AUTHORIZATION TO PROCEED WITH THE FINAL DRAFT

This thesis of Berta Ann Youtie for the Master of Science degree with a major in Entomology and titled "The Insect Fauna associated with Great Basin wildrye (Elymus cinereus Scribn. & Merr) in southern Idaho" was reviewed in rough draft form by each committee member as indicated by the signatures and dates given below and permission was granted to prepare the final copy incorporating the suggestions of the Committee; permission was also given to schedule the final examination.

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ABSTRACT

Herbivorous and parasitic insect guilds associated with Great Basin wildrye (*Elymus cinereus* Scribn. & Merr) were investigated at the Idaho National Engineering Laboratory and Craters of the Moon National Monument during 1982 and 1983. Life-stage, abundance, plant part utilized and study site were recorded for each insect species collected. Forty-six species of phytophagous insects were observed feeding on various anatomical regions of the bunchgrass. Eight parasitoid species were reared from insect hosts in the plant culms and identified.

The relatively high diversity of phytophages on basin wildrye was likely due to its tall, caespitose growth form, its abundance within its habitat, its broad geographic range, and the large number of related species of grasses in the region. The majority of the species that constitute the wildrye herbivore guilds were oligophagous (restricted to grasses). Many of the species identified are known to feed on grain crops as well as other native and introduced grasses.

The wheat stem sawfly (*Cephus cinctus* Nort., Hymenoptera: Cephidae), a pest species associated with wheat, feeds internally in basin wildrye culms. The life history of this insect on wildrye and its impact on seed production of the bunchgrass were examined. From 62 to 88% of wildrye plants were infested with the sawfly. Adults sawflies

emerged from wildrye culms at the time the inflorescences emerged from the grass sheaths. Larvae developed within culms, consumed vascular tissues and may have impaired transport of water and carbohydrates through the culm. Seed weight and number of caryopses developing within wildrye florets were significantly reduced in culms containing sawfly larvae ($p<0.006$, $p<0.018$, respectively). Differences in germination rates of seeds from infested and noninfested culms were not significant ($p>0.05$).

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INTRODUCTION

Herbivory, the consumption of plant tissues by animals (Krebs 1978), is an important ecological process and evolutionary force (Ehrlich and Raven 1964). Herbivores are a special group of predators that do not necessarily kill their hosts. Evidence extending through the fossil record from the Precambrian (Garrett 1970, Awramik 1971) documents the continuous importance of herbivory as a regulator of the distribution and abundance of both plants and herbivores. Until recently, plant ecologists have under-estimated its relevance (Gillett 1962) and given much more attention to physical factors such as climate and soils. The natural evolution of plants is subject to multiple pressures of which insect herbivory is just one. Plants have evolved many chemical and morphological barriers to reduce the impact of herbivory. Conversely, herbivores have evolved means of penetrating these plant defenses (Brues 1924, Dethier 1954, Gillett 1962, Feeny 1975). A limited group of herbivores are able to adapt to a plant's defenses and coevolve with that species (Ehrlich and Raven 1964).

Both contemporary distributions and the fossil record suggest that plant-herbivore coevolution has followed two distinct lines (McNaughton 1983a). The older line involves insects and non-graminoid plants that have evolved a highly toxic secondary chemistry. The other involves graminoids and mammalian and orthopteran herbivores (McNaughton 1983a).

These plants, of the more recently evolved families Poaceae and Cyperaceae, have evolved morphological and physiological adaptations such as protected meristems and compensatory vegetative growth to tolerate grazing herbivores. They also depend on general physical defenses like silicification, lignification and trichomes on leaf margins. Chemical barriers are present in the grasses, but they are commonly general feeding deterrents such as alkaloids, tannins and flavonoids.

Insects that feed on grasses and other graminoids have adapted to the high silica and lignin content in these monocots. Some insect herbivores seem to be able to discriminate between plants with high and low silica content and will preferentially feed on the latter (Wadham and Perry 1981). Mandibles of grass-specializing grasshoppers show chisel-like incisors and flattened, grooved molar cusps (Isley 1944, Williams 1954, Mulkern 1961, Ganguer 1961, Chapman 1963, Patterson 1984) analogous to adaptations in the teeth of grazing mammals (McNaughton et al. 1985). A study of the genus *Spodoptera* (Lepidoptera: Noctuidae) shows grass-specialist caterpillars have mandibles with chisel-like edges while other species display pointed incisor cusps (Brown and Dewhurst 1975). Bernays (1986) examined 82 grasshopper and 76 caterpillar species. In both groups the grass feeders had consistently greater head masses than the other foliage feeders of similar body size. Insects with piercing-sucking mouthparts may not have needed to evolve special mechanisms

to feed on grass. However, they may have modified their strategies for locating conductive tissues in leaves when they shifted from feeding on dicots with toxic chemistry to the large, innocuous resource that grasses provided.

Insects on grasslands play a largely beneficial role unless they are competing for limited forage with livestock and wildlife as is the case on rangelands in the western United States. Each year insects may consume greater amounts of plant biomass than livestock (Haws 1978). However, insects are the most poorly understood component of range ecosystems. Much research is needed to identify rangeland insects, describe their biologies and determine impacts on their host plants.

Great Basin wildrye (*Elymus cinereus* Scribn. & Merr) (Fig. 1) is a valuable rangeland grass. Hitchcock (1950) recognizes this species as belonging to the grass tribe Triticeae. The Triticeae of North America is in great need of revision and Dewey (1982) has suggested many changes in the taxonomy and nomenclature of the tribe. Based on genome analysis, he places this species in the genus *Leymus*. This change may be accepted in the future, however, the more familiar nomenclature will be used in this study.

This large, caespitose grass occupies many different habitats including riparian areas, saline flats and sagebrush slopes. It grows from Minnesota to British Columbia and south to Arizona and California (Hitchcock 1950).



Fig. 1. Great Basin wildrye (Elymus cinereus Scribn. & Merr) and its distribution in North America.

Basin wildrye was once very important as a winter forage in parts of Nevada, Utah, Idaho, and Oregon, but overgrazing during the spring months has greatly reduced or eliminated many stands. A number of publications have reported the forage quality and grazing sensitivity of this plant (Hillman 1896, Griffiths 1901, Krall et al. 1971, Perry and Chapman 1974, Murray et al. 1978, Lawrence 1978). Energy values are high and protein content is low compared to other rangeland grasses. Basin wildrye is very sensitive to clipping during the growing season and utilization by livestock may need to be limited to winter months to conserve populations of this species.

Stands of basin wildrye provide important cover for elk, deer, antelope, small mammals, and birds (Walker and Brotherson 1982). In reclamation related studies, the grass has been considered to have good potential for erosion control and long term revegetation. Low seed germination rates and poor seedling vigor tended to frustrate breeders (Frelich et al. 1973). However, a new cultivar, 'Magnar', with relatively high rates of germination has been developed by the Soil Conservation Service. The Idaho National Engineering Laboratory will be seeding 'Magnar' basin wildrye over buried nuclear waste because of its deep roots and excellent water extraction capabilities which may help avoid water penetration of the waste (Anderson pers. comm.).

Restoring certain types of rangelands to optimum productivity may well involve the seeding of Great Basin

wildrye. Knowledge of wildrye's insect predators and parasites may be useful to grass breeders, seed companies, and range managers. Seventy-four insect species from 21 families in 9 orders have been found to feed on *Elymus* species (Thomas and Werner 1981) (Appendix 1). The majority of these host plant records have come from insect taxonomic and food habit studies.

Several important agricultural pest species are known to utilize wildryes. These include corn rootworms (*Diabrotica longicornus* (Say) and *D. virgifera* LeConte, Coleoptera: Chrysomelidae) (Branson and Ortman 1971), army cutworm (*Euxoa auxiliaris* (Grote), Lepidoptera: Pyralidae) (Burton et al. 1980), bluegrass webworm (*Sphenophorus parvulus* Gyllenhal, Coleoptera: Curculionidae) (Ainslie 1930), grain bug (*Chlorochroa sayi* Stal, Hemiptera: Pentatomidae) (Caffrey and Barber 1919), virus transmitting aphids (Boyd and Pitre 1968), and the wheat stem sawfly (*Cephus cinctus* Norton, Hymenoptera: Cephidae) (Krombein et al. 1979). Of these, only the sawfly has been found on basin wildrye in southern Idaho.

The wheat stem sawfly is a primitive hymenopteran belonging to the suborder Symphyta. Symphyta larvae are nearly all plant feeders. Females utilize their ovipositors to insert eggs into plant tissues. The wheat stem sawfly infests Great Basin wildrye as well as cereal grains and other native grasses. Due to the economic pest status of the

sawfly, there is an abundance of literature concerning this species.

The life history of *C. cinctus* has been described by many entomologists in a variety of climates (Ainslie 1920, Criddle 1923, Seamans et al. 1944, Wallace and McNeil 1968). In the wheat growing areas, adult sawflies usually emerge from June 1 to July 15 by chewing a hole at the top of their overwintering stub. Soon thereafter, the eggs are deposited within the growing culms and the larvae develop through the summer consuming parenchyma and vascular tissues (Holmes 1954). In late summer, larvae move towards the base of the stem in response to visible and infrared light, stem moisture and gravity (Holmes 1975). There they girdle the stem, form a cocoon, and overwinter in the remaining stub. Pupation occurs in May after the larvae undergo an obligatory diapause which is completed after a minimum of 90 days at 10° C or cooler (Salt 1947). This univoltine species may be induced into a two-year life cycle. Unusually warm temperatures (35° C and above) and low moisture conditions in the spring may re-induce diapause (Church 1955, Villacorta et al. 1971). These environmental conditions may affect the brain neuroendocrine system by inactivating or inhibiting prothoracicotropic hormone preventing activation of the prothoracic gland and thus production of an ecdysone titer sufficient to trigger metamorphosis (Villacorta et al. 1971).

The wheat stem sawfly is found in all northern states west of the Mississippi River and in southeastern Alberta,

southern Saskatchewan and the southwestern corner of Manitoba. In the United States, it has caused serious cereal grain crop damage in Montana, North Dakota, South Dakota, Wyoming and Nebraska. With the use of resistant varieties and cultural practices, its pest status has been diminished. However, new, no-till agricultural practices may contribute to the build up of sawfly populations in the wheat growing areas of the Northwest.

Sawfly damage reduces grain yields in two ways. The girdled grain stems lodge and fall to the ground, thus they are lost to harvest. Sawfly tunneling in the culm also interferes with nutrient transport and reduces the number and weight of grain kernels per head (Seamans et al. 1944, Munroe et al. 1949, McNeil et al. 1955, Holmes 1977). Seamans et al. (1944) found a bushel of wheat weighed 0.91 kg less from infested stems and rated one grade lower than wheat from non-infested stems. Loss of yield in native grasses has not been investigated.

Wheat varieties have been bred for sawfly resistance. Solid-culm varieties seem to be the most resistant (Kemp 1934, Platt and Farstad 1946, Platt et al. 1948, O'Keeffe et al. 1959). Farstad (1940) determined that solid-culm resistance was due to a mechanical difference and not a nutritional difference in the pith. Density of a variety's culms may be subject to change in varying light, temperature or moisture conditions (Platt 1941).

Many other measures were investigated to control sawflies. Luginbill and McNeil (1958) found infestations decreased as seeding densities increased and row spacing decreased. Burning stubble, deep plowing and crop rotations are all effective in reducing sawfly populations. Chemical control is not recommended. Biological control methods have not been very successful, but many potentially effective sawfly parasites have been identified (Gahan 1918, Munro et al. 1949, Nilsson 1949, Muesebeck 1953, Nelson 1953 Somsen and Luginbill 1956, Holmes et al. 1963).

Impacts of the wheat stem sawfly on Great Basin wildrye have not been addressed. Few investigators have examined insect-wildrye interactions. Entomologists have sampled Great Basin wildrye communities in Idaho (Horning and Barr 1968, Stafford pers. comm. 1982), but no special attempt was made to relate the biologies of the insects to wildrye (Appendix 2). No known investigation has yet attempted to identify the phytophagous insect guilds of basin wildrye or to examine the effects of insects on this bunchgrass.

The objectives of this study were to identify the relationships between Great Basin wildrye and its associated insect fauna, to describe the life history of the wheat stem sawfly on wildrye and to determine the impacts of the wheat stem sawfly on the seed production of basin wildrye.

STUDY AREA

The study area was located in south-central Idaho along the northwestern edge of the Snake River Plain (Fig. 2). Two sites were selected. One was located at Craters of the Moon National Monument (CRMO) and one within the boundaries of the Idaho National Engineering Laboratory Site (INEL). These areas were chosen because they were protected from livestock grazing and they contained relatively large stands of Great Basin wildrye.

Craters of the Moon National Monument lies 29 km southwest of Arco, Butte Co., Idaho. The climate of the Monument is semi-arid with hot, dry summers and cold winters (Fig. 3.). The mean monthly high temperature, 29^{o} C, occurs in July. December and January, the coldest months, have an average mean daily high temperature of -1^{o} C. Mean annual precipitation was 426 mm between 1959 and 1983 (Day 1985). Annual precipitation has a bimodal pattern with a major peak in December and January in the form of snow and a smaller peak in May in the form of rain. A period of relative drought occurs from mid-June through September. CRMO receives substantially more moisture than surrounding areas on the Snake River Plain due to the rise in elevation.

Cinder cones and lava flows along a large volcanic fissure, the Great Rift Zone, are the dominant topographic features. The most recent volcanic activity occurred 2000 years ago. "Aa" and "pahoehoe" lava flows are in various

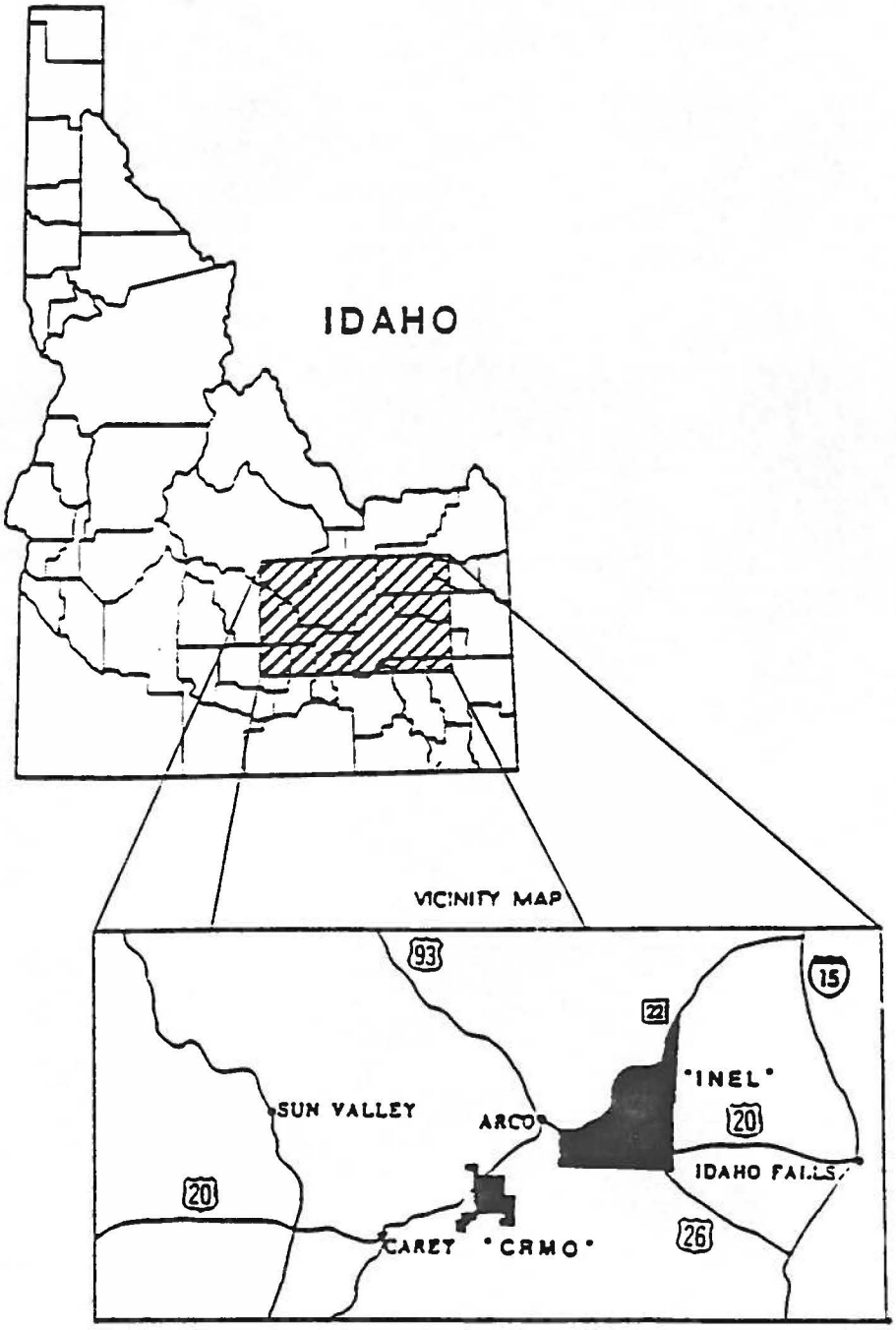


Fig. 2. Location of the study area at the Idaho National Engineering laboratory Site (INEL) and Craters of the Moon National Monument (CRMO).

