LYGUS BUG DAMAGE TO ALFALFA IN RELATION TO SEED PRODUCTION

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INTRODUCTION

Investigations have shown that many factors affect seed setting in alfalfa (Medicago sativa L.). No fully satisfactory explanation, however, has been found to account for the major declines in yields of alfalfa seed and the seed-crop failures that have occurred in widely separated regions in recent years. Exceptionally high yields, ranging from 400 to 1,000 pounds or more of seed to the acre, have been reported for earlier years of production in the Arkansas Valley of Colorado and in the Uinta Basin and Millard County of Utah (1, 4). In 1925 Utah produced 22 million pounds of alfalfa seed, which was approximately 40 percent of the Nation's total of that year. This peak in production was followed by a decline in acre yields and a low total production, which since 1930 has frequently not exceeded 5 million pounds annually.

The general decline in yield of alfalfa seed in Utah appears to be partly attributable to bud damage and flower fall that have recently been shown to result from injury caused by Lygus bugs (Lygus hesperus Knight and L. elisus Van Duzee). L. elisus was early recognized by McGregor (8) as a pest of cotton in California and as having occurred on alfalfa as an alternate host. The Lygus problem in alfalfa-seed production has been studied by Sorenson (10), who has contributed a knowledge of the biology and life history of Lygus in alfalfa under Utah conditions. Stitt (11) likewise has made an investigation of the occurrence and activities of Lygus in relation to alfalfa-seed production in Arizona. The present investigation was conducted in an attempt to determine the nature of Lygus damage to alfalfa and to obtain evidence of the importance of these insects in relation to a rapid decline in alfalfa-seed production in several formerly highly productive regions of the Western States.
TYPES OF BUD AND FLOWER DAMAGE IN ALFALFA

SYMPTOMS OF LYGUS DAMAGE

Severe bud damage and flower fall in alfalfa that are attributable to Lygus infestation are indicated in the field by whitish-yellow areas or strips that are conspicuous in contrast to the normal deep green of undamaged and healthy alfalfa. The discoloration results from the presence on the plants of dead, dried, and bleached buds and numerous Rachises from which flowers have fallen. The symptoms of damage vary with the age of the alfalfa and with the intensity and time of the infestation. New growth under heavy Lygus infestation is often noticeably retarded. Stems are sometimes unusually short and thick and may be terminated by a cluster or rosette of many small and distorted racemes of buds. Heavy and prolonged infestation of older growth may frequently result in an appearance of "stringiness" of the plants, due to excessive branching and leafiness that develop from profuse proliferation. In fields that have been recently irrigated or in areas of a field where the growth for some reason is exceptionally rank and succulent, alfalfa appears to be particularly susceptible to this damage when heavily infested with Lygus.

General bud damage in alfalfa is illustrated in figure 1. For comparison, figure 2 shows racemes of healthy buds, flowers, and seed pods that are borne on long peduncles or stalks.

METHODS AND MATERIALS

The nature of Lygus damage to alfalfa buds was studied in artificially infested material, with the raceme or cluster of buds taken as a unit. Undamaged specimens were obtained for infestation by tying parchment bags over the tips of stems or branches from which previously formed buds and flowers had been removed, thus permitting the development of new buds in the complete absence of Lygus. Racemes of buds from one-eighth to three-eighths of an inch in length were enclosed in sets of four per bag for infestation with either one or two adult Lygus, or were exposed to the natural bug population of the seed fields. Check treatments were obtained by enclosing racemes of buds without infestation. The different treatments were applied to racemes of buds on the same plant, and they were repeated with a large number of racemes on several varieties and strains of alfalfa at different times during the seed-setting season. The period of infestation was varied from 20 to 48 hours, after which the insects were released and the bags were replaced to protect the buds from further damage through chance infestation. For evidence of damage based on color, condition, and general appearance, an examination of the racemes of buds was made on the fifth to seventh day after the initiation of the infestations.

A similar procedure was followed in an attempt to determine the effects of Lygus bugs on alfalfa flowers, except that the individual flower and not the raceme of flowers was taken as the unit. The flowers on approximately one-half of the racemes were tripped by hand, after which infestation was effected in the manner described for the buds.

Infested and uninfested buds and flowers were preserved in formalin acetic alcohol for histological study. Green and unpreserved material
was useful in a study and description of the general symptoms of damage. Further details of *Lygus* injury could be identified best from a microscopical examination of buds and flowers embedded and stained by ordinary methods. Microtome sections were cut 12μ thick and mounted in serial and chronological order to facilitate tracing the course and rate of spread of the cell disintegration origi-

![Figure 1. Terminal portions of three alfalfa stems showing *Lygus* damage. The racemes of buds are small, unusually numerous, crowded, and generally discolored. A tendency to excessive branching and the development of short internodes near the stem terminals is shown. Specimens from an alfalfa field heavily infested with *Lygus* bugs. (Approximately one-half natural size.)](image-url)
nating from punctures. Various stains were used. The best results were obtained with Delafield's haematoxylin and with a combination of safranin with light green. Details of cell structure and embryo development were shown especially well with Heidenhain's iron-alum

**Figure 2.** Terminal portions of three alfalfa stems showing an approximately normal development of buds, flowers, and seed pods. A normal elongation of the internodes and the occurrence of the racemes of buds and flowers on long peduncles are shown. Crowding of the inflorescences is not apparent and most of the racemes have a large number of buds and flowers, a large proportion of which develop into seed pods. Specimens from an isolated plant far from cultivated fields of alfalfa. (Approximately one-half natural size.)
haematoxylin. Generally unsatisfactory results followed a few attempts to trace the origin and course of the damage in buds and flowers without the embedding and staining technique.

