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Mirid-Bug Injury as a Factor in Declining Alfalfa-Seed Yields

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and With the compliments
the best wishes of
the writer.
Charles J. Emerson
Mary J. Emerson
3, 1946

FIFTH ANNUAL FACULTY RESEARCH LECTURE

Mirid-Bug Injury as a Factor in Declining Alfalfa-Seed Yields

By

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THE FACULTY ASSOCIATION

UTAH STATE AGRICULTURAL COLLEGE

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FIFTH ANNUAL FACULTY RESEARCH LECTURE DELIVERED AT THE COLLEGE APRIL 29, 1946

THIS LECTURE by Professor Charles J. Sorenson is the fifth in a series presented annually by a scholar chosen from the resident faculty at the Utah State Agricultural College. The occasion expresses one of the broad purposes of the College Faculty Association which is a voluntary association of members of the faculty. These lectures appear under the Association's auspices as defined in Article II of its Constitution, amended in May, 1941:

> The purpose of the Organization shall be . . . to encourage intellectual growth and development of its members . . . by sponsoring an Annual Faculty Research Lecture . . . The lecturer shall be a resident member of the faculty selected by a special committee which is appointed each year for this purpose and which shall take into account in making its selection, the reasearch record of the group and the dignity of the occasion . . . The lecture shall be a report of the lecturer's own findings in a field of knowledge . . . The Association shall express its interest by printing and distributing copies of the Annual Research Lecture.

Professor Sorenson was elected by the committee to the fifth lectureship thus sponsored. On behalf of the members of the Association we are happy to present Professor Sorenson's paper: "MIRID-BUG INJURY AS A FACTOR IN DECLINING ALFALFA-SEED YIELDS."

COMMITTEE ON FACULTY RESEARCH

FOREWORD

DURING the forty or more millions of years that insects have inhabited the earth they have developed remarkable adaptations and great powers of reproduction that have enabled them to spread over most of the world and occupy all of its habitable environments. In cultivating the land and in growing crops, man has disturbed the balance in nature which formerly prevailed. By doing this he has unwittingly assisted many insect species to multiply in unprecedented numbers by providing them with more delectable food in abundance and by transporting them from place to place and from continent to continent in his migrations and commerce.

Several species of insects, previously harmless, have become destructive pests of farm crops. It is highly probable that human activities have been largely responsible for local outbreaks of new insect pests which have attacked various crops with serious consequences.

All insect species are not detrimental to human interests. Bees and other pollinizing insects are essential to profitable crops of certain fruits and agricultural seeds. The silkworm, honeybee, and lac insect produce silk, honey, beeswax, and shellac, the value of which aggregates hundreds of millions of dollars annually.

Acknowledgements: The writer expresses his gratitude to the Faculty Association for the opportunity of presenting this treatise to its membership. Acknowledgement is made of the kind consideration of Director R. H. Walker, Utah Agricultural Experiment Station, who approved the use of the research data contained herein for this additional purpose. Thanks is also expressed to the Faculty Research Committee for suggestions given in connection with preparation of the manuscript.

Valuable assistance rendered in the original research work by the following former students is greatfully acknowledged: Dr. L. Floyd Clark, Dr. Ray L. Janes, Lowell Cutler, and Farrell H. Gunnell.

CHARLES J. SORENSON

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MIRID-BUG INJURY AS A FACTOR IN DECLINING ALFALFA-SEED YIELDS

Charles J. Sorenson

MIRID BUGS constitute the insect family Miridae of the order Hemiptera. These bugs are largely plant feeders, foraging on both native and cultivated vegetation, and often occurring in immense numbers on farm crops. Some species of mirid bugs carry and transmit causative organisms of various plant diseases; in others the secretion of the salivary glands is apparently toxic to plant tissues, and still other species are beneficial to man's interests by reason of the fact that they feed upon and destroy the eggs or the living bodies of certain noxious insect pests. During recent years a few mirid species have been supected of causing injuries in alfalfa contributing to unprecedented declines in seed yields.

For a more comprehensive understanding of the economic importance of the subject of this treatise, it seems desirable to present at the outset a few figures indicating the significance of alfalfa as an agricultural crop and also the recent trends in the production of alfalfa seed.

Approximately one-third of the entire 1,361,263[1] acres of cultivated land in Utah and 38.43 percent of all the irrigated land in the state are devoted to alfalfa production. During the ten-year period 1936-1945, an annual average of 34,500 acres of this alfalfa has produced a seed crop, usually after yielding a crop of hay. In addition to its value as forage and seed, alfalfa holds a major place in crop rotation and soil improvement practices.

Because of the ravages of bacterial wilt, stem nematode, and other diseases and pests, it is now necessary to replant alfalfa acreages every three or four years if profitable yields are to be obtained. This is in marked contrast to conditions under which alfalfa was grown in Utah 40 or 50 years ago when one planting of the crop persisted as a productive stand for 20 years or more.

During recent years alfalfa plantings have gradually increased and extended throughout the north central and northeastern United States. However, seed production in the latter area has heretofore usually been unsuccessful. In consequence of damage and destruction to growing alfalfa by various plant diseases and crop pests, the demand for, and the use of, alfalfa seed has greatly expanded.

Quite ironically it would seem, while needs for alfalfa seed have increased at home and in many parts of the nation, its production has greatly declined. The trend in seed yields from 1920 to 1945 in Utah and the United States is seen in the data presented in table 1.

With an all-time record production of 439,000 bushels in 1925, Utah produced 42 percent of the total alfalfa seed grown in the United States. The average yield that year was 6.37 bushels per acre on 69,000 acres. The

[1] Data from the U. S. Bur. Agr. Econ., Div. Agr. Statistics.

maximum per-acre yield for the United States also occurred in 1925 with 2.85 bushels on 365,000 acres.

