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THREE SPECIES OF THE GENUS LYGUS AND THEIR RELATION TO ALFALFA SEED
STITT, L.L. 1 OF 1

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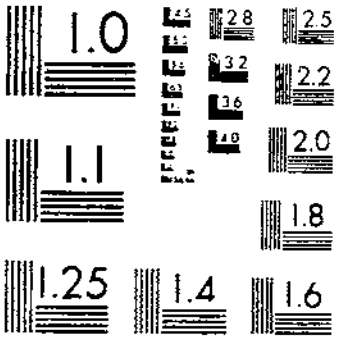

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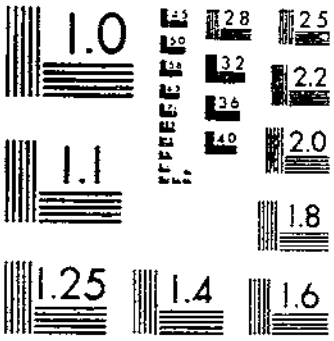

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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Three Species of the Genus Lygus and Their Relation to Alfalfa Seed Production in Southern Arizona and California [1]

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CONTENTS

	Page
Introduction	1
The species of *Lygus* and their distribution	2
History of the three species	3
Host plants	4
Character of *Lygus* injury to alfalfa seed	5
Economic importance of *Lygus* bugs in alfalfa seed production	7
Seasonal activity of *Lygus*	10
Lygus populations in relation to plant development	11
Percentage of each species of *Lygus* in the first seed crop	14
Life history	14
Incubation period of eggs of *Lygus hesperus*	14
Instar development of the nymphs of *Lygus hesperus*	15
Location of *Lygus* eggs in the alfalfa plant	16
Natural enemies	17
Control	17
Summary	18
Literature cited	19

INTRODUCTION

In the alfalfa seed-producing areas of Arizona and California three species of *Lygus* have been present, namely, *L. hesperus* Knight, *L. elisus* Van Duzee, and *L. pratensis oblineatus* (Say),[3] but not until recently have these insects been considered as pests in alfalfa seed production. Damage has occurred in varying degrees in different fields every year since 1934, when the investigations were begun to determine the injury that *Lygus* does to the alfalfa seed, to study the activity of the bugs under field conditions, and to find out what factors, if any, could be used in cultural control. The information obtained indicates certain lines of investigation which may lead to the control of *Lygus* bugs as pests of the alfalfa seed crop. The results presented herein were obtained during the 4 years ending with 1937, except where a few items from the work of 1938 were used.

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[2] The author's thanks are due to V. L. Wildermuth, senior entomologist, in charge of the Tempe, Ariz., laboratory of the Bureau of Entomology and Plant Quarantine, under whose immediate supervision the project was conducted, for his interest, constructive suggestions, and criticisms; to Robert H. Peebles, of the Bureau of Plant Industry laboratory at Sacaton, Ariz., for determining the host plants and for the photograph of the alfalfa seeds; and to the alfalfa growers who cooperated in granting the use of their fields for the investigations.
[3] Order Hemiptera, family Miridae.

Alfalfa is one of the main crops grown in southern Arizona and southern California, and the crop is grown both for forage and for seed. These bugs have damaged the floral parts and the young seeds of the alfalfa plants sufficiently to cause failures of the seed crop in some of the fields under observation. In the alfalfa seed fields one or two hay crops are harvested before the alfalfa is "turned" to seed, as the individual grower elects. The first seed crop is usually harvested in July and the second late in September and in October. When only the first seed crop is produced, the alfalfa produces hay or pasture in the fall, but sometimes a December hay crop is harvested when a two-seed crop system is practiced. Irrigation was used in all the areas covered by this investigation.

The production of seed in the more arid regions of the United States, such as in the Rocky Mountains and the Great Plains, is more stable and continuous than in the more humid regions such as the North Central States. In the humid regions alfalfa usually produces satisfactory seed crops only during very dry, warm periods.

The fields studied in detail were in the Salt River, Buckeye, Yuma, and Mohawk Valleys of Arizona, and the Bard area of California, all of which are important alfalfa seed-producing areas.

Investigations have been begun recently by workers of the Bureau of Entomology and Plant Quarantine to find out more about the interrelation of the movements of *Lygus* among sugar beets, cotton, and alfalfa, but enough progress has not been made thus far for a report on this study. There are indications, however, that considerable movements of *Lygus* from alfalfa to cotton occur when the alfalfa is maturing just prior to the harvesting of the seed crop.

Insecticidal control of hemipterous insects on cotton has given satisfactory results [4] according to Cassidy and Barber (*1*).[5]

THE SPECIES OF LYGUS AND THEIR DISTRIBUTION

Species of *Lygus* have been swept from alfalfa in all the alfalfa seed-growing areas as well as the more important hay-producing areas of the Southwest. The seed areas examined were as follows: Yuma, Mohawk, South Gila, Arlington, Buckeye, Salt River Valley, and Safford in Arizona, and Bard and Hemet in southern California. The main hay-producing areas surveyed were Salt River Valley, St. Johns, and Safford in Arizona, and the Imperial Valley of California. *Lygus hesperus* was taken from every area surveyed. It is the most common of the three species found in the alfalfa fields of Arizona and southern California and is well distributed throughout the Rocky Mountain region, which is also one of the main alfalfa seed-producing regions of the United States. *L. elisus* was captured in the Hemet, Bard, and Imperial Valley districts of California and in the Yuma, Mohawk, and South Gila areas of Arizona. In the Arlington, Buckeye, and Salt River Valley areas of Arizona an occasional specimen of *L. elisus* was taken by sweeping alfalfa. *L. pratensis oblineatus* occurred in all the alfalfa areas, except Hemet, Calif., according to the records to date. This is the common eastern species of *Lygus*.

From distributional records in the United States National Museum,

[4] CASSIDY, T. P., and BARBER, T. C. HEMIPTEROUS COTTON INSECTS OF ARIZONA AND THEIR ECONOMIC IMPORTANCE AND CONTROL. U. S. Bur. Ent. and Plant Quar. Cir. E-139, 14 pp., illus. 1938. [Mimeographed.]

