5-1961

Alfalfa Resistance to the Clover Seed Chalcid *Bruchophagus gibbus* (Boheman)

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ALFALFA RESISTANCE TO THE CLOVER SEED CHALCID

BRUCHOPHAGUS GIBBUS (BOHEMAN)

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Agronomy

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1961

ACKNOWLEDGMENT

I would like to express my sincere appreciation to my major professor, Dr. DeVere R. McAllister, and to the other members of my thesis committee for their assistance and direction in this study. My thanks are also extended to my wife, Carolyn, for her help and inspiration received through the development of this thesis. I also wish to acknowledge the financial aid received through the Jenkins W. Jones Memorial Scholarship.

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INTRODUCTION

The destructive nature of the clover seed chalcid has been known since the latter part of the 19th century. This jet-black Hymenoptera, often called the "chalcis-fly," destroys from 10 to 20 percent of the alfalfa seed in Utah each year. Damage as high as 85 percent has been reported.

The insect is widely distributed and causes damage to its host plants wherever they are grown and produce seed. The complete development of the pest occurs within the alfalfa seed. For this reason damage may be completely unnoticed except for a reduced yield when a higher yield was estimated.

Control by cultural methods has been suggested since early in this century. Success with these methods has usually been difficult because of its demand for community cooperation, which is not always feasible. No other method of control has been found.

The objectives of this study were to determine: (1) if any commercial varieties of alfalfa available for study were resistant to the clover seed chalcid; (2) to ascertain if other varieties and clones presently being bred and/or checked for hay and/or seed yield in Utah manifest any resistance to this seed pest.

REVIEW OF LITERATURE

Classification

Bruchophagus gibbus (Boheman), family Eurytomidae, superfamily Chalcidoidea and order Hymenoptera is the present classification of the clover seed chalcid. It was first described by Dr. L. O. Howard in 1879 as Eurytoma funebris Howard and considered a parasite of the clover seed midge. In 1894 Dr. W. H. Ashmead referred this species to the genus Bruchophagus supposing it a parasite of seed weevils (Bruchidae). In 1891 Dr. Hopkins through careful observation of infested seeds found that the insects were feeding upon the seeds (Urbahns, 1920).

This insect may occasionally be referred to as Bruchophagus funebris Howard which was for many years the scientific name of the clover or alfalfa seed chalcid.

Kolobova (1950) reported that there are two distinct races present. One is more favorably adapted to the cooler Northern regions and to clover, and the other better adapted to the warmer regions and alfalfa. Differences also existed in length of abdomen and thorax. A third race found in 1948 develops in the seeds of birdsfoot trefoil. The eggs of this race differ from both of the other two. Of the former two races, the one infesting clover is accepted as the typical one, since the insect was described from clover. The race from alfalfa is named subspecies medicaginis.

Importance

Damage attributed to this insect has been very evident since Hopkins found the larvae within infested clover seeds. According to Peairs and Davidson (1956) this insect is one of the most important pests in alfalfa and clover seed production.

Urbahns (1914) reported the insect increasing rapidly, causing serious annual loss and in some areas threatening the production of alfalfa seed. Damage from 10-30 percent was reported for the early crops and from 20-70 percent for the late crops, with some samples showing 85 percent damage. Urbahns (1920) refers to the clover seed chalcid as the most destructive pest of alfalfa seed in the United States. Carter and Ruggles (1925) also give it the same appellation for both clover (probably red clover) and alfalfa seed production. They reported damage in some places from 70 to 80 percent. For the year 1911 Freeman (1914) indicated losses ranged from 26 to 88 percent in Yuma, Arizona. Seed set was low for samples taken in late August and September. Sorenson (1930) reported an average loss of 15.84 percent for Millard County and the Uintah Basin area for the years 1926-1929. A similar loss was reported for the following four years (Sorenson, 1934).

MacDonald (1946) reported losses ranging up to 50 percent in birdsfoot trefoil. Present losses in Utah range from 10 to 20 percent (Lieberman and Knowlton, 1955) while those in the areas of West Fresno County of California average near 20 percent (Bacon, et al., 1959).

According to Vinogradov (1941), up to 15.3 percent of the threshed clover seeds were damaged and up to 37.1 percent of all seeds thrown out with the chaff were damaged in 43 regions sampled in the Soviet

Union. Kolobova (1950) states that alfalfa seed is infested to a higher proportion than clover seed.

Damage

Damage from the clover seed chalcid is not readily obvious. Only by careful observation in the field does it become apparent that the insect may be associated with the alfalfa seed. Further, the insect is very small, carrying out its destructive work entirely within the alfalfa seed.

According to Sorenson (1930) and Urbahns (1914), the tiny larvae feed upon the semifluid or jelly-like albumen of the developing seed. This is about the time the cotyledons begin to develop. Feeding progresses quite rapidly after the first 2 days with most of the seed being eaten, except the seed coat, prior to the normal period of seed hardening.

Infested seeds are usually dwarfed, misshapen and discolored. In very few instances do infested seeds appear normal; when this does occur, they lack the glass which is associated with normal seed color. Nearly all infested seeds are soft and easily crushed with the fingers. They are also lighter than normal seeds and usually pass out of the harvester in the chaff and screenings. Low yield, when a higher yield was indicated by pod set, may be the only indication of chalcid damage.

Host plants

The adaptation of the clover seed chalcid does not confine its damage to clover and alfalfa seeds. Following is a list of the plants known to be attacked by the insect.

Medicago arabica (Urbahns, 1920)
Medicago falcata-alfalfa (Urbahns, 1920)
Medicago hispida deniculata-bur clover (Urbahns, 1920)
Medicago hispida nigra-bur clover (Urbahns, 1920)
Medicago hispida terebillum-bur clover (Urbahns, 1920)
Medicago ruthemia (Urbahns, 1920)
Medicago sativa-alfalfa (Urbahns, 1914 and 1920, Sorenson, 1930 and others)
Medicago tuberculata (Urbahns, 1920)
Medicago tunetana (Urbahns, 1920)
Lotus corniculatus-birdsfoot trefoil (MacDonald, 1946)
Trifolium incarnatum-crimson clover (Sorenson, 1930)
Trifolium pratense-red clover (Urbahns, 1920)
Astragalus douglasii-Douglas or milk vetch (Bridwell, 1923)
Oxytropis lambertii-crazy weed (Bridwell, 1923)

The following plants, though closely related, are not attacked.

Melilotus alba-white sweet clover (Urbahns, 1920 and Sorenson, 1930)
Melilotus indica-sour clover (Urbahns, 1920)
Melilotus officinalis-yellow sweet clover (Urbahns, 1920 and Sorenson, 1930)
Trifolium hybridum-alsike clover (Urbahns, 1920 and Sorenson, 1930)
Trifolium repens-white clover (Urbahns, 1920 and Sorenson, 1930)

Distribution

Sorenson (1930) states the clover seed chalcid occurs in many parts of both the Eastern and Western hemispheres. Its distribution is general throughout most of the United States. Wildermuth (1931) and Peairs and Davidson (1956) report that the largest numbers are found in the irrigated regions of the Western and Southwestern states and in the seed producing areas of the Midwest. Urbahns (1914 and 1920) states that it has been found in seeds imported from Germany, Turkestan and Chile and reported in South Africa. Its distribution throughout the Soviet Union, according to Kolobova (1950), is very wide.

Description

The eggs (Figure 1), larva (Figure 2), pupa (Figure 3), and adults (Figure 4) are described by Sorenson (1930).

Life cycle

Emergence. Sorenson (1930) states that with the arrival of spring and warmer weather the overwintering clover seed chalcid larvae pupate and transform to the adult stage. In this stage they chew through the seed coat of the alfalfa seed and through the enveloping pod, if it is still surrounding the seed. The adult escapes through these small round holes into the outer surroundings. They usually crawl or fly about the alfalfa plant, mating soon afterwards.

Using cage traps and sweeping checks, Sorenson (1930) found that emergence begins from May 1 to May 15 and continues through July 15 in the Uintah Basin area of Utah. Further, the males were usually the first to emerge and predominate in numbers throughout the season.

Laboratory and field observations by Vinogradov (1941) in Russia showed that adults emerge when the mean temperature is from 64.4° to 68° F. providing the moisture content of the surrounding seed is not less than 15 percent. According to Sorenson (1930) the first brood begins to emerge from seed crops about July 20 and the second brood about a month later. Emergence is continuous with considerable overlapping of generations.

