Forage Losses Caused by the Grasshopper *Aulocara elliotti* on Shortgrass Rangeland

GEORGE B. HEWITT, WAYNE H. BURLESON, AND JEROME A. ONSAGER

Highlight: *A field-cage study was conducted in 1973 and 1974 to determine the amount of forage (mainly grasses) destroyed by different population densities of the grasshopper* Aulocara elliotti. *The amount of forage consumed during the third instar and through the adult stage averaged 34.5 mg of forage per grasshopper per day. Thus, an estimated loss of 23.1 lb of forage per acre will result from a density of one* Aulocara/m^2 *if the grasshopper lives for 75 days (45 days as a nymph and 30 days as an adult). Based on total available forage (standing dead and new growth), a 63% forage loss was recorded in 1973 at one site and losses of 26% and 29% at two sites in 1974 resulting from about 20 grasshoppers/m^2. Severe grazing by grasshoppers also resulted in reduced production of forage during the subsequent (1974) season.*

Grasshoppers are the principal invertebrate consumers of forage on approximately 665 million acres of rangeland in the western United States. The damage they do to forage varies geographically and from year to year depending on the grasshopper complex present, the density of the insects, the vegetation complex, and the weather patterns. Thus, the amount of forage that may be destroyed at any location is difficult to predict. Federal, state, and private landowners need a reliable method of predicting potential forage losses due to grasshoppers in any growing season. With such information, it would be possible to make sound decisions concerning grasshopper control.

Several workers in the United States have attempted to measure forage losses caused by grasshopper populations of known densities (Morton, 1936, 1939; Pepper et al., 1951; Anderson and Wright, 1952; Nerney and Hamilton, 1966, 1967). However, Anderson (1961) pointed out that determination of the losses resulting from a particular grasshopper population on the basis of numbers alone is not valid because the food preferences of individual species are ignored. To quantitatively assess these losses, one must determine the amount of forage destroyed (forage consumed plus forage clipped and let fall to the ground) by individual species. Other workers (Parker, 1930; Smith, 1959; Misra and Putnam, 1966) have studied food consumption by individual grasshopper species in the laboratory; however, laboratory results of this type cannot usually be applied to field conditions.

We therefore attempted to determine the amount of preferred rangeland grasses destroyed at two sites by known populations of *Aulocara elliotti* (Thomas), an economically important grasshopper on shortgrass rangeland. Our loss figures were then compared to the forage loss figures due to grasshoppers determined by other workers. In general, *Aulocara elliotti,* the species chosen for the test, is among the most damaging grasshopper species on rangeland (Mulkern et al., 1969). It has been reported as a pest on rangeland over a long period (Cooley, 1904; Swenk, 1913; Corkins, 1923; Strand, 1937; White and Rock, 1945; Anderson, 1961; Brusven and Lambley, 1971). The species apparently prefers the wheatgrasses (Pfadt, 1949b; Brooks, 1958; Anderson, 1961; Mulkern et al., 1969). Pfadt (1949a) estimated forage losses due to this species on Wyoming rangeland by using field cages. He concluded that populations of 15 to 35/yd^2 could destroy as much forage as is normally produced each year on shortgrass rangeland.

Materials and Methods

1973 Study

A 15.7 ha area of native rangeland near Three Forks, Mont., was selected as the 1973 study site because one grass species, needleandthread (*Stipa comata*) was dominant, that is, it comprised approximately 92% of the vegetation (dry weight basis). The entire site was fenced to exclude large herbivores. Then 10 plots of approximately 36 m^2 each were established in 2 rows, 5/row. Eight cages measuring 6 × 6 × 1 m and constructed of Saran® screen were placed over 8 of the plots in two rows of four cages each (Fig. 1). One plot in each row was not covered by a cage. Twenty-five steel rods 25 cm high were placed at 1-m intervals within each cage (and throughout the uncovered plots) to provide resting sites for the grasshoppers and thus a more uniform distribution within the cages or plots.