By 1944, yields in Utah and the nation had declined 81 and 59 percent, respectively, from the record yields of 1925. In other words, the average yield of alfalfa seed for 1944 in Utah was only 19 percent of that in 1925; for the entire United States, it was only 41 percent of the 1925 yield. Preliminary reports for 1945 indicate a further decline in Utah to one bushel per acre or only 16 percent of the 1925 yield. In the country as a whole, the 1945 yield was 1.37 bushels per acre, an increase of 7 percent over 1944 and a decline of 52 percent from the mean yield in 1925.

Table 1. *Alfalfa-seed acreage and yields**

Period	Acres harvested		Per-acre yield		Decline since 1925	
	Utah	U.S.	Utah	U.S.	Utah	U.S.
	thousands of acres		*bushels*		*percent*	
1920-24	37	223	4.93	2.51	..	..
1925	69	365	6.37	2.85	..	..
1926-30	57	405	2.49	2.35	61	18
1931-35	25	485	2.01	1.92	68	33
1936-40	37	710	2.10	1.67	67	41
1941	30	791	1.50	1.29	76	55
1942	27	612	1.50	1.60	76	44
1943	30	672	1.60	1.52	75	47
1944	35	968	1.20	1.18	81	59
1945	33	835†	1.00†	1.37†	84	52

* From Agricultural statistics. U. S. Dept. Agr. and U. S. Census, 1944

† Preliminary

These serious declines in alfalfa-seed yields have induced growers and seedsmen to theorize concerning the causes and research workers to begin investigations in quest of them. Most research agronomists and entomologists throughout the country now recognize the seriousness of this problem. Some of these men (9) believe that the failure of seed development in alfalfa is largely the result of inadequate tripping and pollination of alfalfa flowers. Others (1) (7) have research data indicating that the feeding activities of certain insect pests are mostly responsible for declining yields in alfalfa seed when other environmental conditions are generally favorable. Despite these varying viewpoints, all investigators agree that the combined operation of several different factors is responsible for failure of alfalfa to develop its seed normally.

Among the many insect pests inhabiting growing alfalfa, the following are known to inflict injuries which seriously interfere with the development of the seed: mirid bugs, including three species of lygus bugs and the superb plant bug; the seed chalcid; several species of grasshoppers; the alfalfa weevil, and the Say plant bug.

Other insect pests that feed on growing alfalfa and perhaps cause some damage include various species of thrips, the pea aphid, blister beetles, leafhoppers, and the alfalfa looper. With the exception of the pea aphid and the alfalfa looper, the type and degree of damage inflicted by the latter group of insects is not yet fully known.

MIRID BUGS AS A CONTRIBUTING FACTOR TO REDUCED SEED YIELDS IN ALFALFA

Insects of the family Miridae are frequently called mirid bugs. The terms *miridiae* and *mirid* are derived from the Latin word *miris*, meaning wonderful. The Miridae constitutes one of approximately 150 families of the order Hemiptera. This order now contains some 48,000 species and new ones are being added annually. Hemipterous insects are characterized in general by the possession of two pairs of wings; the front pair are thickened and horny at the base with thin membranous extremities overlapping on the dorsal surface of the body. The hind wings are entirely membranous and when not in use are concealed beneath the front pair. Mouth parts are fitted for piercing and sucking, and the metamorphosis of the insect is incomplete. Insects of the family Miridae are usually of medium or small size, oblong, somewhat flattened, fragile, and variable in color. They are distinguished by the following principal morphological features: rostrum (beak) and antennae are 4-segmented with tarsi normally 3-jointed; at the base of the membranous portion of the front pair of wings are two cells and one longitudinal anal vein.

LYGUS BUGS

Of all the insect pests infesting alfalfa in Utah, none has been found to be more injurious to the seed of this crop than lygus bugs. This is because of their universal distribution in alfalfa fields, heavy population density, wide range of host plants, high reproductive potential, and the previous difficulty of controlling them.

Recognition and determination of the type, degree and extent of damage inflicted by lygus bugs is relatively recent. Entomologists had observed and collected these insects in Utah prior to 1926 but apparently no special attention had been given theretofore to their activities and abundance, nor to the probable injury caused by them.

Annually during the period 1926-29, survey work was done by entomologists of the Utah Agricultural Experiment Station in alfalfa-seed growing areas of the state which showed that all alfalfa fields were infested with *Lygus* and some fields harbored immense numbers of these insects.

In the survey work extensive collections were made of lygus bugs which, then and prior to that time, were generally known collectively in the west as

the tarnished plant bug, *Lygus pratensis* (Linn.). In 1930, however, Dr. H. H. Knight[2], identified two different species of *Lygus* from Utah, i.e., *L. elisus* Van D. and *L. hesperus* Knight.

Other species of *Lygus* which have been collected in Utah are *L. oblineatus* (Say), *L. rubicundus* (Fall.), *L. campestris* (Linn.), *L. cristatus* Dist., *L. sallaei* Stal, *L. convexicollis* var. Reut., and *L. robustus* Uhl. Of these nine species, *L. elisus* Van D. and *L. hesperus* Kngt. are predominant in the alfalfa fields of Utah, the former being relatively more numerous than the latter. *L. oblineatus* has been infrequently collected in alfalfa fields and canyons of various counties of the state from Cache on the north to Washington on the south. This species has been taken more frequently in Washington County than elsewhere in the state but in relatively fewer numbers than either *L. elisus* or *L. hesperus*. Of the remaining six species, five were collected in various canyons of Cache County, and *L. rubicundus* was taken in an orchard at Farmington.

Because of the intensity and widespread nature of these infestations, a project was organized at this station in 1930, having for its basic purpose an investigation of the activities of lygus bugs in alfalfa and primarily to ascertain whether they were causing damage to the alfalfa plant or its seed. Intensive studies of various phases of the problem were made in the field at Fort Duchesne and Delta.

Distribution

Bugs of the genus *Lygus* are found in most countries of the world. The tarnished plant bug has long been known in Europe and America. It was first described in 1746 and named *Cimex griseus* by the noted Swedish naturalist, Linneaus. In the 10th edition of his *Systema Naturae*, published in 1758, he gave the name *Cimex pratensis* to this insect. The tarnished plant bug was first named in America by Thomas Say in 1831. He gave it the name *Capsus oblineatus*. The specific name for the tarnished plant bug, *pratensis*, given by Linneaus, still persists. The specific name, *oblineatus*, given by Say, is also retained for a different species of *Lygus*. Both of these species have since been assigned to the genus *Lygus*.