Adult. Wildermuth (1931) indicated that the adults apparently feed in the alfalfa blossoms and possibly remain alive for several weeks when conditions are favorable. They often have been observed in large numbers like a cloud of gnats, occasionally being confused by

Figure 1. Eggs of the clover seed chalcid

Figure 2. Larva of the clover seed chalcid

Figure 3. Pupa of the clover seed chalcid

Figure 4. Adult clover seed chalcids

feed apace with the developing seeds. Death often results due to starvation when the seeds become too hard to chew.

When the female has, after careful examination, selected the seed for oviposition she "bends her abdomen ventrally and forward, extrudes her stinger-like ovipositer and thrusts it through the pod and seed coat into the soft substance of the kernel where the egg is deposited." (Sorenson, 1930). According to Urbahns (1920) about 1 minute is required for oviposition. The eggs are usually placed just beneath the inner integuments but sometimes are placed between the cotyledons or in the semifluid contents of a cotyledon.

The female clover seed chalcid may fly around from 3 to 4 weeks after emergence, in favorable weather, before finding a suitable host for oviposition. In the summer only a few days elapse before the emerging chalcids oviposite. The positioning of the female is directly over the slight enlargement of the pod caused by the growing seed (Urbahns, 1920).

As many as six eggs have been observed deposited in one raceme. Time elapsing for this has been noted to take from 15 minutes to an hour. To determine the potential offspring of clover seed chalcid females, Sorenson (1930) dissected 50 gravid females which he had kept in captivity for 48 hours. The eggs counted from these females varied from 24 to 66 with an average of 42.24 eggs.

Egg. Under favorable summer conditions most clover seed chalcid eggs hatch in 4 days. Time from oviposition, however, varies from 3 to 6 days under Utah conditions (Sorenson, 1930). In Pasadena, California, Urbahns (1920) reported that it may take from 7 to 12 days early in the season, 5 days in June and 4 days during the warm season for incubation.

Larval. The larval stage of the clover seed chalcid appears in the seed about a week after the pods have begun to curl. This is between June 20 and July 1 under field conditions and about a week earlier with volunteer plants.

Feeding usually continues from 10 to 15 days with an average near 10 days (Sorenson, 1930). According to Urbahns (1914 and 1920), the larvae do not feed for the first day or two and usually complete feeding before the pods have time to ripen. If sufficient moisture in the seed pod exists transformation to the pupal stage may take place within a day or two. Urbahns (1920) further states that should the seeds be quite dry when larval development is complete, dormancy may occur with no further development taking place until the following spring or later depending upon moisture and temperature.

This period of aestivation has a great influence upon the life cycle of this insect. It may continue for 2 years or longer. Infested seeds collected in September, 1912 and kept dry continued hatching clover seed chalcids through September, 1914 (Urbahns, 1920). The work of Wildermuth (1931) agrees with these findings.

Pupa. The actual length of this stage is from 8 to 16 days for the summer brood, with an average of near 10 days. From 8 to 21 days are required for the winter brood, with an average of about 16 days. Environmental conditions influence both transformation and duration of the pupal stage (Sorenson, 1930).

Generations per year. In the seed producing regions of Utah it is thought that there are 2 to 3 generations per year (Lieberman and Knowlton, 1955). As many as 6 generations per year are reported in the warmer regions of Arizona where frost seldom occurs. Thirty to 40 days are needed for each generation (Wildermuth, 1931). It is possible, however, for a new generation to occur every 23 days. Bacon, et al. (1959) state this has been reported in Utah. The most important factors influencing generation time are moisture and temperature.

Overwintering. The clover seed chalcid overwinters in the larval stage within the alfalfa seed. Neglected fields of alfalfa and host plants which produce seeds along ditches and waste places contribute greatly to the number of overwintering chalcid. Chaff stacks, screenings and infested seed pods which have fallen to the ground in alfalfa seed fields also serve as overwintering sites for future infestations (Urbahns, 1914).

It was observed for the 4 year average, 1926 to 1929, that 76.26 percent of the infested seeds produced on first growth alfalfa contained overwintering larvae. The remaining 25.74 percent contained chalcids which emerged the same season the seed was produced. Infested seed from the second crop alfalfa for the same period had about 84 percent overwintering larvae. Both summer broods and overwintering broods may emerge during the same period of time (Sorenson, 1930). The number overwintering from either crop will change from year to year as environmental factors vary.

Control

Natural. A summary of 10 parasites known to affect the clover se seed chalcid population is given by Butler and Hansen (1958). All those included are of the order Hymenoptera, superfamily Chalcidoidea. In the family Eulsphidae there is Tetrastichus bruchophagi Gahan which is generally distributed throughout the United States. It is the most active parasite of *B. gibbus* in Central California where according to Urbahns (1917) it destroyed 52 percent of the clover seed chalcid larvae in alfalfa seed in 1913. Butler and Hansen (1958) further state that this same insect is a hyperparasite on the alfalfa weevil parasite *Bathyplectes cuiculionis* (Thorn). *Tetrastichus venustus* Gahan is a rare parasite of this same family and is distributed in Arizona, California, Indiana and Iowa.

In the family Eupelmidae, *Eupelmus* sp. only a single larva was found from alfalfa seed dissected by Urbahns in 1920. *Eupelmella Visicularis* (Retzius) has a wide host range among which is *B. gibbus*. It is found from Maine to Virginia and also in Colorado, Oregon, Tennessee, Utah and Washington.

In the family Torymidae there are three species parasitic to the clover seed chalcid: *Liodontomerus insuetus* Gahan, *L. longfellowi* (Girault) and *L. perplexus* Gahan. The former is found in Arizona, California, Kansas, New Mexico and Oklahoma but only rarely collected. The second also known as *L. pecundus* is found mainly in the Northern States and only associated with the clover seed chalcid or red clover. *L. perplexus* is found associated with the clover seed chalcid on alfalfa. It has a wide distribution being found in Arizona, California, Colorado, Idaho, Iowa, Nebraska, North Dakota, Oklahoma, South Dakota, Utah and Washington.

Three species are also listed in the family Peteromalidae as parasites on the clover seed chalcid. The first, *Amblymerus bruchophagi* (Gahan) also known as *Eutelus bruchophagi* Gahan has a distribution which includes Idaho, Utah and Northern California. It usually emerges earlier than other clover seed chalcid parasites. _Habrocyptus medicaginis_ Gahan, the female of which closely resembles _A. bruchophagi_ Gahan, is found in the Western and Northern Central States. _Trimeromicrus maculatus_ Gahan is a very important species in Arizona and California and is found also in Illinois, Kansas, New Mexico, South Dakota, Utah and Washington. Results in research by Butler (1959) from over 190 fields sampled throughout Arizona, California, Idaho, Utah and Washington show the following distribution of four previously mentioned clover seed chalcid parasites. _L. perplexes_ was the most abundant in all areas. _T. bruchophagi_ was significant in Arizona only. _H. medicaginis_ and _A. bruchophagi_ could not be distinguished and were grouped. The latter two were particularly important in Utah, Idaho and Washington.

It was also shown that row spacing influenced the numbers of parasites and hosts. The 6 inch rows had the fewest and the 40 inch hills had the greatest infestation (Butler, 1959).

Butler (1959) further states that infestation of seed samples increased from 6 to 61 percent for the June 18, 1953, and July 23, 1953, samples respectively. During this same period the clover seed chalcid parasites increased from an average of 1 percent on June 30 to 39 percent on July 7, 7 percent on July 16 to 86 percent on July 22. In all treatments _L. perplexus_ was the main parasitic species collected, representing 68 percent of the total. In all trials the clover seed chalcid parasite population is very closely associated with its host so far as ecological conditions are concerned.

The following is a list of parasites in order of frequency which bred in alfalfa in Poltava, Russia, from _B. gibbus_ in alfalfa seeds:

H. medicaginis Gahan, T. bruchophagi, Ashm., L. perplexus Gahan, Eupelmus microzonus, Torst, E. atropurpurens, rosellea Miers and Eutelus sp. The rate of parasitism in Poltava ranged from 23.8 to 80.9 percent. Of this H. medicaginis and T. bruchophagi accounted for 90 percent of the parasitism (Nikol'skaya, 1932).

