2	198	5	193	6
189	5	146	4	201	9
193	8				
210	3				
205	10				

emergence at Perkins fell between the last week of July and the middle of August and that the first generation started with June 14. As very few chalcids from overwintering or from first generation were available for oviposition, the early harvest had, consequently, little damage. The seeds examined on August 28, were more infested than the ones examined on August 15; the reason being the increase in chalcid population which belonged to second generation and were fairly abundant. The third crop in the late season, was most infested, for it was exposed to the highest number of ovipositing chalcids. For practical purposes, the late maturing crop appeared to be most susceptible to the chalcid damage.

TABLE III

CHALCID DAMAGE TO ALFALFA SEED CROP AT PERKINS, OKLAHOMA, 1967

Date of Harvest	No. seeds examined	No. seeds infested	Percent infested
August 15, 1967	3293	93	2.82
August 28, 1967	2743	99	3.60
September 7, 1967	2500	97	3.90

CHAPTER V

SURVEY OF DAMAGE IN WESTERN OKLAHOMA

In order to estimate the actual level of chalcid damage during the season, seed samples from various fields were collected from different parts of the state. The survey was made in parts of northwestern and southwestern Oklahoma, and in each county at least three representative fields were selected. Samples were taken a few days before the fields were harvested by their owners. The seeds from these fields were collected each year, kept in paper bags, and the name and exact location of the fields noted. The seeds were then dried, cleaned, and separated by the method described previously. The three year record of chalcid infestation is given in Tables IV-VIII.

Results

The data from Table VIII indicated that southwestern Oklahoma had more chalcid infestation than the northwestern.

Wildermuth (1931) and Strong (1962) found out that chalcid damage was greater in western and southwestern states than in the northern and mid-western states. This could mean that the higher temperatures and dry climate are most favorable for the chalcids. In the northern United States, where the winter temperatures are below freezing, and the blizzards are more prevalent, these areas are rendered less suitable for the chalcid activity.

TABLE IV

ALFALFA SEED CHALCID INFESTATION IN MATURE SEED MANUALLY COLLECTED AT RANDOM FROM 30 FIELDS IN OKLAHOMA IN 1965[a]

Northwestern				Southwestern			
Field No.	No. Seeds Examined	No. Seeds Infested	Percent Infested	Field No.	No. Seeds Examined	No. Seeds Infested	Percent Infested
1	633	73	11.5	1	417	46	11.00
2	832	89	10.8	2	523	71	13.6
3	646	34	5.3	3	507	65	12.8
4	564	35	6.2	4	480	35	7.3
5	849	93	10.9	5	475	80	16.8
6	873	9	1.	6	439	97	22.1
7	811	45	5.5	7	537	129	24.0
8	896	22	2.5	8	543	93	17.1
9	847	33	3.9	9	457	89	19.5
10	757	29	3.8	10	498	95	19.1
11	867	31	3.6	11	453	70	15.5
12	231	5	2.3	12	505	77	15.2
13	784	33	4.2	13	574	100	17.4
				14	526	53	10.1
				15	533	56	10.5
				16	414	71	17.1
				17	461	126	23.3

[a]From Project H1274 departmental files, R. R. Walton, 1965.

TABLE V

ALFALFA SEED CHALCID INFESTATION IN MATURE SEED MANUALLY COLLECTED AT RANDOM FROM 45 FIELDS IN OKLAHOMA IN 1966[a]

Northwestern				Southwestern			
Field No.	No. Seeds Examined	No. Seeds Infested	Percent Infested	Field No.	No. Seeds Examined	No. Seeds Infested	Percent Infested
1	1317	1	0.08	1	3242	27	0.83
2	1771	12	0.67	2	1718	95	5.52
3	1375	23	1.72	3	3008	42	1.43
4	1712	0	0.00	4	2427	17	0.72
5	1914	0	0.00	5	3670	33	0.08
6	1551	4	0.25	6	1879	14	0.72
7	1370	0	0.00	7	3065	407	13.32
8	1313	12	0.91	8	2645	33	1.21
9	1519	2	0.13	9	3350	87	2.64
10	875	30	3.43	10	2960	20	0.67
11	1495	12	0.80	11	3534	125	3.52
12	1700	22	1.3	12	3391	73	2.24
13	1494	9	0.60	13	2693	44	1.62
14	1830	0	0.00	14	5189	10	0.31
15	1755	44	2.53	15	5028	104	2.13
16	1711	20	1.24	16	2418	96	4.00
17	2008	1	0.04	17	3075	81	2.62
18	1881	33	1.84	18	2585	182	7.04
19	1825	18	0.93	19	1860	107	5.81
20	1635	22	1.33	20	2567	93	5.62
21				21	2499	30	1.22
				22	3101	74	2.43
				23	2803	14	0.49
				24	2774	23	0.92
				25	3297	25	0.75

[a]From Project H1274, departmental files, R. R. Walton, 1966.

