Black Grass Bugs (Labops hesperius) Uhler (Hemiptera: Miridae) and Other Insects in Relation to Crested Wheatgrass

B. Austin Haws and George E. Bohart

ABSTRACT: The history and present status of entomological observations and research in Utah and other states as related to crested wheatgrass is reviewed. The black grass bug Labops hesperius Uhler is the principal insect discussed but a few other major insects and grasses involved in resistance studies are considered. Research methods and six strategies using Integrated Interdisciplinary Pest Management (IIPM) procedures of insect control are presented. Approximately 160 insects collected from crested wheatgrass are classified as to their beneficial or injurious impacts. Grasses along highways as sources of problems with insects and their weed hosts are described. Reasons that insect-free plants are needed for standardization of range grass research are explained.

ACKNOWLEDGMENTS: The authors are indebted to numerous individuals and institutions who have helped in many ways in the planning, execution, and the financial or human resource support of some of the projects reported in this paper. Recognition is given to them through the citation of their written contributions.

Special thanks are given to those who provided photographs: E. J. Araya, P. S. Brewer, W. F. Campbell, E. M. Coombs, W. P. Nye, and J. Spillett. The assistance of A. H. Roe in use of his computer talents and the editorial expertise of G. H. Haws have greatly facilitated revisions of the manuscript.

INTRODUCTION

This paper will briefly overview studies conducted at Utah State University (USU) of range insects in relation to crested wheatgrass, mainly Fairway [Agropyron cristatum (L.) Gaert.] and standard [A. desertorum (Fisch. ex Link) Schult.], and review the reports of others. The present status of the studies and needs for future research are discussed. Our research aim is to improve the quality, quantity, and longevity of crested wheatgrass (and other grasses) by developing range management practices to control injurious insects and protect beneficial ones.

During the past 14 to 15 years, many new details of the biology of several insects directly or indirectly affecting crested wheatgrass have been learned in Utah and other western states, including Arizona, Colorado, Nevada, New Mexico, Montana, Oregon, and Wyoming.

We understood at the start of our studies in Utah that a major aspect of the insect problem would be the black grass bug Labops hesperius Uhler. We got this impression from some of the literature, such as Denning (1948), who referred to this insect as the crested wheatgrass bug. Markgraff (1974) stated that Labops hesperius was first described in 1872 from specimens collected in Colorado and Montana and that only four or five studies of the insect had been conducted to that time. We now know that wherever Labops hesperius is present nearly all introduced and native grasses are hosts to some degree. Several black grass bugs of similar appearance occur in crested wheatgrass, notably Irbisia species (Hansen 1986), but unless otherwise indicated we refer to Labops (Fig. 1).

The most acceptable solutions to rangeland problems will require interdisciplinary consideration of all major components of rangeland ecosystems and the effects of manipulating any components on the rest of the system. Our rangeland insect research has been guided by these principles. Researchers have developed insect pest control strategies known as Integrated Pest Management (IPM) (Metcalf and Luckmann 1982, Huffaker 1980). To clarify this statement of methodology, we have added "Interdisciplinary" (IIPM). In IIPM, a pest is considered to be any agent that decreases the quantity, quality, or longevity of target plants (i.e., insects, mites, nematodes, diseases, weeds, rodents or larger animals). IIPM specialists (such as those in soils, plant science, entomology, plant

B. Austin Haws and George E. Bohart are, respectively, Professor, Biology Department, Utah State University; Collaborator, USDA Agricultural Research Service, Logan, Utah.

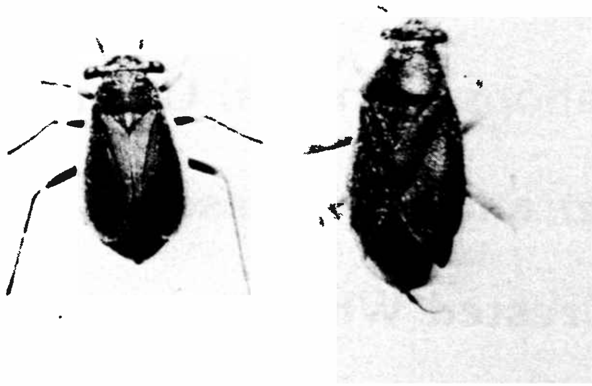


Figure 1.--Black grass bug adults: Irbisia brachycera (right) with completely black wings is often mistaken for Labops hesperius (left), distinguished by buff-colored margins around the borders of its wings.

pathology, economics, climatology, ranching, etc.) try to integrate their knowledge and experience into effective pest control strategies that are economically and environmentally acceptable. Potential benefits of the IIPM approach are discussed by Haws (1979).

Because the taxonomic classification of certain grasses has recently been changed, the authors have faced a problem of consistency in using the new nomenclature. It was decided that generally names written in earlier publications will not be changed, with few exceptions. Where possible the new names are used. The recent publications of Dewey (1983) and Barkworth et al. (1983) contain the new terminology.

RANGE GRASS INSECTS IN GENERAL

For this symposium the authors have examined their collections and records of crested wheatgrass insects. It has not been possible to sort and list all of the insects now on record, but those collected by G. E. Bohart in 1973-4 from Curlew Valley, Utah near the north shore of Great Salt Lake have been identified as far as possible (Appendix). These insects were collected by regular sweepings with an insect net throughout the season. Moths were generally so damaged by sweeping that they could not be identified and are therefore poorly represented in the collection. Fast flying insects, such as mature grasshoppers, usually evaded capture. For unknown reasons some of the major insects found in crested wheatgrass elsewhere have not been found in the Curlew Valley, e.g. Labops spp. Only a few specimens of Irbisia spp. were collected.

The collection illustrates four important facts about grassland insects: (1) It demonstrates the number and variety of insects that occur on range grasses and indicates briefly the possible role of each insect or group. (2) It presents an overview of the present status of knowledge about insects in rangeland ecosystems. (3) It underlines the rather primitive state of taxonomic work relating to insects of crested wheatgrass and many other rangeland plants. (4) It shows the practical and scientific limits of utility of the information available. The following notes provide some knowledge about the insects listed in the Appendix.

1. Many specimens can only be identified to genus at best and some of these names may not be acceptable to all taxonomists. It will take years to obtain reliable taxonomic names for many rangeland insects because often the specimens must be sent to specialists for identification. This list of insects does not represent the insects found everywhere in crested wheatgrass. To help solve problems relating to insects, specific collections are needed for each problem area.

2. Even when a species is positively identified, biological information concerning it often is lacking, scarce, or incomplete. Impacts of the insects listed are often based on generalized "common knowledge" of a particular group of insects. For example we may know that a species belongs to a group which is parasitic, phytophagous, or predaceous. Much of the information is drawn from annotations in exiting catalogues.

3. The behaviors and impacts of immature and adult forms of a species may differ completely. A given insect life stage may have more than one ecological role. Some insects may exhibit both injurious and beneficial roles. The impact column indicates the role of the most "important" stage of the insect as we understand it. The assessment of impacts is also partially based on the number of insects collected and the frequency of their capture during sampling. Insect species captured only once or twice were generally considered to be accidental visitors, although such an assessment is obviously subject to error.

4. Approximately 70 percent of the species listed could be considered neutral or beneficial (from the human point of view) to crested wheatgrass, that is, they are decomposers of organic matter, parasites, predators, helpful in soil genesis or in penetration of water and air into the soil, etc. However, some parasites would have to be considered harmful when they are hyperparasitic on primary beneficial parasites.

5. The majority of plant feeding insects were not found in sufficient numbers to suggest they were having a detrimental influence on the plants, but, as is noted, others have at least the potential of being substantial pests of crested wheatgrass. Several well known grass-infesting members of the family Miridae, such as Leptoterna, Litomiris, and Trigonotylus, were present in populations sufficient to damage the grass.

Several other individuals or groups have studied (or are now studying) rangeland grass-inhabiting insects. Knight (1982) listed 1,095 insect species collected during 1978-1979 from crested wheatgrass and other grasses in the Great Basin Experimental Range in Ephraim Canyon, Utah. This study was USU's first attempt to compile a list of insects found in grassland communities. Knight selected the following insect groups for future biological studies because of their apparent importance: leafhoppers, scale insects, click beetles (wireworms), thrips, ground beetles (mostly beneficial--26 species found), and snout beetles (weevils). Knight indicated that most of the injurious insects he observed appeared to feed indiscriminately on all the grasses. In Nevada, Knight and Lauderdale (1982) reported that Irbisia brachycera preferred feeding on squirreltail [Elymus elymoides (Raf.) Swezey], crested wheatgrass and intermediate wheatgrass [Elytrigia intermedia (Host) Nevski], but also fed on most other grasses. Thomas and Werner (1981) have published a list of grass feeding insects of western ranges.

The kinds and numbers of nematodes present in crested wheatgrass and other range grasses are largely unknown. Examination of soil samples (220 grams) from crested wheatgrass enclosures in Diamond Fork Canyon, Utah showed 8 Tylenchorhynchus spp. from a plot treated with a nematacide, and 80 Tylenchorhynchus spp. and Pratylenchus neglectus from an untreated plot. Research with nematodes associated with range grasses has been expanded. This work will be important in the grass breeding programs of the USDA Agricultural Research Service (ARS) in the search for pest-resistant grasses.

Through the years spittlebugs [Philaronia bilineata (Say)] have been collected on crested wheatgrass in Salina Canyon and from many other places in Utah. Severe damage by these insects has been observed, but little is known concerning their biology or economic impacts. These observations are of concern because one of the most destructive pests of grass reported by entomologists in Monterrey, Mexico are the spittlebugs commonly called "mosca pinta" (pinkfly). These insects are not flies, but belong to the Order Homoptera, (Aeneolamia spp. and Prosapia spp.). Spittlebugs are able to destroy or severely damage even the tough semitropical grasses (Enkerlin and Velarde 1973).

Hewitt and Onsager (1982) state that grasshoppers are considered to be the most important invertebrate pests on western rangelands. They report that one grasshopper per square yard is estimated to consume 12 pounds of forage per acre (this represents a generalization because grasshoppers vary considerably in size and food preferences). There are approximately 120 species of grasshoppers listed for Colorado (Capinera and Sechrist 1982).

The average number of grasshoppers per square yard in the United States from 1936-1969 was calculated to be 3.84 per square yard. Grasshoppers are reported to destroy 21-23 percent of western rangeland forage each year. In 1984, grasshoppers were estimated to be 50-100 per yard on some ranges in central Utah. Generally, eight grasshoppers per square yard is considered to be the approximate level of abundance justifying control with insecticides. Those who doubt the capacity of insects to consume vegetation had a demonstration in 1984-5. The grasshoppers consumed all of the grass on some ranges, then the sagebrush, rabbitbrush, musk thistle, and finally pinyon and juniper trees.

The economic benefits of chemical control of grasshoppers depend on the value of the forage being destroyed, costs of control, and other factors such as the weight losses of livestock, costs of relocating livestock, additional costs for feed, and forced sales of livestock. Even though many of approximately 600 grasshopper species found in the United States have different host preferences, they all contribute to reducing available forage.

DISTRIBUTION, ABUNDANCE, HOSTS, AND BEHAVIORS OF BLACK GRASS BUGS

The distribution of L. hesperius appears to be related to cool or cold temperatures. First instar nymphs have often been seen feeding a few yards from melting snow banks. We have observed feeding on crested wheatgrass when the air temperature was 22°F (-5.5°C), but at the same time the temperature in the crowns of the crested wheatgrass was 45°F (7.2°C). Evidently, the microhabitats where the insects live need to be considered in calculating correlations of insect behavior with temperatures. This early development of the bugs puts them out of phase with many other animals (including beneficial insects) and provides a period when the insects may be controlled without endangering other organisms. In the northwest, Todd and Kamm (1974) found grass bugs from the native sagebrush communities to the high deserts of the mountain parks near the timber line. Bugs were sparse in native vegetation and plentiful in modified, reseeded wheatgrasses.

Knowlton (1967) indicated that in the higher mountainous areas of Utah 95-99 percent of the infestations of grass bugs were on crested wheatgreass. Irbisia spp. were more commonly found at lower elevations and were often the dominant grass bugs in highway grasses.

Thirty-six native and introduced grasses are reported to have been fed upon by L. hesperius (Haws 1978). In 1972 Haws reported collecting 900 bugs per sweep (L. hesperius) from crested wheatgrass growing in Diamond Fork Canyon, Utah. Much lower populations are reported in some areas of Utah: 45-90 at Sterling Ranch in the same canyon in 1977; an average of 38 bugs per sweep in Cedar Breaks (Haws 1978).

Labops hesperius has not been found in crested wheatgrass in several areas of Utah such as certain ranges in Duchesne County and western Box Elder County. There is no verifiable evidence to explain this lack of infestation, inasmuch as the bugs infest grasses in 18 western states and Canada (Ostlie 1979). We have speculated that isolation from sources of bug infestation (such as bug-infested freeways) or unfavorable winter conditions may not permit the bugs to become established or the eggs to survive in some areas.