In the warmer areas, according to Wildermuth (1931), the parasites are able to develop nearly as rapidly as the chalcids themselves. Six generation of chalcids have been noted in the warmer regions and only 2 generations usually occur in cooler regions. Parasitism in the warmer regions is so effective that infestation by the chalcid is no greater than that of cooler regions.

It should be noted that all of the foregoing parasites usually attack the clover seed chalcid in the larval stage.

Cultural. Inasmuch as overwintering occurs within the hollowed out alfalfa seed, which the chalcid has destroyed, all practices for its control are associated with this part of the alfalfa plant. Urbahns (1914, 1920), Sorenson (1930), Sorenson and Knowlton (1951) and Lieberman and Knowlton (1955) discuss methods for cultural control. They suggest to: (1) burn chaff stacks, (2) feed or destroy all screenings, (3) eliminate all host plants, (4) irrigate for rapid seed set, (5) leave second crop for seed, and (6) cultivate to bury infested seeds which have fallen to the ground.

Chemical. Effective chemical control has not been developed. The developing insect is well protected in the alfalfa seed and thus safe from presently used insecticides in alfalfa fields. Systemic insecticides are presently being checked to see if heavy enough concentrations will penetrate the seed and destroy the larvae.

The activity of the adult chalcid is coincident with that of pollinating insects. Endeavoring to control the insect at this period of time would also destroy pollinators. Because of a continuously emerging and migrating chalcid population, spraying operations would also need to be continuous to be effective (Bacon, *et al.*, 1959).

Host resistance

According to Bunker (1959), in his study of infestation of alfalfa varieties by *B. gibbus*, all varieties were not infested at the same rate. Significance at the 1 percent level was evident in all varietal studies. Observations on 8 varieties at Logan had mean infestations ranging from 28.78 to 61.40 percent. Results of studies on 40 different alfalfa varieties at Delta, however, seemed to consistantly place Rhizoma and Vernal with the highest and Lahontan and Nemastan with the lowest infestation.

Bacon, *et al.* (1959) found no significant differences between alfalfa varieties. High and low infestations were observed in all varieties where sufficient fields were sampled to make adequate comparisons.

METHODS AND PROCEDURE

The 1959 varietal and clonal studies

At Delta, Utah, 40 varieties of alfalfa were studied for resistance to the clover seed chalcid. At Pleasant Valley, 40 varieties were also available, with only three being different from those in the Delta plots. An additional 26 varieties in a Western Uniform Seed Nursery trial grown by Dr. Marion W. Pederson were checked. This nursery had a total of 30 varieties, four of which were also found in the Delta plots. This nursery was located at the Evans Experimental Farm near Logan, Utah. Also checked at the Evans Farm was a clonal nursery which included 13 clones and two varieties. These two varieties, Rhizoma and Vernal, were included in the Western Uniform Seed Nursery. This gave a total of 82 different varieties and clones checked for resistance in 1959.

Delta plots. The varieties at Delta were planted April 28, 1955, on the Cameron Adams' farm 1 mile north of Delta. A randomized block design with 4 replications was used. Each plot consisted of 4 rows, 8 inches apart and 25 feet long. A distance of 16 inches was maintained between plots.

On June 11, 1959, the first crop was cut for hay. The second crop was left for seed. Where mixed fields of first and second are left for seed the second crop usually exhibits the higher infestation. Such a condition existed in Delta.

The plots were dusted with 10 percent DDT on July 9, and sprayed with a mixture of DDT and parathion on July 28, for lygus control. Racemes were tagged on July 15, July 27, August 4 and August 17. Those last tagged were frosted before being sufficiently ripened for harvesting and were not included in the data. A tag was placed on 12 racemes throughout each varietal plot on each date. A different colored tag was used to identify tagging dates. All racemes tagged had no more than four buds and no flowers had fallen. The purpose for tagging was to see the variation of one variety from another due to difference in bloom stage. All of the tagged racemes were harvested separately the week of September 20 and taken to the laboratory for threshing.

Seed was threshed as described by Bunker (1959). Bunker used a homemade rubbing board. The rubbing board consisted of a bottom piece covered with heavy inner tubing and a hand operated crushing board similarly covered with inner tubing. The seed to be threshed was placed between these two rubber surfaces and light pressure applied with the crushing board to break open the pods. The crushed pods were transferred to small seed screens where the seeds were separated from the pods. The chaff was removed by the use of a cleaning tray. This cleaning tray was constructed of pasteboard, covered with Kleenex table napkins and tapered at one end. Cleaning was accomplished by holding the cleaning tray at approximately a 45-degree angle, narrow end down, and adding the uncleaned samples to the top. By slightly shaking the cleaning tray the whole seeds quickly moved down the container for catching cleaned seeds. This process had to be repeated several times before the seed was sufficiently clean for examination.

The seed samples were counted with the aid of a fluorescent light and a three power magnifier having a 5 inch lens. Questionable seeds were checked by pinching with dissecting tweezers. Dry infested seeds are easily crushed. In most instances samples were small, therefore all seeds were counted.

Since infestations in most samples were less than 20 percent, arc sin transformations were made on each sample percentage. An analysis of variance was made on the arc sin values in a factorial arrangement of a randomized block design.

Western Uniform Seed Nursery. Included in this nursery were 30 high forage and seed yielding varieties being tested by Dr. Marion W. Pedersen. Six replications were seeded in a randomized block design on April 24, 1958. Each plot consisted of three rows 2 feet apart and 19 feet long.

Bulk samples were taken when the racemes were ripe by randomly stripping 25 racemes from each plot. The samples were threshed and cleaned as previously described.

Subsamples of approximately 200 seeds each were drawn from each sample by the use of a precision divider. These seeds were counted and the percentage of infestation determined. An analysis of variance was made on the arc sin conversion values for the different percentages.

Evans Farm Clonal Nursery. During the first half of March 1959 cuttings were made from 13 clones obtained from Dr. Marion W. Pedersen. The 13 clones plus the varieties, Vernal and Rhizoma, were transplanted on the Evans Farm near Logan, Utah, during the first week of May. The plants were placed $1\frac{1}{2}$ feet apart within plots and 3 feet between plots.

There were 10 plants in each of the plots. A randomized block design was used with each belt comprising a complete replication.

Racemes were tagged on July 31, August 10, 20 and 31. Those last tagged were frosted before being adequately ripened for harvesting and were not included in the data for analysis. Twelve tags were placed on racemes in the same stage of bloom within each plot. The tagged racemes were harvested the week of September 13 and the samples threshed with the rubbing board. All seeds within each sample were counted and examined for infestation. The data collected were analyzed in a factorial arrangement for a randomized block design.

Pleasant Valley plots. On June 7, 1957, 40 varieties were planted on Howard Roberts' farm in Pleasant Valley, Duchesne County, Utah, approximately 11 miles south by southeast of Myton, Utah. Plots were 50 feet long, consisting of four rows 8 inches apart and with 14 inches between plots. There were four belts with each belt a complete replication in a randomized block design. Border plots of several varieties were placed around the trial.

The first crop was cut for hay June 12, 1959. The second crop was left for seed. The first racemes, commencing July 16, were tagged three times at 10 day intervals. Plots were dusted on July 10 with 10 percent DDT to control lygus bugs and pea aphids. Toxophene was applied July 16 to control grasshoppers and lygus bugs. Drought conditions and a lack of irrigation water caused the plots to become very dry. Dodder infestation was severe and grasshopper numbers were high. A combination of these conditions caused severe stripping of racemes. This made it necessary to take bulk samples instead of tagged samples as planned. Seeds were threshed with the rubbing board and the percentage infestation of each variety determined. An analysis of variance was made on the data.

The 1960 varietal and clonal studies

The Pleasant Valley plots were not included in the 1960 clover seed chalcid studies. All other varieties and clones tested were the same as for the 1959 studies and in the same locations.

Delta plots. The first crop of alfalfa was left for seed. On August 2, ripened racemes were taken from each variety in all replications. The pods were stripped from the racemes, mixed, and two approximately equal subsamples drawn by selecting a pie section of the desired size.

The subsamples were hand threshed by pulling the pods from around the seed to avoid crushing the soft infested seeds. Each observation totaled about 100 seeds. Seeds were counted with the aid of the fluorescent light and magnifier. Questionable seeds were checked with dissecting tweezers. The percentage of damage by the clover seed chalcid was determined separately for each sample. The arc sin transformations were made on these percentages and an analysis of variance made in a factorial arrangement for a randomized block design using the two samples for each variety.