[5] Italic numbers in parentheses refer to Literature Cited, p. 19.

the three species of *Lygus* have been taken from all the Southwestern and Rocky Mountain States. *Lygus hesperus* is recorded from New Mexico, Arizona, California, Utah, Nevada, Colorado, Wyoming, Washington, and Idaho. *L. elisus* is recorded from Texas, New Mexico, Arizona, California, Colorado, Utah, Wyoming, Washington, Idaho, and South Dakota. *L. pratensis oblineatus* has been taken from New Mexico, Arizona, California, Wyoming, and Idaho.

The National Museum records indicate alfalfa, cotton, and sugar beets as the main cultivated crops from which *Lygus hesperus* and *L. elisus* were taken.

HISTORY OF THE THREE SPECIES

Lygus hesperus was described by Harry H. Knight in 1917 as *L. elisus* var. *hesperus* (*6*). The type specimens were collected from alfalfa fields in California. The variety was later given specific rank by Shull (*9*). Since the original description by Knight there have been several references to the bug as a pest of cotton. Morrill mentioned serious damage by *L. elisus* var. *hesperus* to cotton and called the bug the "cotton square dauber" (*8*). King and Cook (*5*) found that feeding by *L. pratensis* caused lesions on cotton. Ewing (*3*) found that it caused young cotton squares to shed or become blasted. The damage he reported occurred during the period from 1914 to 1917, inclusive. E. A. McGregor reported on *L. elisus* as a pest of cotton in Arizona and California (*7*). From recent collections and a review of the specimens collected from cotton in past years, it appears that *L. hesperus* was the main species present in cotton.

It was not until Sorenson's work in Utah, which was published in 1932 (*11*), that the damage caused by *Lygus* spp. to the alfalfa seed crop was given consideration. Sorenson's publication was on *Lygus pratensis* but in a later publication he referred to the species as *L. hesperus* and *L. elisus*. He concluded that the species of *Lygus* were responsible for varying amounts of "flower drop" depending on the degree of infestation and time of exposure. In a later publication (*12*) he reported a study of the relation of the *Lygus* bugs to shriveled seeds. His work was begun in 1932 and continued for three seasons, and his results indicated that these bugs increased the number, but were not the exclusive cause, of shriveled seeds. Shull, Rice, and Cline (*10*), in 1934, gave evidence by cage work with *L. hesperus* and *L. elisus* of the effect that *Lygus* had upon the seed production of alfalfa. Information received by the author indicated that as early as 1930 some of the seed growers in the Mohawk, Ariz., area believed that *Lygus* bugs were the cause of the "blasted buds" which were a total loss in seed production.

Lygus elisus was described in 1914 by Van Duzee as a variety of *L. pratensis* and raised to specific rank in 1916. The type specimens of *L. elisus* were collected from *Chenopodium* in California. This species has been recorded (*7*) as a pest of cotton, Shull (*9*) reports it as a pest of beans, and Sorenson (*12*) and Shull (*9*) have shown that it was present and caused damage in alfalfa-seed fields. According to observations by the writer, *L. elisus* has been present in extremely small numbers in the alfalfa seed fields of Arizona and southern California since 1934. These observations indicate that this species prefers to breed on weeds rather than alfalfa. During May and June

1937 less than 2 percent of the *Lygus* captured were *L. elisus*. The first seed crop of alfalfa is usually grown during these two months.

Lygus pratensis var. *oblineatus* was described in the eighteenth century and its name has been changed repeatedly since that time according to the synonymical table by Crosby and Leonard (*2*). *L. pratensis oblineatus* is the common species found in the eastern part of the United States and reported many times as a pest of numerous cultivated plants. Crosby and Leonard gave a full account of its life history, food habits, and economic importance, and gave a complete bibliography in their publication. Haseman (*4*) published on *L. pratensis oblineatus* and gave its life history and effect on crops under Missouri conditions.

HOST PLANTS

These species of *Lygus* have been observed breeding on cultivated and wild plants and weeds of several different families in Arizona and southern California. The polyphagous habit of these bugs makes their range and dissemination widespread even in the semiarid region of the Southwest. Breeding has been common in this region on alfalfa (*Medicago sativa* L.) and sugar beets (*Beta* sp.) and has been observed on sourclover (*Melilotus indica* (L.) All.) and some of the garden vegetables, but the damage to these plants is undetermined. Sourclover is used as a cover crop in citrus orchards and also as a green manure crop. The bugs usually were observed breeding on beets and turnips when these were going to seed. *Lygus* populations have been abundant in cotton, especially when the first alfalfa seed crop was maturing and being harvested.

The host plants here mentioned are those on which definite breeding records have been obtained, and it is probable that all the hosts of *Lygus* are not included. Of the weeds, winter mustard (*Sisymbrium irio* L.) and sowbane (*Chenopodium murale* L.), both winter annuals, are the most important breeding plants of *Lygus* during January, February, March, and April. These two plants are found within and near cultivated areas. They occurred in the greatest abundance in the Salt River Valley and the Buckeye area. Bitter rubberweed (*Actinea odorata* (DC.) Ktze. of the family Compositae) is another important host plant for the breeding bugs. It occurred in fairly thick stands along the lower Gila River, in Yuma County, especially in years when the winter rainfall was heavy or the river was at flood stage. *Lygus elisus* breeds abundantly on this plant, as does *L. hesperus*, the principal species found in alfalfa.

Two fall weeds, marestail (*Erigeron canadensis* L.) and slender aster (*Aster exilis* Ell.), have produced heavy populations of *Lygus* nymphs. The majority of the *Lygus* present on these weeds have been *pratensis oblineatus*, which to date has occurred only in small numbers on alfalfa during the stage of seed production. *Lygus hesperus* breeds on these plants in small numbers.