On June 13, three in each row were infested with one of three densities of field-collected 3rd- and 4th-instar *A. elliotti,* 28/m^2 for the high density cages, 14/m^2 for the medium density cages, and 7/m^2 for the low density cages. The desired densities were 20, 10, and 5 adults/m^2, but the higher rates of infestation allowed for some mortality of nymphs as they developed to the adult stage. Density was monitored weekly beginning July 9 by counting the number of grasshoppers in eight 1-m^2 quadrates within each cage, the four corner quadrates plus the four quadrates that touched the corner quadrates and were located on a diagonal line from the center toward the opposite corner. Quadrates were not selected randomly because the center quadrates could not be observed without removing the cage top, cages would disturb the grasshoppers. The vegetation in the two empty cages (which contained miscellaneous species that hatched within the cage) and in the two plots without cages were used to measure forage production and to determine the effect of the cages on plant growth.

The standing crop of vegetation on all 10 plots was estimated twice during the test, at 27 days after infestation when needleandthread seed heads were mature and at 55 days after infestation, when grasshopper mortality approached 100%. To make these estimates, we randomly

Authors are research entomologist, research technician, and research entomologist, U.S. Department of Agriculture, Agricultural Research Service, Rangeland Insect Laboratory, Montana State University, Bozeman, 59715. Burleson now is graduate research assistant, Range Science Department, Montana State University, Bozeman.

The authors would like to thank the Animal and Range Science Department, Montana State University for providing one of the study sites, the Red Bluff Ranch.

Manuscript received February 21, 1976.