Several different species of *Lygus* occur in the United States and Canada. *L. pratensis* is more commonly found in the eastern half of the United States, whereas *L. elisus*, *L. hesperus*, and *L. oblineatus* are relatively more abundant in the western half of the country.

Descriptions

One of the most characteristic features of all insects is that the young are morophologically different from the adults. In growing to adulthood, the

[2] Entomologist, Iowa State College, and specialist in the taxonomy of the family Miridae, order Hemiptera.

young pass through a series of developmental changes which are collectively termed metamorphosis. The orders of insects exhibiting this phenomenon are usually divided into two main groups, Paurometabola and Holometabola. The first term is applied to those lower orders wherein the young insects pass through simple, direct growth processes, generally called an incomplete metamorphosis. In developing to the adult stage, the young included in this group are always active and do not pass through a quiescent pupal period. Young insects which undergo an incomplete metamorphosis are called nymphs. The group Holometabola embraces the higher orders of insects, the young of which pass through a succession of complex, indirect growth changes, commonly referred to as a complete metamorphosis. In this group, the young are wormlike, and are called larvae. These pass through a quiescent pupal stage in transforming to the adult form.

Prominent among morphological characteristics distinguishing hemipterous insects are the possession of piercing-sucking mouth parts and an incomplete metamorphosis.

All species of *Lygus* bear a general resemblance to each other, particularly with respect to shape, size, and color. The body is flattish, varying from 5/32 to 3/16 of an inch long and approximately one-half as wide. Body color varies in different species from pale green to reddish or dark brown. Some species are mottled with brown, whereas others are plain colored. A characteristic marking of many lygus species is a v-shaped yellowish figure on the scutellum of the antero-dorsal surface.

Lygus elisus is slightly smaller than *L. hesperus;* its color is bluish- or yellowish-green, whereas *L. hesperus* varies in color from yellowish- or reddish-brown to dark brown. The principal morphological characteristic which distinguishes one species of *Lygus* from another is a difference in the length of the rostrum in various species. The rostrum in hemipterous insects is a jointed sheath which enclosed the stylets or piercing apparatus of the mouth parts when the bugs are not feeding.

Host Plants

Lygus bugs feed on scores of varieties of cultivated and wild plants, numerous native and introduced weeds. Principal cultivated host plants include alfalfa, sugar beets, cotton, tobacco, potatoes, beans, various garden crops, most deciduous and small fruits, also many flowering plants. Foremost of weed hosts in Utah are Russian-thistle, *Salsola kali* L., var. *tenuifolia* Tausch., smotherweed, *Bassia hyssopifolia* (Pall.) Kuntze, and the halogeton weed, *Halogeton glomeratus* (Bieb.) Mey.

Type of Damage Inflicted

Mirid bugs feed by inserting their piercing-sucking mouth parts into plant tissues and sucking up the sap. For the purpose of ascertaining the type

of damage done to the fruiting structures of alfalfa by mirid bugs, the following procedures were executed: (1) Plots of alfalfa growing in the field, either in hills, rows, or in thin stands with well-segregated, individual plants were selected because plants growing under such conditions have access to a larger feeding area, have space for development of greater vegetative growth, usually produce more seed, and are infested by fewer mirid bugs than when growing in a dense stand. In order to reduce, as much as practicable, hereditary and/or environmental variations probably occurring in different alfalfa plants, one or more replications of each test was made on individual plants. (2) Cages were constructed from 18-mesh wire screening, either 3x3x3 feet in size or as cylinders, 12 inches long and 6 inches in diameter. On each end of these cylinders a 6-inch cloth sleeve was tightly fitted. Each square cage was used to protect a freshly-cut alfalfa plant from infestation by mirid bugs until the new growth reached the stage of development desired for the tests. When this development was attained, the large cage was removed and the desired number of alfalfa stems, pruned so as to possess the proper number of reproductive structures, was enclosed within one of the small cages. The cloth sleeves of the latter permitted convenient entrance to the cages as well as tight closure about the bases of the alfalfa stems and attachment of the top end of each cage to a supporting wooden stake, 2x2x48 inches, driven into the ground. (3) After the smaller cage was in place, mirid bugs were collected from the field and put into the various cages in desired ratios to the selected reproductive structures on the enclosed alfalfa stems. These bugs were then left in the cages for varying lengths of time according to the particular phase of the study being made in different cages.

Lygus Injury to Alfalfa Buds. Most conspicuous injury resulting from lygus feeding on alfalfa was found to be a blasting or killing of the buds. Two to five days after they had been fed upon by these insects, buds turned gray or whitish and died. In certain cages where the lygus infestation was purposely made excessively heavy, apical ends of alfalfa stems wilted downward from one to two inches and drooped over within 24 hours of the beginning of the exposure. Buds usually showed characteristic symptoms of blasting within 48 hours.

Results of lygus feeding on young, growing alfalfa buds when exposed to these insects in wire-screen cages are indicated in table 2.

Table 2. *Destruction of young alfalfa buds when exposed for 5 days to lygus bugs*

Number of buds exposed	Ratio of infestation 1 bug to	Buds destroyed (percent)
1200	40 buds	82
1200	20 buds	83
1200	10 buds	100

Progressive destruction of buds and flowers and morphological modifications in the vegetative growth of alfalfa were often observed when some of the experimental plots were cut while others were left standing. This resulted in a mass movement of adults from the cut alfalfa to that which was left growing. Extreme damage first occurred on the outer margins of uncut plots. Within a few days, buds and flowers of the alfalfa on the latter plots were totally destroyed.

Bud-blasting frequently occurs so completely over an entire alfalfa field that the plants are unable to produce blossoms and in consequence, the field presents a grayish, abnormal aspect.