Lygus spp. have been found to breed on several other plants, but the distribution of these plants was spotted and usually in small acreages, and the numbers of *Lygus* developed apparently were not sufficient to influence the bug population in alfalfa. In the Polygonaceae, *Lygus* have been found breeding on dock (*Rumex crispus* L.) and knotweed (*Polygonum camporum* Meisn. ?). *Astragalus diphysus* Gray, a legume, is host to large numbers of nymphs, but the plants are of limited

numbers and scant distribution in the area investigated. Wild heliotrope (*Heliotropium curassavicum* var. *oculatum* (Heller) Johnston), of the Boraginaceae, on which large numbers of nymphs are produced, occurred on a very limited area. The majority of the host plants on which *Lygus* spp. breed belong to the Compositae. In addition to those mentioned above, other Compositae on which they breed successfully are pineapple weed (*Matricaria matricarioides* (Less.) Porter) crownbeard (*Verbesina encelioides* var. *exauriculata* Rob. and Greenm.), *Senecio* spp., *Aplopappus heterophyllus* (Gray) Blake, and *Heterotheca subaxillaris* (Lam.) Britt. and Rusby, although to date nymphal infestations on these species have been low.

With the exception of *Sisymbrium irio* and *Chenopodium murale*, the indications are that wild host plants have not to date covered a large enough acreage or produced enough nymphs to appear as a factor in the infestations found in the alfalfa fields. There are indications, however, that host plants growing on ditchbanks in the alfalfa fields or fields of host plants adjoining an alfalfa field influence the *Lygus* infestation in the alfalfa.

All three species of *Lygus* under consideration have been observed on several host plants, and to date the observations indicate that both adults and nymphs prefer to frequent the buds, flowering parts, and tender terminal parts of the plants. Few *Lygus* bugs have been swept from mature alfalfa or from alfalfa stubble containing little or no new growth, whether the stubble resulted from pasturing or from cutting the alfalfa.

CHARACTER OF LYGUS INJURY TO ALFALFA SEED

The effect of *Lygus* bugs on alfalfa seed production is of two types, injury to flower buds and injury to seeds. The first type is caused by their feeding and egg laying in the young, tender parts of the growing alfalfa, especially the floral parts. When they feed on the young floral buds before elongation of the rachis, the buds usually turn white and fail to develop. Such injured buds are a total loss in seed production, and the injury has been termed "blasted bud." In the field blasted bud can be distinguished from flower fall, the term "blasted bud" being applied to racemes that turn white before flower development has reached the color stage, and the term "flower fall" being used for the condition in which the flowers fall after they have opened. In examining sample racemes, all basal attachments of flower pedicels which do not show evidence of pod development are classed under flower fall. Some fields containing high *Lygus* populations have an extremely high percentage of blasted buds, and the flowers are not the normal color. Figure 1 shows a comparison between fruiting parts of normal and injured plants. All the buds on the raceme injured by the bugs bloomed abnormally and had the characteristic white appearance, whereas the buds on the other raceme produced normal bloom and fruiting pods.

Fields having high *Lygus* populations usually contained extremely large numbers of blasted buds and failed to produce normal bloom or set of seed. In the field from which the plant illustrated in figure 1, *B*, was taken only 4 percent of the flowers produced pods, whereas in two other fields in the same area 41 and 49 percent of the flowers produced pods.

When feeding begins after the lower flowers of the racemes start to bloom, the *Lygus* bugs apparently destroy only a portion (three to seven) of the flowers. These are considered to be in the localized area close to the feeding puncture of the *Lygus* where the injury apparently has a toxic effect on the plant tissue. Carlson's recent work [6] shows that *Lygus* feeding on the fruiting parts of the alfalfa causes a break-down of the cells around the feeding area. If it is very young at the time it is fed upon, the entire raceme may be blasted;

FIGURE 1.—Injury by *Lygus* bugs to alfalfa racemes: *A*, normal buds, blooms, and pods; *B*, buds blasted by feeding of the bugs.

but if it has enlarged to the point where flower color is evident, only a portion of the flower cluster is damaged. This damaged portion may be located anywhere on the raceme.

The feeding of the nymphs on the individual flowers is one of the main factors causing heavy flower fall. Both adults and nymphs feed on the young ovary, which, if damaged, means the loss of a seed pod.

The second type of injury is the formation of brown seeds caused by the feeding of the bugs on the seeds before they are mature. The proportion of brown seeds varies considerably in different samples.

[6] CARLSON, JOHN WILFORD. LYGUS BUG DAMAGE IN ALFALFA IN RELATION TO SEED PRODUCTION. Thesis for Ph. D. degree, Univ. of Wisconsin. 1939

When these bugs were confined on alfalfa in cages the production of good seeds was greatly decreased, and the percentage of brown seeds increased over that found in cages from which they were excluded.

No definite punctures are visible on the seeds fed upon by *Lygus* spp., whereas pentatomid bugs leave definite punctures. The seeds on which *Lygus* bugs were observed to feed showed a discoloration within 24 hours after the feeding. Examinations made at longer periods after feeding resulted, in some cases, in finding proliferations on the inside of the pod opposite the daubs left by *Lygus* on the outside. When *Lygus* bugs feed on the very young seeds in the pod,

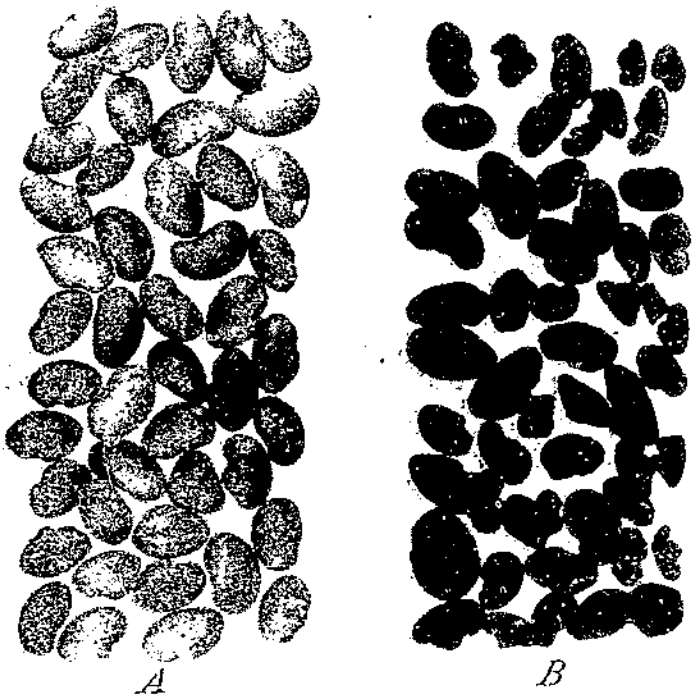

FIGURE 2.—Alfalfa seeds: *A*, Normal seeds, large and plump; *B*, small, irregular, and darkened seeds damaged by the feeding of *Lygus* bugs. × 5.

these become papery and shrivel to a very small size. The feeding of *Lygus* on partially developed seeds causes loss of viability and produces a discolored area darker than the rest of the seed. This condition is shown in figure 2 in the comparison between good seeds and brown seeds.