Western Uniform Seed Nursery. As in the 1959 season the first crop was left for seed. The field was sprayed at frequent intervals for lygus bug control. On August 4, the first ripened racemes were taken from each plot and the pods stripped from these racemes. Two subsamples were selected from each sample by taking a pie section equal to at least 100 threshed seeds for each observation. The pods were mixed before drawing each subsample.

The pods were hand threshed and counted using the technique previously described and the percentage infestation calculated for each variety. The data were transformed to arc sin values and analyzed by analysis of variance in a factorial arrangement for a randomized block design.

Evans Farm Clonal Nursery. The first crop was left for seed and dusted July 25 and sprayed August 1 with toxophene for lygus bug control. Unripened pods were stripped from each plot on August 10, and a 100 seed subsample hand threshed from the pods. The pods were threshed and all seeds were dissected and counted with the aid of a binocular dissecting microscope to determine chalcid infestation. An analysis of variance was made on the data obtained.

The lygus bug studies

In each experiment for the 1960 studies the percentage lygus bug, *Lygus elisus* and *L. hesperus*, damage was determined for each variety in conjunction with the clover seed chalcid infestation.

An analysis of variance was made for a randomized block design using the arc sin values for the percentage of damage in all experiments except the Evans Farm Clonal Nursery where the percentages were used.

RESULTS

The 1959 varietal and clonal studies

Delta plots. Data from the tagged racemes indicated no significant differences in chalcid infestations among the 40 varieties. The mean percentages for infestation ranged from 21.10 for DuPuits to 8.45 in Syn. 7-Clone. Table 1 shows the average percentage infestation for each variety. Varieties X replications interaction was highly significant as was the taggings X varieties interaction. Taggings were not significant, the percentages being 14.68 for the first, 13.10 for the second and 13.81 for the third (Figure 5).

Western Uniform Seed Nursery. Data in this experiment showed differences to be highly significant among the 30 varieties. The results of a Duncan's Multiple Range test on the mean arc sin values for chalcid infestation are given in Table 2. Nevada Syn. E. had the lowest average rate of infestation with 3.24 percent and Teton had the highest with 14.02 percent. This corresponds with 10.25 and 21.56 respectively for arc sin values.

Evans Farm Clonal Nursery. An analysis of variance on data for tagged racemes in this experiment showed differences among clones to be highly significant. The two clones from Nemastan, C-84 and C-900, were least infested having 35.60 and 36.11 percent infestation respectively.

A Duncan's Multiple Range test was run on the mean percentages for the different varieties. Results of this test are shown in Table 3.

Table 1. Ranked means for the percentage of clover seed chalcid infestation in tagged samples from the Delta plots, and their corresponding arc sin values, 1959

Rank	Variety name	Mean percentage	Mean arc sin value
1	DuPuits	21.10	26.48
2	Vernal	19.73	26.18
3	Terra Verde	19.60	25.41
4	Atlantic	17.18	22.84
5	Ranger	17.12	23.45
6	Buffalo	16.94	23.14
7	Talent	16.74	23.22
8	A-169	16.49	23.51
9	A-225 Northern Syn.	16.03	23.00
10	Narragansett	15.89	22.40
11	Common (Cameron Adams)	15.45	22.14
12	Grimm	15.04	21.73
13	Syn. X	14.88	22.07
14	Meeker Baltic	14.84	22.09
15	Ladak	14.09	21.00
16	Rhizoma	13.95	21.13
17	919 (15)	13.57	21.00
18	Hairy Peruvian	13.41	20.90
19	Lahontan	13.25	20.81
20	A-224 Syn. 1	13.07	20.47
21	Cossack	13.06	20.41
22	Kansas Common	13.06	20.65
23	Arizona Chilean	12.96	19.66
24	Syn. Y	12.82	20.14
25	Syn. Z	12.76	20.68

Table 1. (Continued)

Rank	Variety name	Mean percentage	Mean arc sin value
26	B. Y. Strain	12.72	20.38
27	919 (20S)	12.58	19.69
28	Stafford	12.48	19.77
29	Nemastan	12.33	20.14
30	Caliverde	12.27	19.96
31	Turkish Wild	12.27	19.81
32	919 (Nev.)	12.05	19.64
33	Williamsburg	12.02	20.02
34	Sevelra	11.97	19.15
35	African	11.92	19.61
36	South African	11.21	18.87
37	Uruguay Clone #10	10.13	18.05
38	Nomad	9.81	17.28
39	Syn. 4-Clone A-252	8.84	15.84
40	Syn. 7-Clone A-253	8.45	15.55
$\bar{X}$ percent		13.85	20.96
F value for varieties		1.04 N.S.[a]	
F value for replications		1.56 N.S.	
F value for varieties X replications		1.95**	
F value for taggings		1.17 N.S.	
F value for taggings X varieties		1.56**	
$s\bar{x}$		2.30	
C.V. percent		37.93	

a Not significant.

** Significant at the 1 percent level of probability.

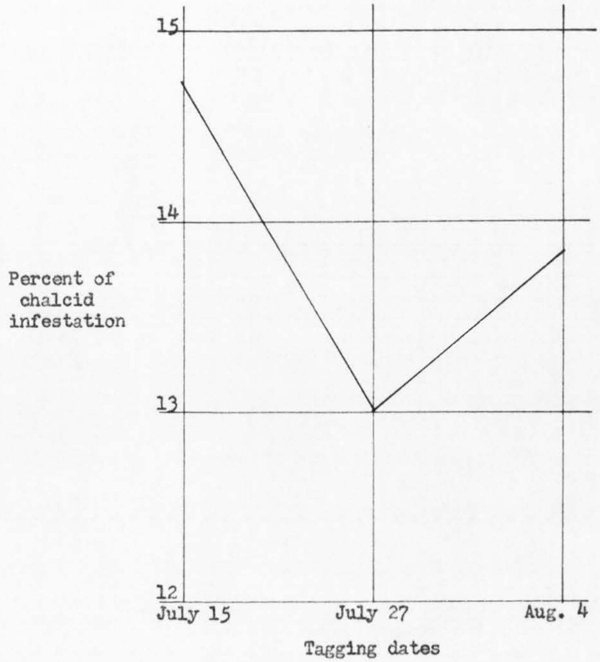

Figure 5. Histogram indicating the average percentage of clover seed chalcid for the three tagging dates, Delta plots, 1959

Table 2. Ranked mean arc sin conversion values for the percentage of clover seed chalcid infestation in the Western Uniform Seed Nursery, Logan, 1959

Rank	Variety	Mean percentage	Mean arc sin value	Least significant ranges[a] at the 5 percent level (Duncan's Multiple Range test)
1	S. D. Teton	14.02	21.56	
2	Cardinal	11.07	19.24	
3	N. C. Syn. D (51) 12	10.87	19.05	
4	Vernal	10.81	18.67	
5	N. C. Syn. F (56) 1	9.54	17.95	
6	Minn. Syn. F	9.19	17.41	
7	N. J. 57-44	8.69	16.71	
8	Iowa 2187	7.26	15.52	
9	Alberta Syn. 2	7.33	15.00	
10	N. C. Syn. B	7.15	14.79	
11	N. Y. Syn. A	7.03	14.79	
12	Alberta Syn. 1	7.03	14.72	
13	Kansas Syn. B 1	7.16	14.69	
14	N. C. Syn. A (51) 5	6.82	14.69	
15	Lahontan	6.70	14.52	
16	Buffalo	7.51	14.51	
17	Wyo. 56	6.61	14.47	
18	Alberta Syn. 4	6.53	14.44	
19	Ind. A-600	6.60	14.38	
20	Utah Syn. C 2	6.26	14.11	
21	Alberta Syn. 5	6.25	13.69	
22	Nebr. A-239-2	5.78	13.65	
23	Nev. A-233	5.76	13.56	
24	Nev. Hybrid 9	5.61	13.22	
25	Alberta Syn. 3	5.48	13.22	
26	Ranger	5.96	13.20	
27	Nebr. Syn. A-242-2	5.30	12.92	
28	Utah Syn. C X Lahontan	4.51	11.85	
29	Nev. Hybrid 6	4.29	11.40	
30	Nev. Syn. E	3.24	10.25	
	$\bar{X}$ percent	7.21	14.93	

F value for varieties 1.93**

F value for replication 1.96 N.S.[b]

$s\bar{x}$ 1.77

C.V. percent 11.85

a A significant difference exists between any two means which are not found in the same range.

b Not significant.