UTAH STUDIES ON BLACK GRASS BUGS (LABOPS AND IRBISIA)

Historical Background and Overview

Although crested wheatgrass and other introduced grasses were established in Utah as early as 1942, and acreages had increased substantially by 1966, Cook (1966, 1967) did not mention problems with insects even though black grass bugs were already of much concern to state and federal agencies, ranchers, and entomologists.

In Utah, Knowlton (1945, 1967) and Lindsay (1970) reported damage to thousands of acres of rangeland grasses by black grass bugs. The Federal Plant Pest Control Division, now known as the Animal and Plant Health Inspection Service (APHIS), had detected widespread grass bug damage in its surveys. APHIS had attempted to solve the problem in several areas by applying insecticides to infested ranges, especially in the East Fork of the Sevier River, Utah. A series of letters and reports from Thornley[1] provide valuable information about the range grass/insect situation in 1967. Thornley wrote that:

1. Problems with the black grass bug had been observed periodically for the past 25 years (approximately since 1942), but infestations had been "spotty" and irregular. (The USU insect collection has specimens of Labops hesperius collected at least as early as 1939).

2. The bugs seemed to thrive best at elevations between 6,000-9,000 feet (1829-2743 m).

3. Crested wheatgrass and intermediate wheatgrass appeared to be the favorite host plants, but native grasses were acceptable if there were many bugs.

4. Populations of bugs in excess of 1,000 per square foot (0.093 m^2) were observed (Fig. 2). Feeding by the bugs resulted in removal of the green color from grasses, and left the grass straw colored. Severely damaged plants failed to produce seed.

5. Scant information was available about where or when the insects laid their eggs, or about other details concerning the life cycle and the seasonal history of black grass bugs.

6. Ninety-five percent malathion applied at 8 oz per acre by fixed-wing aircraft reduced the populations of bugs from more than 1,000 to about one per square foot (0.093m^2). Results were variable, partly because there was little biological information upon which to base control programs. Sometimes control was ineffective because the insecticide was applied after the female bugs had laid their eggs. Young nymphs and the adult bugs sometimes were not found early enough to implement successful control programs.

Studies by USU entomologists and others have since confirmed most observations reported by Thornley.

An administrative report from New Mexico (Brandt)[2] stated that Labops hesperius infested about a quarter of an acre (0.618 ha) of crested wheatgrass in the Laguna Seca Allotment in 1962. By 1963 an infestation of 500 acres (1,235.5 ha) was discovered and control was attempted by applying malathion with a mist blower. An estimated 10,000 acres (24,710 ha) were reported infested in 1966. Chemical controls were tried with variable success. Some unanswered questions Brandt pointed out were:

Figure 2.—Nymphs of Labops hesperius on the ground and leaves of crested wheatgrass on Whiteman Bench, Garfield County, Utah. There are about 800 bugs per square foot in this photograph.

Where are the insect eggs laid? How can outbreaks of the pest be forecast? What factors influence the infestation patterns? What are the sources of infestation? What are the preferred plant hosts and why are they preferred? How many generations of the bugs are there per year? What are effective methods of control? Some, but not all, of these questions can now be answered.

Dewey[3] has conducted genetic and breeding research with grasses since 1956. He has traveled extensively, collecting and examining grasses in the United States, Iran, Russia, and China. He indicates that he and other scientists had a general lack of awareness of range grass insects until about 1972, when the USDA/ARS Crops Laboratory staff at Logan, Utah began cooperative studies with USU entomologists. Grass bugs have not been a problem in the ARS experimental plots (they usually are kept too clean—free of dead stems and debris—and they are harvested frequently) but billbugs (Coleoptera: Curculionidae) have been a problem (Haws 1982a).

Details of these historical beginnings in Utah and subsequent interstate cooperative research are given in various publications and reports (Haws 1972, 1975, 1978, 1982a, 1982b; Haws et al. 1973). A detailed review of the history, distribution, hosts and status of research on Labops has been written by Ostlie (1979). The Society for Range Management commissioned a publication concerning range insects (Hewitt et al. 1974). A review of rangeland entomology has been published (Watts et al. 1982).

Tasks undertaken by entomologists, and their associates from other disciplines, concerning black

[1] Thornley, H. F. 1967. Letter to Jim R. Dutton, Regional Supervisor. In Range Insect Literature File R-56, Utah State Univ., Logan. Other valuable letters: R-55, 57, 59, 88, and 89.

[2] Brandt, C. J. 1966. Administrative study of Labops hesperius. Santa Fe National Forest. In Range Insect Literature File R-4, Utah State Univ., Logan.

[3] D. R. Dewey, USDA/ARS, Logan, Utah, personal communication, 22 Feb. 1984.

grass bugs include: (1) finding out where the bugs lay their eggs, (2) determining where and how fast the eggs and immature forms (nymphs) develop, (3) learning what the impacts of all life forms of the bugs are and when, where, and how each might be most vulnerable to strategies for interrupting the life cycle, (4) developing basic principles and practical methods of control (cultural, biological, plant resistance, or chemical).

Our main objective in Utah has been to develop strategies for controlling black grass bugs infesting all rangeland grasses--not only crested wheatgrass. This symposium has influenced the authors to review their observations and research as specifically related to crested wheatgrass. However, many of the observations and principles presented here apply to other grasses as well. Our present research also includes studies of insects of rangeland forbs and shrubs as related to range improvement and management, and rehabilitation of perturbed sites such as surface mines.

Black Grass Bug Development--Eggs, Nymphs, Adults

To formulate management strategies for Labops control, it was necessary first to understand their biology. Haws et al. (1973) removed eggs from the ovaries of female Labops to determine their shape and size, and observed that their ovipositors were designed for injecting eggs. Kamm and Ritcher (1972) reported a technique for removing eggs from Labops females. Entomologists in Oregon (Markgraff 1974; Fuxa 1975; Kamm 1974; Fuxa and Kamm 1976a; Todd 1974) and Utah (Haws 1972, 1975; Higgins 1975) studied the seasonal and life cycles of Labops. It was found that the insects laid their eggs mostly in dry grass culms (Fig. 3), that there were five nymphal instars (Fig. 4), and that there was only one generation of the bugs per year.

Early reports related bug development to calendar days. Later studies related growth and development to growing degree hours (GDH) (Coombs 1985). Because GDH is becoming so widely used, and has such general applicability, mostly GDH data are reported here. Methods for calculating GDH are available in several publications (Haws 1982a; Richardson et al. 1975, 1983; Richardson 1985).

Grass bug eggs were gathered in the fall of 1971 for greenhouse studies of bug development through the winter. When the eggs would not hatch, cooperative efforts resulted in the development of growing degree hour models useful in predicting the development of black grass bugs in the laboratory and in the field:

	GDH (°C)
Hatch	4,800
1st Instar	5,560
2nd Instar	6,500
3rd Instar	7,940
4th Instar	9,426
5th Instar	11,357
Adult	13,666
Mature adult	15,257

Growing degree hours are likewise quite accurate in predicting the developmental stages of crested wheatgrass (Table 1). Models similar to that shown in Figure 5 have been developed for crested wheatgrass and several other grasses (Richardson et al. 1983). Development of growth models for other insects and range plants, including other growth factors besides GDH, are continuing. When the impacts of factors such as moisture, soil nutrients, diseases, and plant competition are known and incorporated into growth formulae, the precision of predictive models is expected to increase substantially.

In 1971, after black grass bug eggs were found in intermediate wheatgrass culms (Haws 1972), they were sought in crested wheatgrass. Despite lengthy searches in Utah, only a few eggs have been found in either green or dry crested wheatgrass culms. Later, it was discovered that bulbous bluegrass (Poa bulbosa L.), in a bug-infested crested wheatgrass pasture, contained large numbers of black grass bug

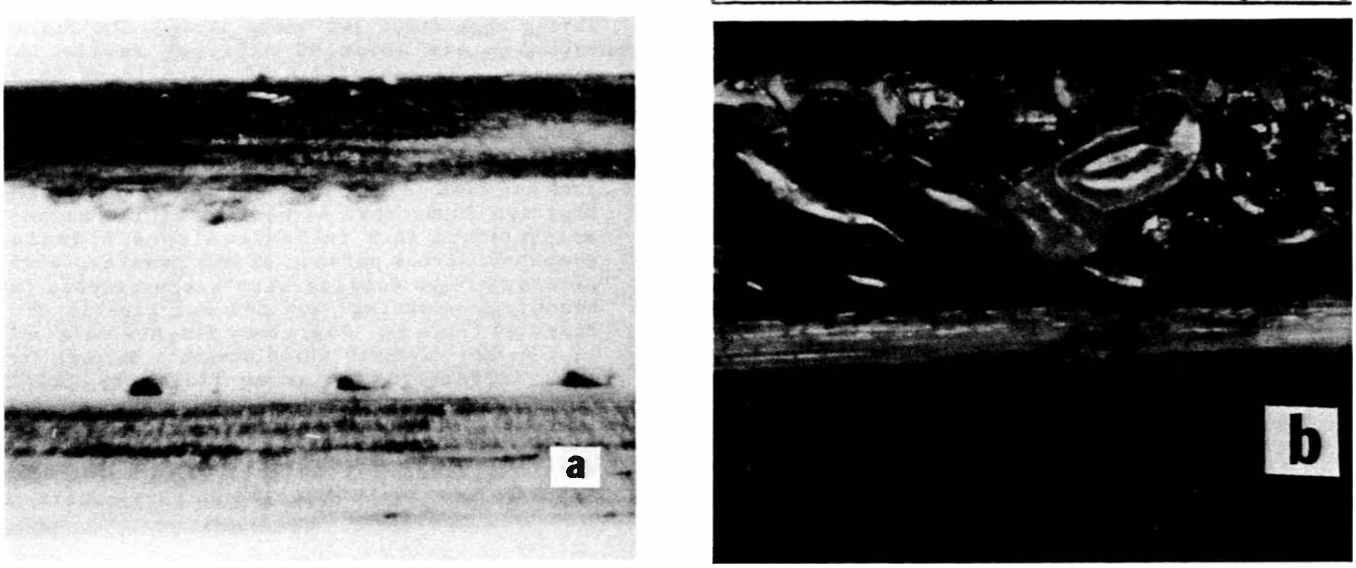


Figure 3.--Caps of Labops eggs protruding from a grass stem (a, top); caps of insect predator eggs (damsel bug or nabid) below. Nymphs (b) emerge from the overwintered eggs very early in the spring, often as the snow melts.

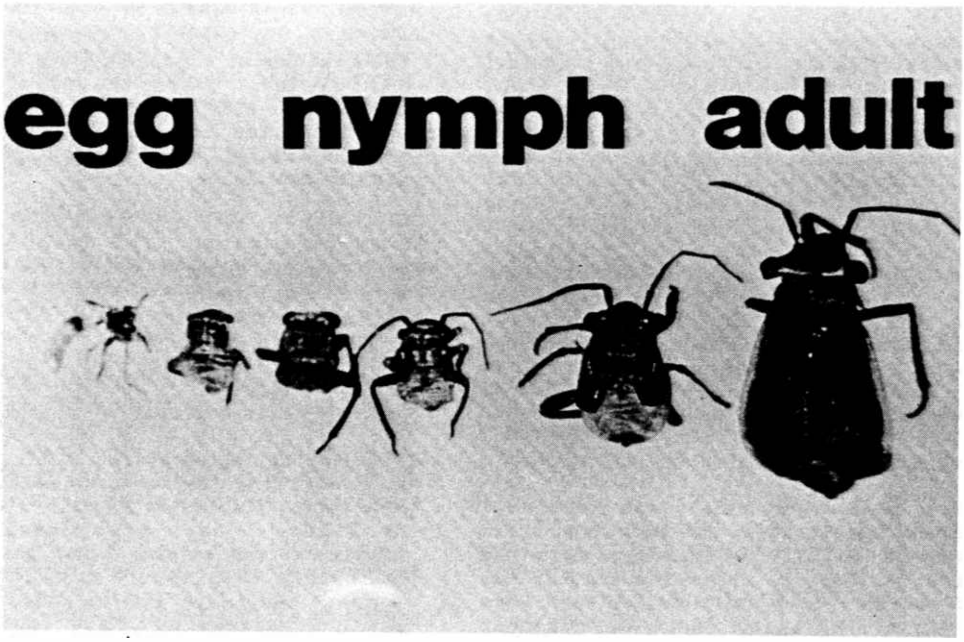


Figure 4.--Life cycle of Labops hesperius: egg, five nymphal instars, and the adult.

eggs. Subsequently, this grass has been the basic source of the eggs gathered for laboratory research. Todd and Kamm (1974) found Labops eggs in crested wheatgrass, blue bunch wheatgrass [Pseudoroegneria spicata (Pursh) Love], and especially in bulbous bluegrass. They found few eggs in green culms or broken stubble. In Utah, eggs have been found on other range plants such as dandelion, asters, clovers, and yarrow. Black grass bugs belong to the family Miridae, the same family as lygus bugs, one of the most destructive pests of alfalfa. Inasmuch as alfalfa is being planted with range grasses in some areas to improve the quality of the feed and of the soil, we decided to see if black grass bugs feed on alfalfa. Grass bugs were caged on Nomad and Ranger alfalfa in the greenhouse. The bugs fed at once on the alfalfas, and almost immediately oviposited eggs in the alfalfa stems. It was too late in the season to obtain bugs for longer term studies, so we were unable to determine if the bugs survived and reproduced when fed alfalfa. We have not observed the bugs feeding on alfalfa in the field when they have a choice between it and grasses.