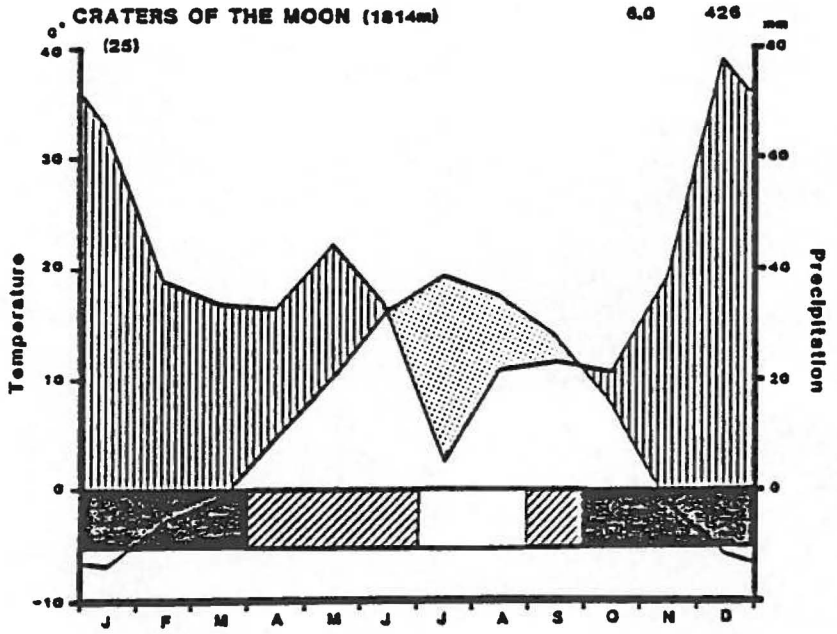


Fig. 3. Ecological climate diagram for Craters of the Moon National Monument, Idaho, from 1959 to 1983 weather records. Format is after Walter (1979): dotted region is period of relative drought; vertically shaded region is relatively humid period; darker shaded region is months with mean daily temperature below freezing; and diagonally shaded region is months with absolute minimum temperature below freezing. (Adapted from Day 1985).

stages of plant succession. Approximately 60% of the Monument still remains devoid of vegetation.

Mountain big sagebrush (*Artemisia tridentata* subsp. *vaseyana* (Ryberg) Beetle) and bitterbrush (*Purshia tridentata* (Pursh) DC.) dominate the vegetation. Limber pine (*Pinus flexilis* James) stands are common on cinder cones and lava flows in the southern portion of the Monument. Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco.), quaking aspen (*Populus tremuloides* Michx.), and chokecherry (*Prunus virginiana* L.) are common on the more mesic sites in the northern end. Native bunchgrasses; bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. and Smith), Sandberg's bluegrass (*Poa sandbergii* Vasey), needle and thread grasses (*Stipa comata* Trin. and Rupr. and *S. thurberiana* Piper), Indian ricegrass (*Oryzopsis hymenoides* (R. and S.) Ricker), and bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) Smith) are abundant. Great Basin wildrye occurs scattered throughout the area.

The large stand (8.5 ha) of wildrye sampled in this study occupied the mouth of Cottonwood Creek Canyon at the base of the Pioneer Mountains (T.2N R.24E S.27), elevation approximately 1817 m. The creek disappeared into the deep alluvial deposits and was lost in the porous cinder substrate. Vegetation covered 78% of the site of which 100% of the canopy coverage was occupied by wildrye. Big sagebrush and goldenrod *(Solidago gigantea* Ait.) were found in the stand.

The other wildrye site was located 40 km east of CRMO on the western edge of the INEL Site (T.4N R.29E S.16). This site occurs at an elevation of 1475 m. Mean annual precipitation of 246 mm is approximately half that received at the CRMO site (Fig. 4). The distribution of precipitation is similar to CRMO with the peak of spring rains occurring in May and June. However, much less snow accumulates at INEL during the winter. Winters are cold with occasional subzero temperatures; summers are hot with extreme temperatures reaching 38^{o} C.

Native vegetation on the INEL site is dominated by Wyoming big sagebrush (*Artemisia tridentata* subsp. *wyomingensis* Beetle). Gray and green rabbitbrush (*Chrysothamnus nauseosus* (Pall.) Britt. and *C. viscidiflorus* (Hook.) Nutt.) are also abundant shrubs. Dominant grasses are similar to those at CRMO. Saltbrush (*Atriplex confertifolia* (Torr. and Frem.) Wats.), winterfat (*Ceratoides lanata* (Pursh) J.T. Howell), bud sagebrush (*Artemisia spinescens* Eat.), and greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.) occur in depressions and open areas of more saline soils. Basin wildrye is the most important grass in these latter communities.

The stand utilized for this study occurred in a depression where excess moisture accumulated during the winter and spring. The site occupied 1.1 ha and approximately one-half of the area was burned in a controlled fire during 1981. Wildrye on the burned section of the stand

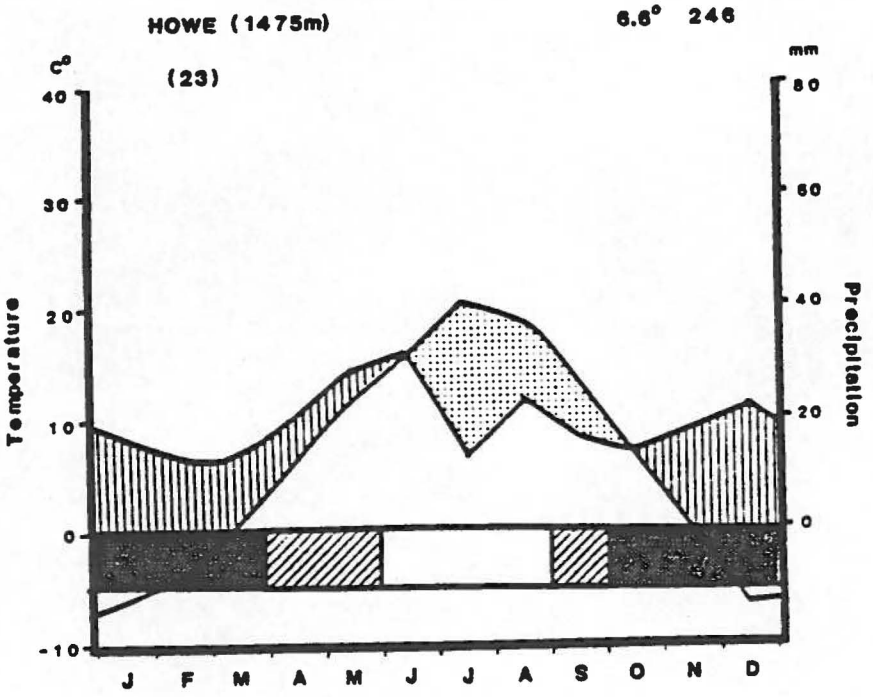


Fig. 4. Ecological climate diagram for Howe, Idaho, from 1957 to 1983 (not including 1961-64) weather records. Format is after Walter (1979): dotted region is period of relative drought; vertically shaded region is relatively humid period; darker shaded region is months with mean daily temperature below freezing; and diagonally shaded region is months with absolute minimum temperature below freezing.

appeared more vigorous than that on the unburned portion. Basin wildrye occupied almost 100% of the canopy coverage on the site. Only 50% of the stand was covered with vegetation with most of the remaining area being open space with a few dead sagebrush and perennial forbs. The sagebrush on the site probably died due to periodic flooding.

CHAPTER I: HERBIVOROUS AND PARASITIC INSECT GUILDS ASSOCIATED WITH GREAT BASIN WILDRYE (*Elymus cinereus* Scribn. & Merr) IN SOUTHERN IDAHO

ABSTRACT

Insects inhabiting Great Basin wildrye (*Elymus cinereus* Scribn. & Merr) were surveyed at two sites on the Idaho Snake River Plain during 1982 and 1983. Forty-six species of phytophagous insects were observed. In addition, eight parasitoid species were reared and identified from insect hosts in the plant culms. Life-stage, abundance, plant part utilized and study site were recorded for each insect species collected. Insect guilds at the two sites were compared based on species presence utilizing Sorensen's similarity index. Overall, twenty-six insect species were common to both sites yielding a moderate similarity index of 0.62.

The majority of the species that constitute the wildrye herbivore guilds were oligophagous (restricted to grasses). Many of these insects feed on grain crops as well as other native and introduced grasses. The relatively high diversity of phytophages on wildrye may be due to its tall, bunchgrass growth form, its abundance within its habitat, its broad geographic range, and the large number of related species of grasses in the region.

INTRODUCTION

Great Basin wildrye (*Elymus cinereus* Scribn.& Merr) is one of the largest and most widespread native bunchgrasses in the western U.S. (Lesperance et al. 1978). It is an important component of both the salt desert shrub and sagebrush/grass ecosystems. Every spring and summer the plant produces enormous amounts of biomass that may be exploited by vertebrate and invertebrate herbivores. Much is known of wildrye's palatibility and utilization by large ungulate grazers (Perry and Chapman 1974, 1975, Krall et al. 1971, Lesperance et al. 1978, Murray et al. 1978), but there has been no comprehensive study of its phytophagous insect communities. An attempt was made to partition the plant into anatomical regions and identify the associated insect herbivore guilds. The impacts and diversity of these guilds are discussed.

METHODS

Insects associated with Great Basin wildrye were surveyed at two sites on the Idaho Snake River Plain during 1982 and 1983. The lower elevation (1475 m) and drier (246 mm precipitation/yr) site was located on the Idaho National Engineering Laboratory (INEL) 10 km south of Howe, Butte Co. Wildrye occupied low, saline areas surrounded by Wyoming big sagebrush (*Artemisia tridentata* subsp. *wyomingensis* Beetle).

The second site was located in the north end of Craters of the Moon National Monument (CRMO) 29 km southwest of Arco at 1817 m elevation. The precipitation is almost twice as abundant at this site (426 mm/yr). Wildrye grew on a 8.5 ha wet meadow surrounded by mountain big sagebrush (*Artemisia tridentata* subsp. *vaseyana* (Ryberg) Beetle).

Insects were monitored on the host plant from its three-leaf phenological stage in May through seed maturation in late August. Fifteen plants were randomly selected at each of two sites along 50 m random transects at weekly intervals. The insect fauna on each host plant was visually examined and observed for 5 minutes. Insect life-stage, behavior, relative abundance, and plant parts utilized were recorded. Insects were hand picked or aspirated from the grass for later identification. Presence of internal feeders was determined by dissecting five to ten tillers from each plant. Each week five plants at each site were excavated, examined for root and root crown infesting insects and placed into Berlese funnels to collect the resident insects.

Insect feeding was determined by direct observation such as mouthpart insertion and plant damage. While not absolutely definitive in all cases, this method is more accurate than that obtained from earlier sweep-net sampling programs (Horning and Barr 1968).

RESULTS AND DISCUSSION

Forty-six insect species in 22 families and seven orders were identified as feeding on wildrye. Each species was catagorized as to abundance, life-stage feeding on wildrye, region of the host plant utilized, and host specificity. (Table 1). Eight species of parasitoids were also reared from insect hosts in the culms and identified (Table 2). The host plant was partitioned into five anatomical components; roots, culms, leaves, flowers, and seeds. Each region supported a variety of insect species that employed different feeding strategies. Many of the insects utilized more than one plant part and were identified in more than one guild.

Root Feeders

Aphids, mealybugs and beetle larvae were the most abundant insects feeding on wildrye roots. The aphids, *Forda marginata* and *F. olivacea*, were collected in low numbers in the spring and early summer. Both species have been reported to feed only on grass roots and are associated with ant nests (Gillette 1918, Patch 1939, Gittins et al. 1976, Smith and Parron 1978).

Two pseudococcids were less frequently collected on the roots of the host plant. One, *Cryptoripersia trichura*,

Table 1. Insects collected and observed feeding on Great Basin wildrye at Craters of the Moon National Monument (C) and the Idaho National Engineering Laboratory Site (I) in 1982-3.

Taxa	life[a] stage	plant[b] parts	loca- tion	host[c] spec.	abun-[d] dance
Orthoptera					
Acrididae					
Melanoplus bivittatus (Say)	n,a	c,l	C	p	co
Melanoplus femurrubrum (DeGeer)	n,a	c,l	C	p	co
Melanoplus foedus Scudder	n,a	c,l	C	p	un
Melanoplus sanguinipes (Fabricius)	n,a	c,l	C,I	p	co
Phoetaliotes nebrascensis (Thomas)	n,a	c,l	C	o	co
Thysanoptera					
Aeolothripidae					
Aeolothrips auricestus Treherne	a	f,s	C,I	p	co
Aeolothrips sp.	n,a	f,s	C,I	u	co
Thripidae					
Aptinothrips rufus (Gmelin)	a	f,l	C,I	o	co
Frankliniella occidentalis (Pergande)	n,a	f,s	C,I	p	co
Frankliniella sp.	n,a	f,s	C	u	co
Sericothrips sp.	n,a	f,s	C,I	u	co
Homoptera					
Cicadidae					
Okanogana bella Davis	a	c,l	C	p	co
Cicadellidae					
Dikraneura carneola (Stal)	n,a	c,l	C,I	p	co
Hecalus viridis (Uhler)	n,a	l	I	p	co
Delphacidae					
Eurysa obesa Beamer	n,a	c,l	C,I	o	co
Aphididae					
Forda marginata (Koch)	n,a	r	I	o	un
Forda olivacea Rohwer	n,a	r	C	o	un
Pseudococcidae					
Cryptoripersia trichura (Cockerell)	n,a	r	C	o	un
Phenacoccus sp.	n,a	r	I	u	un
Trionymus smithii (Essig)	n,a	c,l	C	o	co
Eriococcidae					
Eriococcus insignis Newstead	n,a	c,l	C	o	un
Hemiptera					
Miridae					
Irbisia pacifica (Uhler)	n,a	c,l	C,I	o	co
Labops utahensis Slater	n,a	c,l	C	o	co
Litomeris debilis (Uhler)	n,a	c,l	C,I	o	co
Stenodema laevigatum (Linnaeus)	n,a	c,l	C,I	o	co
Pentatomidae					
Aelia americana Dallas	a	f,l	C,I	p	co
Rhytidilomia uhleri Stal	a	f	C,I	o	co

Table 1. Insects collected and observed feeding on Great Basin wildrye at Craters of the Moon National Monument (C) and the Idaho National Engineering Laboratory Site (I) in 1982-3.

Taxa	life[a] stage	plant[b] parts	loca- tion	host[c] spec.	abun-[d] dance
Coleoptera					
Elateridae					
Anchastus cinereipennis Eschscholtz	l	r	C,I	o	co
Cardiophorus sp.	l	r	C	u	co
Limonius infuscatus Motschulsky	l	r	C	o	co
Limonius sp.	l	r	I	u	co
Melyridae					
Attalus glabrellus Fall	a	f	I	p	co
Attalus morulus smithi Hopping	a	f	I	p	co
Collops bipunctus (Say)	a	f	I	p	co
Anthicidae					
Notoxus serratus LeConte	a	f,s	C,I	p	co
Phalacridae					
Phalacrus pencillatus Say	a	f	C,I	p	co
Scarabaeidae					
Dichelonyx sp.	l	r	C	u	co
	a	c,l	C	u	co
Cerambycidae					
Cortodera barri Linsley & Chemsak	l	r	C,I	o	ra
	a	f	C,I	p	co
Chrysomelidae					
Altica sp.	a	f	C,I	u	co
Anisostena californica Van Dyke	a	l	C,I	o	co
Curculionidae					
Brachyrhinus ovatus (Linnaeus)	a	r	C	p	co
Sphenophorus gentilis LeConte	l	r	I	o	--
	a	s	I	o	co
Lepidoptera					
Pyralidae					
Faronta diffusa (Walker)	l	f,s	C,I	o	co
Hymenoptera					
Cephidae					
Cephus cinctus Norton	l	c(i)	C,I	o	co
Eurytomidae					
Tetramesa elymophaga (Phillips)	l	c(i)	C,I	m	co
Tetramesa sp.	l	c(i)	C,I	u	co

a) n=nymph; l=larva; a=adult
b) c=culm; l-leaf; r=root; f=flower; s=seed; (i)=internal
c) p=polyphagous; o=oligaphagous; m=monophagous; u=unknown
d) ra=rare (less than 10 insects collected); un=uncommon (10-50 insects collected); co=common (greater than 50 insects collected)

Table 2. Insect parasitoids reared from insect hosts in Great Basin wildrye culms collected from Craters of the Moon National Monument (C) and the Idaho National Engineering Laboratory (I) in 1983.