**NATURE AND EXTENT OF DAMAGE**

The initial damage resulting from feeding punctures by *Lygus* is definitely localized. The extent of damage to young buds that may occur under different intensities of infestation is shown in table 1. A single puncture may be seen under the microscope as a small perforation surrounded by a collarlike area of discoloration. (See pl. 1 and fig. 6.) Superficial evidence of damage to buds is indicated by a slight bleaching that becomes apparent 24 to 48 hours after infestation. Death and complete disintegration of the injured buds may follow in a few days. Dead buds frequently remain attached to the floral axis and retain more or less the size and shape they had at the time of injury. Discoloration and disintegration of injured buds begin at the punctures and are apparently caused by a toxic or irritant substance that is emitted with the saliva of the insects at the time of feeding. This observation is supported by the work of Smith (9), who studied the feeding methods of capsid bugs (Miridae) which are closely related to *Lygus*. He showed by removing the salivary glands of harmful and harmless species and placing them on apple fruit and foliage and prickling slightly the cells beneath with a fine needle that the damage is chemical rather than physical in character. King and Cook (7) showed that *Lygus* bugs and closely related species feed by the same process, namely, by inserting their mouth parts into plant tissue and sucking the sap, but that more serious pathological effects follow feeding by some species and individuals than by others.

**Table 1.**—Average percentage of racemes of buds apparently normal and of those apparently injured (after 20 to 48 hours' infestation with *Lygus* bugs ¹

<table>
<thead>
<tr>
<th>Infestation</th>
<th>Plants</th>
<th>Racemes</th>
<th>Racemes apparently in condition indicated</th>
<th>Normal</th>
<th>Injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of <em>Lygus</em> to 4 racemes of buds¹</td>
<td>Number</td>
<td>Number</td>
<td>Percent</td>
<td>Percent</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>20</td>
<td>116</td>
<td>80.0</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>17</td>
<td>68</td>
<td>15.6</td>
<td>84.3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>80</td>
<td>13.7</td>
<td>86.2</td>
<td></td>
</tr>
<tr>
<td>Natural (field)</td>
<td>25</td>
<td>100</td>
<td>25.0</td>
<td>75.0</td>
<td></td>
</tr>
</tbody>
</table>

¹ Condition of buds determined from evidence of damage based on color and appearance on the fifth to seventh days after infestation began.

The inception and development of *Lygus* damage in alfalfa buds was shown by infesting four normal racemes of buds with four bugs for a period of 12 hours. After the insects were released, the buds were again enclosed and left sufficiently long to allow for the development of different degrees of damage. One raceme of buds was fixed for histological study at the end of the 12-hour infestation period, while others were collected for preparation and study after periods of 24, 36, and 48 hours. In some trials the infestation period was increased by 12-hour intervals up to 60 hours, after which fixation of buds for histological study was made at 12-hour intervals. It was
EXPLANATORY LEGEND FOR PLATE 1

A, Longitudinal section through a young bud from a plant damaged under a natural infestation in the field. The course of a puncture through the floral envelope is shown; it extends into the ovary where an area of cell disintegration has been initiated. (Approximately 42 times natural size.)

B, Longitudinal section through an older bud that was artificially infested with Lygus. Localized areas of discoloration and disintegration are shown in which the evidence of punctures has been largely obliterated (B, a). Recently made punctures are shown near the basal portion of the ovary and in the floral envelope near the apex of the bud. A general disorganization of the bud has resulted. (Approximately 42 times natural size.)

C, Longitudinal section of a young bud that was infested for 48 hours. An advanced stage of disintegration is shown. Arrows point to punctures and centers at which disintegration began. (Approximately 42 times natural size.)

D, Small puncture made by an insertion of the proboscis and showing the early stages of cell discoloration and disintegration. (Approximately 42 times natural size.)

E, Two approximately 24-hour-old punctures showing a comparatively extensive area of disorganization and discoloration. (Approximately 740 times natural size.)
Lygus Bug Damage to Alfalfa

PLATE 1

CAMERA LUCIDA DRAWINGS OF ALFALFA BUDS DAMAGED BY LYGUS.
FOR EXPLANATORY LEGEND SEE OPPOSITE PAGE.
difficult to trace the origin and course in the development of the damage after long infestation, or in material that had developed to advanced stages of deterioration. An infestation of from 12 to 24 hours, with a comparatively short period in which the deterioration might develop, gave evidence that the bud damage had in most cases been initiated from *Lygus* punctures. Extensive disintegration of buds appeared also to have resulted, apparently from the effects of the toxic substance injected into the plants by the insects.

A determination of the nature of *Lygus* damage in alfalfa cannot always be made from material infested in the field. Advanced stages of bud disintegration sometimes obliterate all evidence of the original punctures. Identification, however, can usually be successfully made from artificially infested racemes of buds when sectioned on the microtome, stained, and examined under the low power of the microscope. Numerous punctures made by repeated insertions of the proboscis of the insect have been found within a portion of a single bud. Areas of disintegration absorb the stain more readily than the undamaged parts of buds and can thereby be easily recognized. Mechanical damage resulting directly from *Lygus* feeding punctures is apparently of local and rather limited effect. It appears that major damage develops from secondary or indirect effects, such as distorted vegetative growth and profuse proliferation, which are discussed in detail in a later section of this paper. Recovery from the effects of an infestation of short duration is sometimes noticeable from 5 to 10 days after the application of an insecticide to remove the insects.