TABLE VI

ALFALFA SEED CHALCID INFESTATION IN MATURE SEED
MANUALLY COLLECTED AT RANDOM FROM 22 FIELDS
IN OKLAHOMA IN 1967

	Northwestern parts of state		
Field No.	No. Seeds Examined	No. Seeds Infested	Percent Infested
1	225	3	1.3
2	230	6	2.6
3	160	1	0.6
4	270	6	2.2
5	130	4	3.0
6	250	5	2.0
7	137	4	2.9
8	210	4	1.9
9	250	5	2.0
10	105	1	0.9
11	293	3	1.0
12	135	0	0.0
13	190	3	1.5
14	130	0	0.0
15	173	2	1.1
16	137	4	2.9
17	60	0	0.0
18	70	0	0.0
19	85	3	3.5
20	110	6	5.4
21	150	7	4.6
22	200	6	3.0

TABLE VII

ALFALFA SEED CHALCID INFESTATION IN MATURE SEED MANUALLY COLLECTED AT RANDOM FROM 37 FIELDS IN OKLAHOMA IN 1967

	Southwestern parts of State		
Plot No.	No. Seeds Examined	No. Seeds Infested	Percent Infested
1	478	101	21.1
2	229	29	12.6
3	492	106	21.5
4	532	39	7.3
5	318	29	9.1
6	263	18	6.8
7	286	18	6.2
8	247	9	3.6
9	408	86	21.0
10	338	80	23.6
11	284	30	10.5
12	238	10	4.2
13	270	19	7.0
14	338	114	33.7
15	410	71	17.3
16	476	37	7.7
17	265	65	24.5
18	312	47	15.0
19	216	12	5.5
20	203	6	2.9
21	315	27	8.5
22	332	14	4.2
23	375	44	11.7
24	245	32	13.0
25	304	34	11.1
26	239	22	7.2
27	316	39	12.3
28	315	31	9.8
29	374	69	18.4
30	287	21	7.3
31	238	7	2.9
32	342	30	8.7
33	287	50	17.4
34	220	13	5.9
35	441	27	6.1
36	226	23	10.1
37	333	40	12.0

TABLE VIII

ALFALFA SEED CHALCID INFESTATION IN MATURE SEED MANUALLY COLLECTED AT RANDOM FROM FIELDS IN NORTHWESTERN AND SOUTHWESTERN OKLAHOMA

	1965		1966		1967	
	N.West	S.West	N.West	S.West	N.West	S.West
Average Infestation	5.6	16.2	0.8	2.5	1.97	12.2
No. fields	13	17	20	25	22	37

In Oklahoma, the cold fronts which come from the northern regions, often begin to loose their movements and severity by the time they reach the central and northern areas of the state. As a result, temperature decreases are more frequent and pronounced in the northwestern than in the southwestern areas. The temperature record for the past 5 years of these regions indicates that southwestern Oklahoma has from 1-4^{o}F higher temperatures, which makes it more adaptable to the chalcid. The temperature and humidity for both the areas is given in Table IX.

TABLE IX

ANNUAL MEAN TEMPERATURE AND PERCENT RELATIVE HUMIDITY IN NORTHWESTERN AND SOUTHWESTERN OKLAHOMA[a] (DEGREES FARENHEIT)

Year	Northwestern		Southwestern	
	^{o}F	R. H.	^{o}F	R. H.
1962	60.4	30.30	64.8	21.10
1963	60.9	24.82	63.7	18.85
1964	60.2	30.55	62.7	26.31
1965	60.5	26.45	62.9	25.81
1966	58.8	18.10	61.2	20.33

[a]Climatological data obtained from Weather Bureau, U. S. Department Commerce, Washington.