** Significant at the 1 percent level of probability.

Table 3. Ranked means showing the percentage of clover seed chalcid infestation for the tagged samples from the Evans Farm Clonal Nursery, Logan, 1959

Rank	Clone[a] or variety name	Mean percentage	Least significant ranges[b] at the 5 percent level (Duncan's Multiple Range test)	
1	34 (99-N-1370-53)	48.99	│	
2	57 (99-Wis. Syn. B)	48.74	│	
3	55 (99-Wis. Syn. D)	48.38	│	
4	Rhizoma	46.07	│	
5	70 (99-Wis. Syn. B)	45.28	│	│
6	Vernal	43.96	│	│
7	7 (UV-C-16)	43.85	│	│
8	3 (799-N-137-315)	42.64	│	│
9	9 (79-N-1243-55)	41.85	│	│
10	5 (799-N-1370-340)	41.36	│	│
11	4 (799-N-1370-333)	41.10	│	│
12	1 (2-225-248)	40.76	│	│
13	2 (A-225-282 CW)	37.00		│
14	C-900 (from Nemastan)	36.11		│
15	C-84 (from Nemastan)	35.60		│
	$\bar{X}$ percent	42.39		

F value for clones	2.23**
F value for replication	4.80**
F value for clones X replications	.98 N.S.[c]
F value for tagging	54.50**
F value for tagging X clones	1.18
$s\bar{\bar{x}}$	3.18
C.V. percent	38.00

a The clones were obtained from Dr. Marion W. Pederson, Legume Seed Laboratory, U.S.D.A.-A.R.S., Utah State University, Logan, Utah. C-84 and C-900 are stem nematode and wilt resistant clones from Nemastan which went into the synthetic Lahontan. These clones also have resistance to the spotted alfalfa aphid. Clones 1, 2, 3 and 4 make up the synthetic A-252. Clones 1, 2, 3, 4, 5, 6 and 7 make up the synthetic A-253. Clones 1 and 2 are selections from A-225 Northern synthetic. Clones 3, 4 and 5 are high seeding selections made by Dr. Marion W. Pederson from seed provided by Dr. R. J. Evans. Clones 9, 34, 55, 57 and 70 make up Utah Synthetic C. All of the above clones are wilt resistant with the exception of 6 which was not available for the experiment, Logan, 1959.

b A significant difference exists between any two means which are not found in the same range.

c Not significant.

** Significant at the 1 percent level of probability.

Replications were highly significant while the clones X replications interaction was not. Taggings were also highly significant. These results are shown in Figure 6. Tagging X clones interaction was not significant.

Pleasant Valley plots. An analysis of variance on data for bulk samples of the 40 varieties in this experiment indicated no significant differences for chalcid infestations. Both high and low rates of infestation occurred for similar varieties within different replications. The chalcid damage was high for the experiment ranging from 63.06 percent for Rhizoma to 29.71 percent for Sevelra. The mean percentages for chalcid infestations of the different alfalfa varieties are given in Table 4.

The 1960 varietal and clonal studies

Delta plots. Data from the subsamples indicated highly significant differences in chalcid infestations among the 40 varieties. A-169, Vernal and DuPuits were most highly infested with 9.76, 9.65 and 9.00 percent respectively. Those least infested were Nomad, 919 (Nev.) and Stafford. These latter varieties were below 2 percent infestation as shown in Table 5. Table 5 also shows the ranking of variety means by arc sin and the Duncan's Multiple Range test.

The analysis of variance showed replications to be highly significant. Subsamples and the varieties X replications interaction were also highly significant. The subsamples X varieties interaction was not significant.

Western Uniform Seed Nursery. Results from analysis of variance for the data in this experiment showed that the varieties were not

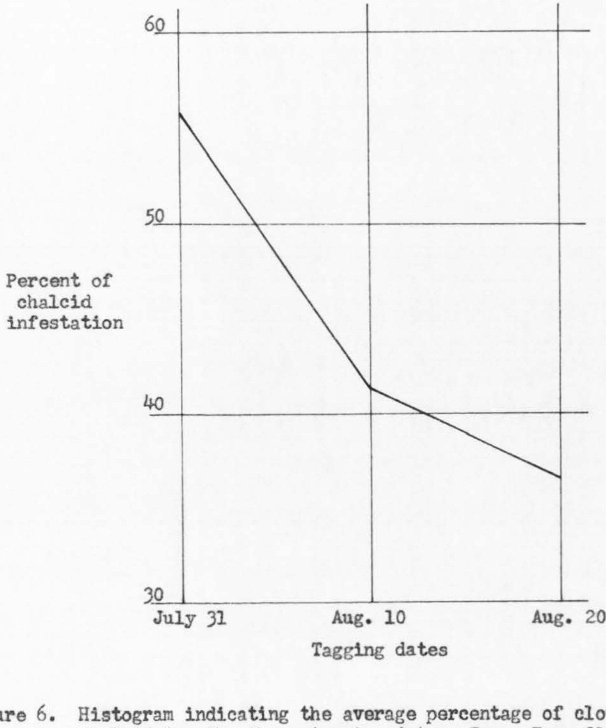

Figure 6. Histogram indicating the average percentage of clover seed chalcid for the three tagging dates, Evans Farm Clonal Nursery, Logan, 1959

Table 4. Ranked means showing the percentage of clover seed chalcid infestations for bulk samples from the Pleasant Valley plots, 1959

Rank	Variety name	Mean percentage
1	Rhizoma	63.06
2	Narragansett	52.62
3	Williamsburg	51.30
4	Terra Verde	50.33
5	Buffalo	50.07
6	919 (Nev.)	50.03
7	African A 4-35	49.79
8	DuPuits	48.20
9	Bamm	47.97
10	Common	47.71
11	Hairy Peruvian	46.65
12	Syn. #7 Clone	46.37
13	Ranger	44.63
14	919 (20S)	44.49
15	Cardinal	44.07
16	Meeker Baltic	43.58
17	A-225 Northern Syn.	43.49
18	Syn. #4 Clone	43.48
19	B. Y. Strain	43.33
20	Stafford	43.12
21	919 (15)	42.01
22	Vernal	41.54
23	Talent	41.29
24	Lahontan	41.17
25	Ladak	40.95

Table 4. (Continued)

Rank	Variety name		Mean percentage
26	Cossack		40.41
27	Nemastan		40.31
28	Atlantic		39.15
29	Nomad		38.19
30	Syn. Y		38.11
31	Kansas Common		38.02
32	Rambler		37.67
33	Syn. Z		37.64
34	Uruguay Clone #10		37.58
35	South African		35.87
36	Caliverde		35.36
37	Vernal (foundation)		34.09
38	Arizona Chilean		30.38
39	Grimm		30.21
40	Sevelra		29.71
$\bar{X}$ percent			42.59
F value for replications		9.40**	
F value for varieties		1.12 N.S.	
$s\bar{x}$		6.34	
C.V. percent		29.75	

** Significant at the 1 percent level of probability.

Table 5. Ranked mean arc sin conversion values for the percentage of clover seed chalcid infestation in the Delta plots, 1960

Rank	Variety	Mean percentage	Mean arc sin value	Least significant ranges[a] at the 5 percent level (Duncan's Multiple Range test)
1	Vernal	9.85	17.09	
2	DuPuits	9.00	16.64	
3	A-224 Syn. 1	7.17	15.10	
4	Rhizoma	6.98	15.04	
5	A-225 Nor. Syn.	7.20	15.03	
6	Cossack	6.99	14.71	
7	Sevelra	7.01	14.54	
8	A-169	9.76	14.51	
9	African	6.97	13.94	
10	Grimm	7.05	13.04	
11	Ladak	5.29	13.01	
12	Meeker Baltic	6.03	12.81	
13	Syn. #7 Clone	4.85	12.15	
14	Caliverde	4.89	12.03	
15	Atlantic	5.45	11.86	
16	Talent	4.30	11.62	
17	919 (20S)	4.09	11.49	
18	Terra Verde	5.22	11.43	
19	Narragansett	4.76	11.18	
20	Kansas Common	5.52	11.00	
21	Williamsburg	4.95	10.94	
22	Syn. Z	3.69	10.87	
23	Syn. X	4.77	10.49	
24	Arizona Chilean	3.51	10.28	
25	B. Y. Strain	3.50	9.97	
26	Hairy Peruvian	3.30	9.97	
27	Syn. #4 Clone	3.96	9.55	
28	Syn. Y	3.21	9.35	
29	Ranger	2.77	9.32	
30	South African	2.99	9.08	
31	Turkish Wild	2.29	8.29	
32	919 (15)	2.87	8.18	
33	Common (C. Adams)	3.60	8.15	
34	Nemastan	2.39	8.12	
35	Buffalo	2.55	7.67	
36	Uruguay Clone #10	2.46	7.65	
37	Stafford	1.74	5.81	
38	Lahontan	2.12	5.78	
39	Nomad	1.37	5.57	
40	919 (Nev.)	1.41	4.62	
	$\overline{X}$ percent	4.69	10.95	

Table 5. (Continued)

F value for varieties	2.10**
F value for replications	18.77**
F value for varieties X replications	1.68**
F value for samples	17.35**
F value for samples X varieties	0.84 N.S.[b]
$s\bar{x}$	2.14
C.V. percent	55.16

a A significant difference exists between any two means which are not found in the same range.

b Not significant.