**Bud Rosetting**

Especially distinctive symptoms of *Lygus* damage to alfalfa result from the development of racemes of buds near the tips of main stems and branches into disklike or knoblike structures called rosettes (fig. 3).

Bud rosetting has been shown to occur under heavy *Lygus* infestation, but this, apparently, is not the only cause of abnormal bud development. The condition is common in Utah alfalfa fields that are setting a poor crop of seed. The compressed state of the racemes of buds appears to result from a failure of the upper internodes of a stem or branch to elongate to the usual length, and from a differential growth in the individual racemes composing the cluster. Racemes of buds in a rosette are, as a rule, small, discolored, and tightly compressed. Frequently most of them fail to produce well-developed clusters of flowers that set seed pods, although considerable variation has been observed in this respect.

Bud rosetting developed in repeated trials on 8 or 10 seedling alfalfa plants from which all previously formed buds and flowers had been removed, when enclosed in cheesecloth cages and infested with 300 late-instar and adult *Lygus*. The rosetting became noticeable on the third day of the infestation when the original number of insects was doubled to increase the severity of the effects. The heavier infestation resulted in a condition that was typical also of field plants outside of the cages. A still further increase in the intensity of the infestation was made at the end of the fourth week by the addition of 150 *Lygus* to the survivors of the original number of bugs in each cage, which resulted in severe and continued damage to the buds for
the remainder of the season. Uninfested plants in check cages did not develop the rosetting, but produced an abundance of flowers from which only a few seeds pods were obtained, owing probably to the unfavorable effects of shading during the long period of enclosure and the failure of the flowers to become fertilized.

The exact nature of bud rosetting has not been determined. Microscopic examinations of rosettes produced under controlled infestation have shown punctures and a bud disintegration generally characteristic of *Lygus* damage. In addition, however, a disturbed growth and development in the stem terminal and bud primordia is apparent. Eggs of insects, which measurements have shown to correspond closely in size and form to those of *Lygus*, have frequently been found in rosettes and in the upper nodes of a stem. Large cavities are also sometimes made in the stem terminals during oviposition, and mechanical destruction of plant tissue may result in some degree. Com-

![Figure 3](image-url)---A suppressed elongation of the apical internodes of alfalfa stems and the development of racemes of buds in clusters called rosettes. The condition occurs under severe *Lygus* infestation. Compare with normal condition (fig. 2). (Approximately one-half natural size.)

paratively little disintegration of cells has been noted surrounding egg cavities. It is possible, nevertheless, that extensive mechanical destruction of cells near the stem tips during oviposition may affect the normal development of structures initiated from the growing point and result as well in a suppressed elongation of terminal internodes.

**Bud Abortion**

Damage to alfalfa described as bud abortion occurred in 20 percent of the racemes of buds from which *Lygus* was excluded in the controlled infestation experiments (table 1). Physiological conditions affecting growth and development of the buds, however, appear to be the principal causes contributing to this type of damage. Bud abortion is apparently not unusual, since it has been observed in greenhouse plants and was shown to develop in 21 of 29 field plants on which racemes of buds were enclosed for protection from *Lygus*. 
Bud abortion in alfalfa is illustrated in figure 4. The important characteristics are the small size of the racemes of buds and the intense buff-colored bleaching that is conspicuous against the green of healthy stems and leaves. The microscopic character of the bud disintegration and break-down is shown in figure 5, in which it appears to occur uniformly and over the whole raceme at approximately the same time. Damage resulting from bud abortion is distinctly unlike that which develops from *Lygus* infestation. Bud abortion in alfalfa seed fields sometimes complicates the identification of *Lygus* damage, although the two types of damage appear distinctly unlike under microscopic examination.

FLOWER FALL

Flower fall in alfalfa may result from various causes of which insect damage is of great importance. *Lygus* injury to alfalfa flowers is shown in sectioned and stained material as punctures and lacerations in the ovaries similar to that occurring in young buds. Damaged individual flowers, however, abscise and are shed so soon after injury that discoloration or disintegration is not conspicuously noticeable while they remain attached to the plant. Excessive flower fall in alfalfa occurred under controlled *Lygus* infestation when either 3 or 5 bugs were enclosed with 7 to 10 flowers for 48 hours (table 2). The percentage of flowers falling was about the same with artificially tripped flowers as with those under natural development, although a higher percentage of the surviving tripped flowers set seed pods. Numerous observations have shown *Lygus* bugs to be an important cause of excessive flower fall in alfalfa seed fields, although these insects are by no means the only cause of low yields and poor seed crops.

Alfalfa is highly variable in its reproductive behavior and is sometimes known to shed its flowers in the apparent absence of destructive
insects. Brink and Cooper (2) have shown that the degree of effective pollination is very commonly a limiting factor for seed production. Cooper et al. (6) have demonstrated that a failure of seed setting in alfalfa where the flowers have been tripped to insure effective pollination is apparently due to lack of fertilization even though pollen tubes are present. The pollen tubes sometimes fail to reach all the ovules, and even when fertilization is effected, embryo abortion may occur at various stages in development. More recently Tysdal (12) has shown the importance of tripping insects, particularly wild bees of Nomia and Megachile species, as pollinators of alfalfa flowers, and he has shown that the presence of these insects in alfalfa seed fields is frequently correlated with satisfactory yields of seed.