ECONOMIC IMPORTANCE OF LYGUS BUGS IN ALFALFA SEED PRODUCTION

Owing to the number of variable factors there is no apparent way to determine the actual percentage of damage caused by *Lygus* bugs.

Variations in the alfalfa plants, in farming methods, in the time of growing the seed crop, in soil, in weather, and in moisture all have some effect on the normal processes of blooming and setting of pods.

Losses caused by *Lygus* spp. have been estimated by comparing heavily infested alfalfa fields that showed serious damage with lightly infested fields that showed no noticeable damage. The difference in yield between these has been as much as 200 to 300 pounds of seed per acre in certain fields in the area of heavy seed yield.

Seed production in Arizona amounts to approximately 6,000,000 pounds annually, and at 12 cents per pound, the estimated average price for alfalfa seed obtained by the growers for the 10-year period 1928–37, the seed crop has a value of $720,000. The average loss, figured from the fields under detailed observation, amounted to over 17 percent, or over 1,000,000 pounds of seed, which would mean a loss of over $120,000 annually in Arizona alone.

In cage experiments *Lygus* damage was evident in flower loss and the increased numbers of brown seeds. In field observations the procedure followed was to determine the relation between the *Lygus* population and the percentage of flower fall. In 1935, 1936, and 1937 detailed observations were made in certain alfalfa fields at intervals of a week or 10 days to determine the *Lygus* populations during the development of the seed crop. These populations were estimated by counting the adults and nymphs captured in a standard 14-inch sweeping net. Four sweepings of 25 sweeps each, or a total of 100 sweeps, were taken in fields where the populations were low. In fields containing heavy bug populations 5 sweepings of 5 sweeps each, or a total of 25 were made. Just previous to the cutting of the seed crops samples of alfalfa seed heads were collected from each field under observation for microscopic examination at the laboratory. From each seed sample 50 racemes were examined, and the number of flowers that produced pods and the number of flowers that fell without producing pods were recorded. An estimate of the percentage of flower fall was thus secured for each field studied, and correlation coefficients between *Lygus* population and flower fall as shown in table 1 were computed. The population figures used in these correlations were the maximums observed in the respective fields during the growth of the seed crop. These positive correlations indicate a rather close relationship between abundance of *Lygus* spp. and loss of flowers.

TABLE 1.—*Coefficients of correlation between the numbers of Lygus spp. and fallen alfalfa flowers, Yuma, Ariz., 1935–37*

Year and crop	Fields	Coefficient of correlation
1935	*Number*	
First crop	20	0.782 ± .0708
Second crop	9	.921 ± .0341
1936		
First crop	22	.619 ± .089
Second crop	14	.793 ± .067
1937		
First crop	27	.813 ± .0665
Second crop	18	.726 ± .1054

The higher percentages of flower fall accompanying higher *Lygus* populations are shown in table 2, in which 110 sets of field records obtained during 1935, 1936, and 1937 are summarized. Although populations of 0 to 0.50 bug per sweep probably caused some injury, such a population was considered to be low, and was used in the table as a basis for determining the increase in injury due to higher populations. Observations yielding 9.51 bugs or more per sweep were consolidated into one group because there were only a few representatives in this class.

TABLE 2.—*Relation between Lygus populations and percentage of flower fall in 110 sets of field records obtained in Arizona and southern California during the years 1935, 1936, and 1937*

Peak *Lygus* population per sweep	Fields sampled	Average flower fall	Increase in flower fall	Proportion lost of the 47.50 percent expected to set seed
	Number	*Percent*	*Percent*	*Percent*
0.00–0.50	24	52.50	0.00	0.00
0.51–5.00	61	59.50	7.00	14.74
5.01–9.50	16	69.08	16.58	34.91
9.51 and over	9	78.10	25.60	53.89

As the *Lygus* population increased, the flower fall increased and the pod set lessened. In figuring the economic importance of the bugs, the best criterion was considered to be the percentage of loss to the part of the crop above the 52.50-percent flower fall in the basic group, or the 47.50 percent which could be expected to produce pods. Table 2 shows that the number of flowers producing seed was reduced 53.89 percent as the *Lygus* population increased from the 0–0.50 per sweep to 9.51 or more per sweep. The average loss for all fields was 17.66 percent.

To determine the effect of *Lygus* spp. on the seeds, bugs were caged on newly set alfalfa pods without removing them from the plants. At the same time check cages containing no bugs were placed over a similar number of pods on the same plants. In these tests females, males, and nymphs all reduced the number of good seeds. Thirty-one cages were used, of which 17 inclosed bugs and 14 did not. At the end of the experiments the cages containing no bugs averaged 113.4 good seeds per cage while those containing *Lygus* averaged only 4.9 good seeds per cage, indicating a destruction of 108.5 seeds per cage. In this test 23.35 seeds were destroyed per individual bug. From this cage work it was concluded that *Lygus* bugs were also a potential factor in reducing the number of good seeds matured as well as the number originally set. In the cages containing *Lygus* there were also a number of brown seeds typical of the damage done to alfalfa seed by these insects.