** Significant at the 1 percent level of probability.

significantly different from one another. Infestations ranged from a high of 8.18 percent for Ranger to a low of 3.61 percent for North Carolina Syn. F (56) 1 (Table 6). Replications and the varieties X replications interaction were highly significant. Subsamples and the subsamples X varieties interaction were both nonsignificant.

Evans Farm Clonal Nursery. In this experiment clones were significantly different. Rhizoma was the most highly infested, having an average of 50.72 percent damage in the alfalfa seeds sampled. The Duncan's Multiple Range test on the mean percentage of infestation for the different clones or varieties is given in Table 7. Replications were not significant.

The lygus bug studies

Delta plots. In this experiment varieties were not significant. Damage was generally high ranging from 28.54 percent to a low of 16.34 percent (Table 8).

Western Uniform Seed Nursery. Varieties were also nonsignificant in this experiment. The damage attributed to lygus was quite low, the high being 4.15 percent and the low 1.47 percent (Table 9).

Evans Farm Clonal Nursery. Contrary to the previous two experiments, clones and varieties were highly significant for the damage attributed to lygus. C-900 from Nemastan showed the highest, and clone 1 (2-225-248) the least damage. A Duncan's Multiple Range test was run on the mean percentages for varieties (Table 10).

Table 6. Ranked means for the percentage of clover seed chalcid infestations in the Western Uniform Seed Nursery and their corresponding arc sin values, Logan, 1960

Rank	Variety name	Mean percentage	Mean arc sin value
1	Ranger	8.18	16.14
2	Nebr. A-233	7.63	15.24
3	Alberta Syn. 1	7.56	15.59
4	Utah Syn. C X Lahontan	7.43	15.05
5	Kan. Syn. B 1	7.43	14.62
6	Alberta Syn. 2	7.34	15.04
7	Nev. Syn. E	6.92	14.49
8	Nebr. Syn. A-242-2	6.76	14.43
9	Alberta Syn. 3	6.76	14.49
10	Cardinal	6.75	14.25
11	Buffalo	6.70	14.03
12	N. C. Syn. A (51) 5	6.69	14.63
13	S. D. Teton	6.68	13.93
14	Utah Syn. C 2	6.46	14.51
15	Nev. Hybrid 9	6.27	13.28
16	Alberta Syn. 5	6.14	13.74
17	Vernal	6.10	13.50
18	Lahontan	5.99	13.81
19	Iowa 2187	5.87	13.42
20	Ind. A-600	5.33	12.47
21	Nebr. A-239-2	4.96	12.39
22	Alberta Syn. 4	4.91	12.46
23	Wyo. 56	4.89	12.59
24	N. C. Syn. B (51) 7	4.80	11.97
25	Nev. Hybrid 6	4.79	11.96
26	N. Y. Syn. A	4.75	11.65
27	Minn. Syn. F	4.05	10.65
28	N. C. Syn. D (51) 12	3.93	10.79
29	N. J. 57-44	3.65	10.89
30	N. C. Syn. F (56) 1	3.61	10.09
$\bar{X}$ percent		5.98	13.42
F value for varieties		1.04 N.S.[a]	
F value for replications		3.91**	
F value for varieties X replications		2.03**	
F value for samples		0.01 N.S.	
F value for samples X varieties		1.19 N.S.	
$s\bar{x}$		1.54	
C.V. percent		39.75	

a Not significant.
** Significant at the 1 percent level of probability.

Table 7. Ranked means showing the percentage of clover seed chalcid infestation in the Evans Farm Clonal Nursery, Logan, 1960, first crop seed harvested August 10

Rank	Variety name	Mean percentage	Least significant ranges[a] at the 5 percent level (Duncan's Multiple Range test)				
1	Rhizoma	50.72	|				
2	55 (99-Wis. Syn. D)	47.76	|	|			
3	57 (99-Wis. Syn. B)	44.10	|	|	|		
4	2 (A-225-282 CW)	42.73	|	|	|	|	
5	9 (79-N-1243-55)	38.05	|	|	|	|	
6	Vernal	37.62	|	|	|	|	
7	C-900 (from Nemastan)	37.36	|	|	|	|	|
8	70 (99-Wis. Syn. B)	34.92		|	|	|	|
9	34 (99-N-1370-53)	30.57			|	|	|
10	7 (UV-C-16)	28.90				|	|
11	5 (799-N-1370-340)	28.77				|	|
12	3 (799-N-1370-315)	26.75				|	|
13	C-84 (from Nemastan)	23.75					|
14	4 (799-N-1370-333)	22.19					|
15	1 (2-225-248)	21.61					|

$\bar{X}$ percent	34.39
F value for varieties	5.14**
F value for replications	2.04 N.S.[b]
$s\bar{x}$	4.09
C.V. percent	31.46

a A significant difference exists between any two means not found in the same range.

b Not significant.

** Significant at the 1 percent level of probability.

Table 8. Ranked means for the percentage of lygus damage to the alfalfa varieties in the Delta plots, and their corresponding arc sin values, 1960

Rank	Variety name	Mean percentage	Mean arc sin value
1	Williamsburg	24.06	28.25
2	Stafford	23.77	28.06
3	A-225 Northern Syn.	23.32	28.54
4	919 (15)	22.92	28.18
5	Syn. #4 Clone	22.30	28.15
6	Cossack	21.19	26.73
7	919 (20S)	21.03	26.71
8	Lahontan	21.02	26.34
9	Syn. X	20.73	26.80
10	Caliverde	20.68	26.50
11	Ladak	20.55	25.32
12	Grimm	19.68	25.50
13	Narragansett	19.63	25.12
14	Arizona Chilean	19.58	24.53
15	Atlantic	19.38	25.81
16	Syn. Z	18.52	23.97
17	Buffalo	17.53	24.52
18	South African	17.13	23.46
19	Vernal	17.10	24.14
20	Syn. #7 Clone	17.01	24.30
21	B. Y. Strain	16.81	23.92
22	Syn. Y	16.61	23.77
23	Turkish Wild	16.09	23.53
24	Sevelra	14.88	20.81
25	Common (Cameron Adams)	14.64	21.92

Table 8. (Continued)

Rank	Variety name	Mean percentage	Mean arc sin value
26	A-224 Syn. 1	14.16	21.81
27	Talent	13.21	21.10
28	Kansas Common	12.59	20.41
29	Meeker Baltic	12.23	20.00
30	919 (Nev.)	11.88	19.46
31	Nemastan	10.87	18.46
32	Hairy Peruvian	10.86	18.22
33	African	10.41	17.46
34	A-169	10.40	18.35
35	Uruguay Clone #10	9.89	18.05
36	Ranger	9.53	17.83
37	Nomad	8.80	16.67
38	Terra Verde	8.77	16.34
39	DuPuits	8.55	16.63
40	Rhizoma	8.09	16.44
$\bar{X}$ percent		16.16	22.80
F value for varieties		1.36 N.S.[a]	
F value for replications		12.82**	
$s\bar{x}$		3.33	
C.V. percent		29.21	

a Not significant.
** Significant at the 1 percent level of probability.