CHAPTER VI

CHEMICAL CONTROL

Methods and Materials

The test area consisted of 84 plots of 9 x 40 ft. located on the NE side at the Perkins Experiment Station (Fig. 10). This area was sufficient for each insecticide to be replicated four times. Each insecticide was assigned a plot number by use of a random number table. One larger area of 50 x 50 ft. was also provided for malathion at 0.5 lbs. per acre, at approximately 300 ft. from the other plots. A 3 ft. swath was mowed along the east margin of each test plot to de-limit it from the other plots. Each plot was marked with a 24 inch stake and labelled with a plot number. The insecticides tested are listed in Tables X-XI along with their rates of application.

The granular materials were applied by Gandy Granular Applicater, in a strip down the center of the test plot. The granulars were applied once when the crop height was about 6-12 inch before bloom, and once when the crop was 30-34 inches, with 70% flowers on bloom.

The sprays were applied with a 6 ft. boom using #4 gal. hollow cone nozzles. A pressure of 40 psi was maintained to produce 10 gallons per acre at a ground speed of 2 3/4 miles per hour. For the application of wettable powder #9 G hollow cone nozzles were used. Dates of application of the insecticides are shown in Table XII. The sprays were also used twice; the first application was made when the alfalfa was 14-22

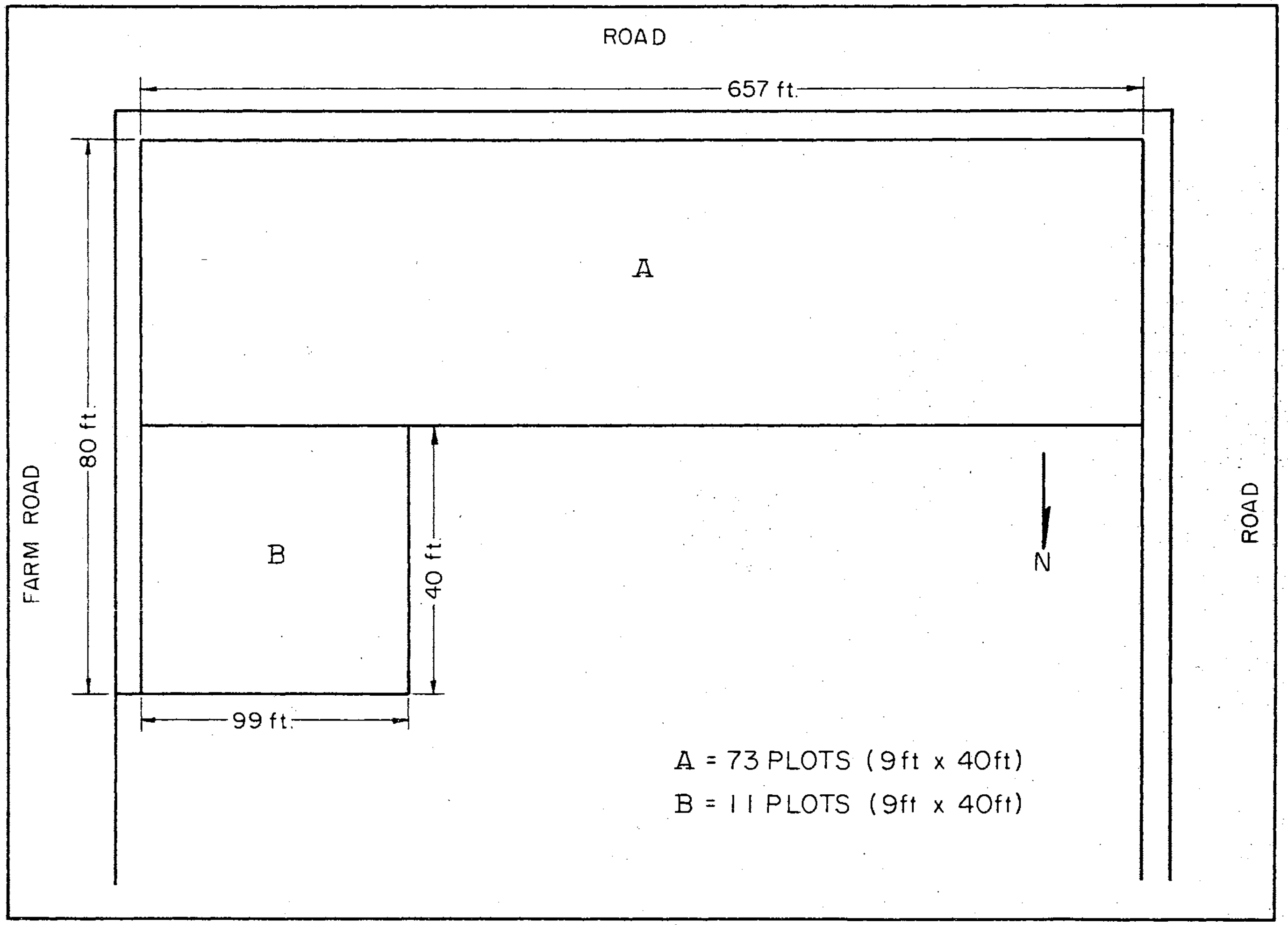

Figure 10. Location of the test plots for chalcid chemical control, Perkins, Oklahoma, 1967.

TABLE X

CONTROL OF THE ALFALFA SEED CHALCID ON ALFALFA USING GRANULAR INSECTICIDES, PERKINS, OKLAHOMA, 1967[a]

Insecticide and Application rate per acre	Percent Seed Infested Sample Number								Total Seeds		Mean Percent Infested
	I	II	III	IV	V	VI	VII	VIII	Examined	Infested	
Niagra 10242 10G 15 lbs./A	1.54	0.00	1.20	0.00	1.17	1.15	2.10	0.67	1434	14	0.97
Dasanit 10G 15 lbs./A	0.95	1.15	2.04	0.99	0.99	0.00	1.03	1.09	1253	13	1.03