Samples were also collected from the detailed study fields and examined to determine the percentages of good seeds, brown seeds, seeds injured by pentatomids, and seeds injured by *Bruchophagus gibbus* (Boh.). The two classes, good seeds and brown seeds, were the ones especially important in this investigation. It is recognized that

other factors may cause brown seeds to appear in the alfalfa seed pod. It was therefore decided to check the relationship between the percentage of brown seeds and *Lygus* population. In the second crop of 1936 a seed sample from a field showing 8.14 *Lygus* per sweep had 46.67 percent of brown seeds, whereas the seed sample from a field showing only 0.054 *Lygus* per sweep had only 2.82 percent. A field with a *Lygus* population of 2.82 per sweep, which was the only population intermediate between the high and low populations, had a seed sample with 36.22 percent of brown seeds. The correlation coefficients for 3 crops, 1 in 1936 and 2 in 1937, were as follows: 1936, second seed crop, 14 fields, 0.899 ± 0.0357; 1937, first seed crop, 27 fields, 0.3959 ± 0.1654; second crop, 18 fields 0.5195 ± 0.1588. These 3 correlations were all significant and were substantiated by other field records. These correlations and the observation that the percentage of brown seeds varies with the different *Lygus* populations clearly indicate that *Lygus* bugs are a real causative factor in the proportion of brown seeds present in the seed samples from the different fields.

Two fields under detailed observation in 1937 in the same locality and season yielded 536 and 165 pounds per acre, respectively. The peak *Lygus* population was 0.23 bug per sweep in the high-yielding field and 7.20 bugs per sweep in the low-yielding field. The cultural methods, climate, and soil were similar in both fields and the only noticeable difference between the two fields was in their *Lygus* population. The difference in yield was 371 pounds, which at the 1937 price of 15 cents per pound meant a reduction of $55.65 per acre in returns from the field showing high *Lygus* population. Information obtained from the fields studied over a period of 3 years has shown that the low-yielding fields were not always the same from year to year, but that when the alfalfa stand was sufficient to produce reasonable yields the one factor common to low-yielding fields in every case observed was a high *Lygus* infestation.

SEASONAL ACTIVITY OF LYGUS

The population of *Lygus* bugs on alfalfa has shown a wide variation throughout each year observed. Their numbers were relatively low, usually less than 1 *Lygus* per sweep, until after May 1, in 1935, 1936, and 1937. High populations on alfalfa occurred in June, July, August, and the first half of September. The maximum population of 20.92 *Lygus* spp. per sweep was observed in August 1936 on alfalfa in full bloom. Unless otherwise stated, population records given in this bulletin include both nymphs and adults. After the first of October the bugs, in the main, have been reduced to small numbers in alfalfa. A few of the late-fall records on weeds showed *L. pratensis oblineatus*, one of the species of minor importance in alfalfa seed fields, to be abundant on *Erigeron canadensis* and *Aster exilis*. A few individuals of *L. hesperus* were also captured from these weeds. The peak fall population on these weeds, taken on October 27, 1936, was 22.88 *Lygus* per sweep.

The adults of *Lygus* have been swept from alfalfa, *Chenopodium murale*, or *Sisymbrium irio* in small numbers during December, January, and February. This indicates that the adults do not truly hibernate in the Southwest as they do in the colder regions of the United

States. A further indication of winter activity is the fact that eggs apparently continued to develop in the ovaries of the female during the winter months. Nine females were dissected on November 26, 1935, and four contained eggs. On December 1, nine more females were captured, and four contained eggs. Only two females were captured on December 10, but one of these contained eggs. The next collection of females occurred on January 25, 1936, when four females were captured and all four contained eggs which appeared to be fully developed and ready to be laid. Ten females collected on January 29 and 30 were dissected on January 30 and all contained apparently fully developed eggs. Four females collected in February contained fully developed eggs.

On January 24, 1936, the first nymphs were collected and they were in the first and second instars. Some individual history records were planned for these early nymphs, and on January 25 they were caged individually in the outdoor insectary. One of the nymphs had molted and was already in the third instar. This record shows that the earliest hatching was previous to January 24. The first adult emergence from the individual caged nymphs was on February 27. Newly emerged adults were also observed on this date in the field.

The winter months of 1936–37 were colder than those of 1935–36, and the first nymphal development was not observed until February 18. This was 24 days later than the earliest recorded for 1935–36. December of 1937 was 5.1° F. above the normal mean at Yuma, Ariz. Nymphs of the first, second, and third instars were found in this area on January 12, 1938. Observations in the Yuma area indicate that the *Lygus* bugs were breeding throughout December, January, and February of 1937–38. Some nymphs must have hatched before January 1, 1938, as there were nymphs in the third instar by January 12. A few were in the fourth instar when the field observations were made on January 26, when nymphs of the first, second, and third instars were also captured. On February 10 and 11 at Yuma, Ariz., a few *Lygus* nymphs had advanced to the fifth instar, and nymphs in the first, second, third, fourth, and fifth instars were swept from alfalfa and *Sisymbrium irio*.

LYGUS POPULATIONS IN RELATION TO PLANT DEVELOPMENT

In the course of the observations in Arizona and southern California *Lygus* abundance has varied a great deal in alfalfa during the season and also at the same time in fields in the same area where the plant development was different. *Lygus* bugs, in the main, were always more abundant in the summer than at other seasons of the year, and populations usually have been the highest when the alfalfa was blooming. Very few have been captured in any of the sweepings on alfalfa hay stubble, seed stubble, or pasture stubble. The heaviest infestation usually occurred in a developing seed crop, as would be expected in view of the fact that a seed crop requires coniderably longer to develop than does a hay crop. The hay crops were usually cut before the alfalfa reached the full-bloom stage of development. To correlate *Lygus* populations with plant development, the stage of alfalfa growth was noted at the time each population record was made, by use of the following classification: New growth, budding and starting to bloom,

full bloom, late full bloom, alfalfa maturing, alfalfa mature, and stubble.