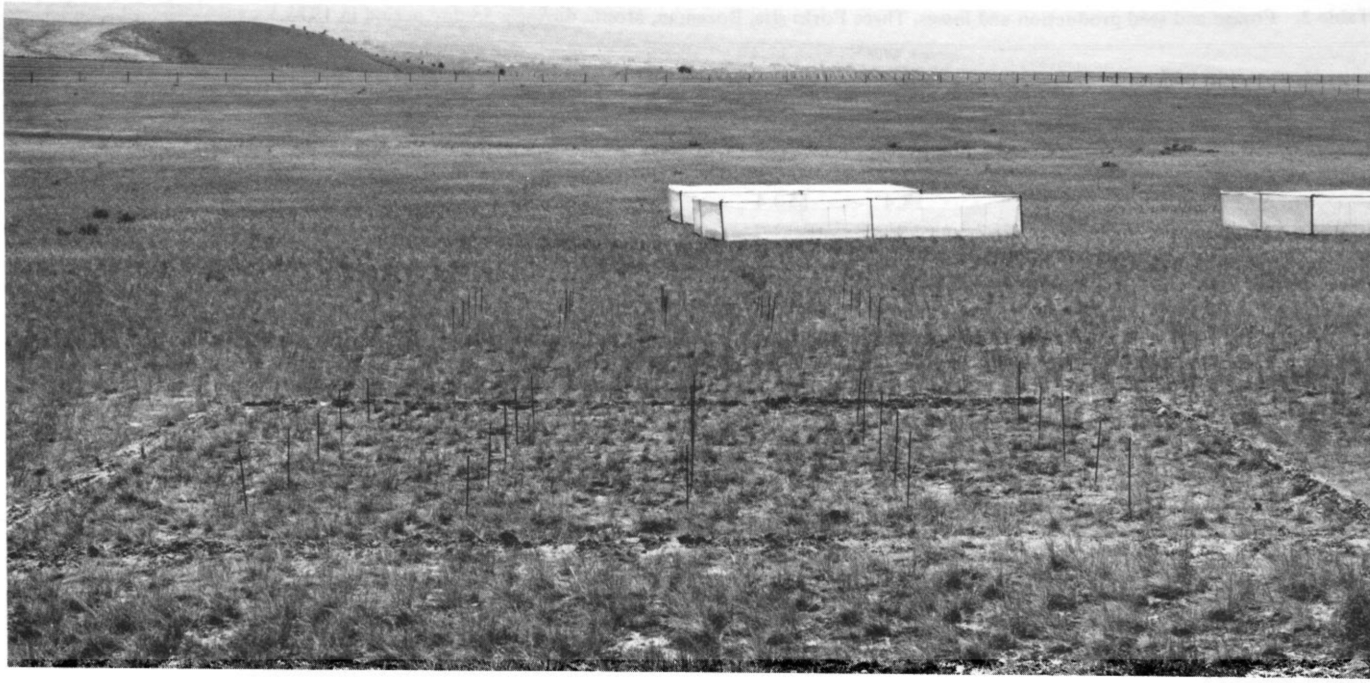

Fig. 1. *Study site showing cages used in the study.*

selected 18 quadrates measuring 25 × 40 cm (0.1 m^2) in each plot and clipped all growth to the ground. It was felt that this amount of clipping would not drastically affect grasshopper distribution within the cages. Clipped plants were divided into three groups (needleandthread, forbs, and other grasses), dried at 60°C, and weighed. Standing dead vegetation was not separated from the current-year's growth. The number of inflorescences on eighteen 1-m^2 quadrates in each plot was also counted at the time of the first clipping.

1974 Study

In 1974, the 15.7-ha area near Three Forks was used again, and another 1.2-ha area near Norris, Mont., was fenced in the spring and used. At the Norris site, western wheatgrass (*Agropyron smithii*), a preferred food plant of *A. elliotti*, was one of the major grasses (24% by dry weight). However, bluebunch wheatgrass (*Agropyron spicatum*) and prairie Junegrass (*Koelaria cristata*) were also abundant, as were two forbs, fringed sagewort (*Artemisia frigida* Willd.) and broom snakeweed [*Xanthocephalum sarothrae* (Pursh.) Shinners].

At each site, eight plots (36 m^2) were established. Cages were errected as in 1973 and two plots in each row were not covered by cages. On June 18, four cages on each site were infested with 3rd- to 5th-instar field-collected *A. elliotti*, two cages with a high density (28/m^2) and two with a low density (8/m^2). Two were not infested. The test was terminated August 12, after 55 days, at the Three Forks site and August 2, after 46 days, at the Norris site. Weekly estimates of grasshopper density were not made in 1974, but counts were made of the number of live grasshoppers of each species in the cages at the end of the study.

In this year, 18 randomly selected quadrates (0.5 m^2) were clipped from each plot, on August 12, at the Three Forks site and on August 2 at the Norris site. Also, the plots established at the Three Forks site in 1973 were resampled in 1974 to assess carry-over effects of grasshopper feeding. Sixteen quadrates (0.5 m^2) were clipped from each of the 10 original plots. Clipped plants from the Three Forks site were divided into three groups (needleandthread, forbs, and miscellaneous grasses); those from the Norris site were divided into five groups (western wheatgrass, prairie Junegrass, bluebunch wheatgrass, forbs, and miscellaneous grasses). All clipped plant material was dried at 60°C and weighed. Standing dead vegetation was not separated from new growth.

Results

1973 Study

Linear regression was used to develop a formula for predicting daily grasshopper density within each infested cage (Table 1). Such a model is theoretically not tenable for an entire generation of grasshoppers (from egg through adult stages), but our data for 3rd-instar nymphs through adults did not suggest a significant departure from linearity. Therefore, the linear model was considered an acceptable means of predicting daily grasshopper density with the cages. Integration techniques were then used to determine the area under each regression line for days 1 through 28 (time to first clipping) and for days 1 through 55 (time of second clipping). These areas represented the estimated cumulative number of grasshoppers that fed for 1 day on 1 m^2 within each plot (designated grasshopper feeding days [GFD]). The GFD were considered a reliable index of grazing pressure because they took into account both the density and longevity of grasshoppers per unit area. However, they did not take into account sex differences in feeding habits of adults, which may be important. When GFD are plotted vs the amount of unconsumed forage, the slope of the regression curve equals the rate of daily consumption.