Lygus Bugs in Relation to Blossom-Drop in Alfalfa. In studies of the relation of lygus bugs to blossom-drop, data showed that 75.95 percent of 10,400 alfalfa flowers dropped to the ground without forming pods when the plants were growing under natural field conditions at Fort Duchesne. Although nature in all organisms produces many more germ cells than can reach complete development or full maturity, this amount of flower-fall in alfalfa seemed abnormal. Replicated tests in which flower-bearing alfalfa stems growing naturally in the field were caged for 24 hours with *Lygus* in ratios of one bug to 5, 10 and 20 flowers, showed that the amount of blossom-drop was increased 4.14, 6.58 and 8.89 percent, respectively, over that which occurred in uninfested cages.

Seed Injury. Many brown, shrivelled and misshapen seeds form in alfalfa. These have a low germination value and are mostly lost in the threshing and seed-recleaning operations. The ratio of this worthless seed to the yellow, plump, viable seed varies from year to year, apparently with differing seasonal and environmental conditions. Damage to alfalfa seed by *Lygus* is undoubtedly caused by these insects feeding on the "milk" of young, developing seeds.

For the purpose of ascertaining the possible relationship of *Lygus* to the incidence of shrivelled alfalfa seed, adult bugs were caged on growing alfalfa stems bearing young pods in ratios of 1 bug to 5 pods, 1 to 10, and 1 to 20 for 48 hours, and during the entire period of seed-pod development, approximately three weeks, in two series of tests. In addition to the devolping seed pods, these alfalfa stems bore leaves, buds and flowers, furnishing the infesting *Lygus* with a choice of alfalfa parts upon which to feed. Results obtained in the tests showed that feeding by these insects significantly increased the percentage of shrivelled seed in all three ratios of infestation. A summary of the results of this experiment is contained in table 3.

It was also found experimentally that the vegetative growth of alfalfa was adversely affected by lygus feeding. Total length of young stems was reduced, generally in proportion to the intensity of the bug infestation. Stems became excessively branched with short internodes and frequently the leaves were also distorted.

Table 3. *Resulting effects on seed quality when alfalfa stems, each bearing 2 racemes of buds, flower, and/or young pods, were exposed to lygus adults until the seed in the latter was ripe, after 10 days*

Intensity of infestation	Seeds		
	Total	Plump	Shriveled
no. of bugs	*number*	*percent*	*percent*
		12 replications	
1	784	69.77	30.23
2	742	68.46	31.54
4	653	45.42	54.58
0 (check)	800	87.37	12.63
Grand total	2,979	....	....
		11 replications with ratio of infestation doubled	
2	484	42.56	57.44
4	504	31.15	68.85
8	673	28.04	71.96
0 (check)	654	89.70	10.30
Grand total	2,315	....	....
		10 replications with two racemes of pods only	
1	433	66.05	33.95
2	446	53.59	46.41
4	432	42.13	57.87
0 (check)	628	89.65	10.35
Grand total	1,939	....	....

Relative Amount of Injury Inflicted by Lygus Adults and Nymphs. Comparison of the amount of damage caused by adults and nymphs was made by exposing growing alfalfa stems during the period of their development from the prebud stage to the time when mature seeds had formed to varying numbers of *Lygus* in cages.

Results of 52 replicated tests indicate that the nymphal forms were definitely more destructive to buds than adults, destroying 5.8 times more than did adults, 5 percent more flowers and 18 percent more pods.

Nature of Injury

The injury inflicted by lygus bugs to alfalfa buds and flowers is apparently caused, not so much by the amount of sap extracted, as by the toxic reaction of the saliva injected into the feeding punctures.

Structure of the piercing-sucking type of insect mouth parts is such that the salivary duct parallels the food canal through the long, bristle-like stylets which penetrate the plant tissues in the feeding process. Saliva is pumped down the salivary duct and poured out at the tip of the penetrating stylets.

A few investigators have studied the nature of the injury caused by mirid feeding. Kenneth M. Smith (5), adviser in agricultural entomology at Manchester University, England, found that when the salivary glands of

Plesiocoris rugicollis, a mirid bug which normally feeds on apple leaves and fruit, and of *Lygus pabulinus*, a mirid harmful to potato foliage, were placed on a freshly cut slice of potato in a petri dish, a violent reaction was produced which killed much of the tissue surrounding the glands.

In studying the effects of mirid feeding on cotton, Ewing (2) reports that in

> Experiments with six hemipterous insects belonging to the family of Miridae *(Psallus seriatus, Lygus pratensis, Adelphocoris rapidus, Creontiades debilis, Poeciloscytus basalis,* and *Lygus apicalis)* proved that each species when allowed to feed on cotton plants caused the young squares to shed or become blasted, produced lesions along the main stem, branch stems, and leaf petioles, and caused multilations of leaves.

No evidence was found to show that the damage caused by the insect extended more than two millimeters from the point of puncture and never more than five millimeters.

King and Cook (3) in an investigation to determine, if possible, whether the injury to cotton following the feeding by mirids was the result of a transmissible virus or caused by mechanical or chemical injury concluded that the "damage is due to injected substances normally present in the insect and toxic to the plant, rather than to a transmissible disease."

Discussing results of histological studies of lygus feeding, Carlson (1) says that

> A mechanical localized damage [of buds] 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.

Life History of Lygus Bugs

Lygus species prevalent in Utah overwinter in the adult stage, hibernating in grass clumps, under weeds, leaves, crop refuse, and other litter occurring along ditch banks, fences, in willow and brush patches and in fields.

Winter survival varies with temperature and snow cover. Heavy snow cover and uniform temperature during winter are more favorable to all overwintering insect forms than winter seasons with little or no snow cover and intermittent freezing and thawing temperature.

Lygus bugs are among the first insects to become active during warm days in early spring. After feeding for a few days, reproductive activity also begins. Eggs are soon laid in apical portions of alfalfa stems, branches and leaf petioles. Many other host plants are also utilized by *Lygus* for ovipositing as well as in feeding. Lygus eggs were found in alfalfa stems at Logan as early as April 17. Latest date that egg-laying was found to occur during the period of the investigation was September 25.