Taxa	Host	Location
Hymenoptera		
Eulophidae		
Pediobius utahensis (Crawford)	*Cephus cinctus* Nort.	C,I
Zagrammosoma nigrolineatum Crawford	unknown[a]	I
Eupelmidae		
Calosota sp.	*Tetramesa* sp.	I
Torymidae		
Torymus thalassinus (Crosby)	*Tetramesa* sp.	I
Pteromalidae		
Homoporus atriscapus Gahan	unknown[b]	C
Homoporus sp.	*Tetramesa* sp.	C
Eurytomidae		
Eurytoma pachyneuron Girault	*Tetramesa* sp.	C
Eurytoma sp.	*Tetramesa* sp.	C,I

a
previously reported to be a parasite on *Argyresthia* sp. (Lepidoptera: Yponomeutidae). (Krombein et al. 1979).

b
probably parasite on *Tetramesa* sp.

inhabits grass roots in Arizonia and New Mexico (MacGillivray 1921).

Elaterid larvae, wireworms, were very common in the soil surrounding the roots and are known as major pests of grains and range grasses. A species of chafer, *Dichelonyx* sp., was found to infest Great Basin wildrye roots at Craters of the Moon. Adult weevils, *Brachyrhinus ovatus*, were also very common in the root masses at the Monument site. At INEL this niche seems to be filled primarily by billbugs, *Sphenophorous gentilis*. Although the larvae of the latter species were not located, they are known to feed on the roots of a variety of grasses including wildrye (Asay et al. 1983, Tashiro and Personius 1970, Kamm 1969). Cerambicid larvae were collected in the root mass of wildrye and identified to the subfamily Lepturinae. *Cortodera barri*, a common cerambicid feeding on wildrye pollen as an adult, was the only species belonging to this subfamily found in the area. Therefore, it seems likely that the larvae belonged to this species.

Culm and Leaf Feeders

A large number of herbivores utilize both the culms and leaves of grasses, therefore these two anatomical regions are discussed together. Grasshoppers are one of the most common and destructive groups of insects on western ranges (Watts et al. 1982). They are the most visible pests and have been

studied more than any other graminivorous insects. Five species of acridids were collected on wildrye in the summers of 1982 and 1983. Four of these species are in the genus *Melanoplus*, with the migratory grasshopper, *M. sanguinipes*, being most abundant.

A few beetles were also found to be external chewers. Adult *Dichelonyx*, fed on the host plant in July at Craters of the Moon. *Anisostena californica*, a chrysomelid, was observed feeding on wildrye leaves at both sites.

Larvae of three species of Hymenoptera fed internally in the grass culm. *Cephus cinctus*, larvae tunnelled down the stems consuming parenchyma and vascular tissues. Larvae eventually cut the stems and overwintered in the remaining stubs. Sawfly herbivory may impair transport of water and nutrients through the stem thus detrimentally affecting grain production (Holmes 1977, Seamans et al. 1944). Jointworms, *Tetramesa* spp., and their parasites were reared from wildrye culms. *Tetramesa* larvae fed on internal tissues. At least one species formed "bump galls" on the stem below the inflorescence. Spears and Barr (1985) reported that these larvae adversely effect the growth and reproduction of several range grasses. Dipteran larvae, probably chloropids, were also collected within the stems, but were not reared to adults.

Although injury due to defoliators is more apparent, fluid feeding Homoptera and Hemiptera may have the greatest impact on wildrye and other native grasses (Haws 1982). By

pumping saliva into the plant and extracting plant fluids, these insects remove essential plant sap and cytoplasm and may inject toxic compounds or transmit viruses. Cicadas, *Okanogana bell*a, were very visible in the summer clinging to wildrye stems at Craters of the Moon. Leafhoppers and delphacids were the most common insects feeding on wildrye. Over 50 individuals of a delphacid, *Eurysa obes*a, were counted at one time on an individual grass tiller. Less common were the scales found on the stems under the leaf sheaths. Impacts from these Homoptera could not be seperated from the damage due to the fluid feeding hemipterans.

Many species of mirids cause injury to range grasses through toxemia and loss of plant fluids (Watts et al 1982). *Irbisia pacific*a, *Litomeris debilis*, and *Stenodema laevigatum* frequently fed on wildrye at both sites. In June 1983 at CRMO, a large section of the study site was observed turning brown. Basin wildrye plants were stunted in the 4 leaf stage by an infestion of the black grass bug, *Labops utahensis*, and the delphacid *Eurysa obesa*. An annual weedy mustard, *Thlaspi arvense* L., gained prominence on the site. When insect numbers declined later in the summer, wildrye resumed growth but did not produce any reproductive tillers. Adequate soil moisture and carbohydrate reserves may have enabled the plants to recover. However, the black grass bug can significantly reduce forage production and may cause death if droughty conditions prevail (Todd and Kamm 1974, Haws 1978).

Flower and Seed Feeders

Thrips, pentatomids, adult beetles and larvae of a species of Lepidoptera were collected on wildrye inflorescences. Seven species of beetles consumed the pollen. Most of these beetles were polyphagous herbivores that can switch hosts to take advantage of the available nutritious food source (Thomas and Werner 1981). This may also have been true of the pentatomids that were found feeding on the developing seeds. However, adult billbugs seemed to be monophagous on wildrye in this area. They were observed chewing on the developing seeds of *Elymus*. After seed maturation, adult billbugs were no longer observed. Thrips were collected during the entire season. Two families and six species of Thysanoptera were represented in the Great Basin wildrye insect community. *Frankliniella occidentalis*, the western flower thrips, is a widespread, generalist feeder which has previously been reported on grasses (Tingey et al. 1972, Watts and Bellotti 1967, Knowlton and Thomas 1933). *Aptinothrips rufus* occurs on the foliage of various grasses (Tingley et al. 1972, Bailey and Knowlton 1949, Bailey 1948). Thrips are often cited as causing damage to grass seed (Thomas and Werner 1981, Riherd 1954, Bailey 1948). The only lepidopteran associated with wildrye, *Faronta diffusa*, fed on the inflorescence at both sites. This species is especially destructive to wheat, oats and rye (Walkden 1950) and has

THE INSECT FAUNA ASSOCIATED WITH GREAT BASIN WILDRYE (*Elymus cinereus* Scribn. & Merr) IN SOUTHERN IDAHO

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been reported on a variety of native grasses in Arizona, New Mexico and Utah (Godfrey 1972, Watts and Bellotti 1967).

Parasites

Eight chalcid parasitoids (Hymenoptera: Chalcidoidea) were reared from insect hosts in Great Basin wildrye culms. *Pediobius utahensis* was reared from sites of developing wheat stem sawflies in stubs of wildrye culms. The other parasitoids were collected within the culms in the second, third and fourth internodes and were probably associated with *Tetramesa* species. It is not known whether any of these wasps were hyperparasites.

Herbivore Guild Complexity

Twenty-six of the 46 insect species collected on basin wildrye were found at both the CRMO and INEL sites (Table 3). Presence or absence of a species was utilized as an indicator of insect fauna similarity between sites. Similarity indices were estimated using Sorensen's (1948) coefficient (Wolda 1981). Each guild was examined individually. Internal chewers, pollen feeders, flower and seed fluid feeders and chewers showed the greatest similarity. The small number of grasshopper species at the INEL site may account for

Table 3. Sorensen coefficients of insect community similarity by guild on Great Basin wildrye at Craters of the Moon National Monument (CRMO) and the Idaho National Engineering Laboratory (INEL) in 1982 and 1983.

Guilds	Number of Species CRMO	INEL	Common	SI[a]
Fluid feeders-roots	2	2	0	0.00
Chewers-roots	3	2	1	0.40
Fluid feeders-leaves & culms	14	11	8	0.64
Chewers-leaves & culms	10	4	3	0.43
Fluid feeders-flowers & seeds	5	4	4	0.89
Chewers-flowers & seeds	2	3	2	0.80
Internal chewers-culms	3	3	3	1.00
Internal parasites	5	5	2	0.40
Pollen feeders	6	9	6	0.80
Total species[b]	45	38	26	0.62

[a] $SI = \frac{2(\text{Common})}{\text{CRMO} + \text{INEL}}$ (Sorensen 1948, Wolda 1981)

[b] Columns do not add up to total because some insects overlap guilds.

differences in leaf and culm external chewers. Low similarity indices for root insects may reflect the very different soil types of the two stands. Although occurring only 40 km apart, the CRMO and INEL sites are two different habitat types and represent the wide ecological amplitude of basin wildrye. Climatic and edaphic differences may account for much of the difference in insect species collected from the two sites.

The majority of the species that constitute the wildrye herbivore guilds are oligophagous, also feeding on cultivated grains as well as other native and introduced grasses. Rangelands are thought to be a source of most insect pests of cereal grains (Watts et al. 1982). Wildrye, a large, structurally diverse plant, supports a sizable fauna and thus may serve as a reservoir for many of these herbivores. However, wildrye stands also may function as reservoirs for potentially useful predator and parasite species.

The number of phytophagous insect species exploiting Great Basin wildrye was quite large relative to other native grasses in the area. Very few studies have identified the total phytophagous insect community associated with an individual grass species. Watts (1963) collected 120 species on black grama grass, *Bouteloua eriopoda* Torrey, however, these included grass feeders, parasites and predators, and casual visitors. Wight (1986) identified 33 phytophagous insects on the introduced crested wheatgrass, *Agropyron cristatum* (L.) Gaertn. in southern Idaho. Beisler and his

colleagues (1977) collected phytophagous insects associated with three weedy grasses in the eastern U.S. They found 33 species feeding on Johnson grass, *Sorghum halepense* (L.) Pers.; 39 on fall panicum, *Panicum dichotomiflorum* Michx.; and 35 associated with large crabgrass, *Digitaria sanguinalis* (L.) Scop.

Plant structural diversity, species area relationships, and taxonomic isolation are thought to explain much of a host plant's insect species richness (Lawton and Schroder 1977, Southwood 1961, Strong and Levin 1979). Grasses and forbs are less structurally diverse than trees and shrubs and usually have fewer associated species (Niemela et al. 1982, Strong et al. 1984). However, wildrye's height and foliage diversity provide a greater variety of micro-habitats than do most range grasses. Tallamy and Denno (1979) found the more structurally complex grass *Distichlis spicata (L.) Greene* supported a richer community of sap-feeders than the simpler *Spartina alterniflora* Loisel.

Taxonomically isolated plants may have impoverished insect faunas (Strong et al. 1984). Wildrye belongs to the grass tribe Triticeae. Idaho is included as one of the areas of the world with the greatest concentrations of species in this tribe (Hartley 1972). Therefore, many closely related grass genera, such as *Agropyron*, *Sitanion*, and *Hordeum*, are well represented in the area. Many insects that feed on wildrye are likely to feed on alternate hosts in related genera, thus increasing the area they may exploit.

Insect species found on a particular host plant are influenced by the local abundance of the plant, both its density and extent (Strong et al. 1984, Fowler and Lawton 1982, Root 1973). On the study sites wildrye grew in almost pure stands, but in very different habitats. Wildrye has a large geographic range, grows in a variety of habitat types (Walker and Brotherson 1982) and is locally abundant within these types. Insects feeding on this grass find a large, conspicuous food source that remains available longer into the summer than all other C_3 grass species in the area.

Graminivorous insects were identified that have the potential to reduce forage and seed production of wildrye. This information may be valuable to grass breeders, seed companies and range managers interested in revegetation of certain types of rangelands with basin wildrye. Some of the phytophagous insects in this study apparently reduced reproductive potential of wildrye and may have detrimental effects on reseedings. Although grasses are very tolerant of herbivory and have evolved many means of tolerating grazing (McNaughton 1979, Stebbins 1981), insect populations fluctuate greatly and in some years they could reach injurious levels. Therefore, it is important to identify which plants and plant parts are fed upon by various members of the insect community and to determine the impact of herbivory on an individual plant species and its population dynamics.

LITERATURE CITED

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

Bailey, S.F. 1948. Grain and grass infesting thrips. J. Econ. Entomol. 41:701-706.

Bailey, S.F., and G.F. Knowlton. 1949. The Thysanoptera of Utah. Proc. Entomol. Soc. Wash. 51:231-234.

Beisler, J.M., R.L. Pienkowski, L.T. Kok, and W. H. Robinson. 1977. Insects associated with three weedy grasses and yellow nutsedge. Environ. Entomol. 6:455-459.

Gillette, C.P. 1918. Some grass-root aphids. Entomol. News. 29:281-284.

Gittens, A.R., G.W. Bishop, G.F. Knowlton, E.J. Parker. 1976. An annotated list of the aphids of Idaho. Agric. Exp. Sta. Res. Bull. No. 95. 47 pp.

Godfrey, G.L. 1972. A review and reclassification of larvae of the subfamily Hadeninae (Lepidoptera:Noctuidae) of America north of Mexico. USDA Tech. Bull. 1450. 265pp.

Hartley W. 1973. Studies on the origin, evolution, and distribution of the Graminae V. The subfamily Festucoideae. Austral. J. Bot. 21:201-234.

Haws, B.A. 1978. Economic impacts of *Labops hesperius* on the production of high quality range grasses. Utah St. Univ. Agric. Exp. Sta. Rep. 269 pp.

Haws, B.A. 1982. Rangeland insects. Utah Agric. Exp. Sta. Special Rep. 23. 64 pp.

Holmes, N.D. 1977. The effect of the wheat stem sawfly, *Cephus cinctus* (Hymenoptera: Cephidae), on the yield and quality of wheat. Can. Entomol. 109:1591-1598.

Horning, D.S. Jr., and W.F. Barr. 1968. Insects of Craters of the Moon National Monument, Idaho. Univ. of Idaho. College of Agric. Mis. Ser. 8. 118pp.

Kamm, J.A. 1969. Biology of the billbug, *Sphenophorus venatus confluens*, a new pest of orchard grass. J. Econ. Entomol. 62:808-812.

Knowlton, G.F., and W.L. Thomas. 1933. Food plants and distribution of some Utah Thysanoptera. Can. Entomol. 65:114-117.

Krall, J.L., J.R. Stroh, C.S. Cooper, and S.R. Chapman. 1971. The effect of time and extent of harvesting basin wildrye. J. Range Manage. 24:414-418.

Lawton, J.H., and D. Schroder. 1977. Effects of plant type, size of geographical range and taxonomic isolation on number of insect species associated with British plants. Nature. 265:137-140.

Lesperance, A.L., J.A. Young, R.E. Eckert, Jr., and R.A. Evans. 1978. Great Basin Wildrye. Rangeman's J. 5:125-127.

MacGillivray, A.D. 1921. The Coccidae. Scarab Co. Urbana, Illinois. 502 pp.

McNaughton, S.J. 1979. Grassland-herbivore dynamics. Pp. 46-81. In A.R.E. Sinclair and M. Norton-Griffiths, (eds.), Serengeti:Dynamics of an ecosystem. Univ. of Chicago Press, Chicago, Ill.

Murray, R.B., H.F. Mayland, P.J. van Soest. 1978. Growth and nutritional value to cattle of grasses on cheatgrass range in southern Idaho. U.S. For. Serv. Res. PAP Int. 199. pp.1-57.

Niemela, P., J. Tahvanainen, J. Sorjonen, T. Hokkanen, and S. Neuvonen. 1982. The influence of host plant growth form and phenology on the life strategies of Finnish macrolepidopterous larvae. Oikos. 39:164-170.

Patch, E.M. 1939. Food plant catalogue of the aphids of the world. Maine Agric. Exp. Sta. Bull. 393. 431 pp.

Perry, L.J., and S.R. Chapman. 1974. Effects of clipping on carbohydrate reserves in basin wildrye. Agron. J. 66:67-70.

Perry, L.J., and S.R. Chapman. 1975. Effects of clipping on dry matter yields of basin wildrye. J. Range Manage. 28:271-273.

Riherd, P.T. 1954. Thrips a limiting factor in seed production. J. Econ. Entomol. 47:709-710.

Root, R.B. 1973. Organization of a plant-arthropod association in simple and diverse habitats: The fauna of collards (*Brassica oleracea*). Ecol. Mono. 43:93-124.

Seamans, H.L., G.F. Manson, and C.W. Farstad. 1944. The effect of wheat stem sawfly (*Cephus cinctus* Nort.) on the heads and grain of infested stems. 75th Ann. Rep. Entomol. Soc. Ont. pp.10-15.

Sorensen, T.A. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content, and its application to analysis of the vegetation on Danish commons. K dan Vidensk Selsk. Biol. Skr. 5:1-34.