The nature of Lygus damage to alfalfa flowers is illustrated in figure 6. A puncture has been made through the floral envelope and into the lower extremity of the ovary. A collarlike area of discoloration surrounds the perforation. The originally small area of injury has become enlarged and has resulted in a partial disintegration of the lower one-third of the ovary. A generally extensive area of damage is shown within the ovary and appears to have destroyed about one-half of the ovules. Most of this damage appears to be traceable to the effects of a single puncture.

A condition of alfalfa flowers that fall from causes other than insect damage is illustrated in figure 7. A shriveling and deterioration of the ovules occurs without evidence of punctures, lacerations, or other mechanical injury, and with no indication of a deterioration due to toxic effects. The appearance of the ovules suggests a failure in development due to a lack of fertilization, or an embryo abortion.
following fertilization that has resulted in the development of shriveled seeds.

### Table 2

**Average percentage of normally developed and of artificially tripped alfalfa flowers that fell while exposed to an infestation of Lygus bugs for 48 hours and average percentage of the total flowers that formed seed pods within 10 days after infestation period**

<table>
<thead>
<tr>
<th>Infestation 1</th>
<th>Plants</th>
<th>Flowers of indicated treatment falling during infestation period and those setting seed pods within 10 days after infestation 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Normal development</td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>Flowers falling</td>
</tr>
<tr>
<td>Number of Lygus per 7 to 10 flowers:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.</td>
<td>40</td>
<td>9.3</td>
</tr>
<tr>
<td>1.</td>
<td>15</td>
<td>32.1</td>
</tr>
<tr>
<td>2.</td>
<td>15</td>
<td>36.0</td>
</tr>
<tr>
<td>3.</td>
<td>5</td>
<td>80.8</td>
</tr>
<tr>
<td>5.</td>
<td>5</td>
<td>97.9</td>
</tr>
<tr>
<td>Natural (field)</td>
<td>40</td>
<td>6.9</td>
</tr>
</tbody>
</table>

1. Adult Lygus enclosed with flowers in paper bags; released at the end of 48 hours, after which the bags were replaced over the flowers.
2. Remainder of the flowers not forming seed pods fell after the infestation period.

### Secondary Effects of Lygus Damage in Alfalfa

**Methods and Materials**

The pathological symptoms appearing in the buds and the damage suffered by alfalfa plants infested with *Lygus* bugs led to inquiry regarding possible physiological disturbances in growth and reproductive development that might impair the plants for seed setting. *Lygus* infestation and insecticide treatments were applied to transplanted, hill-spaced, alfalfa seedlings of Grimm, Hardistan, Kansas Common, and a heavy seed-producing strain of a Wisconsin Grimm selection. The plants of the different alfalfas were spaced 3 by 3 feet apart in random order and within partly isolated blocks a rod square. The special purpose of the isolation was to eliminate the drifting of the insecticide from treated to untreated plots during application.

Treatments were begun on June 20, when all plants were in the prebud stage of development and approximately 8 inches high. Infestation was effected by using cheesecloth cages to confine the *Lygus* bugs to the plants for a period of 24 hours. Once established, the infestation was maintained by adding to each plant, from time to time, the number of bugs necessary to produce a damage approximately as severe as that occurring naturally in nearby alfalfa fields. Prevention of damage by the insects on control blocks was effected by the frequent application of a dry pyrethrum concentrate containing 2 percent pyrethrins, in the proportion of 15 parts to 85 parts of colloidal or electric dusting sulfur as a carrier.

Variations in the rate or frequency of application of the insecticide were not made, since a maximum control of the insects and a prevention of the damage was all that was desired. Infestation and control treatments were applied to blocks in duplicate as follows:
**Treatment 1.**—Infested with *Lygus* bugs from the prebud stage to the full-bloom stage of development. Dusted after the full-bloom stage five to seven times weekly until seed harvest. Objective: To determine the effects of *Lygus* infestation during the early vegetative stages of growth and development of alfalfa, and the later effects on seed setting.

**Treatment 2.**—No infestation; dusted five to seven times weekly from the prebud stage of development of the plants to seed harvest. Objective: To determine the type of growth and development in alfalfa and the effects on seed setting when plants are comparatively free from *Lygus* infestation.

**Treatment 3.**—Same as for 2, except the early buds and flowers were clipped by hand to approximate the damage resulting from *Lygus* infestation under treatment.

**Treatment 4.**—Infested continuously with *Lygus* from the prebud stage of growth and development until seed harvest. Objective: To determine the effects of continuous *Lygus* infestation on alfalfa, with special reference to effects on seed setting.

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**Figure 6.**—Photomicrograph showing the effects of a *Lygus* puncture in the ovary of an alfalfa flower. 

1. Objective: To determine the effects on growth, development, and seed setting in alfalfa when the loss of buds and flowers occurs from causes other than *Lygus* damage.

2. Objective: To determine the effects on growth, development, and seed setting in alfalfa when the loss of buds and flowers occurs from causes other than *Lygus* damage.
Treatment 5.—Uninfested and dusted from the prebud stage to the full-bloom stage of development. Thereafter, infested with Lygus until seed harvest. Objective: To determine the effects of Lygus infestation during the bud and the flower stage of alfalfa development in relation to seed setting.