In making detailed studies of the life history of *Lygus* as it occurs in growing alfalfa in the field, the following procedures were used: (1) The large wire-screen cages, already described, were set over freshly-cut alfalfa plants and left until the new growth was approaching the bud stage. (2) At that time 2 to 4 alfalfa stems were daily enclosed within a small wire-screen cage, together with 5 to 10 adult lygus females. (3) After 24 hours these females were removed from the cage. During this period eggs were invariably laid in the apical two inches of the alfalfa stems, in branches and in leaf petioles. (4) Seven days after removing the females from the cage, the wire-screen cage was replaced with a pyrroline cage of the same size and shape as the wire-screen cage but with close-mesh cloth sleeves and side ventilators. The purpose of this change was to prevent the escape of the tiny, newly-hatched, lygus nymphs from the wire-screen cage. (5) After the change of a cage, daily examinations were made to determine when hatching began. (6) As the nymphs appeared in the oviposition cage, each one was placed in a separate pyrroline cage (⅞ x 2 inches, not including a 2-inch, close-mesh cloth sleeve on each end) which previously had been arranged over a raceme of young buds on a growing alfalfa plant. Each nymph was thus kept in a separate cage during its development from the time of hatching to its transformation to the adult form. (7) These rearing cages were kept shaded by means of a burlap or canvas canopy. (8) Daily examinations were made of each nymph to ascertain when transition took place from one nymphal instar to the next, and to the adult form. This transformation was evidenced by the exuviae (cast-off skin) of the nymph which was always readily found within the small cage.

The incubation period of lygus eggs was found to vary from 19 to 11 days with increasing temperatures from May to August. Mean length of this period for the season was 14.93 days.

After hatching, young lygus bugs pass through five stages of nymphal development in reaching the adult form. Time required for complete nymphal development varied during the season from 13 to 31 days with a mean of 21 days. This added to 14.93 days required for the incubation of eggs, gives approximately 36 days for development from newly-laid eggs to the adult form. The mean preoviposition period of females approximated 10 days. This gives a mean total of approximately 46 days for the production of successive broods of *Lygus* during a growing season in northeastern Utah. With reproduction and development taking place from mid-April to late September in valleys of northern Utah where the elevation varies from 4,310 to approximately 5,000 feet, there is sufficient time for the production of three complete broods. In Washington County with an elevation of less than 3,000 feet, a longer growing season and higher temperatures, it is probable that four or five broods of *Lygus* develop annually.

Population Density

With the exception of thrips during the bloom period, lygus bugs normally have been found in greater numbers than any other insect inhabitant of alfalfa fields in Utah. Beginning with overwintered adults in early spring, the lygus population gradually increases as the summer season advances, usually reaching maximum numbers in midsummer.

Population density of *Lygus* varies from year to year with differing seasonal conditions. Lygus numbers also vary in different alfalfa fields and even in different areas of the same field, coincident with the thickness and succulence of the vegetative growth of alfalfa. The more succulent and vigorous it is, the greater is the number of infesting *Lygus*. This is particularly true of the adult forms because of their ability to fly readily from adverse to more favorable situations.

Trends in lygus population in alfalfa-seed fields were studied during the three-year period 1931-33 in the Uinta Basin and in the Delta area of Millard County. In representative seed fields of each area, insects were collected by making quadrantal sweepings with a 15-inch insect collecting net, totaling 50 strokes in each field at either 10-day or 2-week intervals from May 15 to September 15. Following collection, insects were segregated according to species, counted and tabulated.

Data obtained in these population studies are briefly summarized in table 4. It will be noted that lygus numbers were greater each year of the period in the Uinta Basin than in the Delta area. A likely explanation for this

Table 4. *Population density of Lygus in representative alfalfa-seed fields in the Uinta Basin and in the Delta area as indicated by insect collections made at 10-day or 2-week intervals from May 15, to September 15, 1931, 1932 and 1933 (50 sweeps with a 15-inch insect net in each field and on each date)*

Year	Area	Number of fields sampled	Number of *Lygus* captured: Total	Maximum during season: Date	Maximum during season: Mean per sweep	Mean for season
1931	Unita Basin	20	7,727	Aug. 1	2.58	0.98
	Delta	15	5,371	June 10	1.28	0.58
1931	Unita Basin	18	17,300	Aug. 1	3.70	2.11
	Delta	15	1,872	Sept. 15	0.69	0.32
1933	Unita Basin	18	31,672	June 20	10.58	4.34
	Delta	15	5,029	Aug. 10	1.84	0.91

difference is the fact that first-crop alfalfa was customarily left for seed production in the Uinta Basin, thus providing *Lygus* with a maximum, uninterrupted season in which to reproduce new broods of young, whereas, in the Delta area, first-crop alfalfa was generally cut for hay and second-growth was used for seed development. Cutting of alfalfa destroys myriads of lygus eggs which have been laid in its tissues and the suddenly-changed environment which follows, kills numerous nymphal *Lygus*.

Also worthy of note in table 4 is the great increase of *Lygus* in the Uinta Basin during successive years of the investigation. In 1932 lygus numbers were more than twice those in 1931 and in 1933 they were again more than double the numbers in 1932. Surveys made occasionally in the Uinta Basin and in Millard County during more recent years indicate that lygus populations in alfalfa-seed fields are now denser than during the 1931-33 period.

Counts of *Lygus* in alfalfa fields grown for seed and studies of resulting damage, over a period of eight years, indicate that when the population density reaches more than four bugs per sweep with a 15-inch insect net, damage to the seed crop becomes evident and increases somewhat proportionately with the intensity of the infestation. Lygus numbers have been found to vary in the midseason of seed-crop development from 2 to 20 per sweep. When the population approaches this latter number, complete prevention of the development of a seed crop usually follows.

Factors and Methods of Lygus Control

Natural Control: A wet winter season with little or no snow cover and with alternating mild and low temperatures is conducive to poor survival of hibernating lygus adults. Wet, cold, spring weather retards oviposition activities of overwintered lygus females, the incubation of their eggs, and also nymphal development. It is fatal to a high percentage of young lygus nymphs.