The young growth of alfalfa usually harbored mostly adults and sometimes a few nymphs. As the plant developed through the young growth, budding and starting to bloom, and into the full bloom, the *Lygus* population usually increased as shown in table 3. The average population per sweep was the highest in the full-bloom stage of alfalfa development in every case studied except one, the average peak population in that case occurring when the alfalfa was budding and starting to bloom. The population during the late-full-bloom stage of development was less than that during the full-bloom stage

TABLE 3.—*Populations of Lygus spp. on alfalfa in different stages of growth as indicated by net sweepings from fields in Arizona and southern California producing seed crops*

Stage of alfalfa growth	Sweeps	Adults	Nymphs	Total adults and nymphs	Average per sweep
	Number	*Number*	*Number*	*Number*	*Number*
FIRST AND SECOND SEED CROPS OF 1935, FROM 29 FIELDS					
New growth	2,400	606	60	666	0.28
Budding and starting to bloom	2,000	1,207	1,552	2,759	1.38
Full bloom	3,800	1,917	9,108	11,025	2.90
Late full bloom	3,800	2,436	6,294	8,730	2.30
Maturing	3,400	1,562	1,152	2,714	0.80
Mature	2,000	24	170	194	0.10
Seed stubble	2,400	0	0	0	0.00
FIRST SEED CROP OF 1936, FROM 22 FIELDS					
New growth	4,100	196	100	296	0.072
Budding and starting to bloom	3,600	1,149	2,932	4,081	1.134
Full bloom	4,000	2,361	6,912	9,273	2.318
Late full bloom	2,200	1,747	1,208	2,955	1.343
Maturing	2,400	382	586	968	0.403
Mature	1,200	26	29	55	0.046
Seed stubble	2,200	4	0	4	0.0018
SECOND SEED CROP OF 1936, FROM 14 FIELDS					
New growth	2,000	964	52	1,016	0.508
Budding and starting to bloom	1,700	1,126	1,844	2,970	1.747
Full bloom	1,500	1,019	3,416	6,435	4.290
Late full bloom	1,500	1,672	1,418	3,090	2.060
Maturing	3,000	1,714	1,200	2,914	0.971
Seed stubble	1,500	3	0	3	0.002
FIRST SEED CROP OF 1937, FROM 27 FIELDS					
New growth	4,200	97	59	156	0.037
Budding and starting to bloom	5,300	768	1,708	2,476	0.467
Full bloom	5,200	2,342	8,631	10,973	2.110
Late full bloom	4,400	2,531	4,209	6,740	1.532
Maturing	3,400	1,486	1,831	3,317	0.976
Mature	1,900	358	260	618	0.325
Seed stubble	3,400	26	2	28	0.0082
SECOND SEED CROP OF 1937, FROM 18 FIELDS					
New growth	2,700	1,235	26	1,261	0.467
Budding and starting to bloom	2,200	2,523	4,933	7,456	3.389
Full bloom	2,800	2,826	5,120	7,946	2.837
Late full bloom	2,300	1,504	3,503	5,007	2.177
Maturing	2,300	965	644	1,609	0.700
Mature	2,000	143	48	191	0.095
Seed stubble	1,800	4	0	4	0.0022

in every case. In some individual cases the peak population occurred in a different stage of plant development from that shown by the average of all the fields studied. The increasing population which followed plant development up to and including the full-bloom stage apparently was largely due to the hatching of nymphs from the eggs laid by adults present during the earlier stages of plant development.

As the plant development passed from the late full-bloom into the maturing stage, there was a rapid decrease in the *Lygus* population, which was extremely low in the seed-crop stubble. An occasional bug was swept from the seed-crop stubble when the sweepings were made immediately after seed cutting, but not a single *Lygus* was captured in sweepings made on the dry stubble several days after the seed crop was cut.

The *Lygus* populations were estimated in 1935 from several selected fields which were swept at fairly regular intervals. As only a few sets of observations were made on the second crop, they were included with those made on the first crop in summarizing the data as presented in table 3.

The procedure followed in 1936 was similar to that used in 1935 except that the sweepings in each field were made at weekly intervals during the development of the seed crop. Enough fields were selected in 1936 to provide for a separation of the records of the first and second seed crops. The *Lygus* population in relation to the stage of alfalfa development was very similar to that observed in 1935. The full-bloom stage of development had the peak population. No bugs were caught in the sweepings from the seed-crop stubble in 1935, whereas 4 bugs were captured in 2,200 sweeps in the stubble of the first seed crop of 1936, and 3 were taken in 1,500 sweeps in the stubble of the second seed crop. The average population per sweep was slightly different for the different stages of plant development, but all 3 summaries show similar trends in the *Lygus* populations in relation to the stages of plant development.

The records of *Lygus* population in relation to alfalfa plant development in 1937 were obtained by the same procedure as was used in 1935 and 1936.

Lygus population trends in relation to plant development were the same for the first crop of 1937 as those found for 1935 and 1936. In the second crop of 1937, however, the budding-and-starting-to-bloom stage had the highest average population of any of the different stages of plant development. This was apparently due to an early infestation of the second crop by bugs held in the fields by the growth of new shoots from the plant crowns before the first seed crop was harvested and by additional adults attracted to the fields in large numbers by unusually early new growth after the harvesting of the first seed crop. Many first-instar nymphs were present within 2 weeks after the migration of the new adults into the second crop. In one field the nymphal population alone amounted to 13.76 per sweep, which is a very high infestation. *Lygus* populations on the plants in the other stages of development followed the trends recorded for the other crops and years.

The population in the mature first crop for 1937 averaged 0.325 bug per sweep, which was the highest observed in any crop of mature alfalfa during the 3-year period, and was apparently due to the early growth of new shoots before the first seed crop was harvested. The

population in the second crop of 1937 at time of maturity, following the high population of 0.325 bug per sweep in the mature stage of the first crop, was only 0.095 *Lygus* per sweep.

PERCENTAGE OF EACH SPECIES OF LYGUS IN THE FIRST SEED CROP

Observational records during the development of the seed crops in 1935, 1936, and 1937 indicated that *Lygus hesperus* constituted a high percentage of the *Lygus* bugs taken. While no definite counts were made, *L. hesperus* was observed in the field studies of 1935 and 1936 to be the predominant species of *Lygus* in the alfalfa fields during the production of the first, or main, seed crop.