Caged black grass bugs laid their eggs in many places if ideal sites (seed-bearing stems) were not available. Eggs laid by caged female bugs were inserted in cracks of paper greenhouse pots, through leaf blades or into cut-off stems, and wrapped in grass leaves without being inserted.

Paraqueima (1977) and Coombs (1985) have reared Labops in the laboratory with varying degrees of success. Control of diseases and relative humidity sometimes are problems. It is now possible to rear substantial numbers of bugs (from eggs gathered from the field) for use in winter studies. Coombs has continued previous studies at USU and has an accurate method of identifying grass bug nymphal instars by the measurement of head capsuls. He reports that nymphs of Labops and Irbisia brachycera (Uhler) can be distinguished by the presence of a broad white line bisecting the dorsal thorax of Irbisia nymphs.

Coombs (1985) observed grass bugs mating about one week after they became adults. They began laying eggs about two weeks later. The biological capacity was about 48 eggs per female in his studies. He reported a 60-40 ratio of males to females at the start of the season, but only 5 percent of the population were males toward the end of the life cycle. Todd and Kamm (1974) found eggs in adults about two weeks after the adults emerged. Fuxa and Kamm (1976b) examined the wing condition of bugs and found that 43 percent of the males were macropterous (had fully developed hindwings), compared with 4 percent of the females, while 53 percent of the females were brachypterous (short hindwings--meaning they are not capable of long flights) (Fig. 6). Migratory flights were only up to 2 meters distance which accounts in part for the slow infestation of grass fields by the bugs. Ovaries of the macropterous females appeared delayed in development until approximately three weeks after the "flight period." In one field Coombs found that the bugs lived for 80 days (egg through adult stages), but the life cycle can vary considerably depending on various conditions.

Coombs found a 0.982 correlation between nymphal development and GDH. Our knowledge of lethal cold temperature for bug eggs helps explain some of the

Table 1.--Comparison of predicted and observed dates of occurrence of selected phenological stages and heights of crested wheatgrass based on known GDH values associated with phenological developmental stages of crested wheatgrass (Richardson et al. 1974).

Phenology stage	Predicted date	Observed date	Height of culm	Predicted date	Observed date
	-------GDH-------		cm	-------GDH-------	
3 Leaf	232	230	10	240	233
4 Leaf	246	250	15	258	249
5 Leaf	273	279	20	273	267
Boot	291	292	25	286	281
Full flower	310	306	30	300	290
Seed ripe	341	347			

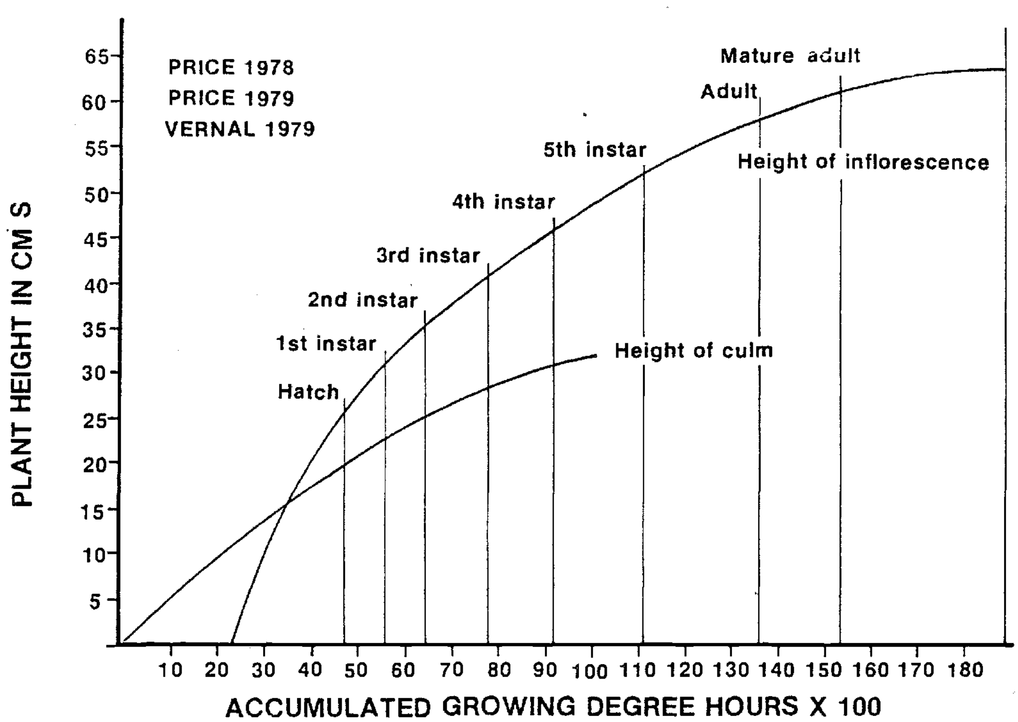


Figure 5.--Development of Labops hesperius and height of culm and inflorescence of crested wheatgrass related to growing degree hours. Adapted from Richardson et al. 1983.

Figure 6.--Labops hesperius adults: the female (left) has brachypterous wings lying over the thorax suggesting it cannot fly; the male (right) has two pairs of fully developed wings.

tremendous variations in bug populations from year to year. For example, Ostlie (1979) estimated that the grass bug population in a crested wheatgrass study area was reduced from approximately 2,256,000 bugs per acre in 1977 to 35,000 in 1978, presumably due to a lack of snow cover that allowed the eggs to freeze.

Biological and Economic Impacts of Black Grass Bugs on Grasses

Staff members and students in several colleges and departments at USU have studied the impacts of black grass bugs on range grasses, including plant physiology, seed production, photosynthesis, root reserves, consumption of grass forage by insects as compared with that of livestock, and certain impacts of insects as related to range economics. These studies have laid a foundation for our present and future research.

Physiology.--Wiebe et al. (1978) studied the physiological impacts of grass bug feeding. The studies included the effects of bug feeding on stomatal openings, chlorophyll content, photosynthesis, and forage yield. They also studied the attractiveness of water-stressed and nonwater-stressed plants. In these studies the impacts of three species of black grass bugs [Labops hirtus, Labops hesperius, and Irbisia pacifica (Uhler)] were compared. Because these were our first physiological studies and much had to be learned about methods, the authors considered the results as tentative and in need of follow-up research.

Plants damaged by the bugs appeared to transpire at rates comparable to those of healthy plants, which resulted in a degradation of water-use efficiency. Extremely high feeding intensities may have resulted in reduced leaf conductance, with consequent water conservation, for at least a period during and soon after feeding. Leaf chlorophyll concentration was correlated loosely with visual bug damage estimates. Feeding intensity predicted relative chlorophyll loss better than it did absolute loss. Some photosynthesis occurred in areas that did not appear green to the human eye. Visual estimates of insect damage were higher than were reflected in lowered rates of photosynthesis. Damage to wheat by I. pacifica (where the bugs had migrated into the wheatfield from roadside grass) resulted in a decrease in the number of grains per head. Bug incidence (BI=percentage of all bugs in an area that were on all plants) and damage to wheat were greatest on dry plants fed on by L. hesperius. The influence of soil moisture on plant attractiveness and on insect feeding merits further investigation.

Growth.--Ansley et al. (1978), Ansley (1979), and Ansley and McKell (1982) studied the effects of "grazing" by insects and livestock on some growth characteristics of crested wheatgrass. Tabulation of the yearly cycle of changes in carbohydrate root reserves as related to development of L. hesperius are shown in Figure 7. The data suggest that the early impact of bug feeding came when the root reserves were already being depleted by the spring growth of the plants. Production of crested wheatgrass protected from all feeding by enclosures and a systemic insecticide (aldicarb), was compared to that produced inside an enclosure where only insects were allowed to feed, and to that fed on by insects and cattle in a customary grazing regime outside the enclosures. Seedhead height was greatest in the aldicarb plots, but seedhead frequency was greatest in the grass outside the enclosures, (aldicarb=420; insect-grazed=880; outside the enclosures=1810). The percentage of plants developing inflorescenses was greatest outside the enclosures, and least in the aldicarb plots. Ansley theorized that perhaps the grass required some grazing or clipping to stimulate seedhead production.

The information we have concerning the impacts of grass bugs on longevity of crested wheatgrass and other grasses is mostly empirical. Long term, replicated longevity data are needed. In 1972, well-established drilled rows of crested wheatgrass were heavily infested with L. hesperius along Red Canyon and on Whiteman Bench, near the East Fork of the Sevier River. By the spring of 1984, only scattered plants of crested wheatgrass remained. Native vegetation is invading the areas along the sides of Red Canyon Road where thousands of black grass bugs have been collected from crested wheatgrass for experimental purposes during a 12 year period. On Whiteman Bench, smooth bromegrass (shown to be significantly less damaged by grass bugs than wheatgrasses in essentially all of our experimental tests) appeared to be the dominating grass. Our yearly observations since 1971, as well as reports of numerous bugs and severe damage since at least 1966, suggest that these insects have been a major influence in decreasing longevity of crested wheatgrass along the East Fork of the Sevier River. Jensen (1971) observed stands of grass damaged by the bugs, but none were killed.

Forage Yield.--In their studies of the impacts of grass bugs on the forage yields and nutrition of mature grass plants, Malechek et al. (1977) were not able to measure significant differences in herbage yields of grasses with moderate bug infestations compared with noninfested plants. Because the grass bugs are sucking insects, their damage is less obvious than that of chewing insects such as

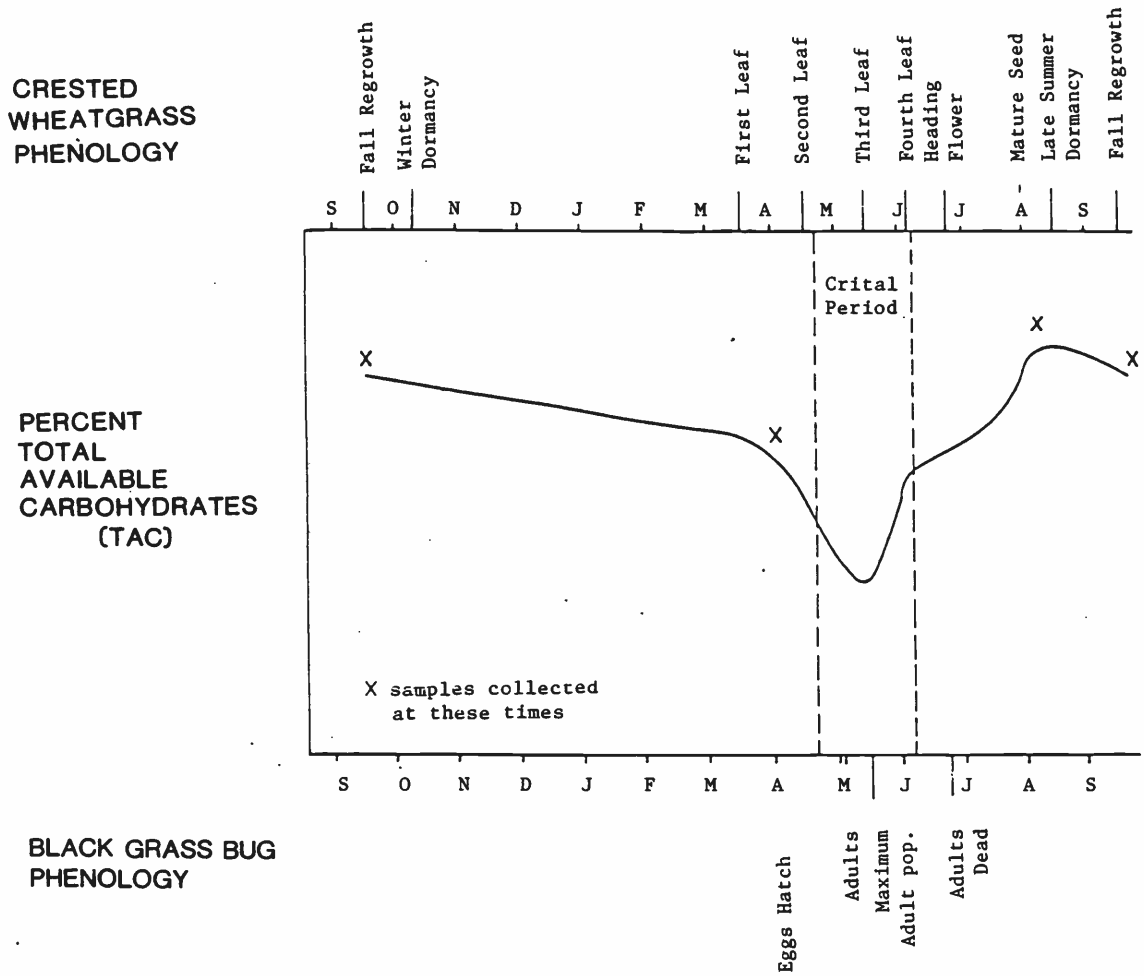


Figure 7.--Corresponding phenology and seasonal development of crested wheatgrass and Labops hesperius, observed in Diamond Fork Canyon, Utah, 1976-1977.