Few natural enemies have been found attacking lygus bugs. *Nabis ferus* Linn., the common damsel bug, occurring abundantly in all alfalfa fields of this state, big-eyed bugs (*Geocoris* spp.), and occasional ants have been observed feeding on lygus nymphs. In September 1933, 47 percent of 36 lygus eggs dissected from alfalfa stems at Ft. Duchesne were parasitized by a mymarid egg parasite. Limited search at that time for additional cases of such parasitism proved unsuccessful.

Farm Sanitation: Inasmuch as lygus adults overwinter in and about alfalfa fields under crop refuse, weeds and rubbish, some control may be obtained by cleaning up such material as thoroughly as practicable in the fall, particularly in alfalfa fields, along ditch banks and fence lines.

Cutural Practices: For the purpose of obtaining more favorable forage and places in which to oviposit, lygus adults move from older, tougher alfalfa to that which is younger and more succulent. Less damage by *Lygus* therefore is done to the seed crop if all growers in a district uniformly use either first-crop or second-crop alfalfa for the production of seed. Also, if second-growth alfalfa is to be used for seed, simultaneous cutting of all first-crop alfalfa in an entire district likewise serves as a check to the multiplication of *Lygus*. Unhatched lygus eggs, already in the tissues of the growing alfalfa, are destroyed when the green plants are cut and dried for hay. Then too,

large numbers of lygus nymphs die whenever alfalfa is cut because they are unable to survive the sudden change from the humid, shady environment, provided by growing alfalfa, to the dry, hot one resulting from cutting the alfalfa.

Further destruction of nymphal *Lygus* may be accomplished by cultural renovation of alfalfa fields in early spring and again immediately after the first-crop hay has been quickly removed.

Insecticides: As soon as it was established in Utah that lygus bugs caused serious injury in alfalfa grown for seed, efforts were made to control them in the field with contact insecticides. Repeated tests with the following insecticidal dusts proved either ineffective or prohibitive in cost for satisfactory field control of *Lygus:* sulfur, nicotine sulfate, calcium cyanide, sulfur plus paris green, sulfur plus pyrethrum, lethane, and Pyrocide. Pryocide was the most efficient of these insecticides, but for the necessary dosage its cost was prohibitive for economical field use.

With the failure of insecticides known prior to 1944 to give satisfactory control of *Lygus,* growers were dependent upon various natural agents, cultural practices, and farm sanitation for whatever degree of control they obtained.

In 1944 two new insecticides became available for experimental use. These were DDT, dichloro-diphenyl-trichloroethane, (technically, 1-trichoro-2, 2-bis [p-clorophenyl] ethane), a synthetic insecticide, and sabadilla dust obtained from the bean of the Mexican, liliaceous, sabadilla plant, *Schoenocaulon officinale* A. Gray.

Immediately thereafter plans[3] were made to test these two insecticides for the control of *Lygus* in alfalfa grown for seed and compare them with Pyrocide, which previously had proved to be the most effective insecticide. The following four insecticidal dusts were included: (1) DDT, 3 percent; (2) DDT, 10 percent; (3) sabadilla, 10 percent; and (4) sulfur-Pyrocide mixture. These were used in dosages of 30 and 50 pounds per acre at weekly and semiweekly intervals on randomized plots in the field and replicated four times. This experimental plan necessitated 64 plots. A separate rotary hand duster was used for the application of each of the four insecticidal dusts and drift from one plot to another was reduced to a minimum by placing a cloth cage over each plot during the treatment.

After the alfalfa had received either two or four treatments during the first two-week period, it was found that lygus numbers on the DDT-treated plots were negligible. Further treatments with this material were therefore withheld until the lygus population again threatened damage after adults moved on to the experimental plots from nearby alfalfa which had been cut

[3] This experiment and those on lygus control referred to hereafter were designed and executed cooperatively by the Utah Agricultural Experiment Station and the Division of Forage Crops and Diseases, U. S. Bureau of Plant Industry, Soils and Agricultural Engineering.

for hay. Because of this change in the original plan, the experimental plots which were to have been dusted with DDT received only one-half as many applications as did those treated with sabadilla or sulfur-Pyrocide.

Results obtained in these 1944 tests were judged by relative yields of mature seed and numbers of *Lygus* occurring on plots receiving the different treatments. Statistical analysis of resulting data showed highly significant differences between means of treatments for both seed yields and lygus numbers. Plots treated with 10-percent DDT produced highest yields of seed and kept *Lygus* to lowest numbers. Three percent DDT gave the next best results. However, the difference between 3-percent DDT and sabadilla was statistically insignificant. Differences between the means of seed yields and lygus numbers for weekly and semiweekly treatments proved to be highly significant. Differences between means obtained with applications of 30 and 50 pounds, respectively, of the various dusts were insignificant. Following the first application of DDT, lygus nymphs, previously numerous, had been destroyed and only an occasional specimen was collected thereafter on the plots treated with this material.

DDT is the first insecticide to give promise in Utah for the effective control of *Lygus* in alfalfa grown for seed. So encouraging were the results of the 1944 tests with DDT that this material and sabadilla were used experimentally again during 1945, but in different strengths and dosages.

The latter work was planned to include DDT 5-percent, DDT 3-percent in sulfur, and sabadilla 20-percent for testing against *Lygus* on alfalfa experimental plots and in a commercial alfalfa-seed field. On the experimental tract the plan called for the use of these three insecticides and one untreated check on 16 randomized blocks, each one having four randomized variations with respect to the stage of plant development at which treatments were to be made and in four replications. This design thus necessitated the use of 64 plots. This tract is sub-irrigated dry-farm land of black loam soil. Size of individual plots was one-eighth acre.

Largely because of the following conditions the alfalfa on the experimental plots harbored an unusually low population of lygus bugs in 1945: (1) This tract is somewhat isolated from other alfalfa fields, there is only one such field immediately adjacent to it; (2) the stand of alfalfa in the experimental field was but one year old and relatively thin; (3) the alfalfa had been thoroughly renovated by cultivation in late spring to destroy weeds, grasshopper eggs, *Lygus*, and other pests.

