



The response to western wheatgrass and needle- and thread grass to grasshopper defoliation
by Wayne Hunter Burleson

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in Range Science

Montana State University

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Abstract:

A study of plant growth response to various intensities of defoliation by grasshoppers was conducted to determine the influence of herbage removal on vigor and growth patterns of two common range grasses, western wheatgrass (*Agropyron smithii*) and needle-and-thread (*Stipa comata*). Greenhouse and field data indicated that increased grazing intensities significantly decreased root growth, tillering, rhizome production and regrowth. It was also determined on a Montana rangeland site that the major portion of grasshopper defoliation occurred after cessation of active growth of the two grass species studied.

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THE RESPONSE OF WESTERN WHEATGRASS AND NEEDLE-AND-THREAD
GRASS TO GRASSHOPPER DEFOLIATION

by

WAYNE HUNTER BURLESON

A thesis submitted in partial fulfillment
of the requirements for the degree

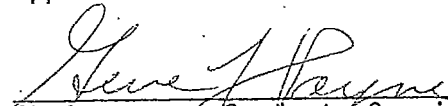
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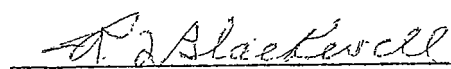
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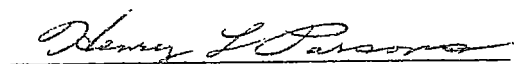
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ABSTRACT

A study of plant growth response to various intensities of defoliation by grasshoppers was conducted to determine the influence of herbage removal on vigor and growth patterns of two common range grasses, western wheatgrass (Agropyron smithii) and needle-and-thread (Stipa comata). Greenhouse and field data indicated that increased grazing intensities significantly decreased root growth, tillering, rhizome production and regrowth. It was also determined on a Montana rangeland site that the major portion of grasshopper defoliation occurred after cessation of active growth of the two grass species studied.

INTRODUCTION

The varied and pronounced effects of defoliation on grass plants should determine in part the basis for sound judgment in managing for the yield and quality of grassland productivity. There are detailed studies of the influence of hand clipping and grazing by livestock on rangeland forage species. Yet, little is known about the effects of insect defoliation, specifically grasshoppers on individual grass plants.

Rangeland grasshopper studies have dealt primarily with direct forage losses and not with the long-term effects of grasshopper defoliation. Research is needed on this latter component of the grassland ecosystem.

Studies reported herein were conducted under both greenhouse and field conditions to ascertain the influence of grasshopper grazing on western wheatgrass (Agropyron smithii) and needle-and-thread (Stipa comata).

LITERATURE REVIEW

Distribution and Importance

Western Wheatgrass

Western wheatgrass is an important perennial native rhizomatous grass distributed generally throughout the United States except in the humid southeastern states. It is most abundant in the northern and central parts of the Great Plains and is often the dominant grass over large areas (U. S. Forest Serv., 1937). Western wheatgrass is alkali-tolerant and grows in dense patches in well-drained bottom lands. It may also be found on open plains and in nearly pure stands on abandoned dryland farms in Montana (U. S. Dep. Agr., 1948).

Western wheatgrass is a valuable forage plant for all classes of livestock and is considered choice forage for elk and deer (U. S. Forest Serv., 1937). It cures well on the ground, thus making high quality winter forage and hay. Western wheatgrass has been used to some extent for revegetation; seed availability is adequate (Vallentine, 1974).

Needle-and-thread

Needle-and-thread is a deep-rooted, long-lived, native bunch-grass which occurs on western United States ranges and is most abundant on sandy soils of the Northern Great Plains (U. S. Dep.

Agr., 1948). It may be found in almost pure stands in an advanced stage of secondary succession on abandoned fields (Booth, 1950).

The forage value of needle-and-thread varies with regions, season of growth, and plant association. It is cut for hay in parts of Wyoming, North Dakota, South Dakota, and Nebraska where it rates as very good forage (U. S. Forest Serv., 1937). This grass provides early spring forage over much of eastern Montana but due to the stiff twisted awns, mechanical injury to livestock can occur at seed maturity (Booth, 1950).

Root Growth Characteristics

Both western wheatgrass and needle-and-thread are cool season grasses. Their principal growth period is in the cool, moist spring with decrease or cessation of growth during the summer. Optimum temperature for growth and net photosynthesis by temperate grass species ranges from 20° to 25° C (White, 1973).