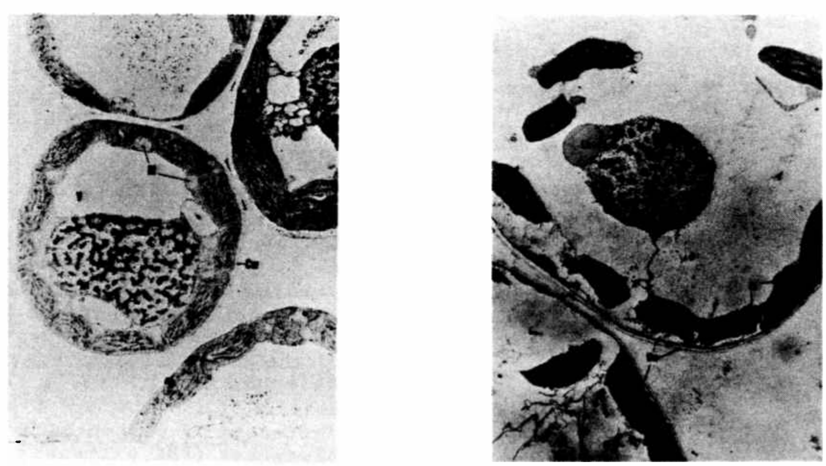


Figure 8.--Grass plant cells that have not been fed on by grass bugs at left. Right disintegration of grass plant cells 60 minutes after being fed on by black grass bugs. This may be caused by mechanical removal of plant substances or by the injection of substances not yet identified.

grasshoppers whose feeding partly or completely removes plant structures. Sucking insects insert small stylets into the grass tissues and remove plant fluids (Fig. 8), but the major external structures of the leaves remain. Thus, unless the bug populations are so numerous that the vegetative growth of the plants are reduced, measurements of damage to mature plants may not show great differences in forage weights. It would be easy to draw a wrong conclusion about bug impacts from these kinds of data if one were to conclude from laboratory studies that the feeding of the bugs was not detrimental to forage production.

A major problem is loss of early growing grasses in the field during the spring. Damage to crested wheatgrass and other introduced grasses occurs very early in the season (April and May--depending on the elevation) when livestock producers are eager to get their animals out of feed lots and onto early spring grass. But often, stockmen found the grasses were heavily damaged or destroyed by the bugs. This substantial loss of spring feed has been the major problem with black grass bugs in drier areas such as Utah. These early losses seem less of a problem in areas of greater moisture and where bug populations are smaller.

According to Bohning and Currier (1967) and Knowlton (1967), the bugs may reduce yields 50 to 60 percent. Todd and Kamm (1974) found no significant differences in forage yields of grass treated with insecticide compared with a nontreated control. Under conditions in Oregon (bug density averaging 120 per 0.97 ft^2), the total loss to mature grass was only two percent. The impact of feeding varied with time of utilization, annual rainfall, and drought. Even severely damaged grass recovers after the bugs complete their life cycle and die, if adequate moisture for growth is available to the plants. If the growing season remains dry after grass has been severely damaged, vegetative growth and seed production continue to be inhibited (Fig. 9).

Nutrition.--Traditional chemical methods of evaluating nutritional qualities of grasses as related to grass bug damage have been inconclusive and have not shown the detrimental effects that

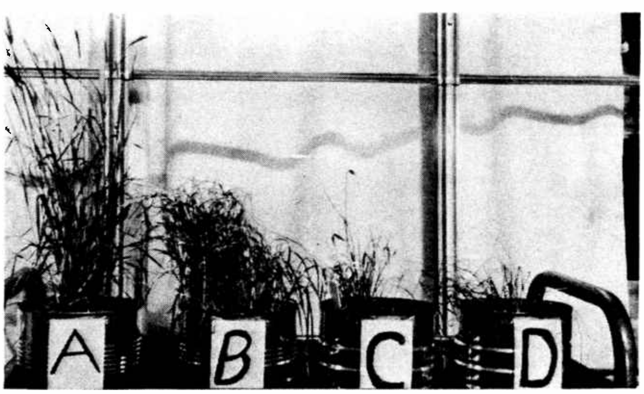


Figure 9.--Clones of crested wheatgrass heavily infested with Labops hesperius in a greenhouse did not produce seed. Bug-free plants (container A) produced seed, while containers with different levels of bug infestations (B,C,D) did not produce seed.

might be expected from the devastated appearance of the damaged grasses (Higgins et al. 1977, Malechek et al. 1977, Markgraff 1974). Todd and Kamm (1974) found a reduced combined value of yield reduction and loss of cell contents of 18 percent midway through the growing season (at the bug density indicated above). Both Malechek et al. and Todd and Kamm found that bug-damaged grass showed a slight increase in crude protein. In Utah, studies of chemical profiling (Windig et al. 1983) have belatedly suggested that grass bug feces covering infested grasses may be confounding the results of chemical analyses. As the bugs feed, they deposit large quantities of liquid feces on leaves and stems. After the liquid dries, it appears as a black deposit. We have not yet tested or determined the chemical content of the feces, or tried to physically or chemically remove the material from leaves being compared for nutritional quality. This must be done to obtain valid data on the impacts of grass bugs on nutritional quality of grasses.

In the field, we have observed that substantial rains remove all or most of the fecal material from the grasses. The nutritional value of the grass contaminated with bug feces may be near that of nondamaged grass because of the chemical contents of the feces. If the feces are washed off, the nutritional value may be considerably less. But ranchers and researchers have reported that even when spring grasses have not been totally destroyed by the bugs, some infested fields appear to be repugnant to cattle. The Green Lake Pasture near Cedar City, Utah had a population of approximately 100 grass bugs per sweep in 1975. Cattle in this pasture ate only a little of the damaged grass, then sought other feed. The basis for this repellence has not been determined. Apparently the black grass bugs inject chemicals into the grasses to liquify some of the plant materials. The bugs also cover the plants with feces as they feed. It is possible that the infested plants, or the bugs themselves, are unpalatable or have characteristics repellent to the livestock. The nutritional value of such repugnant forage is zero if the livestock will not eat it! Just how extensive this problem is or the level of bug damage when it occurs has not been determined.

Seed Production.--It is common to see insects feeding on seed heads of grasses (Bowers 1976). USU has attempted a few studies of the impacts of insects on seed production of plants such as alfalfa (Haws 1982b, p. 13, 35, 36). The damage causes seed to be shriveled, discolored and nonviable. Similar damage can be expected on grasses. To investigate the impacts of insects on seed production in the USDA/ARS grass breeding nurseries, insects were collected from grasses and caged on developing seed. The results indicated that bugs of the genus Labops survived well when caged on the seed while 100 percent of those of the genus Irbisia died (suggesting they did not feed on the seed) (Table 2). Unfortunately elk destroyed the cages and some of the seed in these tests before it was examined. Malechek et al. (1977) found that at an average density of 156 bugs per m^2, seedhead production was depressed 56 percent. In studies of two grasses, bluegrass (Poa pratensis L. cv. Merion) and fine fescue (Festuca rubra L. cv. Cascade), Kamm (1979) found that the plant bugs Leptoterna ferrugata (Fallen) and Megaloceroea recticornis (Geoffrey) reduced seed set and destroyed seed viability when

Table 2.--Percent survival of five insect species caged on green growing seed of Agropyron cristatum for two days.

Insect	No. of insects per cage	Average percent survival
Irbisia pacifica	6	0 a[1]
Irbisia brachycera	6	0 a
Labops hesperius	6	55 b
Melyrid spp.	10	75 b
Stink bugs (Pentatomidae)	5	76 b
Leptoterna spp.	6	77 b

[1]Analysis based on arcsin square root transformation of percentage data. C.V. 0.43. Means followed by the same letter are significantly different at P>0.01. Five replications.

the bugs fed directly on the developing seed. Burning the straw reduced the incidence of feeding injury. At USU, thrips (Chirothrips aculeatus Bagnall) destroyed valuable grass breeding crosses (Haws 1978, p. 102). The impacts of various insects on grass seed should be investigated when both the insects and seed are in different stages of development. Control of insects affecting grass seed production needs to be determined.

Economic Impacts.--Glover (1978) has reviewed some economic impacts of black grass bugs on range grasses. He has outlined two economic methods for analyzing the feasibility of pest control on rangelands [Bayesian (benefit-cost) analysis and an optimizing algorithm approach]. Glover calculated some cost/profit economics of rangeland via insect control (Glover 1982). Using 1979 as the base year, he estimated losses associated with L. hesperius in Utah, New Mexico and Nevada during 1980-1981. He concluded that if the benefits of grass bug control were to continue to accrue one year beyond the first year of control, based on the average internal rate of return, the chemical control investment can be shown to be a highly productive investment. Practical field experiences and experimental studies cited elsewhere in this paper have shown that economical control of black grass bugs by application of chemicals has been achieved. Several years of control have resulted from one proper application of ULV malathion in Morgan County, Utah (Haws 1982a, p. 185), and recently in Beaver County, Utah.

IIPM STRATEGIES FOR CONTROLLING GRASS BUGS

Range Management: Mixed Vegetation vs Monocultures

The consensus of the Utah research team was that the origin of problems with Labops probably was related to range grass management (planting monocultures, undergrazing etc.). Possible changes in management of ranges and livestock were among the first strategies investigated. Logic supporting the strategy of planting heterocultures instead of monocultures is based partly on data suggesting fewer grass bugs have been found in mixed communities of forbs, shrubs, and grasses than in adjacent monocultures of crested wheatgrass. The different insect population of native ranges, together with common knowledge and experiences with insects in other crops, suggest that the beneficial impacts of these insects can be increased by providing proper food and habitat for them.

Greater insect diversity in mixed plant communities is one feasible strategy for insect control. One way of promoting insect diversity, and thus developing a biological balance, is to include those plants in range renovation that will provide continuous food and favorable habitat for beneficial insects. Parasites and predators are particularly important components of an undisturbed ecosystem (Spangler 1984), keeping many injurious insects in check. Promoting beneficial insects usually requires plants which provide pollen and nectar and protection from the elements. One of the ultimate goals for rangeland management is to set up a self-regulating system that would limit the ability of pest insects (such as black grass bugs) to compete with livestock for forage. We do not know enough yet about insect/plant relationships to recommend these favorable combination of plants. After his experiences with grass bugs, Jensen (1971) concluded that the best insurance against heavy Labops infestations is a balance of plants in reseeded range communities.

In 1980 and 1981, Spangler (1984) studied sap-feeding and predatory insects in pure stands of manipulated grass densities compared with mixtures of native plants, including sagebrush. His data suggest that in comparing pure stands of crested wheatgrass with those mixed with sagebrush, the shrubs were more important than density of the grass in determining faunal structure. Fewer sap-feeding insects were found where the grass was interplanted with plants that were taxonomically unrelated. Lower levels of insect predators were found in the reseeded areas. There was a shift from a homopteran-dominated fauna, in a mixed range, to a mirid-dominated one in a monoculture.

Debris-in-place management (in which large plants such as juniper trees or sagebrush are removed, but some grasses, forbs, and shrubs remain) provides habitat and food for many insectivorous animals (birds, lizards, parasites, and insect predators). The studies of Ostlie (1979) (Fig. 10), in which the numbers and behaviors of L. hesperius in a monoculture of crested wheatgrass were compared with those in a native range, suggest that a mix of range plants might also include plants that are repugnant to insects (perhaps sagebrush) or that are otherwise unfavorable to them.