Because of the low lygus population in this field during the entire fruiting period of the alfalfa, only one application of the various insecticides was made. This was on July 3, when the alfalfa was in the late-bud stage and just before the first blossoms began to appear.

Yields of seed, recleaned basis, were found to vary on different plots from 96 to 556 pounds with a mean of 251.5 pounds per acre. Statistical analysis of the data showed that there was no significant difference in seed yields

resulting from application of the various insecticides. This was probably owing to the fact that lygus numbers averaged less than one bug per sweep during the fruiting period of the alfalfa. High yields on different plots, nevertheless, were generally correlated with lowest numbers of *Lygus* and vice versa.

Mean differences in lygus numbers for the two DDT treatments were highly significant in comparison with those for the untreated checks. For sabadilla this difference was significant at the 5-percent point only.

The 35-acre commercial alfalfa-seed field was also on sub-irrigated dry-farm land. Soil type and water relationships on this farm were highly variable. This field was divided into eight plots, each one approximating four acres in size. The same four treatments, i.e., 5-percent DDT, 3-percent DDT in sulfur, 20-percent sabadilla, and one untreated check were used in two replications with one application of 20 pounds per acre by means of a tractor-power-take-off crop duster, provided with a 20-foot canvas trailer. The stand of alfalfa was two to four years old and had been planted in 18-inch rows. The insecticidal tests were made on second-growth alfalfa after the first crop had been cut for hay. The lygus population on the untreated plots in this field averaged 5.16 bugs per sweep during the fruiting period of the alfalfa.

Statistical analysis of the results of the tests showed that reduction in lygus numbers by all insecticidal treatments was highly significant. Mean difference in lygus numbers between treatments with DDT 5 percent and DDT 3 percent in sulfur was slightly under that required for significance at the 5-percent point.

Mean seed yield on plots dusted with 5-percent DDT was 6.48 fold greater than on the untreated check plot. This difference is highly significant. Mean yield on plots treated with the 3-percent DDT in sulfur was 3.36 times more than on those that were untreated. This difference is significant at the 5-percent point only. Plots treated with 20-percent sabadilla yielded 1.36 times more seed than untreated plots. This difference, however, is statistically insiginificant. The correlation coefficient (r) between lygus infestation and seed yields was found to be -0.9893, significant at the 5-percent point.

In consequence of the favorable results obtained with DDT during the past two years it appears that an effective, practical method of lygus control has at last been found for the amelioration or elimination of this seriously limiting factor in alfalfa-seed production.

Questions other than the effectiveness of DDT for this purpose now pose for solution, viz.: (1) What is the minimum effective dosage of DDT to be used? (2) Will this dosage vary or differ with the character of the vegetative growth of the alflafa to be treated; i.e., will a heavier dosage be required for the adequate treatment of a thick, tall stand of alfalfa than for one that is sparse and short? (3) How many applications of DDT are necessary

to provide adequate protection of a seed crop? (4) At what stage or stages in the growth of alfalfa will application be most effective against *Lygus*, afford greatest protection to the potential seed crop, and be least injurious to necessary pollinating honeybees and wild bees, various beneficial, predatory and parasitic insect inhabitants of alfalfa fields? (5) Will control of lygus bugs during the pre-bud and/or bud stages of alfalfa intended for seed production afford adequate protection against lygus injury during the entire period of seed formation and development or will it be necessary to make additional treatments with DDT, primarily to protect the seed while it is in the "milk" stage; furthermore, will the benefits to be derived from treatment at a time when the alfalfa is either near, or at, its maximum vegetative development, be greater than the costs, including the damage inflicted by the machinery used in applying the insecticide? (6) Will any residue of the DDT remain on the plants at harvest time, and if so, will it render the seed chaff harmful to farm animals to which it may be fed? This last question perhaps is not of serious economic importance because the feed value of the chaff is inconsequential in comparison with a good yield of first-quality seed. Nevertheless, the question is of scientific interest and of some economic importance.

THE SUPERB PLANT BUG

The superb plant bug was first described and named in 1875 by Phillip R. Uhler, America's foremost hemipterist. He gave it the name *Calocoris superbus*, but in 1907 the generic portion of the name was changed to *Adelphocoris*. Since the latter date this insect has been known in science as *Adelphocoris superbus* (Uhler). It is taxonomically related to *Lygus*, belonging to the same order and family, i.e., Hemiptera and Miridae, respectively.

Distribution

The superb plant bug is probably a new-world species and native to western United States. Published records (10) show it to have been collected in the following states: Arizona, Colorado, Iowa, Kansas, New Mexico and Utah. It has been collected in 15 counties of Utah as follows: Box Elder, Cache, Carbon, Davis, Duchesne, Grand, Juab, Millard, Morgan, Salt Lake, Tooele, Uintah, Utah, Wasatch, and Weber.

Descriptions

The superb plant bug is somewhat larger than any of the lygus species. Its predominant color is blood-red with mid-portions of both dorsal and ventral surfaces black. In some individuals the red color fades to orange or brownish yellow and the black parts sometimes pale to brownish black or brown.

Nymphs are usually blood-red with some black, but variations occur in which the red color is replaced by green.

Host Plants

Alfalfa is the principal host plant of the superb plant bug in Utah. Repeated efforts to collect it from other likely host plants, both native and cultivated, within the state have failed. Townsend (8) reported that adults and numphs of this insect were numerous on alfalfa in New Mexico and "doubtless cause considerable injury to the plant."

Literature regarding the superb plant bug is extremely limited. In that which is locally available it is reported that this insect has been collected at various elevations from near sea level to 10,000 feet above it. No mention is made of host plants. Nevertheless, it is highly probable that the insect feeds on some of the native vegetation, although it may be "limited to a single host plant, or to a genus of plants," as Knight (4) says is characteristic of probably the greater number of the species of Miridae, while a few, such as *Lygus* and *Halictus citri* Ashm., have a wide range of host plants.