In the field observations during May and June 1937, when the first seed crop was developing, adults were captured for determination of species and calculation of percentages. During May, 763 adults were captured from the alfalfa fields examined in the Salt River Valley, Buckeye, Arlington, Mohawk, Yuma, and Bard districts of Arizona. Of this number 93.18 percent were *Lygus hesperus*, 5.9 percent *L. pratensis oblineatus*, and 0.92 percent *L. elisus*. During June, 928 adults were taken, of which 88.15 percent were *L. hesperus*, 9.91 percent *L. pratensis oblineatus*, and 1.94 percent *L. elisus*.

LIFE HISTORY

No extensive, detailed life-history work on the different species of *Lygus* was attempted in these studies, as the life histories are already available in the literature. Shull investigated the life histories of *L. hesperus* and *L. elisus* (*9*), and Crosby and Leonard (*2*) and Haseman (*4*) have published on the life history of *L. pratensis oblineatus*.

The life-history work at the Tempe, Ariz., laboratory consisted in checking the general effect of the locally prevalent high temperatures on the incubation period of the eggs and the duration of the instars of *Lygus hesperus*. These two phases of the life history showed a similarity to the same phases as observed by the other authors. The high temperatures served to decrease the length of the developmental periods. The incubation period of the egg was relatively long in comparison with that of instar development. Of the five instars, the fifth required the longest time, the first instar was next in length, and the second instar was the shortest. The second, third, and fourth instars all averaged about the same length of time.

Incubation Period of Eggs of Lygus hesperus

Incubation records were obtained from eggs deposited in growing alfalfa plants. Plants in the field were caged several days prior to the introduction of the females in order to allow for the hatching of any eggs that might have been previously deposited in them, and any nymphs so hatched out were removed. Females of *Lygus hesperus* were caged on the plants for 24 hours for egg deposition. Records of the incubation periods were calculated to the nearest day. The tests were continued during July and August 1935, and 52 incubation records were obtained. Four eggs hatched in 7 days, 28 in 8 days,

16 in 9 days, 2 in 10 days, and 1 each in 11 and 12 days; the average being 8.44 days. Temperature readings were obtained from instruments in a standard Weather Bureau shelter. The average mean temperature during the period covered by the incubation records was 85.5° F. The range in the daily mean temperature was from a low of 78° to a high of 92°. This range apparently had no effect on the length of the incubation period.

Instar Development of the Nymphs of Lygus hesperus

The nymphal records for certain instars of *Lygus hesperus* were obtained throughout most of the year. During August and the first week in September 1935, complete records of all instars were obtained for 35 individuals caged on alfalfa in an outdoor insectary near the standard weather instrument shelter. These records are given in table 4. Many of the nymphs in other cages died before completion of all five instars, and the records of these specimens are not included in the summary given in the table. The average mean temperature during these observations was 85° F.

Table 4.—*Length in days of nymphal instars of Lygus hesperus reared from egg to adult during August and early part of September 1935, Tempe, Ariz.*

[Average mean temperature 85° F.]

Instar	Time for development			
	Maximum	Minimum	Average	Mode
First	3.00	2.00	2.69	3.00
Second	3.00	1.00	1.69	2.00
Third	3.00	1.00	1.74	2.00
Fourth	3.00	1.00	1.91	2.00
Fifth	4.60	2.00	3.37	3.00
Total	16.00	7.00	11.40	12.00

Records were also obtained for many individuals that had been collected in the field and had completed one instar or more in the outdoor insectary cages. These records are summarized in table 5, together with the average mean temperatures prevailing during the respective instars.

Table 5 shows that the rate of nymphal development generally varies directly with the temperatures. When the average mean temperature was below 60° F. the nymphal development was very prolonged. The small number of records at the lower temperatures was due to the fact that observations at these temperatures were made during the winter when the nymphs were scarce. This scarcity of specimens also would account for the fact that no very uniform rate of nymphal development at the lower temperatures was evident.

TABLE 5.—*The number of days for nymphal development of Lygus hesperus and the average mean temperature of each period, Tempe, Ariz.*

Instar	Specimens	Length of period	Average mean temperature
	Number	*Days*	*° F.*
First	13	2	83.73
	35	3	82.78
	1	10	54.10
Second	14	1	84.10
	29	2	83.92
	2	3	73.28
	1	7	54.90
	4	8	54.80
	3	9	51.80
	1	12	54.30
Third	18	1	84.13
	44	2	82.77
	15	3	79.36
	10	4	65.30
	1	5	61.20
	1	6	56.80
	5	7	56.10
	2	8	57.70
	3	10	51.20
	1	11	52.90
	1	12	51.30
	1	13	52.50
Fourth	12	1	85.15
	35	2	84.09
	30	3	77.63
	14	4	71.00
	3	5	67.20
	3	8	55.40
	1	9	57.40
	4	10	53.60
	3	11	54.80
	2	12	52.90
	1	19	50.80
Fifth	2	2	88.10
	24	3	83.93
	33	4	84.11
	17	5	69.55
	4	6	68.03
	4	7	64.10
	3	8	63.70
	3	9	59.30
	1	10	54.50
	1	12	57.30
	3	13	57.30
	1	14	57.40
	1	15	53.90
	1	16	56.30
	1	31	47.10

LOCATION OF LYGUS EGGS IN THE ALFALFA PLANT

It was realized that the location of the egg punctures in the alfalfa plant might have a bearing on the setting of seed. Considerable attention was therefore given to the location of the eggs under field conditions. They were always found in the younger, more tender growth of the terminal part of the alfalfa stems and were most frequently located in the bud clusters and internodes. Alfalfa stems were selected for examination in the detailed studies from screen cages in which *Lygus* adults were fairly abundant. All dissections were made under the binocular microscope, and the numbers of eggs were recorded as found in the following parts of the alfalfa plant: Flower buds, internodes, nodes and near nodes of the stems, leaf axils, and rachises. No eggs were found in the leaves or leaf petioles. Of 138 eggs dissected out 44.9 percent were found in the flower buds, which were the preferred location for oviposition as well as the potential source of the alfalfa seed. The nymphs hatching from these eggs

were thus in immediate proximity to the seed-producing organs of the plant, on which part they normally feed. The numbers of eggs and percentages found in different parts of the plant are summarized in table 6.