Smith, C.F., and C.S. Parron. 1978. An annotated list of Aphididae (Homoptera) of North America. North Carolina Agric. Exp. Sta. Tech. Bull. 255. 428 pp.

Southwood, T.R.E. 1961. The number of species of insect associated with various trees. J. Anim. Ecol. 30:1-8.

Spears, B., and W.F. Barr. 1985. Effect of jointworms on the growth and reproduction of four native range grasses of Idaho. J. Range Manage. 38:44-46.

Stebbins, G.L. 1981. Coevolution of grasses and herbivores. Ann. Missouri Bot. Gard. 68:75-86.

Strong, D.R., J.H. Lawton, T.R.E. Southwood. 1984. Insects on plants-community patterns and mechanisms. Harvard Univ. Press. Cambridge, Mass. 313pp.

Strong, D.R., and D.A. Levin. 1979. Species richness of plant parasites and growth form of their hosts. Amer. Nat. 114:1-22.

Tallamy, D.W., and R.F. Denno. 1979. Responses of sap-feeding insects (Homoptera-Hemiptera) to simplification of host plant structure. Environ. Entomol. 8:1021-1028.

Tashiro, H., and K.E. Personius. 1970. Current status of the bluegrass billbug and its control in western New York home lawns. J. Econ. Entomol. 63:23-29.

Thomas, D.B., and F.G. Werner. 1981. Grass feeding insects of the western ranges: An annotated checklist. Univ. of Ariz. Agric. Exp. Sta. Four-Corners Regional Commission, Project No. 602-466-080-4. 50pp.

Tingley, W.M., C.D. Jorgensen, and N.C. Frischknecht. 1972. Thrips of the sagebrush-grass range community in west-central Utah. J. Range Manage. 25:304-308.

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.

Walkden, H.M. 1950. Cutworms, armyworms, and related species attacking cereal and forage crops in the central plains. USDA Circ. 849. 52 pp.

Walker, G.R., and J.D. Brotherson. 1982. Habitat relationships of basin wildrye in the high mountain valleys of central Utah. J. Range Manage. 35:628-633.

Watts, J.G. 1963. Insects associated with black grama grass, *Bouteloua eriopoda*. Entomol. Soc. Amer. Ann. 56:374-379.

Watts, J.G., and A.C. Bellotti. 1967. Some new and little known insects of economic importance on range grasses. J. Econ. Entomol. 60:961-963.

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

Wight, R. 1986. Insect fauna of a crested wheatgrass habitat in the Raft River Valley of southern Idaho. M.S. Thesis. Univ. of Idaho. Moscow, Idaho. 120pp.

Wolda, H. 1981. Similarity indices, sample size and diversity. Oecologia. 50:296-302.

CHAPTER 2: ASSOCIATION OF THE WHEAT STEM SAWFLY, (*Cephus cinctus* Nort., Hymenoptera: Cephidae) WITH GREAT BASIN WILDRYE (*Elymus cinereus* Scribn. & Merr) IN SOUTHERN IDAHO

ABSTRACT

This study investigated the association of the wheat stem sawfly (*Cephus cinctus* Nort., Hymenoptera: Cephidae) and Great Basin wildrye (*Elymus cinereus* Scribn. & Merr) in two wildrye stands in southern Idaho during the spring and summer of 1982 and 1983. From 62 to 88% of wildrye plants were infested with the sawfly at the Idaho National Engineering Laboratory and Craters of the Moon National Monument, respectively. Plant phenology was a good predictor of sawfly emergence. Larvae developed within culms, consumed vascular tissues and may have impaired transport of water and carbohydrates through the culm. Seed weight and the number of caryopses developing within wildrye florets were significantly reduced in culms containing sawfly larvae ($p<0.006, p<0.018$, respectively). Differences in germination rates of seeds from infested and noninfested culms were not significant ($p>0.05$).

INTRODUCTION

Insects are one of the most poorly understood components of range ecosystems (Watts et al. 1982). Biological control programs for rangeland weeds and rangeland revegetation efforts have recently focused attention on the importance of insect herbivory to range management (Tiernan 1978). Insect seed predators may substantially reduce native plant seed pools or reduce the success of rangeland reseedings (Youtie and Miller 1986). Other phytophagous and entomophagous insects may indirectly affect the reproductive potential of a plant species, but these effects are not easily recognized.

Relatively few insects other than grasshoppers and grassbugs have been shown to influence growth and development of rangeland grasses. Much more is known about the array of insects associated with native shrubs (Furniss and Barr 1975). Restoring rangelands to optimum productivity may require seeding of native grasses such as Great Basin wildrye (*Elymus cinereus* Scribn. & Merr). The Idaho National Engineering Laboratory plans to seed basin wildrye over buried nuclear waste due to its deep root system and excellent water extracting ability (Anderson pers. comm.). Excessive spring grazing by domestic livestock has greatly reduced the abundance of this valuable perennial bunchgrass that is adapted to both highly saline and nonsaline soils (Young and Evans 1981). Graminivorous insects may influence the success of revegetaion efforts involving this species.

Little is known of the insect fauna of basin wildrye or its potential to reduce forage and seed production.

The wheat stem sawfly, *Cephus cinctus* Nort., a known economic pest of cereal grains, infests basin wildrye and many other native grasses (Ainslie 1920). Larvae consume parenchyma and vascular tissues within the culms, eventually cut the stems, and overwinter in the remaining stubs (Holmes 1954). Holmes (1977) and others have found reductions in the number of wheat kernels per inflorescence and in the weight of each seed head in sawfly infested stems (Seamans et al. 1944). Impacts of the wheat stem sawfly on native grasses have not been addressed.

The objectives of this study were: 1) to correlate the phenological development of the sawfly and basin wildrye; 2) to determine the degree of sawfly infestation in wildrye stands and 3) to assess the impact of sawfly tunnelling in the culms on the seed crop of this grass.

STUDY AREA and METHODS

The study area was located on the Snake River Plain in southeastern Idaho on a portion of the Idaho National Engineering Laboratory Site (INEL) and on Craters of the Moon National Monument (CRMO). The region is semi-arid with most of the annual precipitation (INEL-246 mm; CRMO-426 mm) occurring during the winter and spring. Temperatures may be

as high as 40° C in the summer and as low as -10° C in the winter. At INEL, wildrye stands occur in depressions that hold vernal pools in the spring (McBride et al. 1978). The stand utilized in this study occurred at an elevation of 1475 m. It covered 1.1 ha and was surrounded by better drained upland Wyoming big sagebrush (*Artemisia tridentata* subsp. *wyomingensis* Beetle) communities. Fifty percent of the stand was covered with vegetation, predominantly wildrye. Most of the remaining area was open space with scattered long leaf phlox (*Phlox longifolia* Nutt.), browse milkvetch (*Astragalus cibarus* Sheld., flixweed tansy mustard (*Descurainia sophia* (L.) Webb), and dead sagebrush. Sagebrush mortality was likely caused by periodic flooding of the site. The CRMO site was a higher elevation (1817 m), meadow habitat in the mountain big sagebrush (*Artemisia tridentata* subsp. *vaseyana* (Rydberg) Beetle) zone. This 8.5 ha site supported nearly a pure stand of basin wildrye which covered 78 percent of the area. Giant goldenrod (*Solidago gigantea* Ait.), field pennycress (*Thlaspi arvense* L.) and western stickseed (*Lappula redowski* (Hornem. Greene) were also present, but accounted for only a small percentage of the canopy cover.

Phenological development of the wheat stem sawfly and basin wildrye were monitored from May 25 through August 20 in 1982 and 1983. Each spring 30 stubs were collected twice weekly; the phenological stage and mortality of the sawfly were recorded. After emergence of adult sawflies, green culms were split and larval development was recorded.

To determine sawfly infestation rates, each study area was divided into quadrants of 225 m^2 (24 quadrants at INEL, 36 quadrants at CRMO). Twice weekly, 15 m transects were established in randomly chosen quadrants in random directions. Five culms from the bunchgrass nearest each meter mark on the transect were sampled. Culms were split longitudinally and insect larvae were collected, identified and their location in the stem noted. Tiller density was estimated by clipping sufficient 0.1 m^2 circular plots to estimate density within 10% ($p<0.10$).

At seed maturity, plants were selected randomly along 50 m transects. Five culms per plant were sampled until approximately 500 sawfly infested culms and 500 uninfested culms were collected. Stem diameter was measured 1 cm above the first internode. The entire seed head (spike) from each culm was placed in an individual paper sack. Each stem was split longitudinally and examined for the presence of a sawfly larva. The length of sawfly tunnels was measured to the nearest cm and the number of internodes with damage was recorded. Spikes were collected only at INEL, as seeds at CRMO were still in the milk stage at the end of the sampling season and therefore were not collected or analyzed for effects of herbivory.

Percent seed fill was estimated by determining the number of seeds present in three subsamples of ten randomly chosen florets from each of the 1009 spikes collected. Seed

weight was estimated by weighing three subsamples of ten seeds from each collected spike.

Twenty samples of 25 seeds from sawfly infested and from non-infested tillers were utilized to calculate germination rates. Seeds were placed in germinators at 20° C without light as recommended for basin wildrye variety 'Magnar' (Evans and Young 1983). Percent germination was determined at one and two weeks.

Analysis of variance and t-tests were used to test for differences in percent seed fill, seed weight, percent germination, and culm diameter between infested and uninfested culms.

RESULTS

From 62 to 88% of Great Basin wildrye plants were infested with the wheat stem sawfly (Table 4). Infestation of individual tillers was lower than for plants and ranged from 22 to 38%. Infestation rates tended to be greater at INEL than CRMO in both years, but these differences were not significant. There were no significant differences ($p>0.05$) between years at either site.

In 1983, grass stubs were examined to determine mortality rates of the wheat stem sawfly. Total mortality and parasitism tended to be greater at CRMO than the INEL (Table 5). Percentage of larvae found dead due to

Table 4. Percent infestation of Great Basin wildrye by thewheat stem sawfly at the Idaho National Engineering Laboratory (INEL) and Craters of the Moon National Monument (CRMO), Idaho in 1982 and 1983.

Year	Location	Mean Percent Infestation		Plant Density
		Plants (sd,n)[a]	Tillers (sd,n)	Tillers m^{-2}(sd,n)
1982	INEL	88 (15.9,12)	27 (10.5,12)	----[b]
	CRMO	73 (16.3,6)	22 (11.7,6)	----
1983	INEL	79 (13.7,6)	38 (13.0,6)	191 (242,448)
	CRMO	62 (17.3,4)	22 (8.4,6)	391 (364,325)

a
No significant differences in mean percent infestation rates between years or sites; sd=standard deviation and n=number of samples of 75 tillers from 15 plants.

For plants:
CRMO 82&83 t=1.08,t0.05(2)8=2.31
INEL 82&83 t=1.25,t0.05(2)16=2.12
CRMO-INEL 82 t=1.87,t0.05(2)16=2.12
CRMO-INEL 83 t=1.75,t0.05(2)8=2.31

For tillers:
CRMO 82&83 t=0.005,t0.05(2)8=2.31
INEL 82&83 t=2.02,t0.05(2)16=2.12
CRMO-INEL 82 t=0.83,t0.05(2)16=2.12
CRMO-INEL 83 t=2.19,t0.05(2)8=2.31

b
No samples taken in 1982

Table 5. Percent mortality of the wheat stem sawfly in wildrye stubs at the Idaho National Engineering Laboratory (INEL) and Craters of the Moon National Monument (CRMO), Idaho, in 1983.

	Percentage Mortality	
Location	Non-Parasite Induced mean (sd,n)[c]	Parasites[d] mean (sd,n)
INEL	9.6 (7.3,16)[a]	2.1 (4.0,16)[a]
CRMO	15.6 (9.5,18)[b]	5.6 (8.0,18)[a]

[a] Columns with different letters are significantly different (mold and desiccation $t=2.17, t_{0.05(2)32}=2.04$; parasites $t=1.57, t_{0.05(2)32}=2.04$).

[c] sd=standard deviation and n=number of samples of 15 larvae each.

[d] Primarily *Pediobius utahensis* Crawford

causes other than parasitism was significantly different between the two sites ($t=2.17$, $t_{0.05(2)32}=2.04$). However, there were no significant differences in percent parasitism ($t=1.57$, $t_{0.05(2)32}=2.04$). A eulophid wasp, *Pediobius utahensis* (Crawford), was the most common parasite collected and reared from the grass stubs at both sites.

Phenological development of the wheat stem sawfly and basin wildrye at INEL was about three weeks ahead of CRMO (Fig. 5 & 6). However, the phenological relationship between the insect and plant was very similar at both sites.

When monitoring began at INEL in 1983, plants were in the three or four leaf stage. The sawflies were all still larvae on May 25, having overwintered in the last larval instar in grass stubs. By this time, the obligatory diapause (completed after a minimum of 90 days at 10^{o} C (Salt 1946)) was completed and larvae were observed pupating in late May and early June. However, 10% of the population at INEL did not pupate and remained in the larval form during the entire monitoring period. This is thought to be a re-induction of diapause, not a failure of winter conditions to break diapause (Salt 1946). This two year life-cycle was not observed at the CRMO site, but other aspects of phenology were quite similar.

In June, adult sawflies emerged by chewing a hole at the top of the stub. Adult activity was observed for approximately two weeks at each site. Female sawflies deposited eggs through the stems during the plants' boot and

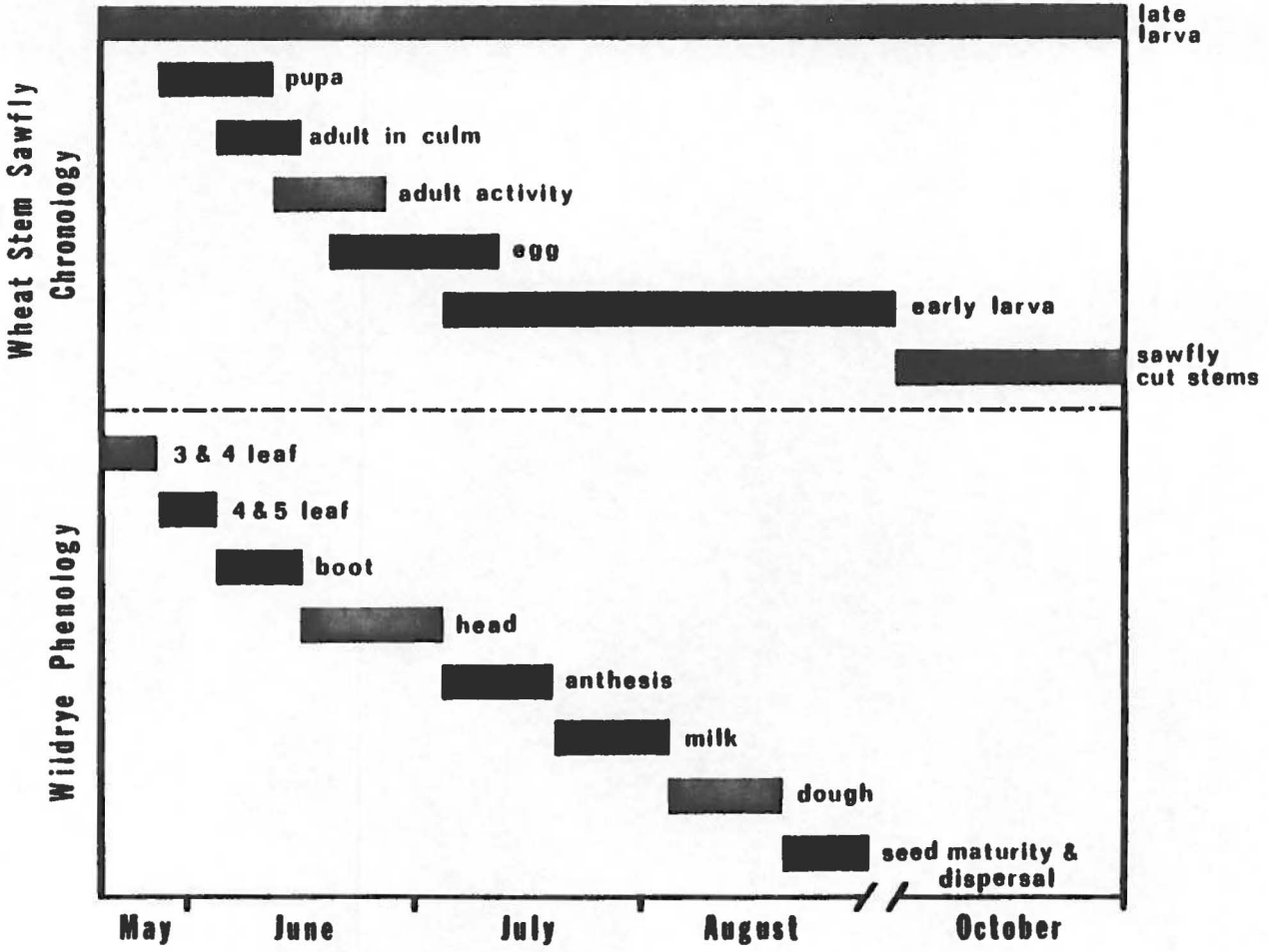


Fig. 5. Phenological development of the wheat stem sawfly and its host, Great Basin wildrye, Idaho National Engineering Laboratory, 1983.