Kind of Damage Inflicted

The manner of feeding by the superb plant bug is similar to that already described for lygus bugs. Resulting damage to alfalfa is also similar to that done by *Lygus*, except that equivalent numbers of *A. superbus*, perhaps because of their larger size, inflict even greater damage to an alfalfa-seed crop than do *Lygus*. Buds which are fed upon become blasted and die. Flower-drop and the amount of brown, shrivelled, nonviable seed is increased in proportion to the intensity of the infestation.

Serious damage in Utah by this insect has heretofore been known to occur only in first-crop alfalfa which was being grown for seed production. This was some years ago (1930-33) when this practice was almost universal in the Uinta Basin. In some districts of that region, particularly in the Ouray Valley, the superb-plant-bug population was relatively more dense than that of *Lygus*. Under such conditions, alfalfa buds became blasted and usually failed completely in the development of flowers or seed.

Life History

A study of the life history of the superb plant bug as it occurs in alfalfa was made in the field near Logan in a similar manner, using the same kind of equipment, as has been previously described in this treatise in connection with the discussion of the life history of *Lygus*.

It was found that the superb plant bug overwinters in the egg stage. This is unlike the lygus species which hibernate in the adult stage.

Superb plant bug eggs are laid singly, but usually close together in various parts of alfalfa stems, branches, leaves, and petioles. In rearing cages, 35 percent of 444 eggs of this insect were laid in the basal 4 inches of the stems and 25 percent in the apical one-inch portion.

Earliest hatching of overwintered eggs in Cache Valley occurred on May 5. Oviposition was found to take place from June 15 to mid-September. Length of the season during which egg-laying occurs undoubtedly varies with fluctuating seasonal conditions in different years.

The preoviposition period during which young females did not lay eggs varied in July from 6 to 13 days with a mean of 9.

Length of the incubation period of 433 eggs during July and August varied from 16 to 27 days with 48.27 percent of them hatching in from 21 to 23 days with a mean of 21.5 days for the total number.

In developing to the adult form, the young pass through five nymphal instars. In rearing cages, total time required for complete development of all nymphal instars was 26 days. Summation of 9, 21.5, and 26 for the length of the preoviposition and incubation periods, and time required for completion of the five nymphal instars, respectively, gives a total of 56.5 days found necessary for development of the superb plant bug from egg to egg.

Although not yet definitely determined by the rearing of two complete broods of *A. superbus* in captivity, nevertheless, the information obtained regarding the time required for the development of one brood, indicates the probability that two generations develop annually in Utah.

Population Trends

With discontinuation, in recent years, of the practice of growing seed on first-growth alfalfa, superb plant bug numbers have become so reduced that damage by this insect is now negligible. Only occasional specimens of it have been captured when making recent insect surveys in alfalfa-seed fields. This is in marked contrast to the numbers of superb plant bugs which formerly prevailed in first-crop fields when they averaged approximately one bug per sweep with a 15-inch insect net.

The probable reason for the current low population of superb plant bugs is that when first-crop alfalfa is cut, few, if any, of these insects have reached the adult stage. At this time, also, a large percentage of their eggs has not yet hatched. All mirid eggs and most young nymphs are destroyed with the cutting of the alfalfa.

Lygus eggs begin hatching approximately a month earlier than do eggs of the superb plant bug. Time required for incubation of eggs and nymphal development of *Lygus* is shorter than for *Adelphocoris*. Because of this, large numbers of new-generation adult *Lygus* are present in alfalfa fields when the first crop is cut. At that time adult *Lygus* fly to uncut alfalfa or to other host plants and thus live to produce new broods in second-crop alfalfa.

Prevention and Control

No parasitic nor predacious enemies have thus far been found attacking the superb plant bug.

Damaging populations of the superb plant bug may be prevented by destroying the overwintering eggs, largely found in the lower parts of alfalfa stems. This may be accomplished by close cutting of the seed crop and volunteer alfalfa, or close pasturing of the latter. Early cutting of first-crop alfalfa destroys all eggs that have been laid in its stems as well as most young nymphs inhabiting it.

In the event that population density should reach injurious proportions, it is probable that treatment with DDT will effect satisfactory control of the superb plant bug in the same manner as when used against the closely-related lygus bugs, although no experimental tests have been made using DDT against *A. superbus*. Because of the extremely low population of this insect currently present in alfalfa-seed fields, there has been no need for the use of insecticidal measures of control.

SUMMARY AND CONCLUSIONS

During the past 20 years yields of alfalfa seed in Utah have declined from a mean of 6.37 bushels per acre on 69,000 acres in 1925 to one bushel per acre on 33,000 acres in 1945. This represents a decline of 84 percent in the per-acre yield of alfalfa seed in the state since 1925.

Research data obtained by the Utah Agricultural Experiment Station in an endeavor to ascertain causes for this serious reduction are presented and indicate that feeding injuries to alfalfa buds, flowers, and young seeds by two species of *Lygus* and the superb plant bug, *Adelphocoris superbus*, constitute one of the important contributing factors.

Type of damage inflicted by each of these mirid species is similar but the amount done by equivalent numbers of *A. superbus* is greater than that by *Lygus*. Population density of *A. superbus* is small in comparison with that of *Lygus*.

Studies of the biology of these insects disclosed that in Utah lygus species overwinter in the adult stage whereas, *A. superbus* passes the winter in the egg stage.

Insecticides available prior to the experimental use of DDT in 1944, proved either ineffective or unsatisfactory for the control of these mirid bugs in alfalfa-seed production.

Results obtained in two seasons of testing DDT for controlling *Lygus* in alfalfa being grown for seed, showed a significant reduction of lygus numbers and increased yields of seed on treated plots in comparison with those on untreated plots. Although DDT at present seems to give promise of being a great boon to the alfalfa-seed grower, nevertheless many questions await answers from further experimentation; such for example, as its most

effective and economical dosage, intervals and time of applications; ultimate effect on necessary pollinating bees and other beneficial, predacious or parasitic insects; effects on livestock to which by-products of the crop may be fed, or to the plant itself.

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