TABLE 6.—*Location, number, and percentage of eggs of Lygus spp. found in different parts of the alfalfa plant, Tempe, Ariz.*

Location	Eggs	
	Number	*Percent*
Flower buds	62	44.9
Internodes of stem	34	24.7
Nodes and near nodes of stem	20	14.5
Leaf axils	12	8.7
Rachises	10	7.2
Total	138	100.0

NATURAL ENEMIES

No parasite of the adult, nymph, or egg of *Lygus* has been noted to date. Predators observed feeding on *Lygus* nymphs were the Hemiptera *Geocoris* spp. and *Nabis ferus* (L.), the ant *Formica perpilosa* Whlr., and two species of spiders. *Formica perpilosa*, which was observed near Hemet, Calif., in the survey of 1937, was the only predator found to date which has noticeably reduced the numbers of *Lygus* nymphs in any area. It was noted that nymphs of *Geocoris* spp., especially *G. pallens* var. *decoratus* Uhl., markedly increased in numbers where the *Lygus* nymphs were abundant.

CONTROL

Promising clues obtained from the detailed field studies are being followed to determine whether or not they may lead to a practical means of control of *Lygus* bugs. One of the most practical appears to be that of uniformity throughout whole districts in times of starting and harvesting the seed crop. In the areas studied, the fields with the highest infestations of *Lygus* bugs usually were those producing a seed crop at a different time during the growing season from the majority of fields in the neighborhood. Not only do these "out-of-time" fields themselves become severely infested, but as they mature they usually become sources of dispersal of *Lygus* to other fields. Lack of uniformity in time of cutting both hay and seed crops appears to be by far the most important factor in the development of serious *Lygus* infestations in seed-producing districts.

In some fields where it was known that very few nymphs were present, adults have been known to increase fivefold to sevenfold in a period of 10 days or less by influx from other fields. Apparently these were heavy migrations of adults into fields of alfalfa from 6 to 12 inches tall, because of reduction in their food supply by the cutting of alfalfa hay in nearby fields. It appears that if all the fields in a neighborhood could be cut at approximately the same time, *Lygus* damage to the seed crop throughout the area would be materially lessened. In the Mohawk area there was a remarkably uniform cutting program in 1936 and 1937, and few fields suffered heavy losses. In 1938, on the other hand, the seed crop in different fields was started

at different times between April 1 and May 15, and the yield per acre that year was approximately 50 percent less, and the *Lygus* population was over four times as great as in the previous two seasons. Several practical difficulties interfere with a uniform cutting program, however, and to date no other generally applicable control measure has been worked out; hence, no report can yet be made on this part of the investigation.

SUMMARY

Three species of *Lygus* are distributed throughout the main alfalfa-seed-producing areas of Arizona and California, where they seriously reduce seed yields. The chief damage has been to the floral parts of the alfalfa plant prior to the formation of the seeds, and to the immature seeds.

Lygus bugs breed on a number of different cultivated and wild plants, and weeds. Alfalfa, cotton, and sugar beets are three of the cultivated plants on which large numbers of *Lygus* have been captured. *Sisymbrium irio* and *Chenopodium murale* are two important host plants for spring breeding. With the exception of these two, the native plants on which *Lygus* bugs breed apparently have not influenced the population of *Lygus* in the alfalfa seed fields.

The preferred habitat of *Lygus* is the tender terminal part of the alfalfa plant, particularly among the buds and flowers.

Significant or highly significant positive correlations between estimates of *Lygus* populations and flower fall in the six alfalfa seed crops produced in southern Arizona and southern California during 1935, 1936, and 1937 indicate that *Lygus* bugs seriously injure the flowering parts of the alfalfa plants.

Cage experiments have proved that *Lygus* bugs affect the seeds by causing them to turn brown and in many cases to shrivel up and become papery. The average destruction per individual *Lygus* in the cages was 23.35 seeds. Samples from 3 seed crops in 1936 and 1937 showed significant positive correlations between the percentage of brown seeds and the *Lygus* populations.

High *Lygus* populations on alfalfa occurred in June, July, August, and part of September. Adults were swept from alfalfa during every month of the year, although the numbers were low in November, December, January, and February. Dissection of the female ovaries during the winter months showed that in January the eggs appeared to be fully developed and ready for oviposition.

Population counts during 1935, 1936, and 1937 showed that *Lygus* populations averaged highest in the full-bloom stage of plant development with the exception of the second crop in 1937, when the high population occurred in the budding-and-starting-to-bloom stage of plant development. The stages of new growth, maturing, mature, and seed-crop stubble have on the average harbored relatively low populations of Lygus.

According to observations, *Lygus hesperus* was the main species of *Lygus* present on alfalfa producing seed. In the records for May and June, the period during which the first seed crop is usually grown, *L. hesperus* constituted 93.18 percent and 88.15 percent, respectively, of the total numbers captured.

The average incubation period of eggs of *Lygus hesperus* in July and August 1935 was 8.44 days. The average nymphal development

for each instar when the average mean temperature was 85° F. was as follows: First instar, 2.69 days; second instar, 1.69; third instar, 1.74; fourth instar, 1.91; and fifth instar, 3.37 days.

The eggs were always found in the younger, more tender growths of the terminal parts of the alfalfa stems, and were most frequently located in the flower buds and internodes of the stems.

The only natural enemies observed attacking *Lygus* bugs were the predatory Hemiptera *Geocoris* spp. and *Nabis ferus*, the ant *Formica perpilosa*, and two species of spiders. These have been observed attacking only the nymphs of *Lygus*. Little reduction in the numbers of *Lygus* bugs by their predacious enemies has been observed.

Lack of uniformity in the time of cutting the alfalfa appears to be a factor favoring heavy infestations of the bugs, and if all the fields in a neighborhood could be cut at one time the damage might be materially lessened. This was demonstrated in the Mohawk area in 1936 and 1937.

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