Table 1. Regression coefficients for the formula $\hat{y}$ = a + bx where $\hat{y}$ is the number of grasshoppers/m^2 in cages and x is the number of days after introduction; Three Forks site, Bozeman, Mont., 1973.

Grasshopper density	a	b
High	26.6100	−0.4212[1]
High	28,8000	− .4470[1]
Medium	13.4792	− .1642[1]
Medium	12.2347	− .1594[2]
Low	6.5374	− .0519[3]
Low	6.7857	− .0553[1]

[1] Slope is significant at the 5% level of error.
[2] Slope is significant at the 6% level of error.
[3] Slope is significant at the 15% level of error.

Table 2. Forage and seed production and losses, Three Forks site, Bozeman, Mont., during a 55-day period in 1973.[1]

Measurement and grasshopper treatment	Avg no. inflorescence/m²[2]	Needleandthread		Forbs		Misc. grasses		Total	
First clipping–27 days after infestation									
Forage production in lb/acre									
Empty cage	9.2	541.5		13.4		12.5		567.4	
No cage	18.4	550.4		7.3		2.7		560.4	
Forage loss in lb/acre (% loss)[3]									
High population	0.8	188.2	(34.8)	0		10.5	(84.0)	198.7	(35.0)
Med. population	8.7	43.7	(8.1)	0		11.7	(93.6)	55.4	(9.8)
Low population	9.3	59.1	(10.9)	0		10.5	(84.0)	69.6	(12.3)
Second clipping–at end of 55 days									
Forage production in lb/acre									
Empty cage	–	680.7		42.9		0		723.6	
No cage	–	507.5		34.8		4.5		546.8	
Forage loss in lb/acre (% loss)[3]									
High population	–	419.3	(61.6)	35.6	(83.0)	0		454.9	(62.9)
Med. population	–	227.4	(33.4)	17.8	(41.5)	0		245.2	(33.9)
Low population	–	262.2	(38.5)	14.2	(33.1)	0		276.4	(38.2)

[1] Seed head counts and clipping weights of vegetation in each quadrate were averaged for both replicates.
[2] Seed head counts were only recorded at the time of the first clipping.
[3] Loss is based on forage production within the empty cage.

The first clipping of the 1973 study showed that a significant total reduction in forage (35%) had been produced by the high population; also, this population reduced the number of inflorescences 91%. During the first part of the test, the populations were near those desired.

In the other cages forage reduction was not consistent with the lower densities, despite the fact that at the end of the test, the second clipping showed a total forage loss of 63% in cages with high density and a loss of approximately 33% in the cages with the other two densities (Table 2). Losses during the first half of the test resulted mainly from *Aulocara*. After the first clipping, the other species that hatched within the cages undoubtedly contributed somewhat to forage losses. However, these species generally did not develop beyond the 4th instar so their forage consumption was minimum compared to that of *Aulocara*. Also, population densities of other species were about the same in all cages so differences in available forage at 55 days were still primarily attributed to differences in densities of *Aulocara*.

The relationship between GFD (*Aulocara*) and available forage of needleandthread is shown in Figure 2. The slopes of the regression curves indicated essentially identical average losses of 22.0 ± 2.12 and 18.8 ± 1.82 mg of forage/m²/GFD for the 27-day and 55-day intervals, respectively.