EFFECTS OF LYGUS INFESTATION ON EARLY GROWTH AND DEVELOPMENT OF ALFALFA

The average height of the plants in the various blocks previous to infestation ranged from 6.9 to 9.1 inches. Fifteen days after infestation the infested plants had an average height of 12.3 inches, as compared with an average height of 17.2 inches for uninfested plants that were dusted frequently. At the end of 22 days, when the plants were in full bloom, the average heights were 14.5 and 21.3 inches for infested and dusted plants, respectively. The effects of the two treatments on growth of the plants are illustrated in figure 8. The photographs were taken to the same scale to show these effects directly.

Infested and dusted plants, with the exception of those in one block, developed approximately the same number of main stems (table 3). An average of 40.5 branches developed on 3 main stems of infested plants, as compared with an average of 25.5 on the uninfested and dusted plants. Wide variations in the tendency to profuse branching was shown by plants within blocks receiving the same treatment. Differences in response to infestation shown by the plants are probably due, at least in part, to a difference in the intensity or duration of the infestation occurring with individual plants within the same block. Excessive branching, which gives to affected plants an appearance of “stringiness,” seems to result from a stimulation into activity of normally dormant axillary branch primordia due to Lygus injury at apical growing points of main stems and branches. Infested and uninfested plants developed approximately the same number of leaves on 3 main stems. The appearance and condition of the leaves, however, was strikingly different. An average of 21.8 percent of leaves from infested plants were crinkled or misshaped, as compared with 1.6 percent of those from the dusted
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Attempts to produce the leaf deformity by exposing young leaves to direct attack by the insects did not give rise to characteristic symptoms. It is possible that injury may occur indirectly to leaf-bud primordia and this results later in the development of crinkled and deformed leaves. An objection to this view arises from the fact that *Lygus* damage to young flower buds, which are probably less sensitive to injury than leaf-bud primordia, results in immediate and complete deterioration. Nevertheless the variability in the number and proportion of crinkled and deformed leaves on plants within the same block and on different blocks and the tendency to profuse branching, as well as crinkled leaves, suggest *Lygus* as a direct cause.
### Table 3.—Comparative growth and development of alfalfa when infested at the prebud stage of development with Lygus bugs and when uninfested and dusted 5 to 7 times weekly with an insecticide

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average height</th>
<th>After 15 days' treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before treatment</td>
<td>After 15 days</td>
</tr>
<tr>
<td>Infested with Lygus:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block A</td>
<td>7.1</td>
<td>11.3</td>
</tr>
<tr>
<td>Block B</td>
<td>9.0</td>
<td>13.3</td>
</tr>
<tr>
<td>Mean</td>
<td>8.0</td>
<td>12.3</td>
</tr>
<tr>
<td>Dusted 5 to 7 times weekly:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buds not clipped:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block A</td>
<td>7.5</td>
<td>15.7</td>
</tr>
<tr>
<td>Block B</td>
<td>9.1</td>
<td>19.0</td>
</tr>
<tr>
<td>Mean</td>
<td>8.3</td>
<td>17.3</td>
</tr>
<tr>
<td>Buds clipped:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block A</td>
<td>6.9</td>
<td>16.1</td>
</tr>
<tr>
<td>Block B</td>
<td>8.8</td>
<td>18.1</td>
</tr>
<tr>
<td>Mean</td>
<td>7.8</td>
<td>17.1</td>
</tr>
</tbody>
</table>

1 16 plants per block.  23 main stems.

**DEVELOPMENT OF PLANTS FOLLOWING REMOVAL OF LYGUS**

The *Lygus* bugs were removed effectively from infested blocks after repeated and frequent application of the insecticide. Evidence of a general recovery from the effects of a relatively brief infestation also became noticeable 10 days after the removal of the insects. Growth occurring subsequent to removal of the insects gave an appearance of having been superimposed on the previously damaged stems and branches. The first buds and flowers to develop after the removal of the insects appeared on short branches, as shown in figure 9. Later, longer stems and branches developed which had internodes of the usual length and buds and flowers borne on long peduncles, as is characteristic of normal and healthy alfalfa (figs. 10 and 2).

No marked effects resulted from clipping of the early formed buds and flowers under treatment 3. Neither were harmful effects observed to follow the use of the insecticide, at this stage of the investigation. Growth and floral development of frequently dusted plants were thought to be generally good and were apparently normal in all respects. Buds and flowers were produced in the abundance and succession characteristic of alfalfa growing under favorable conditions. Later it was observed that applications of insecticides having sulfur as a carrier resulted in a slight burning of the flowers, which damage has since been shown to result in reduced yields of seed.

**EFFECT OF LYGUS INFESTATION IN THE FULL-BLOOM STAGE OF ALFALFA**

*Lygus* infestation initiated in the full-bloom stage of alfalfa resulted in damage to buds and flowers and a condition similar to that commonly observed in commercial seed fields when producing a poor crop of seed. Discolored buds and an excessive flower fall gave early evidence of damage, while rosetting developed as a later effect.
Microscopic examination of injured buds showed characteristic *Lygus* punctures similar to those obtained under more closely controlled infestations. Growth and development of the plants were not retarded by late infestation. The usual "stringiness," however, gave to the plants an appearance of excessive vegetative development. In general flowers were produced abundantly, although most of them abscised early and before seed pods were formed. The production of seed was also generally poor.