Table 9. Ranked means for the percentage of lygus damage to the alfalfa varieties in the Western Uniform Seed Nursery, and their corresponding arc sin values, Logan, 1960

Rank	Variety name	Mean percentage		Mean arc sin value
1	N. J. 57-44	4.15	10.56	10.56
2	Nev. Hybrid 9	4.07		11.13
3	Utah Syn. C 2	4.06		11.43
4	Nev. Hybrid 6	4.04		10.18
5	Alberta Syn. 1	3.92		11.18
6	N. C. Syn. F (56) 1	3.46		10.26
7	Nebr. A-233	3.34		10.00
8	Nev. Syn. E	3.31		10.00
9	Alberta Syn. 5	3.27		9.53
10	Nebr. Syn. A-242-2	3.27		10.01
11	Ind. A-600	3.24		10.02
12	Iowa 2187	3.15		9.73
13	S. D. Teton	3.13		9.83
14	Alberta Syn. 2	3.10		10.04
15	N. Y. Syn. A	3.08		9.89
16	N. C. Syn. B (51) 7	2.97		9.34
17	N. C. Syn. A (51) 5	2.96		8.73
18	Minn. Syn. F	2.89		9.32
19	Cardinal P. I. 237231	2.72		8.60
20	N. C. Syn. D (51) 12	2.69		9.24
21	Vernal	2.63		9.12
22	Nebr. A-239-2	2.52		8.68
23	Lahontan	2.04		7.24
24	Alberta Syn. 3	2.03		8.08
25	Wyo. 56	2.01		7.22
26	Utah Syn. C X Lahontan	1.96		7.33
27	Kan. Syn. B 1	1.77		6.86
28	Alberta Syn. 4	1.60		6.93
29	Ranger	1.50		6.71
30	Buffalo	1.47		6.32
$\bar{X}$ percent		2.88		9.12
F value for varieties			1.68 N.S.[a]	
F value for replications			0.96 N.S.	
$s\bar{x}$			1.47	
C.V. percent			39.36	

a Not significant.

Table 10. Ranked means for the percentage of lygus damage to alfalfa varieties and clones in the Evans Farm Clonal Nursery, Logan, 1960

Rank	Variety name	Mean percentage	Least significant ranges[a] at the 5 percent level (Duncan's Multiple Range test)		
1	C-900 (from Nemastan)	43.57	|		
2	55 (99-Wis. Syn. D)	33.86	|	|	
3	C-84 (from Nemastan)	33.43	|	|	
4	Vernal	29.86	|	|	
5	7 (UV-C-16)	27.81		|	|
6	57 (99-Wis. Syn. B)	27.57		|	|
7	9 (79-N-1243-55)	25.86		|	|
8	34 (99-N-1370-53)	24.86		|	|
9	3 (799-N-1370-315)	23.14		|	|
10	70 (99-Wis. Syn. B)	22.29		|	|
11	5 (799-N-1370-340)	22.00		|	|
12	4 (799-N-1370-333)	21.71		|	|
13	Rhizoma	21.29		|	|
14	2 (A-225-282 CW)	21.11		|	|
15	1 (2-225-248)	13.57			|

$\bar{X}$ percent	26.13
F value for clones	2.46**
F value for replications	3.79**
$s\bar{x}$	4.52
C.V. percent	45.81

a Significant difference exists between any two means not found in the same range.

** Significant at the 1 percent level of probability.

DISCUSSION

The clover seed chalcid studies for 1959 and 1960 showed that the 82 different varieties and clones tested were not infested similarly by the insect. Not all trials, however, showed variety differences to be significant. Variations in environmental factors from year to year and from one area to another possibly influenced this. Differences were significant at the 1 percent level of probability for the varieties and clones checked in the two experiments at Logan in 1959. Differences in varietal infestation in the Western Uniform Seed Nursery were not significant in 1960; however, the Evans Farm Clonal Nursery continued to show highly significant differences. The varieties in the Delta plots, which were not significant in 1959, were highly significant in 1960. Bunker (1959) found them to be significantly different in 1958. The relatively high infestations of Rhizoma, Vernal and DuPuits in the Delta plots were consistent for the two seasons. Nomad and Uruguay Clone 10 were consistently low. Lahontan, which was consistently low according to Bunker (1959), was also low in 1960 (Tables 1 and 6).

The data from Delta were transformed to arc sin values. Arc sin transformations weigh smaller percentages more heavily and tend to give a binomial population a more normal distribution. Percentages below 20 and above 80 tend to have their means and variances associated.

For the Pleasant Valley plots, which were tested only in 1959, Rhizoma, Narragansett, Williamsburg and Terra Verde were most highly infested. All of these varieties except Williamsburg showed high infestation in the work by Bunker (1959). Sevelra, which was highly infested in 1958 (Bunker, 1959), was least infested in Pleasant Valley and quite low for the Delta plots in the 1959 studies. In 1960 this same variety was quite highly infested. No attempt was made to determine why varieties failed to respond similarly in different experiments.

The reasons for the much higher infestation of chalcids in one area over similar varieties in another are undoubtedly multiple. A lack of alfalfa blossoms in the Pleasant Valley plots compared to the Delta plots even with similar chalcid populations should tend towards higher infestation. Drought conditions, dodder and grasshoppers were the main environmental stresses causing fewer blossoms and poor seed set in the Pleasant Valley plots. It is a general observation that fields in Delta were better managed in the control of weeds and insects than was evident in the Pleasant Valley area. Growing field crops for cash is of major importance in Delta, whereas the production of livestock is seemingly more important in Pleasant Valley. Considerable uncut alfalfa in fields and along roadsides in the Pleasant Valley area would tend to increase the chalcid numbers.

Differences among alfalfa varieties in the Western Uniform Seed Nursery in Logan were highly significant in 1959 but showed no significance in 1960. This may be related to the higher coefficient of variation associated with the 1960 study. Some varieties in the different replications showed no infestation by chalcid. Perhaps if samples had been taken near the end of the 1960 season results would have been different. The average mean percent of infestation for both seasons was quite low, being 7.21 percent for 1959 and 5.98 percent for 1960.

During 1959, Nevada Syn. E, Nevada Hybrid 6 and Utah Syn. C X Lahontan were least infested, having 3.24, 4.29 and 4.51 percent damage respectively. Each of the above varieties has Lahontan parentage. From personal correspondence with Smith (1960), the following quote is taken.

> The mother plants of Nevada Syn. E came from crosses between Lahontan plants and wilt-resistant plants from Nebraska and Kansas. Nevada Hybrid 6 is a cross between plant 560 and plant 813. Plant 560 is a selection from a cross C-89 (a parent plant of Lahontan) X a pea aphid-resistant selection from Ranger alfalfa. Plant 813 is a selection from the cross C-89 X N-5. N-5 is a pea aphid-resistant selection from common alfalfa. (Smith, 1960)

Utah Syn. C was developed by Dr. Marion W. Pedersen for high hay and

(C-89 X Ranger 13)		(C-89 X N-5)
560	X	815
	H-6	

seed yield.

Nemastan and Lahontan were consistently least infested according to Bunker (1959). Subsequent experiments have not entirely supported this finding. Clones C-84 and C-900 from Nemastan were least infested in the Evans Farm Clonal Nursery in 1959. C-84 had 35.60 percent and C-900 had 36.11 percent chalcid infestation. The trend in many of the trials indicates that varieties of Lahontan parentage and some clones from Lahontan have a factor or factors of resistance or escape. Further work is indicated to determine what these factors are.

Teton and Cardinal have very different growth habits, yet these two showed the highest infestation of chalcid in the Western Uniform Seed Nursery in 1959. The former variety has a prolonged blossom period, whereas the latter has a short blossom period. Cardinal is similar to DuPuits and blooms earlier than most varieties. These differences may be the reasons for each being highly infested. Teton is vulnerable to chalcid attacks for a long period of time. Cardinal is vulnerable for a short period of time, but prior to any other variety. An average or large population of chalcids coincident with the blossom period of Cardinal would tend to increase infestation for this variety even though it may be no more susceptible than others.

The low rate of infestation in the Western Uniform Seed Nursery compared to the Evans Farm Clonal Nursery is an example of how cultural practices may affect the rate of chalcid infestation. Sufficient reserve moisture was available so that little or no irrigation was applied to the former nursery in either the 1959 or the 1960 season. This resulted in rapid seed set and reduction in the period of vulnerability. The latter nursery was irrigated several times during each season and thus had an extended blossom period. The long blossom season and wide plant spacing may be important factors for increasing chalcid infestation. Butler (1959), in his studies, showed that wide spacing of plants increased infestation.