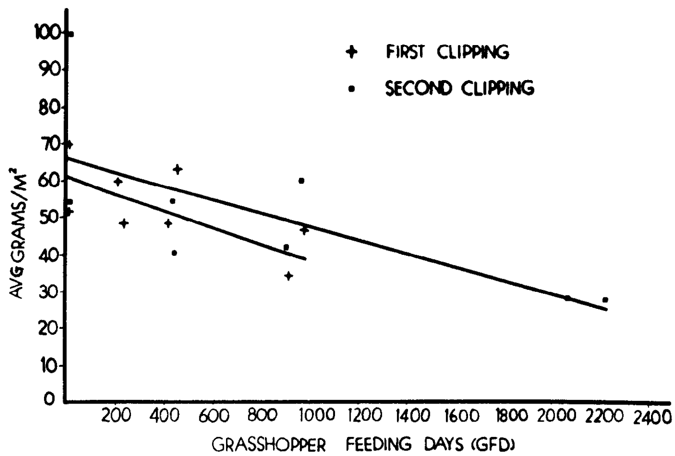

Fig. 2. *Relationship between available forage and grasshopper feeding pressure at two clipping times during a 55-day period.*

1974 Study

The plots that were first established in 1973 at the Three Forks site showed a reduction in total forage (compared with the control in 1974) of 32.5% in plots exposed to the high density population, of 8.2% for exposure to the medium density, and of

Table 3. Forage production and losses, Three Forks site, Bozeman, Mont., in 1974.[1]

Measurement and grasshopper treatment	Needleandthread		Forbs		Misc. grasses		Total	
Forage production on plots treated in 1973 in lb/acre								
Empty cage	339.9		11.3		13.8		365.0	
No cage	307.6		59.1		11.7		378.4	
Forage loss on plots treated in 1973 in lb/acre (% loss)[2]								
High population	105.2	(31.0)	0		13.6	(98.5)	118.8	(32.5)
Med. population	20.2	(6.0)	0		9.6	(70.0)	29.9	(8.2)
Low population	48.6	(14.3)	0		11.8	(85.6)	60.3	(16.5)
Forage production on plots treated in 1974 in lb/acre								
Empty cage	433.0		10.1		1.2		444.4	
No cage	477.5		2.4		1.6		481.6	
Forage loss on plots treated in 1974 in lb/acre (% loss)[2]								
High population	109.3	(25.2)	17.7	(100.0)	1.78	(100.0)	128.7	(29.0)
Low population	113.3	(26.2)	12.9	(100.0)	0		126.2	(28.4)

[1] Weights of vegetation in each quadrate were averaged for both replicates.
[2] Loss is based on forage production within the empty cage.

Table 4. Forage production and losses, Norris site, Bozeman, Mont., in 1974.[1]

Measurement and grasshopper treatment	Western wheatgrass	Bluebunch wheatgrass	Prairie Junegrass	Forbs	Misc. grasses	Total
Forage production in lb/acre						
Empty cage	128.3	61.9	12.8	231.9	283.9	718.8
No cage	151.4	83.2	30.5	188.8	181.1	634.9
Forage loss in lb/acre (% loss)[2]						
High population	12.3 (9.6)	0	0	10.4 (4.5)	165.1 (58.2)	187.8 (26.1)
Low population	11.9 (9.3)	9.3 (15.0)	0	61.2 (26.4)	97.9 (34.5)	180.3 (25.1)

[1] Weights of vegetation in each quadrate were averaged for both replicates.
[2] Loss is based on forage production within the empty cage.

16.5% for exposure to the low density (Table 3). This lower production in 1974 in plots exposed to a medium density reflected the slightly greater losses in those plots in 1973. Thus, the effects of grasshopper feeding seemed to extend beyond the season of feeding. However, less forage was produced in 1974 than in 1973, even in plots where grasshoppers were not present.

The 1974 clippings from the Three Forks site showed no difference in available forage between low and high densities of grasshoppers (Table 3). However, both yields were significantly lower than that of the control cages ($P<0.10$). Miscellaneous grasshopper species again hatched within the cages and contributed to some of the total forage loss.