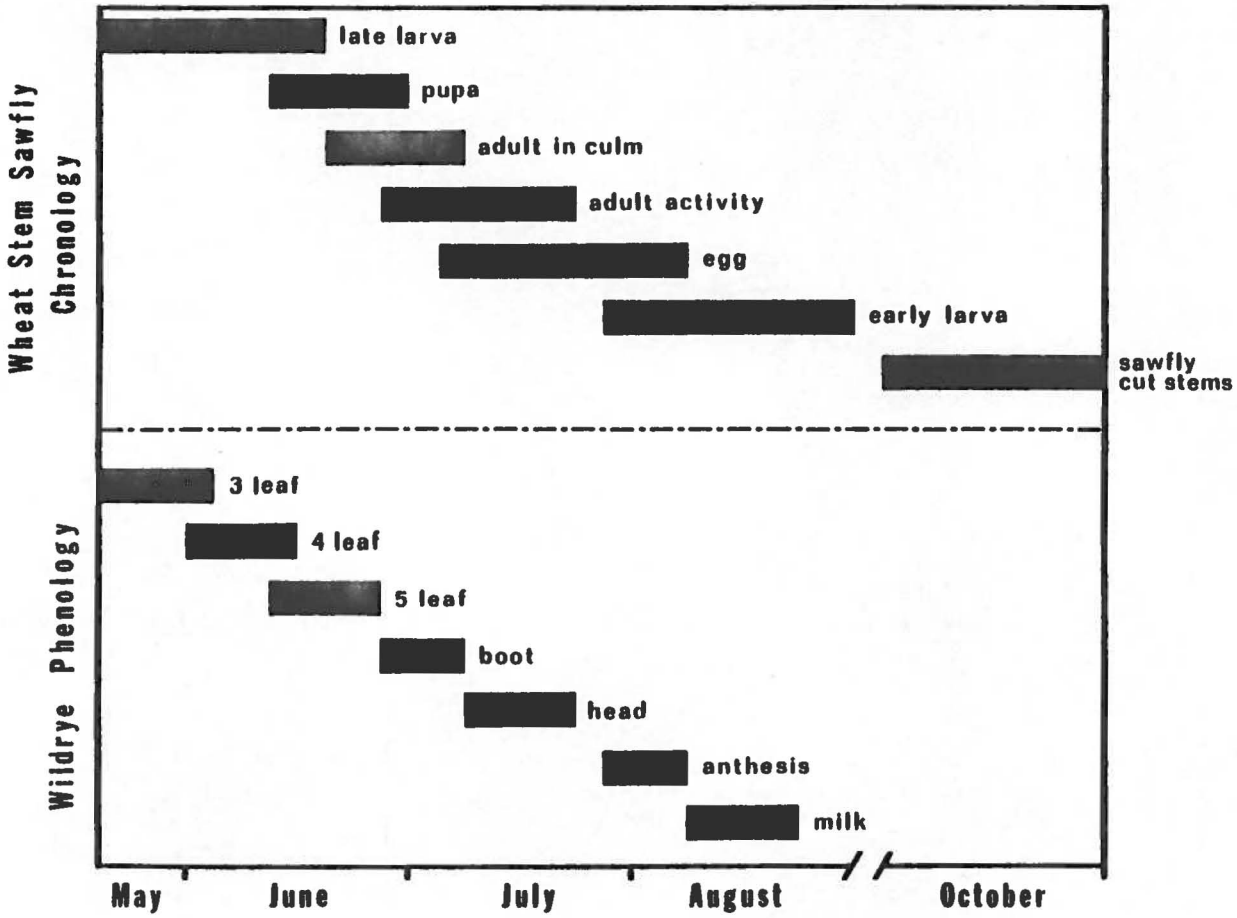


Fig. 6. Phenological development of the wheat stem sawfly and its host, Great Basin wildrye, Craters of the Moon National Monument, Idaho, 1983.

heading out (inflorescence emergence) stages. The majority of eggs were deposited in the third internode. Each female deposits only one egg per stem, but several females may oviposit in the same stem (Holmes 1977). Because larvae are cannibalistic, only one larva survives per stem (Seamans et al. 1944). Internal plant tissues were consumed while seeds were forming on the spike. As the stems began to dry in mid-August the larvae moved downward, cut the stems, and placed plugs of frass in the exposed ends of the remaining stubs. There, the larvae formed cocoons, and over-wintered. Seeds were mature before the larvae cut the stems. Female sawflies at INEL tended to select larger grass culms for oviposition. Mean culm diameter was significantly larger ($t=8.31$, $t_{0.001(2)1007}=3.3$) for sawfly infested stems than for noninfested stems, with means of 2.67 mm and 2.36 mm and sample sizes of 484 and 525 respectively. Therefore, seed set and seed weight were examined in four stem diameter classes.

Infested stems in all size classes showed significantly lower seed weights ($p \leq 0.006$, 2-way ANOVA, Tukey's Studentized t-test)(Appendix 3). Mean seed weights increased as stems became larger, however the proportional difference in seed weight between infested and uninfested culms remained constant (Fig. 7). The average weight reduction was 8.5% over all classes.

Larger stems did not necessarily result in greater seed fill for uninfested stems (Appendix 4). There was a signi-

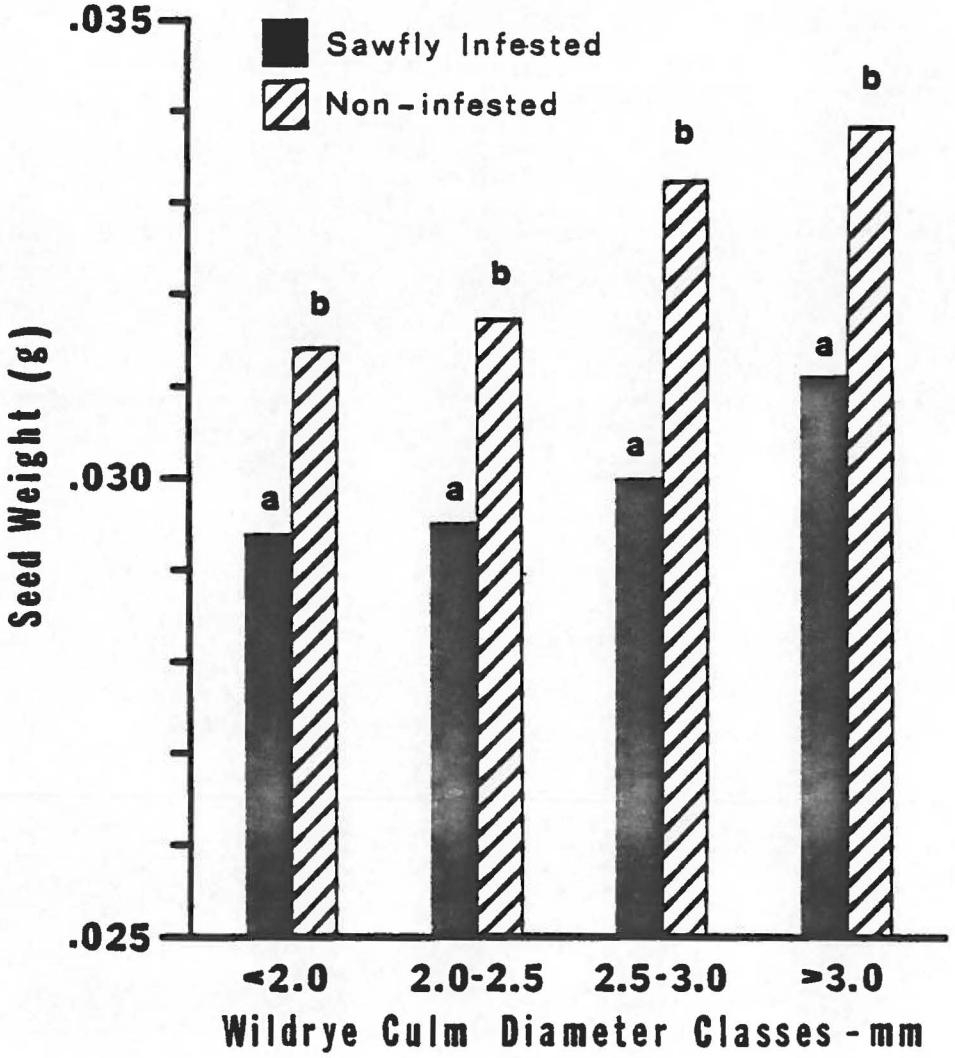


Fig. 7. Mean weight of 10 seeds from Great Basin wildrye tillers infested and non-infested with the wheat stem sawfly, Idaho National Engineering Lab., 1983. Different letters within diameter classes represent significant difference ($p \leq 0.006$; 2-way ANOVA, Tukey's Studentized t-test).

ficant ($p \leq 0.018$, 2-way ANOVA, Tukey's Studentized t-test) reduction in seed fill, about 8%, in infested stems averaged over all size classes. However, infestation did not yield a constant reduction in seed fill over all diameter classes (Fig. 8). Percent seed set decreased with increasing stem size in infested stems, but varied little in uninfested stems.

Germination rates of basin wildrye are normally quite low (Young and Evans 1981). In this study, less than 50% of the seeds had germinated after two weeks in the germinators. Tests were then terminated due to mold growth on some of the seeds. No significant differences ($p > 0.05$) were found between the germination rates of seeds from infested and non-infested tillers (Table 6).

DISCUSSION

Large populations of the wheat stem sawfly were found feeding in Great Basin wildrye tillers in southern Idaho. Insect and plant phenological development were monitored in the hope of developing predictive degree day models based on climatological and phenological data. Due to the diapause requirement of the sawfly, it was too difficult to determine the date at which to begin accumulating degree days for a useful model (Tauber and Tauber 1976). However, wildrye phenology was found to be a valuable predictor of adult

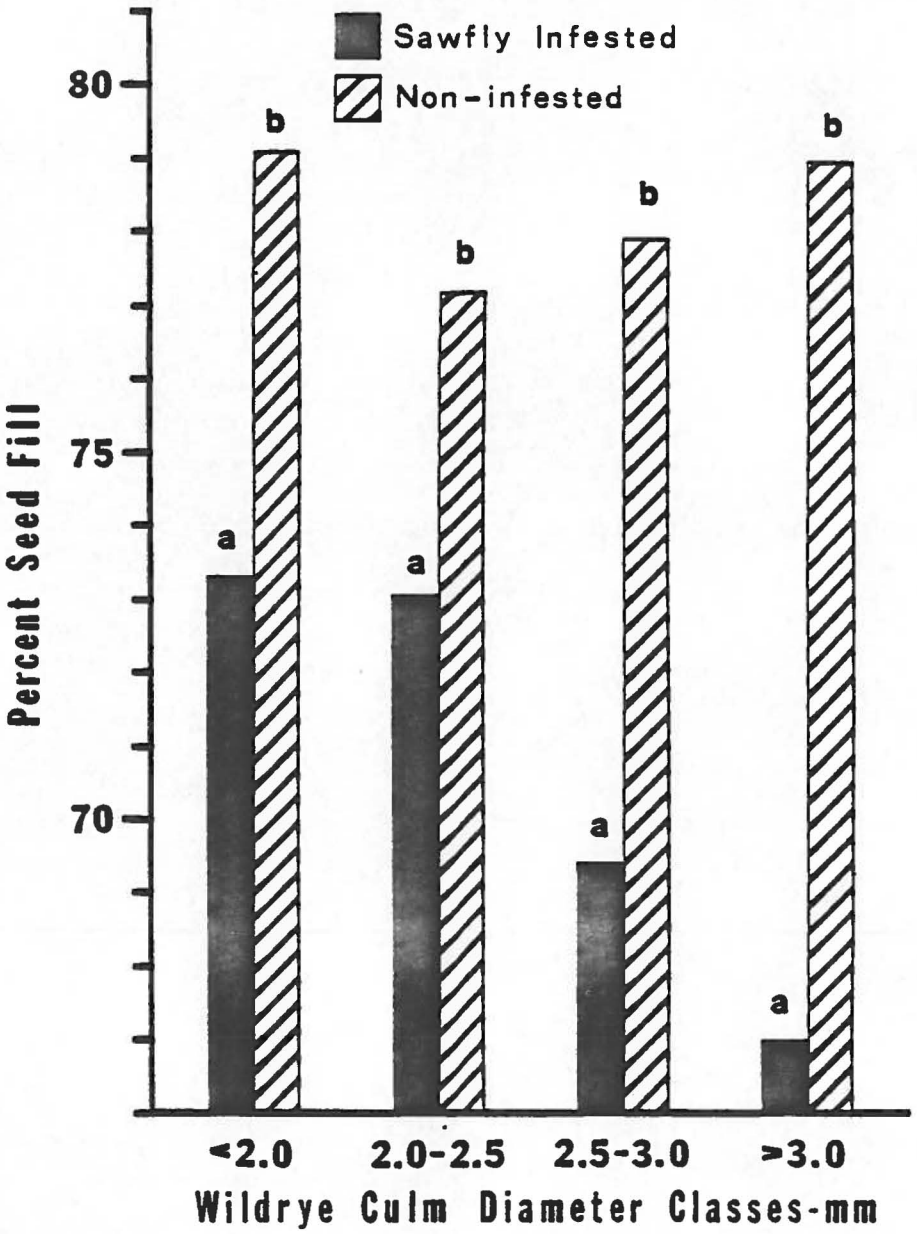


Fig. 8. Mean percent seed set of Great Basin wildrye tillers infested and non-infested with the wheat stem sawfly, Idaho National Engineering Lab., 1983. Different letters within diameter classes represent significant difference ($p \leq 0.018$; 2-way ANOVA, Tukey's Studentized t-test).

Table 6. Percent germination of seeds from wheat stem sawfly infested and non-infested tillers, Idaho National Engineering Laboratory, 1983.

Elapsed Time	Percent Seed Germination	
	Infested Tillers mean % (sd,n)*	Non-infested Tillers mean % (sd,n)
1 week	33.2 (9.6,20)	29.4 (8.6,20)
2 weeks	44.6 (10.2,20)	49.0 (10.8,20)

* There are no significant differences in percent seed germination between infested and non-infested tillers during 1 week ($t=1.31, t_{0.05(2)38}=2.02$) and 2 weeks ($t=1.33, t_{0.05(2)38}=2.02$); sd=standard deviation and n=20 petri dishes of each treatment with 25 seeds per dish.

sawfly emergence. Insects emerged in both years and on both sites when wildrye was in the late boot (inflorescence swelling inside the leaf sheath) and heading out (inflorescence emerging from sheath) stages.

Synchrony between plant phenology and herbivore feeding affects both the success of the herbivore and the type of response from the plant (Crawley 1983). Most damage occurred to wildrye after the inflorescence had been formed, but before most of the translocation from the stem to the spike occurred (Rawson and Evans 1971). Spikelet number was differentiated in the floral primordia (Rawson 1969) before sawfly injury, however, the number of caryopses was reduced (Fig. 8).

Sawfly herbivory reduced the number of wildrye seeds produced and their mean weight. Sawfly consumption of vascular tissues in the stem likely imposed a severe physiological stress on the culms by reducing the carbohydrates available for growth and respiration. In wheat, most of the carbohydrates for seed development come from the flag leaf and the head itself (Bewley and Black 1978), Rawson and Evans (1971), reported that 12.2% of grain weight was provided by stem material through translocation. The net reduction in total seed weight (8.5%) of wildrye found in this study is comparable with their figure.

Sawfly tunnelling may also impair water translocation. Premature drying of infested stems was observed. Under drought stress, stems increase their contribution to grain

development. Holmes (1977) observed a greater reduction of grain weight in sawfly infested wheat stems in years of reduced precipitation. Asana and Basu (1963) studied the effects of water stress on grain development and reported that the transport of stem sugars to the head was inhibited and that photosynthetic activity was reduced resulting from premature drying of the spike and stem. Similar mechanisms may operate in Great Basin wildrye.

The germination rate of the smaller seeds from sawfly infested wildrye stems was not significantly different ($p>0.05$) from the larger seeds of noninfested stems. However, many authors have substantiated the important role of larger seeds in increasing seedling survival (Wulff 1986, Winn 1985, Stanton 1984, Howell 1981, Maun and Cavers 1971, Twamley 1967, Black 1956, Kneebone and Cremer 1955, Rogler 1954). The mass of the endosperm food reserves is an important characteristic associated with plant vigor (McKell 1972). Even a small reduction in seed weight has been shown to place a seedling at a severe competitive disadvantage (Harper et al. 1970). However, in some cases, smaller seeds may have advantages. They may germinate more rapidly and time of emergence can have an important effect on seedling success (Howell 1981, Ross and Harper 1972). Smaller seeds may be subject to less predation, have different dispersal capabililities and find more suitable safe sites (Capinera 1979).