Dimethoate 10G 10 lbs./A	1.58	1.61	2.33	2.15	0.55	0.00	0.97	0.00	1208	14	1.15
Disulfoton 10G 15 lbs./A	0.94	1.50	3.10	0.00	3.01	0.91	0.47	0.47	1300	17	1.30
Temik 10G 15 lbs./A	1.34	2.45	2.55	3.03	1.70	1.72	1.11	0.42	1280	23	1.79
Phorate 10G 15 lbs./A	2.58	1.17	0.97	2.00	3.22	1.92	1.64	0.82	1227	22	1.79
Dimethoate 10G 15 lbs./A	0.54	1.50	1.92	1.80	1.57	0.97	3.03	3.07	1202	22	1.80
Untreated check	2.82	2.60	3.00	2.70	3.40	3.48	4.60	2.04	1232	38	3.08

[a]The number of seeds examined per plot ranged from 66-223.

TABLE XI

CONTROL OF THE ALFALFA SEED CHALCID ON ALFALFA BY SPRAYS, PERKINS, OKLAHOMA, 1967[a]

Insecticide and Application rate per acre	Percent Seed Infested Sample Number								Total Seeds		Mean Percent Infested
	I	II	III	IV	V	VI	VII	VIII	Examined	Infested	
Azodrin 5/g 1 lb./A	0.00	0.60	0.00	0.51	0.00	0.49	0.00	0.32	1214	3	0.24
Phosphamidon 8/g 1.5 lbs./A	0.33	0.77	0.00	0.54	0.51	0.00	1.05	0.00	1245	8	0.40
Phosdrin 2/g 0.5 lbs./A	0.53	0.00	0.32	0.72	0.00	1.19	0.00	1.16	1216	6	0.49
GC-6506 4/g 1.5 lbs./A	0.49	0.93	0.00	0.70	-	-	-	-	561	3	0.53
Systox 2/g 1.5 lbs./A	0.00	-	0.42	-	1.29	-	-	0.41	739	3	0.53
Dimethoate 2-67/g 0.25 lbs./A	0.51	0.00	0.00	1.06	1.19	1.88	0.00	0.56	1213	8	0.65
Bidrin 2/g 1 lb./A	1.29	0.54	0.00	1.40	0.53	0.70	-	1.28	1096	9	0.82
Niagra 10242 W.P. 1.5 lbs./A	2.50	0.86	1.33	0.00	0.00	2.87	1.92	0.52	1272	16	1.25
Dasanit 6/g 1.5 lbs./A	2.66	0.65	1.18	0.35	1.08	2.67	0.61	1.20	1313	17	1.30
Meta-Systox 2/g 1.5 lbs./A	1.07	1.17	0.89	1.28	1.02	1.96	1.26	2.15	1258	17	1.35
Dimethoate 2.67/g 0.75 lbs./A	1.38	0.00	2.81	0.00	2.70	0.78	1.69	2.01	1267	18	1.42
C9491 3/g 1.5 lbs./A	1.17	1.35	1.11	1.42	1.63	0.00	0.53	4.23	1324	19	1.43
Disulfoton 6/g 1.5 lbs./A	0.74	1.11	2.66	2.50	0.00	0.96	3.03	0.84	1214	18	1.48
Malathion 5/g 0.5 lbs./A	-	-	3.80	-	-	3.52	-	-	300	11	3.66
Untreated seed	4.73	2.75	2.05	2.27	2.98	3.41	2.39	4.22	1158	36	3.10

[a]The number of seeds examined per plot ranged from 71-234.