Forage reduction at the Norris site was 26% for the high density population and 25% for the low density population of *Aulocara* (Table 4). The losses can again be attributed primarily to *Aulocara* since the control cages conained as many miscellaneous grasshoppers [mostly *Melanoplus sanguinipes* (F.)] as the treated cages.

Densities of grasshoppers in the cages were not estimated during the test at either site in 1974. Thus, data for population decline such as is shown in Figure 2 were not available for 1974. However, the daily reduction in density of *Aulocara* was assumed to be linear as it had been in 1973. Formulae for estimating the daily densities were therefore determined graphically and subjected to integration to obtain an estimate of GFD for each cage. Then the seasonal forage loss per cage was divided by GFD to estimate forage loss per grasshopper per day. *Aulocara* losses were based on production of needleandthread at the Three Forks site and on total production of grasses at the Norris site. The estimates are shown in Table 5 along with forage loss figures for *Aulocara* reported by other workers.

Table 5. A summary of forage losses (mg/grasshopper/day) caused mainly by *Aulocara elliotti* as reported by several workers.[1]

Reference	Vegetation fed on	Forage loss
Morton (1936) (1939))	Rangeland grasses	35.7
Pfadt (1949a)	Rangeland forage	28.2
		20.4
		23.6
Anderson & Wright (1952)	*Agropyron smithii*	20.3
Anderson (1961)		
1956 Studies–Harlowton Site:	*Bouteloua gracilis*	15.7
	Agropyron smithii	24.6
	Stipa comata	38.4
–Townsend Site:	*Bouteloua gracilis*	63.5
	Agropyron smithii	36.5
	Koeleria cristata	20.3
1957 Studies	*Agropyron smithii*	12.5
Mitchell & Pfadt (1974)	*Bouteloua gracilis*	71.5
Hewitt, Burleson, & Onsager	*Stipa comata*	21.9
		18.8
		27.2
		6.8
		56.7
		24.6
	Rangeland grasses	42.7
		8.8
		97.2
		40.6

[1] The amount of forage lost is based on the feeding of both nymphs and adults in the field except that Mitchell and Pfadt (1974) worked with adults in the laboratory.

Discussion

In the present study, the amount of forage consumed during the 3rd instar and through the adult stage averaged 34.5 mg per grasshopper per day. Thus, an estimated loss of 23.1 lb of forage per acre would result from a density of one *Aulocara*/m^2 if each grasshopper lived for 75 days (45 days as a nymph and 30 as an adult). The loss includes both food consumed and forage wasted or destroyed. According to Mitchell and Pfadt (1974), only 50% of the forage lost due to the presence of *Aulocara* is actually consumed. However, the loss estimate does not take into account feeding differences due to sex. It also does not account for forage lost to grasshoppers that die before they reach the adult stage or that feed beyond 75 days. Also, the actual amount of forage lost at any one location will depend on many environmental variables that cannot be predicted. Putnam (1962) reported forage losses caused by field populations of *Camnula pellucida* (Scudder) and *Amphitornus coloradus* (Thomas), two species of rangeland grasshoppers that are somewhat smaller than *Aulocara*. From his data, a loss of 8.5 mg per day per nymph results when the losses due to the two species are averaged; the loss per adult is 74.5 mg per day. These values convert to a loss of 23.3 lb/acre for a 75-day feeding period, which is only slightly higher than our estimates for *Aulocara*. However, these findings are only an estimate of forage losses and should be validated in the field to determine their validity in estimating actual forage losses.

Literature Cited

Anderson, N. L. 1961. Seasonal losses in rangeland vegetation due to grasshoppers. J. Econ. Entomol. 54:369-378.

Anderson, N. L., and J. C. Wright. 1952. Grasshopper investigations on Montana rangelands. Mont. Agr. Exp. Sta. Bull. 486. 46 p.

Brooks, A. R. 1958. Acridoidea of southern Alberta, Saskatchewan, and Manitoba (Orthoptera). Can. Entomol. 90, Suppl. 9, 92 p.