Society has learned to manage and increase the productivity of many crops by growing them as monocultures (corn, wheat, potatoes etc.). Inasmuch as there are millions of acres of monocultural grasslands, we need to learn how to manage them for pest control. But in the future, some problems with range insects probably can be avoided if the steady state of ecological balances existing in some native rangelands can be imitated. Our hypothesis is that a combination of plants that will help attain a favorable ecological balance of injurious and

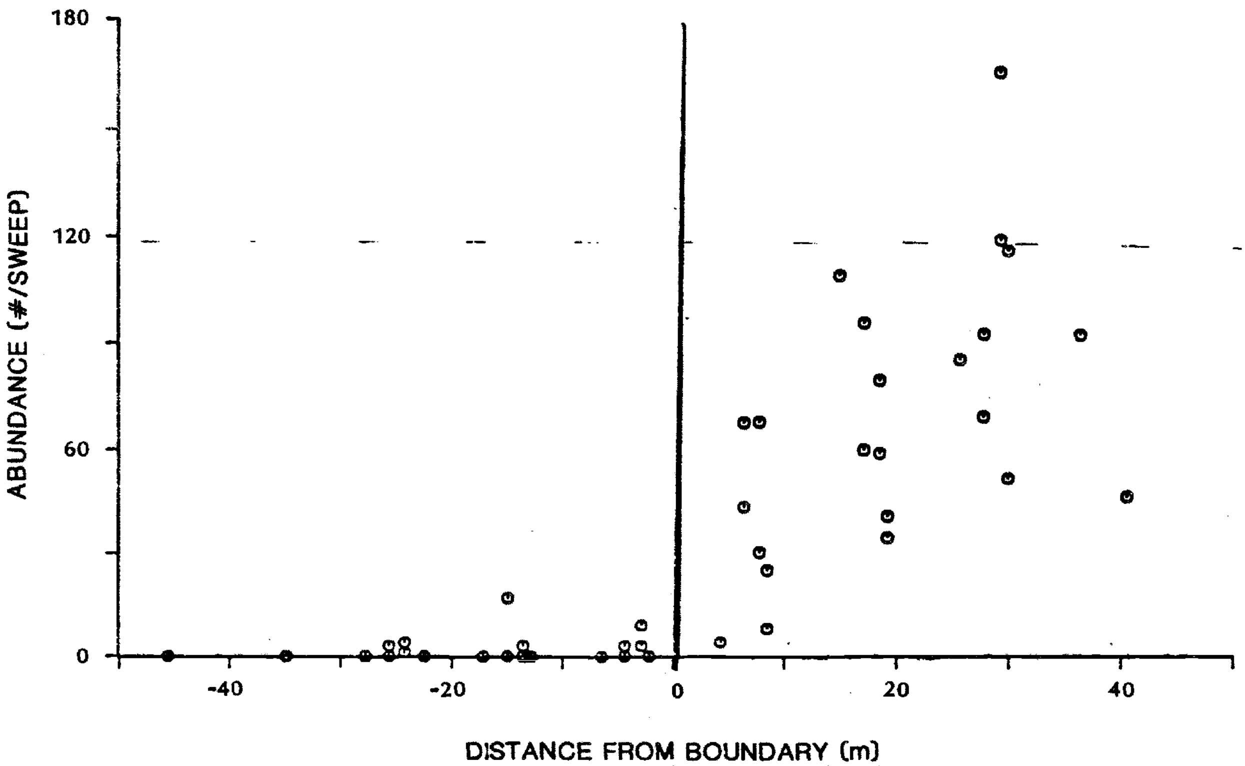


Figure 10.--Abundance of Labops hesperius as a function of sample distance from the boundary of reseeded range (right of midline) with unimproved range (left of midline) Ostlie 1979).

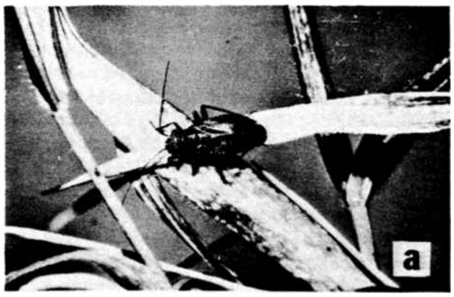
beneficial insects can be realized without resorting to the outright reestablishment of all the original elements of the native range. The strategies proposed for control of black grass bugs are simplified by the fact that the bugs have only one generation per year.

Egg destruction: burning and grazing--Inasmuch as black grass bug eggs usually are inserted in grass stems, they can be destroyed by burning or grazing before they hatch, thus interrupting the life cycle. Grass bugs of the species I. brachycera (Fig. 11) present a different problem than Labops because Irbisia appears to be more mobile.

Information obtained from studies of accidental and controlled burns (Haws 1978 p. 59; Haws 1982a p. 186-193; Huddleston and Smith 1982) suggests that burning lowers grass bug populations for several years. Because grass bugs migrate and reinfest fields slowly, thorough burning of pastures in the fall, when there was enough fuel to support a uniform burn, destroyed most eggs. In Utah, many Labops nymphs survived a spring burn by hiding in cracks in the soil while the fire passed over them. Todd and Kamm (1974) also proposed that removal of straw (where the bugs lay their eggs) by burning or grazing were feasible control strategies. They found an average of 7 nymphs in a burned area compared with 92 in a nonburned one. Their conclusion, after several studies of grass litter, was that reduction of straw preferred by the bugs for oviposition may reduce the densities of the bugs the following year. Hagen (1982) concluded after an eight-year study that L. hesperius populations can be reduced significantly by harvesting crested wheatgrass each year.

The principle of controlling bugs by grazing is the same as that for burning--destruction of the eggs in the fall, and its effectiveness also depends on the thoroughness of egg destruction (Kamm and Fuxa 1977). Undergrazing sometimes permits eggs to remain in the grass stems and develop their biological potential. Substantial reduction of bug populations has been successful where intense grazing by one or more species of livestock was applied, controlled with permanent or electrical fences. Some ranchers remove range litter containing eggs by allowing short periods of intense grazing in the fall and again in the spring. Management by grazing should not violate known principles of protecting the grass. Both in burning and grazing, islands of eggs in grasses that are not removed often provide enough eggs to reinfest an area. The most effective use of grazing that we have observed has been short periods of intense grazing by several kinds of animals at the same time (horses, cows, and sheep).

Insecticides.--Tests of chemicals in small plots and in practical field applications have resulted in effective, economical control and an understanding of certain aspects of the toxicology of black grass bugs (Brindley and Osman 1978; Haws 1979, 1982a; Huddleston and Smith 1982). The present control recommendation is 8 ounces (AI) ultra low volume (ULV) malathion per acre (.4 ha) at temperatures above 65° F (18°C) after all eggs have hatched (3-4 instar, approximately 28,000 GDH) and before the



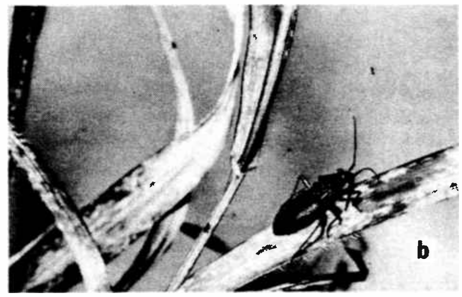
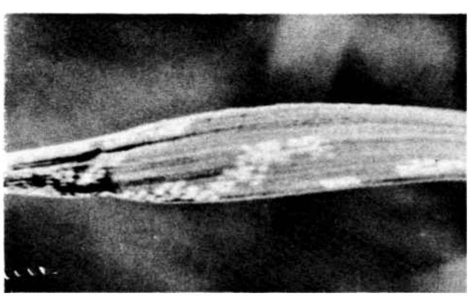


Figure 11.--Irbisia brachycera (a) and Irbisia pacifica (b) are being recognized as serious pests of crested wheatgrass and other grasses. Their damage is similar to that of Labops hesperius but they appear to be more mobile and less delicate.

females have laid their eggs. If more than one year of control can be gained from a single application of malathion, control is usually economically feasible (Glover 1982). Application of the ULV formulation by helicopter or fixed-wing aircraft (if terrain is not too irregular or difficult to permit thorough application of the insecticide) has proven effective in distribution of the toxicant. Our ground sprayer applications of emulsifiable malathion have also resulted in good control. If chemical control is necessary a second year because of poorly timed application of pesticide the previous year, the cost of control may be excessive. When the bugs are effectively controlled before the females lay their eggs, practical experience indicates that because the bugs reinfest or migrate into fields slowly, retreatment may not be necessary for several years. Todd and Kamm (1974) concluded that under their conditions losses attributed to Labops feeding usually didn't justify the use of insecticides.

Early identification of an infestation and proper application of a pesticide are essential elements for successful chemical control. The eggs hatch as snow melts and the nymphs begin to feed as soon as they hatch. This means very early inspection (look for bug damage or sweep fields with a net) of rangeland grasses is necessary (late March or early April and May, depending on the elevation and GDH). Fortunately, the total infestation intensity can be determined early because the bug population will not increase during the year. The eggs present in the spring represent the total potential infestation for that particular year. Close examination of the grasses may reveal the presence of bugs by their damage--whitish or yellowish feeding spots on the leaves. Young nymphs are difficult to see or capture but later instars (3-5), and their damage, are easier to see and are useful in determining the intensity of an infestation (Fig. 12). The general tendency is for range managers to wait until there is too much



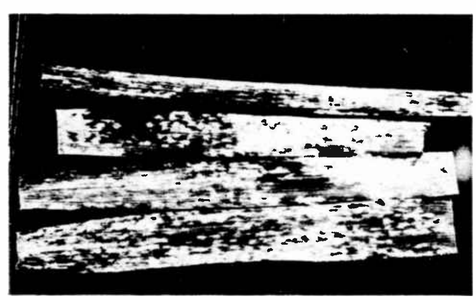


Figure 12.--When grass bug nymphs first hatch, and as the early instars develop, they are difficult to find; however, their damage to grasses is easier to find and utilize as an evidence of the intensity of an infestation. A light infestation (left) and a severe infestation (right).

damage to the grasses and until after the females have laid their eggs, before attempting control with chemicals or other strategies.

Grass bug eggs hatch and nymphs develop fairly uniformly in flat rangelands with a similar exposure to the sun, but have substantially different rates where land contours, elevations and exposures to sunlight influence the accumulation of growing degree hours. Both nymphal stages and adults may be found in clumps of crested wheatgrass (especially "wolf plants"--ungrazed grass containing tall dry stems) because the insects are exposed to various temperatures.

Varying conditions during the winter may also result in anomolous development of grass bugs. By the time the snow melts in the spring, late instars and extensive damage to grasses may already be present. This condition apparently results from winter thaws and temperatures above 40°F (4.4°C) in the microhabitat of the bugs. After the chill requirements of the bugs have been fulfilled, the eggs can hatch and nymphs continue their development on and off as temperature and weather conditions vary during the winter. Where the conditions result in uneven hatching, chemical control should be delayed until all the eggs have hatched.

Plant resistance.--Staff members of the USDA/ARS Crops Laboratory in Logan, Utah, have cooperated with USU entomologists and plant scientists since 1972 in studies of resistance of grasses to Labops. Differences among and within genera of grasses, and among clones and their crosses (Fig. 13) have been demonstrated by Asay et al. (1983), Hansen et al. 1985a, 1985b), Haws (1979, 1982a), Hewitt (1980), and Windig et al. (1983). Fields of intermediate wheatgrass frequently have more Labops than crested wheatgrass and sustain substantial damage (Todd and Kamm 1974; Higgins et al. 1977). Crested wheatgrass and its hybrids along with intermediate wheatgrass were the most susceptible; western wheatgrass was the least preferred. They note that reports of host plant preferences by different persons often are confusing and conflicting. For example, Hewitt (1980) concluded that intermediate wheatgrass was more resistant to Labops than western wheatgrass or bluebunch wheatgrass. Orchardgrass (Dactylis glomerata L.) and reed canarygrass (Phalaris

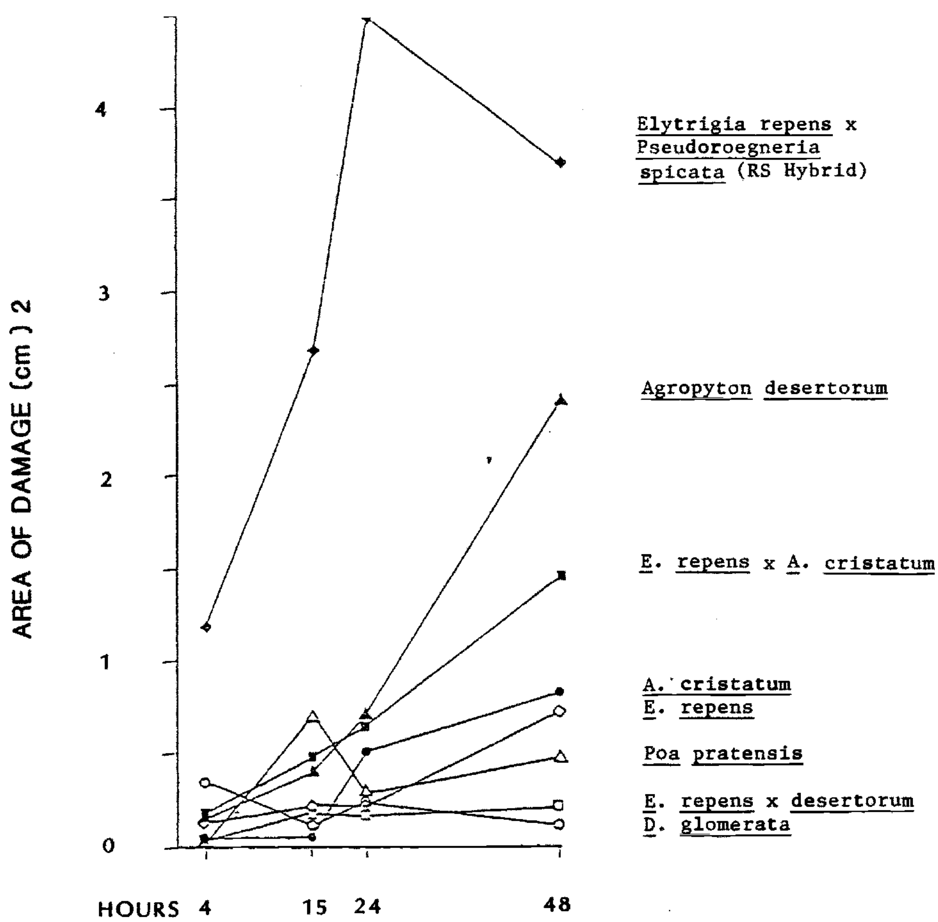


Figure 13.--Average amount of damage to eight grasses by Labops hesperius after 48 hours of feeding. Note that differences in damage become more distinct after 48 hours (Haws et al. 1982a).

arundinacea L.) have usually sustained little damage by black grass bugs in Utah tests (Hansen et al. 1985a; Windig et al. 1983), but Todd and Kamm (1974) list orchardgrass as a host. Campbell et al. (1984) have reviewed the literature concerning grass resistance to Labops.