TABLE XII

DATES OF APPLICATION OF INSECTICIDES

Insecticide Formulations	Dates of Application
I. Granular	1) June 23, 1967
	2) July 20, 1967
II. Sprays (except Phosdrin and malathion	1) June 30, 1967
	2) July 20, 1967
III. Phosdrin spray at 0.5 lbs. per acre	1) June 30, 1967
	2) July 6, 1967
	3) July 13, 1967
	4) July 20, 1967
	5) July 27, 1967
	6) August 4, 1967
IV. Malathion spray at 0.5 lbs. per acre	1) August 11, 1967
	2) August 18, 1967
	3) August 25, 1967
	4) August 31, 1967

inches tall and 1-2 percent of the stems were in bloom. The second spraying was given when the crop was 30-34 inches and about 70 percent of the stems were in full bloom.

Seed samples were collected when all the seeds in the plots were mature. An average of 20 plants per plot was collected and the cleaned seeds separated by the method described earlier. The individual seeds were examined to determine the infestation.

Results and Discussion

Little information is available in the literature on the control of alfalfa seed chalcid with insecticides. Most of the research workers on chalcid emphasized clean cultivation. However, Dobson (1953) recommended 10% DDT, 20% Toxaphene or 2% Parathion, but no data were presented on their effectiveness. Bacon and Riley (1963) attained significant control with dimethoate and telodrin. Bacon et al.,(1964) were able to reduce the overwintering population by applying parathion to moist soil.

The chemical control of the seed chalcid is difficult for the reason that the infestation is restricted to the seed, where it is difficult to implant the insecticides. The application of the chemicals before pollination or at flowering time, when chalcid activity is greatest, often causes the problem of killing pollinating bees and other beneficial insects. This difficulty was apparent early in this investigation. Systemic insecticides were, therefore, selected to test their usefulness in the control of the alfalfa seed chalcid.

In the granular application, all the materials were applied twice. Dimethoate 15 lbs. per acre, Temik 15 lbs., and Phorate 15 lbs. per acre did not show any marked amount of control. Disulfoton 15 lbs., Dasanit

15 lbs. and dimethoate 10 lbs. per acre gave fairly effective control. Among all the granulars, Niagra 10242 gave the best control (Fig. 11).

Liquid sprays seemed to do better than the granular applications. Phosphamidon, demeton, GC-6506 at 1.5 lbs., dimethoate 0.25 lbs., Bidrin 1 lb. and Phosdrin at 0.5 lbs. per acre all showed good results. The best spray control was obtained with Azodrin at 1 lb. per acre (Fig. 12). Dasanit, C9491, di-sulfoton, Meta-Systox at 1.5 lbs. and malathion at 0.5 lbs. per acre did not show any significant reduction in infestation. All these materials were applied twice with the exception of phosdrin and malathion, which were sprayed 6 and 4 times, respectively.

All these tests showed that systemic insecticides offered the best possibility for controlling the alfalfa seed chalcid. The various concentrations of insecticides pointed out that at least 0.5 lbs. per acre of the liquid, with weekly intervals, was necessary to check the insect. This concentration was effective, because it was applied during the growing conditions of the plant, for the translocation of its toxicity. The results of these tests are given in Tables X and XI.