Brusven, M. A., and J. D. Lambley. 1971. The food habits and ecology of grasshoppers from southern Idaho rangeland. Univ. of Idaho, U.S. Dep. Agr. Coop. Project No. 12-14-100-9726 (33) Part I, 85 p.

Cooley, R. A. 1904. Grasshoppers. Mont. Agr. Exp. Sta. Bull. 51:232-242.

Corkins, C. L. 1923. Grasshopper control. Colo. State Entomol. Circ. 38:28-31.

Mitchell, J. E., and R. E. Pfadt. 1974. A role of grasshoppers in a shortgrass prairie ecosystem. Environ. Entomol. 3:358-360.

Misra, S. D., and L. G. Putnam. 1966. The damage potential of the grasshopper, *Camnula pellucida* (Scudd.) (Orthoptera: Acrididae) on pastures and ranges in Canada. Indian J. Entomol. 28:224-233.

Morton, F. A. 1936. Summary of 1936 rangeland grasshopper studies. U.S. Dep. Agr. Bureau Entomol. Plant Quart. Mimeo Rep. Bozeman, Mont. 12 p.

Morton, F. A. 1939. Review of rangeland grasshopper project. U.S. Dep. Agr. Bureau Entomol. Plant Quart. Mimeo Rep. Bozeman, Mont. 33 p.

Mulkern, G. B., K. P. Pruess, H. Knutson, A. F. Hagen, J. B. Campbell, and J. D. Lambley. 1969. Food habits and preferences of grassland grasshoppers of the north central Great Plains. N. Dak. Agr. Exp. Sta. Bull. No. 481. 32 p.

Nerney, J. J., and A. G. Hamilton. 1966. Effect of insecticide and parasitism on range grasshoppers, San Rafael Valley, Ariz. U.S. Dep. Agr., Agr. Res. Serv., Spec. Rep. 192. 14 p.

Nerney, A. J., and A. G. Hamilton. 1967. Field observations of grasshoppers and damage survey on rangeland of San Rafael Valley, Ariz. U.S. Dep. Agr., Agr. Res. Serv., Spec. Rep. 202. 13 p.

Parker, J. R. 1930. Some effects of temperature and moisture upon *Melanoplus mexicanus mexicanus* Saussure and *Camnula pellucida* Scudder (Orthoptera). Mont. Agr. Exp. Sta. Bull. 223. 132 p.

Pepper, J. H., C. R. Hunt, J. P. Corkins, N. L. Anderson, R. Schiedeskamp, and J. C. Wright. 1951. Montana insect pests 1949-1950. Mont. Agr. Exp. Sta. Bull. 474. 35 p.

Pfadt, R. E. 1949a. Range grasshoppers as an economic factor in the production of livestock. Wyo. Agr. Exp. Sta. Memo. No. 7. 7 p.

Pfadt, R. E. 1949b. Food-plants, distribution, and abundance of the big-headed grasshopper, *Aulocara elliotti* (Thos.). Kans. Entomol. Soc. 22:69-74.

Putnam, L. G. 1962. The damage potential of some grasshoppers (Orthoptera: Acrididae) of the native grasslands of British Columbia. Can. J. Plant Sci. 42:596-601.

Smith, D. S. 1959. Utilization of food plants by the migratory grasshopper, *Melanoplus bilituratus* with some observations on the nutritional value of the plants. Ann. Entomol. Soc. Amer. 52:674-680.

Strand, A. L. 1937. Montana insect pests for 1935 and 1936. Mont. Agr. Exp. Sta. Bull. 333. 39 p.

Swenk, M. H. 1913. The principal insects injurious to agriculture during 1911-1912. Nebr. Agr. Exp. Sta. Bull. No. 1. 104 p.

White, R. M., and P. J. G. Rock. 1945. A contribution to the knowledge of Acrididae of Alberta. Sci. Agr. 25:577-596.