**EFFECTS OF LYGUS INFESTATION ON SEED AND FORAGE PRODUCTION**

Seed yields from plants receiving different infestation and insecticide treatments differed strikingly (table 4). The highest yields of seed per plant resulted from uninfested plants that were dusted frequently.
to control *Lygus*, while the lowest yields were obtained from those undusted and continuously infested. Differences in the yield of seed resulted also from variations in the time of applying the infestations to plants in different stages of vegetative and reproductive development. Generally good agreement in yields is shown by replicates of the various treatments, which is evidence of a satisfactory control of *Lygus* under the conditions of the experiment.

Mean yields of slightly more than 12 gm. of seed per plant, which were obtained from the uninsecticided and dusted plants, are estimated to be equivalent to an acre yield of from 200 to 300 pounds. This estimate is based on the yields of many 1-year-old hill-spaced alfalfa plants at the Uinta Basin Alfalfa Seed Experimental Farm of the Utah Agricultural Experiment Station in years when successful seed crops were produced. The approximation is subject to some error owing to differences in the degree to which young hill-spaced alfalfa plants utilize effectively and efficiently the space allotted to each, but is, nevertheless, of value as a means of providing some idea of the beneficial effects that might be expected from a control of *Lygus*. The low average yield of 2.30 gm. of seed per plant obtained from the plots infested with *Lygus* would not, on the same basis of comparison, be expected to pay for the costs of harvesting and threshing.

The differences in yield of seed shown by infested and insecticide-treated plants are highly significant statistically. Differences resulting from varying the time of the infestation in relation to stages in the development of the plants are small but near the border line of low statistical significance. The consistently low yields of seed obtained under continuous *Lygus* infestation are evidence that greater damage to seed production results from long and continued *Lygus* infestation than from short or

**Figure 10.**—Type of growth and reproductive development on severely damaged alfalfa plants following the removal of a *Lygus* infestation. Below the line: Retarded and distorted stem development and excessive branching that is typical of the effects of *Lygus* on early growth and development of alfalfa, except two branches at the extreme right. Above the line: Growth and development that followed the removal of the infestation. Note the normal elongation of the stem internodes and the development of racemes of buds and flowers on long peduncles, as is the normal condition in alfalfa (fig. 2).
periodic infestations of limited duration. More serious damage to seed production seems to have resulted from Lygus infestation in the full-bloom stage than from infestation in the early stages of vegetative development. Infestation at any time, however, may be expected to result in some damage. Clipping the early buds and flowers of uninfested and dusted plants, as in treatment 3, produced no statistically significant effect on seed production as compared with treatment 2, in which they were allowed to grow and to which the same insecticidal treatment was applied.

Table 4.—Average yield of seed in grams per plant of 16 alfalfa plants (per block) spaced uniformly in square rod blocks when infested with Lygus bugs at various stages of growth and development and when uninfested and dusted 5 to 7 times weekly with an insecticide

<table>
<thead>
<tr>
<th>Treatment of alfalfa plants</th>
<th>Average seed per plant</th>
<th>Average proportion of good seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block A</td>
<td>Block B</td>
<td>Mean</td>
</tr>
<tr>
<td>1. Infested during the prebud stage and dusted in later bloom stages</td>
<td>5.80</td>
<td>8.35</td>
</tr>
<tr>
<td>2. No infestation; frequent dusting</td>
<td>11.85</td>
<td>10.13</td>
</tr>
<tr>
<td>3. Same as 2 (early buds clipped)</td>
<td>12.51</td>
<td>14.85</td>
</tr>
<tr>
<td>4. Continuous infestation</td>
<td>3.15</td>
<td>1.46</td>
</tr>
<tr>
<td>5. Dusted during the prebud stage and infested in bloom stage</td>
<td>2.91</td>
<td>4.25</td>
</tr>
</tbody>
</table>

Significant difference (5-percent point)

For complete description of treatments, see p. 803.

Significant differences were obtained in the quality of the seed produced under continuous Lygus infestation and that produced under frequent insecticide treatment (table 4, last column). Lygus is, therefore, shown to affect the quality and value of alfalfa seed, as well as to damage buds and flowers. A high shrinkage in recleaning, which in some cases exceeded 50 percent, has occurred in commercially produced crops in years when Lygus has been suspected as a cause of the low yields.

The average weights of air-dry forage produced by the alfalfa plants under different infestation and insecticide treatments are given in table 5. Generally good agreement in some cases and wide differences in others are shown between the mean weights of the plants in the two replicates of the treatments. A statistically significant difference is shown between the mean weight of the plants under continuous Lygus infestation and that of the plants in the other treatments. The data are probably insufficient to permit definite conclusions as to the effects of Lygus on the vegetative development of alfalfa. General experience and observation in the production of alfalfa seed under Lygus infestation have shown that on good soil and with a not too restricted water supply, vegetative growth sometimes becomes excessive to the extent that cutting and threshing of poor seed crops becomes difficult and costly. It is not known definitely, however, whether this excess growth results from a failure of the plants to set seed or from a stimulation due to Lygus injury (fig. 11).
FIGURE 11.—Comparative growth and vegetative development of *Lygus*-infested and uninfested alfalfa plants: *A*, Continuously infested from prebud stage of development to seed harvest (treatment 4); *B*, uninfested and dusted five to seven times weekly for same period (early buds and flowers clipped; treatment 3). Photographs taken to the same scale. Compare the ground covered by the plants for an idea as to their relative size.
Lygus Bug Damage to Alfalfa

**Table 5.**—Average weight of air-dry forage in grams per plant of 16 alfalfa plants spaced uniformly in square rod blocks when infested at various stages of growth and development with Lygus bugs and when dusted 5 to 7 times weekly with an insecticide.