It can be concluded that the relatively few grasses that have been compared for possible use in resistance as a management strategy show definite differences that might be incorporated into new resistant varieties (Fig. 14), such as intermediate wheatgrass and smooth brome (Bromus inermis Leyss.). There are many more species available for testing in grass breeding institutions and perhaps others to be found elsewhere. There is little doubt where grass is expected to be established for long periods of time that new resistant grasses offer one of the best management alternatives. There remains much to be done before resistant grasses can be expected to be available for practical use, even though the technical skills, germ plasm, and facilities to do most of the needed research are available. Asay (1986) has recently discussed the potential of using resistant grasses as a management strategy to lessen range pest damage.

In most breeding programs, plant characteristics imparting resistance to major pests are sought. To date, studies of only a few insects have been included in the development of resistant grasses. Resistance to other important insects, as well as to plant diseases and nematodes, must be investigated. The plants selected then have to be combined with plants having other desirable characteristics. Finally the new varieties should be fed to livestock to be sure that they are acceptable as forage.

Biological control: insect predators and parasites.--Studies of rangeland insect predators and parasites are few. Research by Araya (1982) indicates that spiders and damsel bugs (Hemiptera: Nabidae) (Fig. 15) are important predators of some range grass insects, including black grass bugs. Parasites of the hymenopterous family Scelionidae have been seen emerging from grass bug eggs reared in the laboratory (Haws 1978, p. 59, 60, 129). Female Labops were found parasitized by dipterous larvae and myrmenthid worms (Coombs 1985). The parasites appeared to render the infested females incapable of producing viable eggs. Our observations of predators feeding on captured hosts in the laboratory and in the field have indicated there is little doubt that large populations of damsel bugs, together with other predators and parasites, reduce grass bug populations. Many details concerning insect predators and parasites and methods of increasing their populations and utilizing them in management strategies are yet to be discovered. Biological controls are common, successful strategies in the solutions of some pest problems in crops and animals. It is reasonable to expect similar solutions can be developed for rangeland pests.

MYTHS ABOUT INSECTS AND CRESTED WHEATGRASS

It was suggested that contributors to the crested wheatgrass symposium call attention to "myths" related to this grass in view of our present status of knowledge. There are a few "myths" related to insects and crested wheatgrass.

Myth 1. Crested wheatgrass is the major host of L. hesperius.

For many years a general impression in the literature has been that crested wheatgrass is the major host of L. hesperius. Denning (1948) referred to L. hesperius as the crested wheatgrass bug. There is no doubt that L. hesperius damages crested wheatgrass severely, but there is substantial evidence that the species prefers at least one grass more than crested wheatgrass. Thomson[4] reported that intermediate wheatgrass was heavily infested with grass bugs, whereas adjacent crested wheatgrass was only lightly infested. Samples of L. hesperius from crested wheatgrass and intermediate wheatgrass in Salina Canyon, Utah, before a chemical control study began, showed there were more bugs in the intermediate wheatgrass (Table 3). This observation is verified in many of our resistance studies.

Myth 2. Labops hesperius is the major range grass pest.

Knowlton (1967) recognized there were various species of insects other than L. hesperius infesting range grasses, but there seemed to be a general use of the term "Labops" among many ranchers and other range specialists when they talked about injury to grasses by almost any black bugs. Pure populations of I. brachycera or mixtures of the two species have been found. I. brachycera may prove to be a more serious pest than Labops in some areas because the females of I. brachycera have functional flight wings while most Labops females do not. This difference in wing development allows I. brachycera to be more mobile than Labops. Other insect pests of crested wheatgrass, such as leafhoppers and click beetles (wireworms), and grub worms (larvae of beetles) may be important under some circumstances (Knight 1982).

Samples of range insects in the past few years suggest that leafhoppers are among the most abundant insects generally found. Studies of leafhoppers on other crops have shown that some of them carry viruses or microplasmas and infect plants with disastrous epidemics of diseases. The substances some sucking insects inject into plants are toxicogenic, and they may substantially change the phenology of plants (Sorenson 1946, Carlson 1940). Grasses are reported to be carriers of disease agents but generally they are immune to pathogenic impacts of viruses (Nielson).[5] Relatively little is known about the impacts of most leafhoppers found on rangeland grasses.

Billbugs are serious pests of crested wheatgrass and some other range grasses (Haws 1982a, p. 123, 136, 138; Nielson 1985). Studies of the biologies, impacts, and control of billbugs and other rangeland insects are underway.

[4] Thomson, R.R. 1969. Report on Labops hesperius. A reconnaissance survey on Labops populations on portions of the Dixie National Forest. In Range Insect Literature File R-8, Utah State Univ., Logan.

[5] M. W. Nielson, USDA/ARS (Ret.); Personal communication, October, 1984.

Figure 14.--Grasses evidently have genetic differences in their susceptibility to black grass bugs as shown by the amount of damage sustained by intermediate wheatgrass (left) compared with smooth brome (right), growing together in an area infested by Irbisia pacifica.

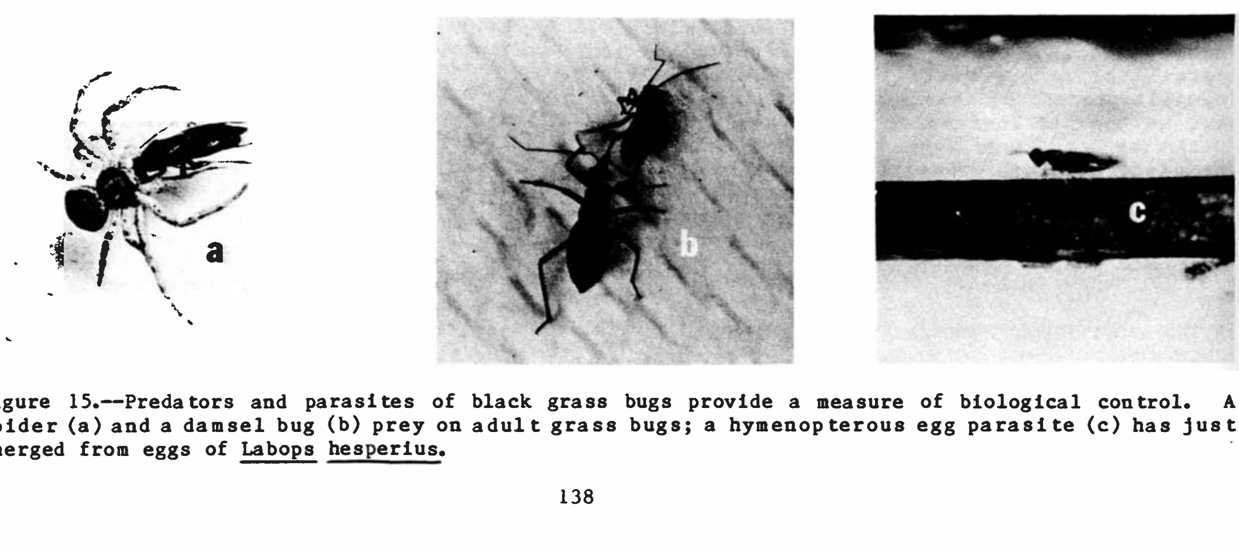


Figure 15.--Predators and parasites of black grass bugs provide a measure of biological control. A spider (a) and a damsel bug (b) prey on adult grass bugs; a hymenopterous egg parasite (c) has just emerged from eggs of Labops hesperius.

Table 3.--Black grass bug (Labops hesperius) concentrations on crested wheatgrass and intermediate wheatgrass during a study of malathion as a chemical control.

Plot[1]	Crested Wheatgrass[2]	Plot	Intermediate Wheatgrass[2]
1	42	26	139
2	45	27	61
3	37	32	203
4	183	33	543
5	66	36	59
7	95	38	144
8	50	39	57
	Mean = 65	40	171
		41	121
		42	226
		43	109
			Mean = 167

[1]Plots of 1/2 acre (.2 ha) each.
[2]Number of bugs per 6 sweeps

Myth 3. Long term rest rotation benefits range grasses.

Benefits of long term rest rotation are not likely if a range is heavily infested by certain insects. The insects continue to "graze" and multiply even if the larger livestock are removed.

A commonly described problem in grasslands is overgrazing, but from the entomological point of view, many of the problems associated with insects have resulted from undergrazing. The problem of undergrazing is that plant litter provides a place for some insects to lay eggs and be protected from unfavorable weather. Range managers can effectively control grass bugs by grazing early to remove eggs inserted in the grass stems. Some of the intensive, short term grazing regimes implemented by certain managers (before bug eggs have hatched) provide an economical, effective control strategy, if the grazing is done in accord with proper range management practices (i.e. not overgrazing at critical periods of grass growth and development).

The oft proposed rule of thumb about grazing, "take half and leave half," nullifies its possibility of controlling grass bugs because most eggs are found in the lower parts of the plants. Empirical studies suggest that eggs of L. hesperius do not survive a trip through the digestive tract of grazing animals. We have observed heavily grazed fields to be practically free of grass bugs while nearby ungrazed fields may be infested. Long-term rest rotations, like inadequate grazing, often allow the majority of black grass bug eggs to hatch unmolested.

SUMMARY AND CONCLUSIONS

1. USU range grass insect research concentrated on the black grass bug, Labops hesperius. This emphasis has been a response to requests for help from state, federal, and private owners and users of range grasses. We have worked with a number of introduced grasses, including pure stands of crested wheatgrass, but for this symposium we have sorted through our data and insect collections to find out what we know specifically about crested wheatgrass.

2. Reports of insect damage to crested wheatgrass by black grass bugs date back to at least the late 1930s in various western states. Cooperative efforts to gather information about insects in grasses of Utah and attempts to apply chemical controls were documented in the 1960s. Using the combined knowledge and experience of scientists and ranchers, six management strategies have been explored in varying degrees. These strategies involve planting (monocultures vs mixes), grazing, burning, development of resistant varieties, biological control, and chemical control. The status of each strategy is discussed.

3. Approximately 160 species of insects were collected from crested wheatgrass. Other insects have also been reported from grasses and these reports are summarized and discussed. The total number of insect species found on crested wheatgrass and their impacts are unknown and under only preliminary investigation. Insects are part of the range grass ecosystem, and they should be put on our check list when we are looking for ways to improve or manage ranges, plan research, or diagnose problems with range grasses.

4. Many of the serious problems with insects in crested wheatgrasses and other range grasses appear to be related to traditional methods of range management, such as planting monocultures, grazing at the wrong times and intensities, planting susceptible varieties, etc. We have learned to cope with problems of many crops grown as monocultures, and we can do the same with grasslands.

5. Range researchers need to include insect-free grass plots as checks or controls in studies of physiology, nutrition, establishment, quality and quantity of forage and seed yields, longevity of stands, soil genesis, penetration of water and air into soils, soil erosion, hydrology, economics, and most other aspects of range improvement and management.

6. A major gap in our information regarding crested wheatgrass and other grasses is the effects of various pests (insects, nematodes, diseases, etc.) on grass phenology. Normal as compared to anomolous phenology, brought about by these pests or by other stresses, must be known in order to select resistant varieties, and to diagnose other problems with range grasses.

7. The main principles of management strategies proposed for controlling insects that inhabit grasses are: (1) break the insect cycles in the egg stage; (b) implement chemical controls after all insects are hatched in the spring, but before they mature and lay their eggs; (c) inspect ranges on a regular basis to detect infestations before critical damage occurs and it is too late to apply effective control; (d) obtain information about the different grazing behavior of sheep, cattle, goats, horses, and perhaps exotic animals (such as llamas), and integrate this with control strategies. Each range may require specific kinds of management based

on information that is unique to a particular area (e.g. a collection of insects or information about growing degree hours, average precipitation, contours of terrain, etc.).

8. The essential biological information required to implement IIPM principles for improvement and management of ranges is available for only a few insects. Little is known about underground pests of grasslands, e.g. cutworms, white grubs, wireworms, etc. Chemical and physical plant characteristics associated with the attraction or repugnance of grasses to animals must be identified for use by plant breeders and range managers. The comparative palatability of grasses to livestock and insects should be determined. Critical information about the most important injurious and beneficial insects needs to be obtained.