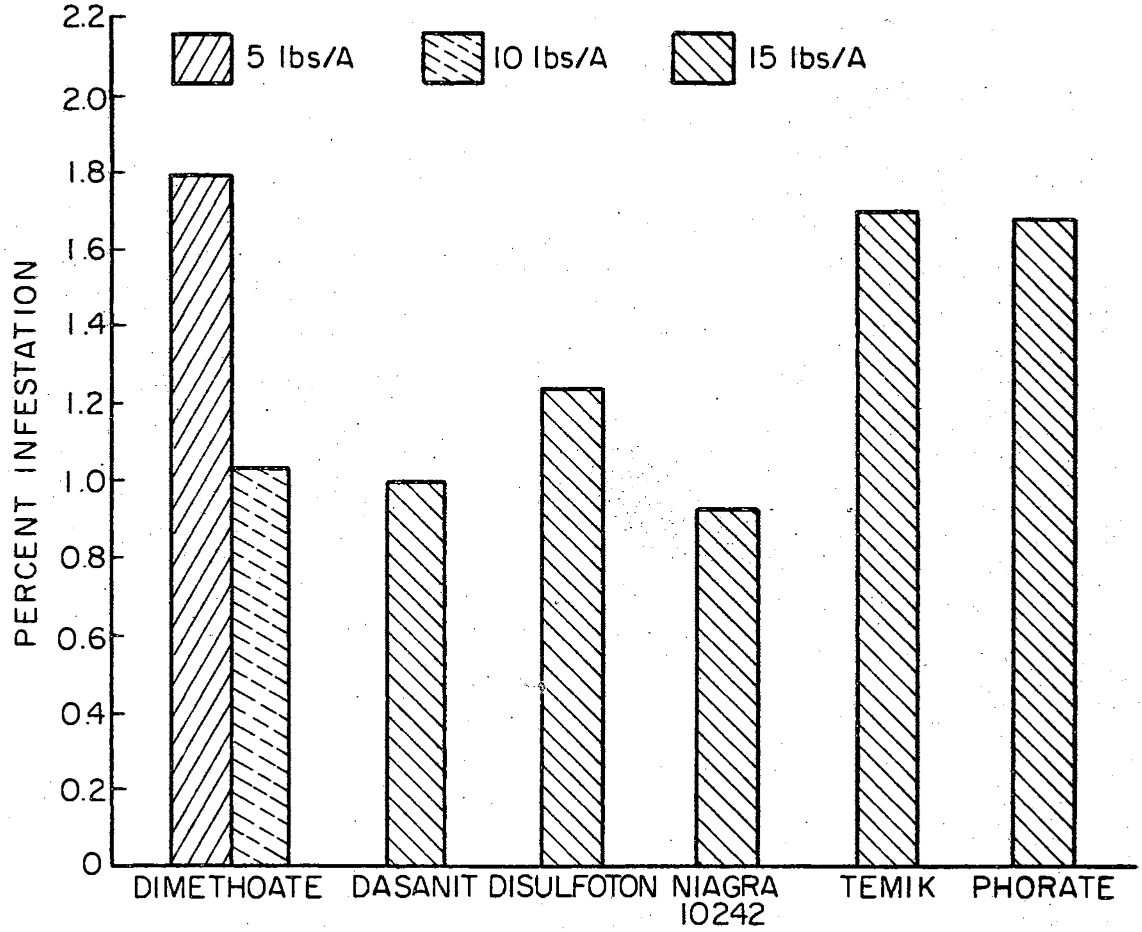

Figure 11. Control of the alfalfa seed chalcid with 10% granular systemic insecticides.