Still, plants that alter their reproductive output are more likely to reduce seed number than seed size (Harper 1977). A sawfly induced reduction in the number of seeds may reduce the chances for successful seedling establishment. With fewer seeds produced, it is less likely that some will escape predation, and find safe sites to germinate.

Although the wheat stem sawfly may significantly affect the wildrye seed crop in the statistical sense, it may not be biologically significant. Because basin wildrye is a perennial bunchgrass, vegetative reproduction plays a much greater role in its population dynamics than does sexual reproduction. Also, compensatory growth responses of plants after herbivore damage may mitigate any deleterious effects of herbivory (Vickery 1972, McNaughton 1979,1983). Tillers without sawflies may have had greater access to the pool of carbohydrates and the available water supply due to the impairment of the sawfly infested tillers. The uninfested tillers may have compensated for the reduction in seed production in the infested tillers with increased seed numbers and seed size. Therefore, on a per plant basis, there may not have been a decrease in the wildrye seed crop.

Additional work will be needed to fully understand the impact of wheat stem sawfly feeding on Great Basin wildrye. However, at this time, it appears that the sawfly does adversely affect the seed production of this grass, which may impact rangeland revegetation efforts with this species.

Literature Cited

Ainslie, G.G. 1920. The western grass-stem sawfly. USDA Bull. 481. 27pp.

Asana, R.D., and R.N. Basu. 1963. Studies in physiological analysis of yield. Indian J. Plant Physiol. 6:1-13.

Bewley, J.D., and M. Black. 1978. Filling of the grain in cereals. *In* Physiology and biochemistry of seeds. vol. I. Development, germination and growth. Springer Verlag, Berlin. 306pp.

Black, J.N. 1956. The influence of seed size and depth of sowing on pre-emergence and early vegetative growth of subterranean clover (*Trifolium subterranean* L.). Austral. J. Agric. Res. 7:98-109.

Crawley, M. 1983. Herbivory: The dynamics of animal-plant interactions. Univ. of Calif. Press, Berkeley, Calif. 437pp.

Evans, R.A., and J.A. Young. 1983. 'Magnar' Basin wildrye germination in relation to temperature. J. Range Manage. 36:395-398.

Furniss, M., and W. Barr. 1975. Insects affecting important native shrubs of the northwestern United States. USDA For. Ser. Rep. INT-19. 64pp.

Harper, J.L., P.H. Lovell, and K.G. Moore. 1970. The shapes and sizes of seeds. Ann. Rev. of Ecol. and Syst. 1:327-356.

Holmes, N.D. 1954. Food relations of the wheat stem sawfly, *Cephus cinctus* Nort. (Hymenoptera: Cephidae). Can. Entomol. 86:159-167.

Holmes, N.D. 1977. The effect of the wheat stem sawfly, *Cephus cinctus* (Hymenoptera: Cephidae), on the yield and quantity of wheat. Can. Entomol. 109:1591-1598.

Holmes, N.D. 1982. Population dynamics of the wheat stem sawfly, *Cephus cinctus* (Hymenoptera:Cephidae), in wheat. Can. Entomol. 114:775-788.

Howell, N. 1981. The effect of seed size and relative emergence time on fitness in a natural population of *Impatiens capensis* Meerb. (Balsaminaceae). Amer. Midl. Nat. 105:312-320.

Kneebone, W.R., and C.L. Cremer. 1955. The relationship of seed size to seedling vigor in some native grass species. Agron. J. 47:472-477.

Maun, M.A., and P.B. Cavers. 1971. Seed production and dormancy in *Rumex crispus*. I. The effects of removal of cauline leaves at anthesis. Can. J. Bot. 49:1123-1130.

McBride, R., N.R. French, A.H. Dahl, J.E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. U.S.D.O.E., Radiol. Environ. Sci. Lab. Rep. No. IDO-12084, Idaho Falls, Idaho. 28pp.

McKell, C.M. 1972. Seedling vigor and seedling establishment. *In* V.B. Younger and C.M. McKell (eds.), The biology and utilization of grasses. Academic Press, New York. pp.76-89.

McNaughton, S.J. 1979. Grassland-herbivore dynamics. pp. 46-81. *In* Sinclair, A.R. and M. Norton-Griffiths (eds.), Serengeti:Dynamics of an ecosystem. Univ. Chicago Press, Chicago. 389 pp.

McNaughton, S.J. 1983. Compensatory plant growth as a response to herbivory. Oikos 40:329-336.

Rawson, H.M. 1970. Spikelet number, its control and relation to yield per ear in wheat. Austral. J. Biol. Sci. 23:1-15.

Rawson, H.M., and L.T. Evans. 1971. The contribution of stem reserves to grain development in a range of wheat cultivars of different heights. Austral. J. Agric. Res. 22:851-863.

Rogler, G.A. 1954. Seed size and seedling vigor in crested wheatgrass. Agron. J. 46:216-220.

Ross, M.A., and J.L. Harper. 1972. Occupation of biological space during seedling establishment. J. of Ecol. 60:77-88.

Salt, R.W. 1946. Some effects of temperature on the production and elimination of diapause in the wheat stem sawfly, *Cephus cinctus* Nort. Can. J. of Res. 25:66-85.

Seamans, H.L., G.F. Manson, and C.W. Farstad. 1944. The effect of wheat stem sawfly (*Cephus cinctus* Nort.) on the heads and grain of infested stems. 75th Ann. Rep. Entomol. Soc. Ont. pp.10-15.

Stanton, M.L. 1984. Seed variation in wild radish: Effect of seed size on components of seedling and adult fitness. Ecology. 65:1105-1112.

Tauber, M.J., and C.A. Tauber. 1976. Insect seasonality: Diapause maintence, termination, and postdiapause development. Ann. Rev. Entomol. 21:81-107.

Tiernan, C.F. 1978. The role of entomology in range management. Proceedings of the first International Rangeland Congress. USDA U.S. For. Ser. pp.477-478.

Twamley, B.E. 1967. Seed size and seedling vigor in birdsfoot trefoil. Can. J. Plant Sci. 47:603-609.

Vickery, P.J. 1972. Grazing and net primary production of a temperate grassland. J. Appl. Ecology. 9:307-314.

Villacorta, A., R.A. Bell, and J.A. Callenbach. 1971. Influence of high temperature and light on postdiapause development of the wheat stem sawfly. J. Econ. Entomol. 64:749-751.

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

Winn, A.A. 1985. Effects of seed size and microsite on seedling emergence of Prunella vulgaris in four habitats. J. of Ecol. 73:831-840.

Young, J.A., and R.A. Evans. 1981. Germination of Great Basin wildrye seeds collected from native stands. Agron. J. 73:917-920.

Youtie, B.A., and R.F. Miller. 1986. Insect predation on *Astragalus filipes* and *A. purshii* seeds. N.W. Science 60:42-46.

SUMMARY

This summary reports the results of an investigation which identified the phytophagous and parasitic insect guilds associated with Great Basin wildrye, and determined the relationship between the wheat stem sawfly (*Cephus cinctus* Norton) and basin wildrye. The study was conducted on Craters of the Moon National Monument (CRMO) and the Idaho National Engineering Laboratory (INEL) on the Snake River Plain in southern Idaho during the summers of 1982 and 1983.

Forty-six species of phytophagous insects in 22 families and 7 orders inhabited Great Basin wildrye at the 2 sites. Thirty of these species had not been previously reported in the literature as feeding on basin wildrye. The insect herbivores that appeared to have had the greatest impact on the grass were the black grass bug (*Labops utahensis* Slater), a delphacid (*Eurysa obesa* Beamer) and the wheat stem sawfly. In addition, 8 chalcid species were reared and identified from insect hosts in the plant culms.

Insect guilds at the two sites were compared based on species presence utilizing Sorensen's similarity index. Overall, 45 insect species were collected at the Craters of the Moon National Monument and 38 were collected at the Idaho National Engineering Laboratory. Twenty-six insect species were common to both sites yielding a moderate similarity index of 0.62. Internal culm chewers (1.0), flower and seed feeders (0.80,0.89) displayed the greatest similarity. Root-

feeders, both fluid feeders and chewers, had the least similarity (0.00,0.40). The study sites were two distinct habitat types that represented extremes in ecological amplitude of basin wildrye. Climatic and edaphic differences probably accounted for much of the dissimilarity in insect communities.

The relatively high number of phytophages on wildrye was likely due to the grass' tall, caespitose growth form, its abundance within its habitat and geographic range, and the large number of related species of grasses in the region.

The majority of the insect species that constituted the wildrye herbivore guilds were restricted to grasses and thus classified as being oligophagous. Many of the species identified are known to feed on cereal crops as well as other native and introduced grasses. Wildrye stands may serve as reservoirs for potential agricultural pest species as well as beneficial predator and parasite species. Therefore, it is essential to identify rangeland insects, describe their biologies and determine their impacts on native hosts.

In this study, the biology and impacts of the wheat stem sawfly, a pest species associated with wheat, on one of its native hosts were investigated. Large populations of the wheat stem sawfly fed in Great Basin wildrye tillers. From 62 to 88% of the plants and 22 to 38% of the tillers were infested with the sawfly. There were no significant differences in infestation rates between years or sites ($p>0.05$).

Phenology of the sawfly and basin wildrye at CRMO was three weeks later than at the INEL site. Plant phenology was a good predictor of sawfly emergence; adult sawflies emerged from wildrye culms when inflorescences emerged from the grass sheaths. Adult sawflies selected larger-stemmed plants for oviposition sites. Culms were cut by sawfly larvae after seed maturation, but larvae consumed vascular tissues inside the culms while the seeds were forming on the spike. Seed weight and number of caryopses developing within wildrye florets were reduced ($p<0.006$, $p<0.018$, respectively) in culms containing sawfly larvae. Sawfly tunnelling in the stems likely imposed a severe physiological stress on the culms by reducing the carbohydrates available for growth and respiration and by impairing water translocation. Compensatory plant growth may reduce the adverse effect of the sawfly on basin wildrye's seed production. Additional work such as determining photosynthetic and respiration rates for infested and non-infested tillers will be needed to further access the impacts of wheat stem sawfly herbivory.

Although vegetative reproduction plays a much greater role in the population dynamics of basin wildrye than does sexual reproduction in the majority of stands, seed production may be very important in the colonization of new sites (Harper 1977). Restoring certain types of rangelands to optimum productivity may well involve the seeding of Basin wildrye. Additionally, the INEL expects to plant basin wildrye above buried nuclear waste due to its deep root

system and excellent water extraction capabilities that should prevent moisture from penetrating to the depth of the waste. Knowledge of wildrye's insect herbivore guilds, predators and parasites may be useful to the Department of Energy for this project as well as grass breeders, seed companies, and range managers for other revegetation endeavors. More investigation is needed to determine the effects of the other important phytophagous insects on the growth and development of wildrye and the influence of their predators and parasites.

LITERATURE CITED

Ainslie, G.G. 1920. The western grass-stem sawfly. USDA Bull. 481. 27pp.

Ainslie, G.G. 1930. The bluegrass webworm. USDA Tech. Bull. 31. 25pp.

Asana, R.D., and R.N. Basu. 1963. Studies in physiological analysis of yield. Indian J. Plant Physiol. 6:1-13.

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

Awramik, S.M. 1971. Precambrian columnar stromatolite diversity: reflection of metazoan appearance. Science 174:825-827.

Bailey, S.F. 1948. Grain and grass infesting thrips. J. Econ. Entomol. 41:701-706.

Bailey, S.F., and G.F. Knowlton. 1949. The Thysanoptera of Utah. Proc. Entomol. Soc. Wash. 51:231-234.

Ball, E.D., E.R. Tinkham, R. Flock, and C.T. Vorhies. 1942. The grasshoppers and other Orthoptera of Arizonia. Ariz. Agric. Exp. Sta. Tech. Bull. 93. 373pp.

Banfill, J.C., and M.A. Brusven. 1973. Food habits and ecology of grasshoppers in the Seven Devils Mountains and Salmon River Breaks of Idaho. Melanderia 12:1-21.

Barnum, A.H. 1964. Orthoptera of the Nevada Test Site. Brigham Young Univ. Sci. Bull. Biol. Ser. 4. 135 pp.

Beirne, B.P. 1971. Pest insects of Canada. Mem. Entomol. Soc. Can. 78:1-24.

Beisler, J.M., R.L. Pienkowski, L.T. Kok, and W.H. Robinson. 1977. Insects associated with three weedy grasses and yellow nutsedge. Environ. Entomol. 6:455-459.

Bernays, E.A. 1986. Diet-induced head allometry among foliage-chewing insects and its importance for graminivores. Science. 231:495-497.

Bewley, J.D. and M. Black. 1978. Filling of the grain in cereals. *In* Physiology and biochemistry of seeds. vol. I. Development, germination and growth. Springer Verlag, Berlin. 306pp.

Black, J.N. 1956. The influence of seed size and depth of sowing on pre-emergence and early vegetative growth of subterranean clover (*Trifolium subterranean* L.). Austral. J. Agric. Res. 7:98-109.

Boyd, F.J., and H.N. Pitre. 1968. Studies on the field biology of *Graminella nigrifrons*, a vector of corn stunt virus in Mississippi. Ann. Entomol. Soc. Amer. 61: 1423-1426.

Branson, T.F., and E.E. Ortman. 1970. The host range of the western corn rootworm: further studies. J. Econ. Entomol. 63:800-803.

Branson, T. F., and E.E. Ortman. 1971. Host range of larvae of the northern corn rootworm: further studies. J. Kans. Entomol. Soc. 44:50-52.

Brown, E.S., and C.F. Dewhurst. 1975. The genus *Spodoptera* (Lepidoptera:Noctuidae) in Africa and the Near East. Bull. Entomol. Res. 65:221-262.

Brues, C.T. 1924. The specificity of food plants in the evolution of phytophagous insects. Amer. Nat. 58: 127-144.

Burton, R.L., K.L. Starks and D.C. Peters. 1980. The army cutworm. Okla. Agric. Exp. Sta. Bull. B-749. 35pp.

Butler, G.D., and F.G. Werner. 1960. Pentatomids associated with Arizona crops. Ariz. Agric. Exp. Sta. Tech. Bull. 140. 16pp.

Caffrey, D.J., and G.W. Barber. 1919. The grain bug. USDA Bull. 779. 35pp.

Calkins, C.O., and V.M. Kirk. 1975. A repeat performance, false wireworms bear watching. So. Dak. Farm and Home Res. 26:3-4.

Capinera, J.L. 1979. Qualitative variation in plants and insects: Effect of propagule size on ecological plasticity. Amer. Nat. 114:350-361.

Chapman, R.F. 1963. Structure and wear of mandibles in African grasshoppers. Proc. Zool. Soc. London 142:107-110.

Chu, I.W., and H. Knutson. 1970. Preferences of eight grasshopper species among eleven species of cultivated grasses. J. Kans. Entomol. Soc. 43:20-31.

Church, N.S. 1955. Moisture and diapause in the wheat stem sawfly, *Cephus cinctus* Nort. (Hymenoptera: Cephidae). Can. Entomol. 87:85-97.

Crawford, C.S., and R.F. Harwood. 1959. Lepidoptera associated with grasses grown for seed in eastern Washington. J. Econ. Entomol. 52:966-969.

Crawley, M. 1983. Herbivory: The dynamics of animal-plant interactions. Univ. of Calif. Press, Berkeley, Calif. 437pp.

Criddle, N. 1923. The life habits of *Cephus cinctus* Nort. in Manitoba. Can. Entomol. 55:1-4.

Crumb, S.E. 1956. The larvae of the Phalaenidae. USDA Tech. Bull. 1135. 356pp.

Day, T. 1985. Plant association and soil factors in primary succession on cinder cones in Idaho. M. S. Thesis. Univ. of Idaho. Moscow, Idaho. 62pp.

Delong, D.M. 1948. The leafhoppers or Cicadellidae of Illinois. Bull. Ill. Nat. Hist. Surv. 24:1-376.

Dethier, V.G. 1954. Evolution of feeding preferences in phytophagous insects. Evolution. 8:33-54.

Dewey, D.R. 1982. New nomenclatural combinations in the North American perennial Triticeae (Gramineae). Brittonia. 35:30-33.

Ehrlich, P.R. and Raven, P.H. 1964. Butterflies and plants: A study in coevolution. Evolution. 18:586-608.

Evans, R.A., and J.A. Young. 1983. 'Magnar' Basin wildrye germination in relation to temperature. J. Range Manage. 36:395-398.