9. Little is known about the interrelationships of insects and mixtures of plants in grassland ranges, e.g. the impacts of mixing alfalfa with grasses. Will it increase problems with insects or decrease them? Which mixtures of grasses, forbs, or shrubs favor or retard insect development? Which plants need to be included to provide food and habitat for beneficial insects? Which mixtures provide a balanced, steady state condition requiring the least expense and monitoring? Interdisciplinary research groups have much to contribute to answering these questions.

10. Problems of biological pollution of our ranges by insects and weeds that develop in the thousands of acres of grasses and other plants growing along our freeways, should be investigated. Cursory studies and observations suggest that the freeways (largely unmanaged) may be a main source of contamination of many rangelands. Our observations indicate more than ten times as many grasshoppers can be found in weedy crested wheatgrass than in weed-free grass nearby.

11. Apparent conflicts in the range literature about densities of insect populations, extent and intensity of insect damage, and impacts on forage, seed and longevity of grasses, may stem from true differences in climatic factors, methods of management, and other conditions. Differences such as those found in various states concerning the impacts of *Labops* on host grasses, emphasize the importance of repeating research in different ecological conditions.

12. Range economists and climatologists can increase the precision of their economic predictive models if they have additional, accurate biological information about factors that influence variations in yields, nutritional values, cost/benefits, etc. Biologists and range specialists need to help provide this information.

PUBLICATIONS CITED

Ansley, R.J. Jr. 1979. The influence of black grass bugs and cattle on the vigor of crested wheatgrass. MS Thesis. Utah State Univ., Logan. 85 p.

Ansley, R.J., C.M. McKell, D.J. Schimpf and H.W. Wiebe. 1978. Effects of grazing by insects and livestock on some growth characteristics of crested wheatgrass, p. 32-34; 145-166. In: B.A. Haws (comp.). Economic impacts of *Labops hesperius* on the production of high quality range grasses. Final report, Four Corners Regional Commission Contract T/A 6XI-366-028. Utah State Univ., Logan.

Ansley, R.J. and C.M. McKell. 1982. Crested wheatgrass vigor as affected by black grass bug and cattle grazing. J. Range Manage. 35:586-590.

Araya, E.J. 1982. Studies of selected predators of black grass bugs on ranges in Utah. MS Thesis. Utah State Univ., Logan. 102 p.

Asay, K.H. 1986. Revegetation in the sagebrush ecosystem. In: J.A. Onsager (ed.). IPM on rangelands: state of the art in the sagebrush ecosystem. USDA Agr. Res. Serv. (in press).

Asay, K.H., J.D. Hansen, B.A. Haws and P.O. Currie. 1983. Genetic differences in resistance of range grasses to the bluegrass billbug *Spenophorus parvulus* (Coleoptera: Curculionidae). J. Range Manage. 36:771-772.

Barkworth, M.E., D.R. Dewey and R.J. Atkins. 1983. New generic concepts in the Triticeae of the Intermountain Region: key and comments. Great Basin Natur. 43:561-572.

Bohning, J.W. and W.F. Currier. 1967. Does your range have wheat grass bugs? J. Range Manage. 20:265-267.

Bowers, D.M. 1976. Insect consumption of seeded rangeland herbage in a selected area of Diamond Fork Canyon, Utah County, Utah. MS Thesis. Utah State Univ., Logan. 45 p.

Brindley, W.A. and D. Osman. 1978. Chemical control, p. 51-56. In B.A. Haws (comp.). Economics impacts of *Labops hesperius* on the production of high quality range grasses. Final report, Four Corners Regional Commission Contract T/A 6XI-366-028. Utah State Univ., Logan.

Campbell, W.F., K.H. Asay, J.D. Hansen and B.A. Haws. 1984. A review of black grass bug resistance in forage grasses. J. Range Manage. 37:365-369.

Capinera, J.L. and T.S. Sechrist. 1982. Grasshoppers (Acrididae) of Colorado: identification, biology and management. Colorado Agr. Exp. Sta. Bull. 584S. 161 p.

Carlson, J.W. 1940. Lygus bug damage to alfalfa in relation to seed production. J. Agr. Res. 61:791-815.

Cook, C.W. 1966. Development and use of foothill ranges in Utah. Utah Agr. Exp. Sta. Bull. 461. 45 p.

Cook, C.W. 1967. Effects of season, spacing, and intensity of seeding on the development of foothill range grass stands. Utah Agr. Exp. Sta. Bull. 467. 73 p.

Coombs, E.M. 1985. Growth and development of the black grass bug (Labops hesperius Uhler) in the state of Utah. MS Thesis. Utah State Univ., Logan. 163 p.

Denning, D.G. 1948. The crested wheatgrass bug. Wyoming Agr. Exp. Sta. Circ. 33. 2 p.

Dewey, D.R. 1983. Historical and current taxonomic perspectives of Agropyron, Elymus, and related genera. Crop Sci. 23:637-642.

Enkerlin, S. D. and C.P. Velarde. 1973. Evaluacion de la efectividad de siete insecticidas para el control del la mosca pinta (Aeneolamia spp. y Prosapia spp.) en la Region de Valles, S.L.P. Institutio Tecnologico y de Estudios Superiores de Monterray. Monterray, Mexico.

Fuxa, J.R. 1975. Biological attributes and alternatives and alteration of habitat to manipulate populations of Labops hesperius Uhler (Heteroptera: Miridae). MS Thesis. Oregon State Univ., Corvallis. 199 p.

Fuxa, J.R. and J.A. Kamm. 1976a. Effects of temperature and photoperiod on the egg diapause of Labops hesperius Uhler. Environ. Entomol. 5:505-507.

Fuxa, J.R. and J.A. Kamm. 1976b. Dispersal of Labops hesperius on rangeland. Ann. Entomol. Soc. Amer. 69:891-893.

Glover, T.F. 1978. Economics and selection of management alternatives (Predictive Models), p. 61-68, and Economics of range pest control strategy, p. 167-175. In: B.A. Haws (comp.). Economic impacts of Labops hesperius on the production of high quality range grasses. Final report, Four Corners Regional Commission Contract T/A 6XI-366-028. Utah State Univ., Logan.

Glover, T.F. 1982. Economics of rangeland improvements via pest control, p. 209-213. In: B.A. Haws (comp.). Interdisciplinary integrated pest management (IIPM) research to improve range--lands, management, and policies. Report, Four Corners Regional Commission Project 602-466-080-4. Utah State Univ., Logan.

Hagen, A.F. 1982. Labops hesperius (Hemiptera: Miridae) management in crested wheatgrass by haying: an eight-year study. J. Econ. Entomol. 75:706-707.

Hansen, J.D. 1986. Differential feeding on range grass seedlings by Irbisia pacifica (Hemiptera: Miridae). J. Kansas Entomol. Soc. 59: 199-203.

Hansen, J.D., K.H. Asay and D.C. Nielson. 1985a. Screening range grasses for resistance to black grass bugs Labops hesperius and Irbisia pacifica (Hemiptera: Miridae). J. Kansas Entomol. Soc. 58:251-254.

Hansen, J.D., K.H. Asay and D.C. Nielson. 1985b. Feeding preferences of a black grass bug, Labops hesperius (Hemiptera: Miridae) for 16 range grasses. J. Kansas Entomol. Soc. 58:356-359.

Haws, B.A. 1972. Preliminary report on black grass bug Labops hesperius Uhler. USDA For. Serv. Intermountain Reg. Range Improve. Notes. 17(2):1-3.

Haws, B.A. 1975. The taxonomy, biology and control of grass bugs (Labops hesperius) affecting introduced wheatgrass and certain native species in Utah and surrounding areas. Final Report, USDA Agricultural Research Service Agreement 122-14-10 9972(33). Utah State Univ., Logan. 61 p.

Haws, B.A. 1979. Something is eating more grass than our livestock. Rangelands 1:135-138.

Haws, B.A. (comp.). 1978. Economic impacts of Labops hesperius on the production of high quality range grasses. Final Report, Four Corners Regional Commission Contract T/A 6XI-366-028. Utah State Univ.,Logan. 269 p.

Haws, B.A. (comp.). 1982a. Interdisciplinary integrated pest management (IIPM) research to improve range--lands, management, and policies. Report, Four Corners Regional Commission Project 602-466-080-4. Utah State Univ., Logan. 282 p.

Haws, B.A. (comp.). 1982b. An introduction to beneficial and injurious rangeland insects of the Western United States. Four Corners Regional Commission Spec. Rep. 23. Utah Agr. Exp. Sta., Logan. 64 p.

Haws, B.A., D.D. Dwyer and M.G. Anderson. 1973. Problems with range grasses? Look for black grass bugs. Utah Sci. 34:3-9.

Hewitt, G.B. 1980. Tolerance of 10 species of Agropyron to feeding by Labops hesperius. J. Econ. Entomol. 73:779-782.

Hewitt, G.B., E.W. Huddleston, R.J. Lavigne, D.N. Ueckert and J.G. Watts. 1974. Rangeland entomology. Range Sci. Ser. 2. Soc. Range Manage., Denver, Colo. 127 p.

Hewitt, G.B. and J.A. Onsager. 1982. Grasshoppers: yesterday, today, and forever. Rangelands 4:207-209.

Higgins, K.M. 1975. The effects of the black grass bug (Labops hesperius Uhler) on several native and introduced grasses. MS Thesis. Utah State Univ., Logan. 81 p.

Higgins, K.M., J.E. Bowns and B.A. Haws. 1977. The black grass bug Labops hesperius Uhler, its effect on several native and introduced grasses. J. Range Manage. 30:380-384.

Huddleston, E.W. and W. Smith. 1982. Impact and control of the black grass bug, Labops hesperius, in New Mexico, p. 83-85. In: B. A. Haws (comp.). Interdisciplinary integrated pest management (IIPM) research to improve range--lands, management, and policies. Report, Four Corners Regional Commission Project 602-466-080-4. Utah State Univ., Logan.

Huffaker, C.B. 1980. New technology of pest control. John Wiley & Sons, New York. 500 p.

Jensen, F. 1971. Reseeding and Labops. USDA For. Serv. Intermountain Reg. Range Improve. Notes 16(1):6-9.

Kamm, J.A. 1974. Labops, a plant bug, on Oregon rangeland. Oregon Ext. Serv. Circ. FS211. 2 p.

Kamm, J.A. 1979. Plant bugs: effects of feeding on grass seed development; and cultural control. Environ. Entomol. 8:73-76.

Kamm, J.A. and J.R. Fuxa. 1977. Management practices to manipulate populations of the plant bug Labops hesperius Uhler. J. Range Manage. 30:385-387.

Kamm, J.A. and P.O. Ritcher. 1972. Rapid dissection of insects to determine ovarial development. Ann. Entomol. Soc. Amer. 65:271-274.

Knight, J.B. 1982. An initial survey of the insects associated with five grassland sites in Central Utah. MS Thesis. Utah State Univ., Logan. 83 p.

Knight, J.B. and R.W. Lauderdale. 1982. Nevada Section Final Report to Four Corners Commission, Rangeland Improvement Demonstration Project, p. 51-81. In: B. A. Haws (comp.). Interdisciplinary integrated pest management (IIPM) research to improve range--lands, management, and policies. Report, Four Corners Regional Commission Project 602-466-080-4. Utah State Univ., Logan.

Knowlton, G.F. 1945. Labops damage to range grasses. J. Econ. Entomol. 38:707-708.

Knowlton, G.F. 1967. Grass bugs: a serious range problem in 1966. Utah Acad. Sci., Arts and Letters 43:20-21.

Lindsay, H.G. 1970. A serious threat: black grass bugs. Utah Farmer 90(15):12. (Aug. 6)

Malechek, J.C., A.M. Gray and B.A. Haws. 1977. Yield and nutritional quality of intermediate wheatgrass infested by black grass bugs at low population densities. J. Range Manage. 30:128-131.

Markgraff, P.M. 1974. Effects of wheatgrass bug infestation on range grasses, p. 31. In: Abstracts, 27th Annual Meeting, Society for Range Management, Tucson, Ariz. Soc. Range Manage., Denver, Colo.

Metcalf, R.L. and W.H. Luckmann. 1982. Introduction to insect pest management. 2nd ed. John Wiley & Sons, New York. 577 p.

Nielson, D.C. 1985. Factors affecting feeding injury to grasses by adult billbugs (Coleoptera: Curculionidae). MS Thesis. Utah State Univ., Logan. 57 p.

Ostlie, K.R. 1979. Labops hesperius Uhler: abundance and dispersal in relation to vegetation. MS Thesis. Utah State Univ., Logan. 184 p.

Paraqueima, O.L. 1977. Some effects of different temperatures on the development of the black grass bug (Labops hesperius Uhler) from the egg through the adult stage. MS Thesis. Utah State Univ., Logan. 84 p.

Richardson, E.A. 1984. Prediction of rangeland growth and production using climatic factors. Progress report 1982-1983. USDI Bur. Land Manage. Contract YA-553-CTI-123. Utah State Univ., Logan. 81 p.