The accurate estimation of the number of chalcid infested seeds in a sample is necessary in finding the percentage of damage to an alfalfa variety. Hand threshing of samples, as was done in the 1960 studies, is thought to give a more accurate and reliable measure of chalcid infestation than the crushing board or any presently known machine method.

Further studies should include C-89 from Lahontan. This clone was included as part of the parentage in the three varieties least infested in the Western Uniform Seed Nursery in 1959. In several trials for the three years, 1958-1960, Lahontan has shown the least, or been near the least, for chalcid infestation. Clone C-89 is possibly a main factor related to this but it damped-off during establishment.

Checking individual plants from the varieties, Lahontan, Nevada Syn. E, Nevada Hybrid 6, Utah Syn. C X Lahontan, Nomad and Uruguay Clone 10, may be helpful to locate alfalfa plants with increased resistance to the chalcid. If significant differences are found among these selections, then a breeding program may be started. Hybridization of those consistently low for chalcid damage may further increase resistance.

Complete information on the habits of the chalcid is lacking. More knowledge about its biology and that of the alfalfa plant as they are related to one another would be helpful. There may be some association for rate of infestation and the number of blossoms and/or the color of blossoms. Both Rhizoma and Vernal bloom profusely and have a variegated flower color. Other possible factors are the differences that may exist in the quantity and quality of the nectar produced by alfalfa varieties.

Studies of lygus damage in the 1960 experiments showed that varieties were not significantly different from one another except in the Evans Farm Clonal Nursery where differences were highly significant. C-900 was the most severely attacked and clone 1 (2-225-248) was least damaged. The coefficient of variation was high, being 45.81 percent. This should not be considered as extreme inasmuch as alfalfa plants and lygus are two very different biological entities. Both are very much influenced by environmental factors. This is also true of the clover seed chalcid and its hosts.

In making counts of lygus damage to samples, it was difficult to determine if all the damage attributed to lygus was actually lygus damage or some physiological or pathological condition. Careful observation may be necessary in some instances to separate lygus from chalcid damage. When it is difficult to determine the source of damage the seed should be dissected and examined under a microscope.

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine: (1) if any of the available commercial varieties of alfalfa were resistant to the clover seed chalcid, and (2) if any new varieties or clones being developed for seed and/or hay production at Utah State University have resistance to the clover seed chalcid.

Eighty-two different varieties and clones were checked for resistance to the clover seed chalcid in the years 1959 and 1960.

Varieties were not significantly different from one another for the Delta plots in 1959, but were in 1960. The latter year's work corresponded closely with the findings of Bunker (1959). Vernal and DuPuits were the most highly infested for both years. Nomad and Uruguay Clone 10 were consistently low for infestation in the Delta plots for both years.

The Western Uniform Seed Nursery trial in 1959 showed that Nevada Syn. E, Nevada Hybrid 6 and Utah Syn. C X Lahontan were least infested. The 1958 and 1960 trials at Delta indicate that some varieties have resistance. Lahontan, varieties of Lahontan parentages, Nomad and Uruguay Clone 10 are the most promising, as indicated in these experiments. In each instance, these varieties are related to Lahontan. Some experiments in 1960 did not bear this out, however, and further studies should be made to check these results.

Clones C-84 and C-900 from Nemastan were least infested in the Evans Farm Clonal Nursery in 1959. The damage by chalcid to these two clones was 35.60 and 36.11 percent respectively. Such a high rate indicates that neither clone has more than a low level of resistance to the insect. Studies in 1960 varied considerably with the 1959 findings, however, C-84 and clone 1 (2-225-248) were the only two clones with low mean percentages of infestation for both years. These clones and C-900 may have low levels of resistance or escape, but it is of sufficiently low magnitude that under severe infestation conditions it is not manifest. Rhizoma, clones 55 (99-Wis. Syn. D) and 57 (99-Wis. Syn. B) had relatively high percentages for both years.

Most of the alfalfa varieties in the Pleasant Valley plots were similar to those in the Delta plots yet the relative level of infestation for each variety was not the same in 1959. Damage by chalcid was high in Pleasant Valley, with none of the varieties significantly different under the environmental conditions which existed there.

LITERATURE CITED

Bacon, O. G., Riley, W. D., Burton, V. E., and Sarquis, A. V. 1959. Clover seed chalcid in alfalfa. California Agriculture 13 (7): 7-11.

Butler, G. D., Jr., and Hansen, H. L. 1958. The parasites of clover seed chalcid in the United States. Reprinted from The Pan-Pacific Entomologist 34 (4): 223-229.

Butler, G. D., Jr., and Hansen, H. L. 1959. Insect parasites in relation to reducing chalcid injury to alfalfa seed crops. Arizona Contributing Project 445.

Bunker, R. C. 1959. A study of clover seed chalcid infestation of various alfalfa varieties in Utah. Unpublished M. S. thesis, Utah State University Library, Logan, Utah. 66 pp.

Carter, W., and Ruggles, H. G. 1925. Common alfalfa insects. Minnesota Agr. Exp. Sta. Tech. Bul. 99.

Freeman, George F. 1914. Alfalfa in the southwest. Ariz. Agr. Exp. Sta. Bul. 73: 233-320.

Lieberman, F. V., and Knowlton, G. F. 1955. Growing alfalfa for seed. Section 11, Injurious insects, mites and their control. Utah Agr. Exp. Sta. Circ. 135.

Kolobova, A. N. 1950. The clover and lucerne races of the seed pest Bruchophagus gibbus Boh. (Hymenoptera, Eurytomidae). Ent. Obozr. 31 (1-2): 63-70. (Original not seen; abstracted in Rev. Appl. Ent. Ser. A 41: 164-165. 1953.)

MacDonald, H. A. 1946. Birdsfoot trefoil (Lotus corniculatus L.), its characteristics and potentialities as a forage legume. New York Agr. Exp. Sta. Mem. 261.

Nikol'skaya, M. N. 1932. The clover seed chalcid (Bruchophagus gibbus Boh.) in alfalfa seeds in U.S.S.R. Plant Prot. 1932, No. 1, pp. 107-111. (Original not seen; abstracted in Rev. Appl. Ent. Ser. A 21: 578-579. 1933.)

Peairs, L. M., and Davidson, R. W. 1956. Insect pests of farm, garden and orchard. 5th ed. New York: John Wiley and Sons, Inc. London: Chapman and Hall, Limited. 661 pp.

Smith, O. F. 1960. Personal correspondence, August 3, 1960. Research Agronomist, U.S.D.A.-A.R.S., University of Nevada, Reno, Nevada.

Sorenson, C. J. 1930. The alfalfa-seed chalcis-fly in Utah, 1926-29, inclusive. Utah Agr. Exp. Sta. Bul. 218.

Sorenson, C. J. 1932. Insects in relation to alfalfa seed production. Utah Agr. Exp. Sta. Circ. 98.

Sorenson, C. J. 1934. Chalcis-fly infestation of alfalfa seed and parasitism of the chalcis-fly in Utah, 1930-33, inclusive. Proc. of the Utah Acad. of Sci., Arts, and Letters 11: 241-244.

Sorenson, C. J., and Knowlton, G. F. 1951. Alfalfa and clover seed chalcid. Utah Agr. Ext. Ser. Bul. 219.

Urbahns, T. D. 1914. The chalcis-fly in alfalfa seed. U.S.D.A. Farmers' Bul. 636.

Urbahns, T. D. 1916. Life history of *Habrocytus medicaginis*, a recently described parasite of the chalcis-fly in alfalfa seed. Jour. of Agr. Res. 7: 147-154.

Urbahns, T. D. 1917. *Tetrastichus bruchophagus*, a recently described parasite of *Bruchophagus funebris*. Jour. of Agr. Res. 8: 277-282.

Urbahns, T. D. 1920. The clover and alfalfa seed chalcis-fly. U.S.D.A. Bul. 812.

Wildermuth, V. L. 1931. Chalcid control in alfalfa seed production. U.S.D.A. Farmers' Bul. 1642.

Vinogradov, V. P. 1941. The clover-seed chalcid, *Bruchophagus gibbus*, and its distribution in the clover areas of the U.S.S.R. Bul. Plant Prot. 1941, No. 1, pp. 20-26. (Original not seen; abstracted in Rev. Appl. Ent. A 30: 375. 1942.)