Farstad, C.W. 1940. The development of western wheat stem sawfly (*Cephus cinctus* Nort.) in various host plants as an index of resistance. Iowa State College. J. Sci. 15:67-69.

Feeny, P.P. 1975. Biochemical coevolution between plants and their insect herbivores. pp.3-19. *In* Gilbert, L.E. and P.H. Raven (eds.). Coevolution of animals and plants. Univ. of Texas. Austin. 246pp.

Fowler, S.V., and J.H. Lawton. 1982. The effects of host-plant distribution and local abundance on the species richness of agromyzid flies attacking British umbellifers. Ecol. Entomol. 7:257-265.

Frelich, J.R., E.H. Jensen, and R.O. Gifford. 1973. Effect and crust rigidity and osmotic potential on emergence of 6 grass species. Agron. J. 65:26-29.

Furniss, M., and W. Barr. 1975. Insects affecting important native shrubs of the northwestern United States. USDA For. Ser. Rep. INT-19. 64pp.

Gahan, A.B. 1918. Description of a new hymenopterous parasite (Braconidae). Wash. Entomol. Soc. Proc. 20: 18-19.

Ganguer, S.K. 1961. A monograph on food selection in Orthoptera. Trans. Amer. Entomol. Soc. 87:67-230.

Garrett, P. 1970. Phanerozoic stromatolites: non-competitive ecologic restriction by grazing and burrowing animals. Science. 169:171-173.

Gillett, J.B. 1962. Pest pressure, an underestimated factor in evolution. Syst. Assoc. Publ. 4:37-46.

Gillette, C.P. 1918. Some grass-root aphids. Entomol. News. 29:281-284.

Gittens, A.R., G.W. Bishop, G.F. Knowlton, and E.J. Parker. 1976. An annotated list of the aphids of Idaho. Agric. Exp. Sta. Res. Bull. No. 95. 47 pp.

Godfrey, G.L. 1972. A review and reclassification of larvae of the subfamily Hadeninae (Lepidoptera:Noctuidae) of America north of Mexico. USDA Tech. Bull. 1450. 265pp.

Griffiths, D. 1901. Forage conditions on the northern border of the Great Basin. Bull. 15. Bureau of Plant Industry, USDA. 60pp.

Harper, J.L., P.H. Lovell, and K.G. Moore. 1970. The shapes and sizes of seeds. Ann. Rev. of Ecol. and Syst. 1: 327-356.

Harper, J.L. 1977. The population biology of plants. Academic Press, London. 892pp.

Hartley, W. 1973. Studies on the origin, evolution, and distribution of the Graminae V. The subfamily Festucoideae. Austral. J. Bot. 21:201-234.

Haws, B.A. 1978. Economic impacts of *Labops hesperius* on the production of high quality range grasses. Utah St. Univ. Agric. Exp. Sta. Rep. 269 pp.

Haws, B.A. 1982. Rangeland insects. Utah Agric. Exp. Sta. Special Rep. 23. 64 pp.

Hillman, F.H. 1896. Field notes on some Nevada grasses. Agr. Exp. Sta. Nevada St. Univ. Bull. 33. 13pp.

Hitchcock, A.S. 1950. Manual of the grasses of the United States. Dover Publ., New York. 1051pp.

Holmes, N.D. 1953. Note on *Scambus detritus* Holmg. (Hymenoptera:Ichneumonidae) a new parasite of the wheat stem sawfly, *Cephus cinctus* Nort. Can. Entomol. 85:339.

Holmes, N.D. 1954. Food relations of the wheat stem sawfly, *Cephus cinctus* Nort. (Hymenoptera: Cephidae). Can. Entomol. 86:159-167.

Holmes, N.D. 1975. Effects of moisture, gravity and light on the behavior of larvae of the wheat stem sawfly, *Cephus cinctus* Nort. (Hymenoptera:Cephidae). Can. Entomol. 107:391-401.

Holmes, N.D. 1977. The effect of the wheat stem sawfly, *Cephus cinctus* (Hymenoptera: Cephidae), on the yield and quantity of wheat. Can. Entomol. 109:1591-1598.

Holmes, N.D. 1982. Population dynamics of the wheat stem sawfly, *Cephus cinctus* (Hymenoptera:Cephidae), in wheat. Can. Entomol. 114:775-788.

Horning, D.S. Jr., and W.F. Barr. 1968. Insects of Craters of the Moon National Monument, Idaho. Univ. of Idaho. College of Agric. Mis. Ser. 8. 118pp.

Howell, N. 1981. The effect of seed size and relative emergence time on fitness in a natural population of *Impatiens capensis* Meerb. (Balsaminaceae). Amer. Midl. Nat. 105:312-320.

Isley, F.B. 1944. Correlation between mandibular morphology and food specificity in grasshoppers. Ann. Entomol. Soc. Amer. 37:47-67.

Johnson, N.E., and R.S. Cameron. 1969. Phytophagous ground beetles. Ann. Entomol. Soc. Amer. 62:909-914.

Kamm, J.A. 1969. Biology of the billbug, *Sphenophorus venatus confluens*, a new pest of orchard grass. J. Econ. Entomol. 62:808-812.

Kemp, H.J. 1934. Studies on solid-stemmed wheat varieties in relation to wheat-stem sawfly control. Sci. Agric. 15:30-38.

Kneebone, W.R., and C.L. Cremer. 1955. The relationship of seed size to seedling vigor in some native grass species. Agron. J. 47:472-477.

Knight, H.H. 1968. Taxonomic review: Miridae of the Nevada Test Site and the western United States. Brigham Young Univ. Sci. Bull. Biol. Ser. 9. 282pp.

Knowlton, G.F., and W.D. Fronk. 1942. Some grass aphid host records (Homoptera). Entomol. News. 53:112-114.

Knowlton, G.F., and W.L. Thomas. 1933. Food plants and distribution of some Utah Thysanoptera. Can. Entomol. 65:114-117.

Krall, J.L., J.R. Stroh, C.S. Cooper, and S.R. Chapman. 1971. The effect of time and extent of harvesting basin wildrye. J. Range Manage. 24:414-418.

Krebs, C.J. 1978. Ecology: The experimental analysis of distribution and abundance. Harper & Row, New York. 678pp.

Krombein, K.V., P.D. Hurd, D.R.Smith, and B.D. Burks. 1979. Catalog of Hymenoptera in America north of Mexico. Vol.I Symphyta and Apocrita (Parasitica). Smithsonian Inst. Press, Washington, D.C. 1198pp.

Lawrence, T. 1978. An evaluation of 30 grass populations as forage crops for southwestern Saskatchewan, Canada. Can. J. Plant Sci. 58:107-116.

Lawton, J.H., and D. Schroder. 1977. Effects of plant type, size of geographical range and taxonomic isolation on number of insect species associated with British plants. Nature. 265:137-140.

Lesperance, A.L., J.A. Young, R.E. Eckert, Jr., and R.A. Evans. 1978. Great Basin Wildrye. Rangeman's J. 5:125-127.

Luginbill, P. Jr., and F.H. McNeil. 1958. Influence of seeding density and row spacing on the resistance of spring wheats to the wheat stem sawfly. J. Econ. Entomol. 51:804-808.

MacGillivray, A.D. 1921. The Coccidae. Scarab Co., Urbana, Illinois. 502 pp.

Mason, C.E., and T.R. Yonke. 1971. Key to species of Cicadellinae (Homoptera:Cicadellidae) of Missouri with notes on their taxonomy, distribution and biology. Trans. Missouri Acad. Sci. 5:93-120.

Maun, M.A., and P.B. Cavers. 1971. Seed production and dormancy in *Rumex crispus*. I. The effects of removal of cauline leaves at anthesis. Can. J. Bot. 49:1123-1130.

McBride, R., N.R. French, A.H. Dahl, and J.E. Detmer. 1978. Vegetation types and surface soils of the Idaho National Engineering Laboratory Site. U.S.D.O.E., Radiol. Environ. Sci. Lab. Rep. No. IDO-12084, Idaho Falls, Idaho. 28pp.

McKell, C.M. 1972. Seedling vigor and seedling establishment. *In* V.B. Younger and C.M. McKell (eds.). The biology and utilization of grasses. Academic Press, New York. pp.76-89.

McKenzie, H.L. 1967. Mealybugs of California. Univ. of Calif. Press, Berkely, Calif. 517pp.

McNaughton, S.J. 1979. Grassland-herbivore dynamics. pp. 46-81. *In* Sinclair, A.R. and M. Norton-Griffiths (eds.). Serengeti:Dynamics of an ecosystem. Univ. Chicago Press, Chicago. 389 pp.

McNaughton, S.J. 1983a. Physiological and ecological implications of herbivory. *In* Lange, O.L., P.S. Nobel C.S. Osmond, and H. Ziegler (eds). Physiological plant ecology III-Responses to chemical and biological environments. Ency. of Plant Physiology New Series 12C. Springer-Verlag, Berlin. 799pp.

McNaughton, S.J. 1983b. Compensatory plant growth as a response to herbivory. Oikos. 40:329-336.

McNaughton, S.J., J.L.Tarrants, M.M. McNaughton, and R.H. Davis. 1985. Silica as a defense against herbivory and a growth promoter in African grasses. Ecology. 66:528-535.

McNeil, F.H., M.A. Berg, and P. Luginbill. 1955. Wheat stem sawfly damage in four spring wheat varieties as influenced by date of seeding. Agron. J. 47:522-525.

Muesebeck, C.F.W. 1953. Three new reared Braconidae (Hymenoptera). Wash Entomol. Soc. Proc. 55:149-151.

Mulkern, G.B. 1961. Food selection by grasshoppers. Ann. Rev. Entomol. 12:59-78.

Munro, J.A., R.L. Post, and R. Knapp. 1947. The wheat stem sawfly as affecting yield. N. Dak. Agric. Exp. Sta. Bimo. Bull. 10:46-51.

Murray, R.B., H.F. Mayland, and P.J. van Soest. 1978. Growth and nutritional value to cattle of grasses on cheatgrass range in southern Idaho. U.S. For. Serv. Res. PAP Int. 199:1-57.

Nelson, W.A. 1953. Biology of *Bracon cephi* Gahan (Hymenoptera:Braconidae). An important native parasite of the wheat stem sawfly, *Cephus cinctus* Nort. (Hymenoptera:Cephidae) in western Canada. Can. Entomol. 85:103-107.

Nielson, C.L. 1949. Biology and seasonal history of *Pleuratropis utahensis* Crawford a parasite of the wheat stem sawfly. Can. Entomol. 81:174-180.

Nielson, M.W. 1968. The leafhopper vectors of phytopathogenic viruses (Homoptera, Cicadellidae). Taxonomy, biology and virus transmission. USDA Tech. Bull. 1382. 386pp.

Niemela, P., J. Tahvanainen, J. Sorjonen, T. Hokkanen, and S. Neuvonen. 1982. The influence of host plant growth form and phenology on the life strategies of Finnish macrolepidopterous larvae. Oikos. 39:164-170.

O'Keeffe, L.E., J.A. Callenbach, and K.L. Lebsock. 1960. Effect of culm solidness on the survival of the wheat stem sawfly. J. Econ. Entomol. 53:244-246.

Oman, P.W. 1949. The nearctic leafhoppers, a generic classification and check list. Mem. Entomol. Soc. Wash. 3. 253pp.

Patch, E.M. 1939. Food plant catalogue of the aphids of the world. Maine Agric. Exp. Sta. Bull. 393. 431pp.

Patterson, B.P. 1984. Correlation between mandibular morphology and specific diet of some desert grassland Acrididae (Orthoptera). Amer. Midl. Nat. 111:296-303.

Perry, L.J., and S.R. Chapman. 1974. Effects of clipping on carbohydrate reserves in basin wildrye. Agron. J. 66:67-70.

Perry, L.J., and S.R. Chapman. 1975. Effects of clipping on dry matter yields of basin wildrye. J. Range Manage. 28:271-273.

Pinto, J.D., and R.B. Selander. 1970. The bionomics of blister beetles of the genus *Meloe* and a classification of the new World species. Illinois Biol. Mono. 42. 22pp.

Platt, A.W. 1941. The influence of some environmental factors on the expression of the solid-stem character in certain wheat varieties. Sci. Agric. 21:139-151.

Platt, A.W., and C.W. Farstad. 1946. The reaction of wheat varieties to wheat stem sawfly attack. Sci. Agric. 26:231-247.

Platt, A.W., C.W. Farstad, and J.A. Callenbach. 1948. The reaction of Rescue wheat to sawfly damage. Sci. Agric. 28:154-161.

Rawson, H.M. 1970. Spikelet number, its control and relation to yield per ear in wheat. Austral. J. Biol. Sci. 23:1-15.

Rawson, H.M., and L.T. Evans. 1971. The contribution of stem reserves to grain development in a range of wheat cultivars of different heights. Austral. J. Agric. Res. 22:851-863.

Riherd, P.T. 1954. Thrips a limiting factor in seed production. J. Econ. Entomol. 47:709-710.

Rogler, G.A. 1954. Seed size and seedling vigor in crested wheatgrass. Agron. J. 46:216-220.

Root, R.B. 1973. Organization of a plant-arthropod association in simple and diverse habitats: The fauna of collards (*Brassica oleracea*). Ecol. Mono. 43:93-124.

Ross, M.A., and J.L. Harper. 1972. Occupation of biological space during seedling establishment. J. of Ecol. 60:77-88.

Sabrosky, C.W. 1950. The genus *Dicraeus* in North America (Chloropidae). Proc. Entomol. Soc. Wash. 52:53-62.

Salt, R.W. 1946. Some effects of temperature on the production and elimination of diapause in the wheat stem sawfly, *Cephus cinctus* Nort. Can. J. of Res. 25:66-85.

Seamans, H.L., G.F. Manson, and C.W. Farstad. 1944. The effect of wheat stem sawfly (*Cephus cinctus* Nort.) on the heads and grain of infested stems. 75th Ann. Rep. Entomol. Soc. Ont. pp.10-15.

Smith, C.F., and C.S. Parron. 1978. An annotated list of Aphididae (Homoptera) of North America. N. Carolina Agric. Exp. Sta. Tech. Bull. 255. 428pp.

Somsen, H.W., and P. Jr. Luginbill. 1956. *Bracon lissogaster* Muesebeck, a parasite of the wheat stem sawfly. USDA Tech. Bull. 1153. 7pp.

Sorensen, T.A. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content, and its application to analysis of the vegetation on Danish commons. K dan Vidensk Selsk. Biol. Skr. 5:1-34.

Southwood, T.R.E. 1961. The number of species of insect associated with various trees. J. Anim. Ecol. 30:1-8.

Spears, B., and W.F. Barr. 1985. Effect of jointworms on the growth and reproduction of four native range grasses of Idaho. J. Range Manage. 38:44-46.

Stanton, M.L. 1984. Seed variation in wild radish:Effect of seed size on components of seedling and adult fitness. Ecology. 65:1105-1112.

Stebbins, G.L. 1981. Coevolution of grasses and herbivores. Ann. Missouri Bot. Gard. 68:75-86.

Strong, D.R., and D.A. Levin. 1979. Species richness of plant parasites and growth form of their hosts. Amer. Nat. 114:1-22.

Strong, D.R., J.H. Lawton, and T.R.E. Southwood. 1984. Insects on plants-community patterns and mechanisms. Harvard Univ. Press, Cambridge, Mass. 313pp.

Swain, R.B. 1944. Nature and extent of mormon cricket damage to crop and range plants. USDA Tech. Bull. 866. 44pp.

Tallamy, D.W., and R.F. Denno. 1979. Responses of sap-feeding insects (Homoptera-Hemiptera) to simplification of host plant structure. Environ. Entomol. 8:1021-1028.

Tashiro, H., and K.E. Personius. 1970. Current status of the bluegrass billbug and its control in western New York home lawns. J. Econ. Entomol. 63:23-29.

Tauber, M.J., and C.A. Tauber. 1976. Insect seasonality: Diapause maintence, termination, and postdiapause development. Ann. Rev. Entomol. 21:81-107.

Thomas, D.B., and F.G. Werner. 1981. Grass feeding insects of the western ranges: An annotated checklist. Univ. of Ariz. Agric. Exp. Sta. Four-Corners Regional Commission, Project No. 602-466-080-4. 50pp.

Tiernan, C.F. 1978. The role of entomology in range management. Proceedings of the first International Rangeland Congress. USDA U.S. For. Ser. pp. 477-478.

Tingley, W.M., C.D. Jorgensen, and N.C. Frischknecht. 1972. Thrips of the sagebrush-grass range community in west-central Utah. J. Range Manage. 25:304-308.

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.

Twamley, B.E. 1967. Seed size and seedling vigor in birdsfoot trefoil. Can. J. Plant Sci. 47:603-609.

Ueckert, D.N., and R.M. Hansen. 1971. Dietary overlap of grasshoppers on sandhill rangeland in north-eastern Colorado. Oecologia 8:276-295.