Richardson, E.A., T.F. Glover and B.A. Haws. 1983. Weather and range management. Utah Sci. 44:23-27.

Richardson, E.A., S.D. Seeley and D.R. Walker. 1974. A model for estimating the completion of rest for Red Haven and Alberta peach trees. Hort. Sci. 9:331-332.

Sorensen, C.J. 1946. Mirid-bug injury as a factor in declining alfalfa seed yields. Fifth Annual Research Lecture. Faculty Assoc. Utah State Agr. Coll., Logan.

Spangler, S.M. 1984. Arthropod fauna of reseeded rangelands: effects of vegetation structure. MS Thesis. Utah State Univ., Logan. 81 p.

Thomas, D.B. and F. G. Werner. 1981. Grass feeding insects of the western ranges: an annotated checklist. Utah Agr. Exp. Sta. Tech. Bull. 243. 50 p.

Todd, J.G. 1974. Labops hesperius Uhler: biology and impact on Oregon rangelands (Hemiptera: Miridae). MS Thesis. Oregon State Univ., Corvallis. 74 p.

Todd, J.G. and J.A. Kamm. 1974. Biology and impact of a grass bug Labops hesperius Uhler in Oregon rangeland. J. Range Manage. 27:453-458.

Watts, J.G., E.W. Huddleston and J.C. Owens. 1982. Rangeland entomology. Ann. Rev. Entomol. 27:283-311.

Wiebe, H.L., D.J. Schimpf, C.M. McKell and J. Ansley. 1978. Physiological effects of grass bug feeding and resistance, p. 28-32. In: B.A. Haws (comp.). Economic impacts of Labops hesperius on the production of high quality range grasses. Final report, Four Corners Regional Commission Contract T/A 6XI-366-028. Utah State Univ., Logan.

Windig, W., H.L.C. Meuzelaar, K.H. Asay, W. F. Campbell and B.A. Haws. 1983. Biochemical differences observed in pyrolysis mass spectra of range grasses with different resistance to Labops hesperius Uhler attack. J. Anal. Applied Pyrolysis 5:183-198.

APPENDIX

Insects of crested wheatgrass collected from Curlew Valley, Box Elder County, Utah by G. E. Bohart, June-August, 1973-74.

Order/Family	Genus & Species	Apparent significance as a visitor of crested wheatgrass*	Nature of insect impact on host
Coleoptera			
Anthicidae	Notoxus serratus	1	chews fruit (?)
Chrysomelidae	Psylliodes sp.	2	skeletonizes leaves
Coccinellidae	Hippodamia convergens	3	preys on aphids
	Hyperaspis fastidiosus	2	preys on aphids
Melyridae	Listrus sp.	2	feeds on pollen
	Listrus interruptus	3	feeds on pollen
Histeridae	Saprinus desertorum	1	preys on scavengers
Leiodidae	undetermined sp.	1	feeds on fungi
Melyridae	Collops utahensis	2	preys on aphids
Staphylinidae	undetermined sp.	2	preys on soil
Collembola			
Sminthuridae	undetermined sp.	2	chews shoot epidermis
Diptera			
Agromyzidae	Agromyza albertensis	3	mines leaves
	Liriomyza sp.	3	mines leaves
	Melanomyza virens	2	mines leaves
	Phytomyza sp.	3	mines leaves
Anthomyiidae	Hylemya cinerella	2	feeds on roots
	Hylemya platura	3	feeds on roots
Bibionidae	Bibio albipennis	1	feeds on decayed veg.
Bombyliidae	Exoprosopa calyptera	2	feeds on grasshopper eggs
	Geron sp.	2	parasitizes insects
	Mythicomyia sp.	2	parasitizes small insects
Cecidomyiidae	undetermined sp. #1	2	makes galls or bores stems
	undetermined sp. #2	2	makes galls or bores stems
	undetermined sp. #3	2	makes galls or bores stem
	undetermined sp. #4	3	makes galls or bores stem
	undetermined sp. #5	2	makes galls or bores stems
Ceratopogonidae	undetermined sp. #1	1	feeds on decayed veg.
	undetermined sp. #2	1	feeds on decayed veg.
	Dasyhelea sp.	1	feeds on decayed veg.
	Forcipomyia sp.	1	feeds on decayed veg.
	Leptoconops sp.	1	feeds on decayed veg.
Chamaemyiidae	Leucopis sp.	3	preys on psyllids
Chironomidae	Chironomus sp.	1	feeds on dead aquatic veg.
	Conioscinella sp.	3	feeds on plants
	Olcella sp.	3	feeds on plants
	Oscinella sp.	2	feeds on plants
	Siphonella sp. #1	2	feeds on plants
	Siphonella sp. #2	3	feeds on plants
	Thaumatomyia apropinqua	3	preys on root aphids
Culicidae	Aedes dorsalis	1	feeds on dead aquatic veg.
Empididae	Drapetis sp.	2	preys on insects
Ephydridae	Hydrellia sp.	1	feeds on equatic plants
	Philygria debilis	3	bores in stems
Muscidae	Haematobia irritans	1	feeds on fresh manure
	Schoenomyza dorsalis	2	bores in stems(?)
Phoridae	undetermined sp.	1	various for family
Pipunculidae	Pipunculus	3	parasitizes leafhoppers
	Prothecus sp.	2	parasitizes leafhoppers
Sarcophagidae	Senotainia rubriventris	1	parasitizes aculeate Hymenoptera
Scenopinidae	Scenopinus albifasciatus	2	
Sciaridae	undetermined sp. #1	3	feeds on decayed veg.
	undetermined sp. #2	3	feeds on decayed veg.
	undetermined sp. #3	2	feeds on decayed veg.
Syrphidae	Eupeodes volucris	1	preys on aphids
	Scaeva pyrastri	1	preys on aphids
Tachinidae	Hyalomyia aldrichii	2	parasitizes true bugs

Tephritidae	Paroxyna clathrata	2	makes galls (?)
	Trupanea jonesi	2	makes galls in comp. heads
	Trupanea bisetosa	2	makes galls in comp. heads
Tethinidae	Pelomyia coronata	3	feeds on decayed veg.
Therevidae	Psilocephala costalis	1	preys on soil insects
Hemiptera			
Anthocoridae	Orius tristicolor	3	preys on thrips
Lygaeidae	Nyssius minutus	3	sucks sap
	Peritrechus saskatchewanensis		preys on insects
Miridae	Clivinema sp.	2	sucks sap
	Coquillettia sp.	2	sucks sap
	Irbisia brachycera	3	sucks sap
	Leptoterna ferrugata	3	sucks sap
	Litomiris sp.	3	sucks sap
	Orthotylus sp.	3	sucks sap
	Stenodyma virens	3	sucks sap
	Trigonotylus ruficornis	3	sucks sap
Nabidae	Nabis alternatus	3	preys on mirid bugs
Pentatomidae	Aelia americana	3	sucks sap
	Thyanta pallidovirens	2	sucks sap
Rhopalidae	Liorrhyssus hyalinus	2	sucks sap
Homoptera			
Aphididae	Acyrthosiphon dirhodum	3	sucks sap
	Acyrthosiphon sp.	2	sucks sap
Cicadellidae	Aplanus albida	3	sucks sap
	Athysanella sp.	3	sucks sap
	Auridius sp.	3	sucks sap
	Balclutha neglecta	3	sucks sap
	Ballana sp.	2	sucks sap
	Commellus sp.	3	sucks sap
	Dikraneura carneola	3	sucks sap
	Empoasca alboneura	2	sucks sap
	Hebecephalus sp.	2	sucks sap
	Parabolocratus sp.	3	sucks sap
	Psammotettix sp.	3	sucks sap
Delphacidae	Delphacodes campestris	2	sucks sap
Issidae	Aphalonema sp.	3	sucks sap
Psyllidae	Aphalara sp.	2	sucks sap
Hymenoptera			
Braconidae	Adialytus sp.	3	parasitizes aphids
	Apanteles sp.	2	parasitizes Lepidoptera
	Apanteles bedelliae	3	parasitizes Lepidoptera
	Bracon sp.	2	probably parasitizes Lepidoptera
	Bracon gelechiae	3	parasitizes Lepidoptera
	Chelonus sericeus	2	parasitizes Lepidoptera
	Hormius sp.	2	parasitizes Lepidoptera
	Lysiphlebus utahensis	2	parasitizes aphids
	Microctonus sp.	2	parasitizes beetles
	Microplitis sp.	2	parasitizes Lepidoptera
	Opius nr. chewaucanus	3	parasitizes Diptera
Chalcididae	Spilochalcis side	2	parasitizes Lepidoptera, Hymenoptera
Encyrtidae	Copidosoma sp.	3	parasitizes Lepidoptera
	Psuedoencyrtus sp.	3	parasitizes scale insects
Eucoilidae	Hexacola sp.	2	parasitizes insects
Eulophidae	Chrysocharini sp. #1	2	parasitizes Diptera
	Chrysocharini sp. #2	3	parasitizes Diptera
	Diaulinopsis callichroma	2	parasitizes leaf mining Diptera
	Diglyphus begini	2	parasitizes leaf mining Diptera
	Diglyphus intermedia	2	parasitizes leaf mining Diptera
	Diglyphus websteri	3	parasitizes leaf mining Diptera
	Hemiptarsenus americanus	2	parasitizes insects
	Necremnus sp.	2	parasitizes snout beetles
	Notanisomorpha sp.	2	parasitizes leaf mining Diptera
	Sympiesis sp.	2	parasitizes leaf miners, rollers (Lepidoptera)
	Tetrastichus sp. #1	3	parasitizes insects

	Tetrastichus sp. #2	2	parasitizes insects
	Tetrastichus sp. #3	2	parasitizes insects
	Zagrammosoma sp. #1	2	parasitizes acalyptera Diptera
	Zagrammosoma sp. #2	3	parasitizes acalypterate Diptera
Eurytomidae	*Harmoleta* sp. #1	2	bores grass stems
	Harmoleta sp. #2	3	bores grass stems
Formicidae	*Formica rufa*	2	feeds on honeydew
	undetermined sp.	2	feeds on honeydew
Ichneumonidae	*Gelis* sp.	2	feeds on honeydew parasitizes insects
	Diadegma insulare	2	parasitizes insects
	Temelucha sp.	3	parasitizesmicro Lepidoptera
Mymaridae	undetermined sp. #1	2	parasitizes insects
	undetermined sp. #2	3	parasitizes insect eggs
Platygasteridae	*Platygaster* sp.	2	parasitizes insect eggs
Pteromalidae	undetermined sp. #1	2	parasitizes insect eggs
	undetermined sp. #2	2	parasitizes insects
	undetermined sp. #3	2	parasitizes insects
	undetermined sp. #4	2	parasitizes insects
	Habrocytus sp. #1	2	parasitizes insects
	Habrocytus sp. #2	3	parasitizes insects
	Homoporus sp.	2	parasitizes insects
	Neocatolaccus sp.	2	parasitizes beetles
	Pachyneuron allograpta	2	Parasitizes parasitic Hymenoptera
	Sphegigastrini sp. #1	2	parasitizes insects, their parasites
	Sphegigastrini sp. #2	2	parasitizes mostly Diptera
	Sphegigastrini sp. #3	3	parasitizes mostly Diptera
	Sphegigastrini sp. #4	4	parasitizes mostly Diptera
	Sphegigastrini sp. #5	3	parasitizes mostly Diptera
Scelionidae	*Scelio opacus*	2	parasitizes mostly Diptera
	Trimorus sp.	2	parasitizes grasshopper eggs
	Trissolcus utahensis	2	parasitizes pentatomid eggs
Torymidae	*Torymus thalassinus*	2	parasitizes eurytomids (stem borers)
Trichogrammatidae	undetermined sp. #1	2	parasitizes insect eggs
	undetermined sp. #2	2	parasitizes insect eggs
Lepidoptera			
Lyonetiidae	*Bucculatrix* sp.	2	chews leaves
Plutellidae	*Plutella xylostella*	2	skeletonizes leaves
Neuroptera			
Chrysopidae	*Chrysopa* sp.	2	preys on aphids
Hemerobiidae	*Micromus variolosus*	2	preys on small, soft insects
Orthoptera			
Acrididae	*Amphitornus coloradus*	2	chews on leaves, stems
	Aulocara elipti	3	chews on leaves, stems
	Melanoplus sp.	2	chews on leaves, stems
Strepsiptera			
Halictophagidae	undetermined sp.	3	parasitizes leafhoppers
Thysanoptera			
Thripidae	*Frankliniella* sp. #1	2	rasps plant epidermis
	Frankliniella sp. #2	3	rasps plant epidermis
	Frankliniella sp. #3	3	rasps plant epidermis
	Scolothrips sexmaculatus	2	preys on mites

*Explanation of code numbers for apparent significance:
1. accidental
2. scarce, possibly accidental
3. abundant, probably not accidental

In: Johnson, K. L. (ed.). 1986. Crested wheatgrass: its values, problems and myths; symposium proceedings. Utah State Univ., Logan.