<table>
<thead>
<tr>
<th>Treatment of alfalfa plants</th>
<th>Treatment of alfalfa plants</th>
<th>Yield of air-dry forage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Block A</td>
</tr>
<tr>
<td>1. Infested during the prebud stage and dusted in late bloom stage</td>
<td>Block A</td>
<td>215</td>
</tr>
<tr>
<td></td>
<td>Block B</td>
<td>204</td>
</tr>
<tr>
<td>2. No infestation; frequent dusting</td>
<td>Block A</td>
<td>192</td>
</tr>
<tr>
<td>3. Same as 2 (early buds clipped)</td>
<td>Block A</td>
<td>254</td>
</tr>
<tr>
<td>4. Continuous infestation</td>
<td>Block A</td>
<td>207</td>
</tr>
</tbody>
</table>

Significant difference (5-percent point) 29

1 For complete description of treatments, see p. 803.

**DISCUSSION AND CONCLUSIONS**

It is in recent years only that attention has been given to *Lygus* bugs as pests in alfalfa seed production. While these insects are known to be widely distributed and to feed on a variety of native and cultivated host plants, comparatively little is known of their occurrence in alfalfa seed fields prior to the general onset of alfalfa seed crop failures in Utah. However, evidence gained from a study of the biology, life history, and general habits of *Lygus* in relation to alfalfa seed production (10); their occurrence and the intensity of the infestations in relation to alfalfa seed setting (11); and the nature of the damage, as determined in the present investigation, leaves little doubt as to the great importance of *Lygus* as a factor in alfalfa seed production at the present time. Since the *Lygus* species damaging alfalfa are native to western America, it is highly probable that they have been present in the alfalfa seed fields of the Western States for many years. It is not clear, however, as to how, when, and why they have apparently only recently become sufficiently numerous to constitute a pest of prime importance.

Brues (3) has shown that insects sometimes change their food habits and are known to leave their wild host plants and adopt new food plants among cultivated crops. Two weeds of the family Chenopodiaceae that are known to harbor *Lygus* in large numbers have become widely distributed in Utah alfalfa seed-producing areas since the land was first brought into cultivation. The best known and most widely distributed is Russian thistle (*Salsola pestifer* A. Nels.) and the other is smother weed (*Bassia hyssopifolia* (Parl.) Kuntze). *Chenopodium* species were early reported by McGregor (8) as the most common of the native host plants of *Lygus elius* in the Imperial Valley of California. Winslow et al. reported declining yields of alfalfa seed as beginning with the advent of sugar-beet seed growing in the Hemet Valley of California, which is significant in view of the fact that *Lygus* is also recognized as a pest of sugar-beet.

Complete information is lacking also as to the conditions under which marked declines in yield of alfalfa seed have occurred. Certain striking similarities may be noted in the general sequence of events that have led to low yields of alfalfa seed in several widely separated regions. Production began in western regions, as a rule, on virgin soil and with a comparatively small acreage. The yields in the early years of production were often high, ranging from 400 to 1,000 pounds or more of seed to the acre. A peak in total production resulted, followed by declining yields and a low total production. While new lands were available, seed-producing areas were developed rapidly in new regions and seed growers continued production with profit for many years in succession. At the present time, certain of these same regions are characterized by frequent seed-crop failures, low acre yields, and generally low total production of alfalfa seed.

A few acres of alfalfa were planted on virgin land in the bottoms of Wah Wah Valley on the western desert of Utah in the summer of 1936. The severe bud damage and flower fall that are typical of Lygus injury were observed in the area the following year. Sweepings with an insect net showed the Lygus population to be as high as that in representative fields in the older alfalfa seed-producing regions of Utah and Idaho. The observation is of special interest because of the fact that the planting of alfalfa was the first to be made in the region and no other alfalfa fields were known within a radius of approximately 30 miles. The infestation had evidently developed through migration of Lygus from the native host plants of the desert. On the other hand, some outstandingly successful seed crops have been reported from fields bordering on the desert during a period of seed-crop failures in older seed-producing areas in Utah.

Carlson and Stewart (5) and Carlson (4) reported yields of alfalfa seed from experimental trials that ranged from less than 50 to more than 800 pounds of seed to the acre, depending upon treatments, varieties, soils, and seasons. The observed symptoms of damage to the buds and the excessive flower fall associated with some of the low yields seem to afford unmistakable evidence that Lygus damage, as it is now known, was present in the fields, and the insects were probably an important cause of the poor seed setting. Plots that produced maximum yields in one year frequently gave exceptionally low yields the following year and vice versa. Wide variations in yields occurred among plots receiving similar treatments in the same year and in different years. It has been shown (table 4) that severe Lygus infestation in the full-bloom stage of alfalfa resulted in greater damage to the seed crop than did infestation in earlier vegetative stages of
plant development. Yield fluctuations among plots receiving the
same cultural treatment are, therefore, at least in part, probably
explainable on the basis of differences in the severity and time of
occurrence of Lygus infestations in the various plots.