Vaurie, P. 1951. Revision of the genus *Calendra* (formerly *Sphenophorus*) in the United States and Mexico (Coleoptera:Curculionidae). Bull. Amer. Mus. Nat. Hist. 98:29-186.

Vickery, P.J. 1972. Grazing and net primary production of a temperate grassland. J. Appl. Ecol. 9:307-314.

Villacorta, A., R.A. Bell, and J.A. Callenbach. 1971. Influence of high temperature and light on postdiapause development of the wheat stem sawfly. J. Econ. Entomol. 64:749-751.

Wade, J.S. 1923. Biology of the false wireworm, *Eleodes suturalis* Say. J. Agric. Res. 22:323-335.

Wadham, M.D., and D.W. Parry. 1981. The silicon content of *Oryza sativa* L. and its effect on grazing behavior of *Agriolimax reticulatus* Muller. Ann. Bot. 48:399-402.

Walkden, H.M. 1950. Cutworms, armyworms, and related species attacking cereal and forage crops in the central plains. USDA Circ. 849. 52 pp.

Walker, G.R., and J.D. Brotherson. 1982. Habitat relationships of basin wildrye in the high mountain valleys of central Utah. J. Range Manage. 35:628-633.

Wallace, L.E., and F.H. McNeil. 1968. Stem sawflies of economic importance in grain crops in the United States. USDA Tech. Bull. 1350. 50pp.

Walter, H. 1979. Vegetation of the earth and ecological systems of the geobiosphere. Springer-Verlag, New York. 274pp.

Watts, J.G. 1963. Insects associated with black grama grass, *Bouteloua eriopoda*. Ann. Entomol. Soc. Amer. 56:374-379.

Watts, J.G. 1965. *Chirothrips falsus* Priesner on black grama grass. New Mexico Agric. Exp. Sta. Bull. 499. 20pp.

Watts, J.G., and A.C. Bellotti. 1967. Some new and little known insects of economic importance on range grasses. J. Econ. Entomol. 60:961-963.

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

Whitmore, R.W., K.P. Pruess, and J.T. Nichols. 1981. Leafhopper and planthopper populations on eight irrigated grasses grown for livestock forage. Environ. Entomol. 10:114-118.

Wight, R. 1986. Insect fauna of a crested wheatgrass habitat in the Raft River Valley of southern Idaho. M.S. Thesis. Univ. of Idaho. Moscow, Idaho. 120pp.

Williams, L.H. 1954. The feeding habits and food preferences of Acrididae and the factors which determine them. Trans. R. Entomol. Soc. London. 105:423-454.

Winn, A.A. 1985. Effects of seed size and microsite on seedling emergence of *Prunella vulgaris* in four habitats J. of Ecol. 73:831-840.

Wolda, H. 1981. Similarity indices, sample size and diversity. Oecologia. 50:296-302.

Wolfe, H.R. 1955. Leafhoppers of the state of Washington. Wash. Agric. Exp. Sta. Circ. 277. 37pp.

Wulff, R.D. 1986. Seed size and variation in *Desmodium paniculatum*. J. of Ecol. 74:99-114.

Young, J.A., and R.A. Evans. 1981. Germination of Great Basin wildrye seeds collected from native stands. Agron. J. 73:917-920.

Youtie, B.A., and R.F. Miller. 1986. Insect predation on *Astragalus filipes* and *A. purshii* seeds. N.W. Science 60:42-46.

Appendix A. Insects of western rangelands identified as feeding on the genus *Elymus*.

Taxa	Reference
Orthoptera	
Acrididae	
Amphitornus coloradus (Thomas)	Ueckert & Hansen 1971
Melanoplus bivittatus (Say)	Banfill & Brusven 1973
Melanoplus femurrubrum (DeGeer)	Chu & Knutson 1970
Melanoplus sanguinipes (Fabricius)	Chu & Knutson 1970
Mermiria maculipennis Bruner	C.S.U. records
Orphulella speciosa (Scudder)	Chu & Knutson 1970
Parapomala pallida (Bruner)	Ball et al. 1942
Trimerotropis fontana Thomas	Barnum 1964
Decticidae	
Anabrus simplex Haldeman	Swain 1944
Dermaptera	
Forficulidae	
Forficula auricularia Linnaeus	Crumb et al. 1941
Thysanoptera	
Thripidae	
Anaphothrips longipennis Crawford	Bailey & Knowlton 1949
Anaphothrips obscurus (Muller)	U. of Ariz. records
Chirothrips aculeatus Bagnall	U. of Ariz. records
Chirothrips mexicanus Crawford	U. of Ariz. records
Chirothrips simplex Hood	Watts 1965
Frankliniella minuta (Moulton)	U. of Ariz. records
Frankliniella occidentalis (Pergande)	U. of Ariz. records
Plesiothrips perplexus (Beach)	U. of Ariz. records
Thrips tabaci Lindeman	U. of Ariz. records
Homoptera	
Aphididae	
Acyrthosiphon palmerae (Lambers)	Smith & Parron 1978
Anoecia corni (Fabricus)	Patch 1939
Forda formicaria Heyden	Patch 1939
Forda marginata Koch	Gillette 1918
Glabromyzus rhois (Monell)	Patch 1939
Macrosiphum avenae (Fabricus)	Knowlton & Fronk 1942
Cicadellidae	
Amblysellus grez (Oman)	Wolfe 1955
Balclutha abdominalis (Van Duzee)	Whitmore et al. 1981
Commellus comma (Van Duzee)	Delong 1948
Dalbulus maidis (DeLong & Wolcott)	Nielson 1968
Dikraneura arizonia Delong	Wolfe 1955
Dorycephalus platyrhynchus Osborn	Oman 1949
Draeculacephala antica Van Duzee	Mason & Yonke 1971
Draeculacephala portola Ball	Mason & Yonke 1971
Graminella nigrifrons (Forbes)	Boyd & Pitre 1968
Helochara communis Fitch	Wolfe 1955
Psammotettix alienus Dahlbom	Whitmore et al. 1981
Psammotettix lividellus (Zetterstedt)	Whitmore et al. 1981

Appendix A. Insects of western rangelands identified as feeding on the genus *Elymus*.

Taxa	References
Homoptera	
Pseudococcidae	
Cryptoripersia salina (Ehrhorn)	McKenzie 1967
Distichloccus californicus (Ehrhorn)	McKenzie 1967
Heterococcus arenae Ferris	McKenzie 1967
Trionymus americanus (Cockerell)	McKenzie 1967
Trionymus utahensis (Cockerell)	McKenzie 1967
Hemiptera	
Miridae	
Irbisia pacifica (Uhler)	Haws 1978
Labops hesperius Uhler	Haws 1978
Labops utahensis Slater	Haws 1978
Lygus desertinus Knight	Knight 1968
Stenodema virens (Linnaeus)	Knight 1968
Pentatomidae	
Chlorochroa granulosa Uhler	Caffrey & Barber 1919
Chlorochroa sayi Stal	Butler & Werner 1960
Coleoptera	
Carabidae	
Harpalus caliginosus Fabricus	Johnson & Cameron 1969
Chrysomelidae	
Diabrotica longicornis (Say)	Branson & Ortman 1971
Diabrotica undecimpunctata (Mannerheim)	Webster 1913
Diabrotica virgifera LeConte	Branson & Ortman 1970
Curculionidae	
Sphenophorus parvulus Gyllenhal	Vaurie 1951
Elateridae	
Ctenicera aeripennis (Kirby)	Beirne 1971
Meloidae	
Meloe angusticollis Say	Pinto & Selander 1970
Tenebrionidae	
Eleodes suturalis (Say)	Wade 1923
Embaphion muricatum (Say)	Calkins and Kirk 1975
Lepidoptera	
Noctuidae	
Nephelodes minians Guenee	Godfrey 1972
Pseudaletia unipuncta (Haworth)	Godfrey 1972
Pyralidae	
Crymodes devastator (Brace)	Crawford & Harwood 1959
Euxoa auxiliaris (Grote)	Burton et al. 1980
Faronta diffusa (Walker)	Watts & Bellotti 1967
Leucania phragmatidicola Guenee	Crumb 1956
Pediasia teterella Zincken	Ainslie 1930

Appendix A. Insects of western rangelands identified as feeding on the genus *Elymus*.

Taxa	Reference
Diptera	
Chloropidae	
Dicraeus aberrans Sabrosky	Sabrosky 1950
Dicraeus elongatus Sabrosky	Sabrosky 1950
Dicraeus incongruus Aldrich	Sabrosky 1950
Hymenoptera	
Cephidae	
Cephus cinctus Norton	Krombein et al. 1979
Eurytomidae	
Tetramesa elymi (French)[a]	Krombein et al. 1979
Tetramesa hesperus Phillips & Emery[a]	Krombein et al. 1979
Tetramesa rufipes Phillips & Emery[a]	Krombein et al. 1979
Tetramesa secale (Fitch)[a]	Knombein et al. 1979
Tetramesa websteri (Howard)[a]	Knowbein et al. 1979
Formicidae	
Pogonomyrmex occidentalis (Cresson)	Rogers 1974

[a] As *Harmolita* in Krombein et al. 1979

Appendix B. Insects previously collected in *Elymus cinereus*, Great Basin wildrye, communities at Craters of the Moon National Monument (CRMO) and the Idaho National Engineering Laboratory (INEL).

Taxa	Col.[a]	Location
Orthoptera		
Acrididae		
Pseudopomala brachyptera Scudder	H.& B.	CRMO
Xanthippus lateritus Sausare	S.	INEL
Hemiptera		
Berytidae		
Neides mutica Say	S.	INEL
Lygaeidae		
Kleidocerys franciscanus (Stal)	H.& B.	CRMO
Nysius ericae Auctorum	H.& B.	CRMO
Miridae		
Irbisia pacifica Uhler	S.	INEL
Lygus hesperus Knight	H.& B.	INEL
Stenodema laevigatum Linnaeus	S.	INEL
Stenodema virens (Linnaeus)	H.& B.	CRMO
Nabidae		
Nabis alternatus (Parshley)	H.& B.	CRMO
Pentatomidae		
Aelia americana Dallas	S.	INEL
Rhytidilomia uhleri Stal	S.	INEL
Homoptera		
Cicadellidae		
Dikraneura spp.	S.	INEL
Macrosteles spp.	S.	INEL
Parabolocrayus viridis Uhler	S.	INEL
Cicadidae		
Okanogana bella Davis	H.& B.	CRMO
Delphacidae		
Eurysa obesa Beamer	S.	INEL
Neuroptera		
Hemerobiidae		
Hemerobius stigmaterus Fitch	H.& B.	CRMO
Micromus variolus Hagen	S.	INEL
Coleoptera		
Anthicidae		
Lappus nitidulus LeConte	H.& B.	CRMO
Notoxus serratus LeConte	S.	INEL
Cerambycidae		
Cortodera barri L.& C.	H.& B.	CRMO
	S.	INEL
Chrysomelidae		
Altica spp.	S.	INEL
Anisostera californica Van Dyke	S.	INEL

Appendix B. Insects previously collected in *Elymus cinereus*, Great Basin wildrye, communities at Craters of the Moon National Monument (CRMO) and the Idaho National Engineering Laboratory (INEL).

Taxa	Col.[a]	Location
Coleoptera		
Coccinellidae		
Brachyacantha ursina uteela Casey	S.	INEL
Hippodamia quinquesignata Kirby	H.& B.	CRMO
Curculionidae		
Miloderoides maculatus Van Dyke	S.	INEL
Sphenophorus gentilis LeConte	S.	INEL
Elateridae		
Anchastus cinereipennis Esch	S.	INEL
Dalopius fuscatus Brown	H.& B.	CRMO
Melanotus texanus Candeze	H.& B.	CRMO
Melyridae		
Amecocerus quadricollis Hatch	H.& B.	CRMO
Anthocomus horni (Fall)	H.& B.	CRMO
Attalus glabrellus Fall	S.	INEL
Attalus morulus smithi Hopping	S.	INEL
Collops bipunctatus Say	S.	INEL
Hoppingiana hudsonica (LeConte)	H.& B.	CRMO
Phalacridae		
Phalacrus penicillatus Say	H.& B.	CRMO
	S.	INEL
Lepidoptera		
Pyraustidae		
Pyrausta semirubralis (Packard)	H.& B.	CRMO
Diptera		
Agromyzidae		
Pytobia spp.	H.& B.	CRMO
Anthomyiidae		
Hylemya montana Malloch	H.& B.	CRMO
Asilidae		
Asilus auriannulatus (Hine)	H.& B.	CRMO
Bombyliidae		
Conophorus fenestratus (Osten Sacken)	H.& B.	CRMO
Chamaemyiidae		
Chamaemyia juncorum (Fallen)	H.& B.	CRMO
Pseudodinia nitens (Melander & Spuler)	H.& B.	CRMO
Sepsidae		
Sepsis neocynipsea Melander & Spuler	H.& B.	CRMO
	S.	INEL
Sphaeroceridae		
Leptocera cryptica Sabrosky	H.& B.	CRMO
Leptocera fontinalis (Fallen)	H.& B.	CRMO
Leptocera spp.	S.	INEL

Appendix B. Insects previously collected in *Elymus cinereus*, Great Basin wildrye, communities at Craters of the Moon National Monument (CRMO) and the Idaho National Engineering Laboratory (INEL).

Taxa	Col.[a]	Location
Diptera		
Tachinidae		
Hyalomya aldrichi Townsend	H.& B.	CRMO
Tephritidae		
Trupanea jonesi Curran	H.& B.	CRMO
Tipulidae		
Dactylolabis spp.	H.& B.	CRMO
Hymenoptera		
Braconidae		
Agathis gibbosa (Say)	H.& B.	CRMO
Orgilus spp.	H.& B.	CRMO
Cephidae		
Cephus cinctus Norton	H.& B.	CRMO
	S.	INEL
Chalcididae		
Trigonura pini Burks	H.& B.	CRMO
Eulophidae		
Entedontini spp.	S.	INEL
Eulophid spp.	S.	INEL
Tetrastichus spp.	H.& B.	CRMO
Eupelmidae		
Eupelmus spp.	H.& B.	CRMO
Eurytomidae		
Eurytoma spp.	S.	INEL
Tetramesa elymophaga Phillips & Emery	H.& B.	CRMO
Tetramesa spp.	S.	INEL
Formicidae		
Camponotus herculeanus modoc Wheeler	H.& B.	CRMO
Formica lasiodes Emery	H.& B.	CRMO
Ichneumonidae		
Barylypa spp.	H.& B.	CRMO
Campoletis spp.	H.& B.	CRMO
Cryptus spp.	H.& B.	CRMO
Glypta spp.	H.& B.	CRMO
Pteromalidae		
Amblymerus verdifer Norton	H.& B.	CRMO
Platyterma spp.	H.& B.	CRMO
Torymidae		
Torymid spp.	S.	INEL

[a] H.& B.- D.S.Horning and W.F.Barr 1968; S.- M. Stafford collector unpublished, University of Idaho museum records

Appendix C. Mean weight (gm) of 10 seeds from Great Basin wildrye tillers infested and non-infested with the wheat stem sawfly, Idaho National Engineering Laboratory, 1983.

Tiller Diameter Classes	Mean seed weight: Infested Tillers mean (sd,n)*	Non-infested Tillers mean (sd,n)
< 2.00 mm	0.0294 (0.0045,59) a	0.0314 (0.0046,154) b
2.00-2.50 mm	0.0295 (0.0047,124) a	0.0317 (0.0051,169) b
2.51-3.00 mm	0.0300 (0.0055,163) a	0.0332 (0.0051,121) b
> 3.00 mm	0.0311 (0.0054,138) a	0.0338 (0.0052,81) b
all diameters	0.0301 (0.0052,484) a	0.0329 (0.0050,525) b

* Means in a row followed by different letters are significantly different ($p \leq 0.006$;2-way ANOVA, Tukey's Studentized t-test); sd=standard deviation and n=number of spikes sampled.

Appendix D. Mean percent seed set of Great Basin wildrye tillers infested and non-infested with the wheat stem sawfly, Idaho National Engineering Laboratory, 1983.

Tiller Diameter Classes	Mean Percent Seed Set: Infested Tillers % (sd,n)*	Non-infested Tillers % (sd,n)
< 2.00 mm	73.3 (1.4,059) a	79.1 (1.4,154) b
2.00-2.50 mm	73.1 (1.6,124) a	77.2 (1.3,169) b
2.51-3.00 mm	69.4 (2.0,163) a	77.9 (1.3,121) b
> 3.00 mm	67.0 (1.9,138) a	78.9 (1.1,081) b
all diameters	70.1 (1.8,484) a	78.2 (1.3,525) b

* Means in a row followed by different letters are significantly different ($p \leq 0.018$; 2-way ANOVA, Tukey's Studentized t-test); sd=standard deviation and n= number of spikes sampled.