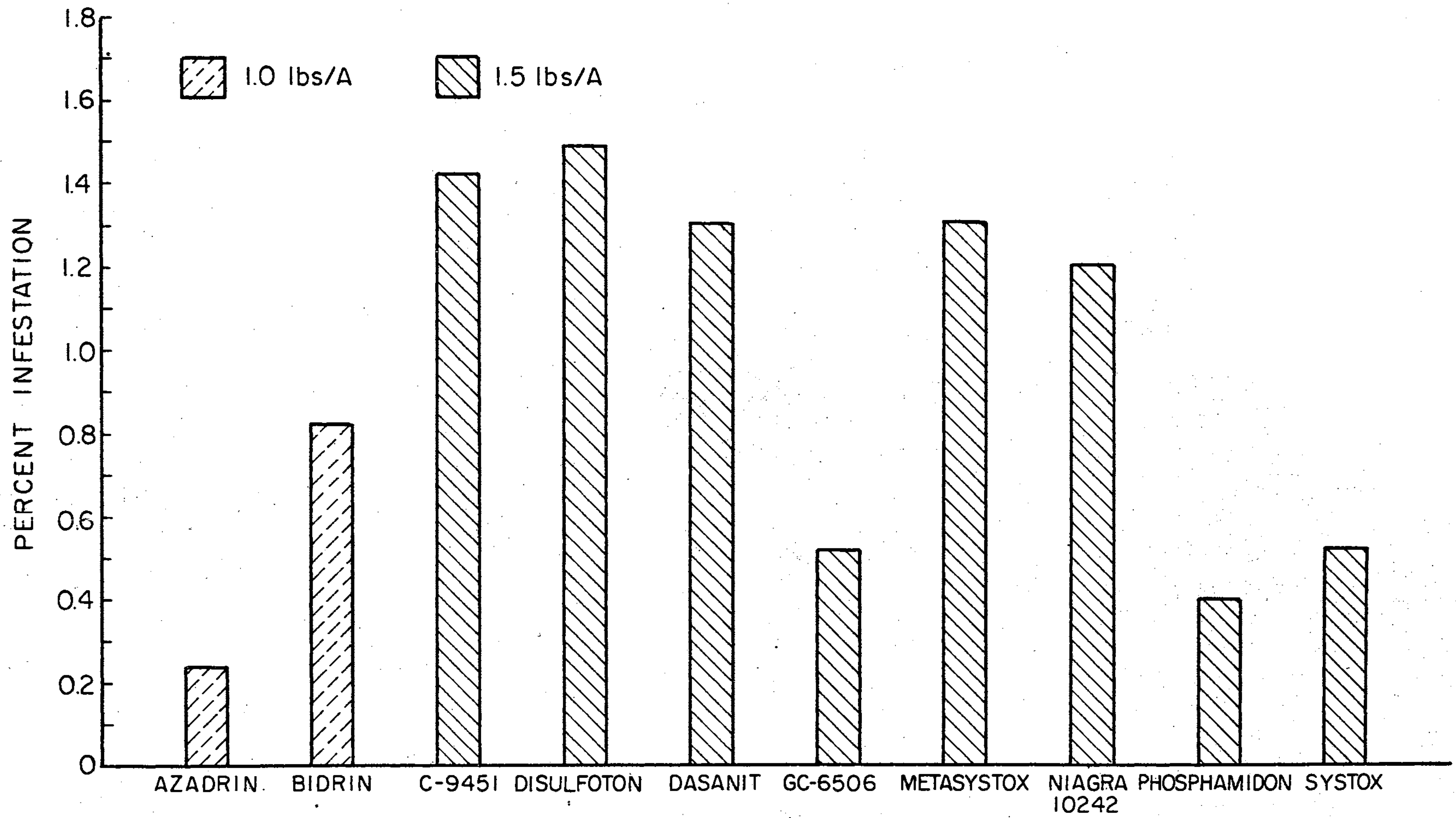

Figure 12. Control of the alfalfa seed chalcid with systemic spray insecticides.

CHAPTER VII

SUMMARY

The biology and control of alfalfa seed chalcid (_Bruchophagus roddi_ Guss.) were investigated at the Perkins Experimental Station during summer 1967.

It is reported from many countries and believed to be world-wide in distribution. In United States it was recorded from most of the alfalfa seed producing areas, causing 5-83% seed losses in western and southwestern states.

The host plants comprise of many species of _Medicago_ such as _M. sativa_ (alfalfa), _M. hispida_ (bur-clover), and _M. falcata_.

Adult chalcids are black, 1/12 inch long, with tarsi and anterior tibiae yellowish-brown. Females are slightly larger than the males with a long pointed ovipositor. There are 4 larval instars. Only the second and third instars are more active and the fourth is without movement. The mature pupa is encased in a thin transparent pupal skin.

In Oklahoma, the life cycle ranges from 24-30 days and there are 3 generations annually. Winter generation is longer than the other generations. The infestation is restricted only to the seed. The largest pupulations occur about first and second week of August. A 3 year survey of seed infestation in western Oklahoma revealed that southwestern Oklahoma had more chalcid damage than the northwestern.

The cultural and biological control of the seed chalcid have not proved practical. The use of resistant varieties is generally recommended. The chalcids can be controlled with systemic insecticides but is expensive. Systemic insecticides such as Niagra 10242 10 G and Azodrin spray at 15 lbs. and 1 lb. per acre respectively offered the best control. Dimethoate 10 G 10 lbs., Dasanit 10 G 15 lbs. and sprays of GC-6505, Phosphamidon, and Systox at 1.5 lbs. per acre were also equally effective.

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