Fluctuations in yield of alfalfa seed in commercial fields are fre-
quently as great as those reported for experimental plots and seem to
be attributable to the same general causes. Yields of alfalfa seed
reported to exceed 800 pounds to the acre were being produced on
scattered and isolated ranches on the western desert of Utah only
90 miles distant from the areas of outstanding seed-crop failures in
Millard County in 1934. Generally high acre yields of seed and high
total production were obtained in northern Utah and southern Idaho
for several years when seed-crop failures occurred in the formerly highly
productive areas of Millard County and the Uinta Basin of Utah.
More recently, a decline in production has been noted in certain
regions of northern Utah and southern Idaho, while a marked im-
provement in conditions favoring seed setting in alfalfa has become
apparent in portions of Millard County. These wide fluctuations in
seed yields within relatively small geographical areas seem to offer
unmistakable evidence of the effects of local factors rather than general
climatic changes. In addition, symptoms of damage attributable to
Lygus and the presence of the insects in seed fields at critical periods in
the development of the seed crops are strong evidence that these bugs
are in some way responsible for the low yields of seed, especially when
conditions are otherwise apparently favorable for seed production.

CONTROL OF LYGUS

Sorenson (10) reported that the application of insecticides for the
control of Lygus on a large scale is insufficiently effective to justify
the cost and that the bugs possess a high natural resistance to most
insecticides now available. However, in the present investigation,
the frequent application of pyrethrum concentrate and sulfur to small
plots resulted in considerable improvement in seed production, but
particularly in the condition of the buds and flowers previous to pod
setting. The average yields of seed per plant on 10 seed-increase plots
that were dusted frequently during the growth of the seed crop in
1938 were approximately 10 times those from similar plots in 1937 when
the insecticide was not applied until after severe bud damage and flower
fall had occurred. The improved yields resulting from the use of the
insecticide in 1938 are especially significant in view of the fact that
the alfalfa seed crop of that year from the commercial fields in the
region in which the trials were conducted was one of the poorest on
record.

Increased yields of alfalfa seed have resulted in some cases from
various cultivation and sanitation practices attempted by commercial
seed growers. Some of these methods have not been tested under
experimental control in Utah, and recommendations cannot, therefore,
be made at this time. In one case, a Lygus-infested alfalfa field in
which dry grass was burned following the removal of the first hay crop
showed a striking improvement in the appearance and condition of the
buds and flowers on the subsequent growth of the alfalfa. The seed
produced after the burning was reported to have exceeded 200 pounds
to the acre and was the best that had been produced in the field for several years. It was obvious from inspection that this seed crop was superior to those in adjoining unburned fields. Owing to prolonged drought during the spring of the following year, the grass was too scanty to make burning an effective method of destroying the insects in the field, and it was not therefore attempted by the seed grower. The hay, however, was cut at the usual time, and the treatment of the field was the same as in the previous year except for the burning of the grass. The effect was that the alfalfa became heavily infested with Lygus, severe damage was caused to the buds and flowers, and a generally distorted development of the plants was in evidence. The seed crop was generally poor and was reported as not exceeding 100 pounds to the acre.

SUMMARY

An investigation was made to determine the effects of Lygus bugs (Lygus hesperus Knight and L. elisus Van Duzee) on alfalfa (Medicago sativa L.) in relation to seed setting, and to gain evidence of the extent to which these insects have been a factor contributing to a rapid decline in alfalfa seed production in several formerly highly productive seed-growing regions of the Western States.

Several types of bud damage are found in alfalfa. A mechanical localized damage has been shown by controlled infestation to result directly from punctures and lacerations made by the mouth parts of feeding Lygus bugs, although pathological effects develop indirectly from the initial damage caused by the insects. Damaged buds show discoloration and evidence of deterioration in from 24 to 48 hours after injury. A rapid disintegration of the buds that apparently results from a toxic substance emitted with the saliva of the feeding insects follows injury.

Rosetting has been shown to occur under heavy Lygus infestation and is characterized by the development of racemes of buds near the tips of main stems and branches into disklike or knoblike clusters.

Bud abortion, another type of damage occurring in alfalfa, is apparently not attributable to Lygus infestation, but rather to physiological factors and conditions unfavorable to bud growth and development.

Individual alfalfa flowers abscise and are shed soon after injury by Lygus. Damage to flowers results mainly from punctures in the ovary or other succulent parts. However, all flower fall in alfalfa is not attributable to insect damage, but may be due also to factors affecting fertilization and embryo development.

Lygus injury apparently also affects the vegetative growth and development of alfalfa. Young growth when heavily infested is definitely retarded, and shows a tendency to excessive branching. A high proportion of the leaves of heavily infested plants may be crinkled or deformed.

Changes in the character of vegetative growth and reproductive development of alfalfa plants follow removal of a Lygus infestation. Evidence of recovery from damage usually becomes noticeable within 10 days.

Bleached and discolored buds give early indications of Lygus damage to alfalfa infested in the full-bloom stage of development. Rosetting
develops as a later effect. Vegetative growth of alfalfa is not retarded by late infestation, but severe damage to the buds and flowers may result.

Uninfested plants that received frequent applications of an insecticide gave significantly higher yields of seed than did infested plants. Infested plants, however, gave a significantly higher yield of air-dry forage, but it is not known whether the increased yield of forage resulted from the effects of *Lygus* injury or from a failure of the plants to set an abundance of seed. Numerous observations made during survey studies to determine the cause of alfalfa seed-crop failures have shown serious damage to alfalfa to result more or less directly in proportion to the *Lygus* population of the seed fields. *Lygus* bugs are, therefore, regarded as an important cause of the major alfalfa seed-crop failures in Utah.

The importance of *Lygus* as a factor affecting alfalfa seed production in Utah is evident also from the nature of the damage to the buds and flowers, and by the significant improvement in the yield of seed that is consistently obtained when *Lygus* bugs are effectively controlled.

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