Mueller (1941) indicated that root growth for western wheatgrass coincides with top growth. Active roots are white in color and vary from 0.2 to 1.0 mm in diameter. The thinner roots rarely exceed 30 cm in length and often grow horizontally while the thicker roots penetrate vertically but branch less densely. Depth of rooting varies considerably with climate, soil, and topography (Coupland and Johnson, 1965). Weaver (1942) determined the average root

growth rate of young western wheatgrass plants to be 8.4 mm/day for a three-month period. Its maximum rooting depth in Nebraska and Kansas ranged from 2.1 to 3.6 m while averaging 1.5 m in the more arid portions of the western United States (Weaver, 1958).

Hopkins (1953) found that the lower roots add little to the total weight of the root system. He indicated that in western wheatgrass only 15 percent of the total root weight occurred below the 30 cm level.

Weaver (1947) found that root decay was somewhat variable with species. Western wheatgrass had a tendency for less rapid decay than other species studied and a few roots retained tensile strength for three years. Weaver and Zink (1946) indicated root survival for western wheatgrass was 42 percent of tagged roots after the second summer.

Needle-and-thread is most extensively rooted in level, stabilized sand, where rooting depth reaches 150 cm with a lateral spread of 35 cm. Active roots are cream colored with two to seven main roots supporting each shoot of the bunch (Coupland and Johnson, 1965). In a study by Weaver (1958), needle-and-thread roots were more profusely branched and crisscrossed when compared to western wheatgrass roots.

Defoliation Studies

Past clipping studies (Aldous, 1930; Biswell and Weaver, 1933; Blaisdell and Pechanec, 1949; Wagner, 1952, Albertson et al, 1953; Heinrichs and Clark, 1960; Pond, 1961) have indicated that with increasing frequency and amount of plant tissue removed by clipping there is generally a decrease in grass productivity. Branson (1956) found that root production was affected more detrimentally than top production in relationship to top growth removal. In contrast to the above studies, Leopold (1949) found that clipping stimulated the production of tillers. In a Wyoming study by Baker and Hunt (1961), intermediate wheatgrass and pubescent wheatgrass clipped at 10 cm produced significantly more tillers than those clipped at 5 cm.

Changes in plant structure induced by prolonged heavy grazing of needle-and-thread appear to favor persistence (Peterson, 1962). Changes were as follows: (1) relatively rapid regrowth after clipping, (2) greener and more vigorous shoots, (3) maintenance of moderate carbohydrate reserve levels, (4) slower spring growth, (5) a shorter and more prostrate growth. Hanson et al (1931) found that western wheatgrass increased more under continuous grazing than under protection from grazing.

In a review, Jameson (1963) stated that, generally, root production was universally depressed when defoliation occurred,

while the yield of above ground parts was somewhat erratic. Crider (1955) reported that removal during the growing season of half or more of the foliage of both cool and warm season grass species (including bunch, rhizomatous, and stoloniferous types) caused root growth to stop for a period of time after each removal. Root growth stoppage usually occurred within 24 hours and continued until tops recovered. Crider (1955) presented the following data:

Percent Top Removal	Percent Root Stoppage	No. Days Complete Root Stoppage
90	100	17
80	100	12
70	78	0
60	50	0
50	2	0

No root stoppage was indicated in this study from a top reduction of 40 percent or less. A study by Parker and Sampson (1931) showed that a single harvest of foliage resulted in temporary cessation of root growth in soft chess (Bromus hordeaceus) and purple needlegrass (Stipa pulchra). This cessation was followed by an immediate increase in growth of the tops.

Branson (1953) listed two factors which affect the resistance of grasses to grazing: (1) the height to which the growing point (apical meristem) is raised, and (2) the ratio of fertile culms

to vegetative culms. His studies found that the vegetative culms of western wheatgrass raised their growing points from 16 cm in June to 40 cm in September. This would allow for their growing points to be removed by grazing so that no new leaves would be produced by those culms. He also noted that removal of the inflorescences has an effect similar to removal of elevated growing points.

Grasshopper Grazing

Grasshopper damage to rangeland has been an economic concern in the United States since the early 1800's (Parker and Connin, 1964). Cowan (1958) listed grasshoppers in the United States as being in the upper 10 most troublesome insect pests to agriculture. In an Arizona study, Nerney (1958) found grasshoppers to be in direct competition with livestock for available forage and were at least partly responsible for the decline in productivity of shortgrass rangelands. He found that preferred habitats of economic grasshopper species were associated with poor rangelands. These poor rangelands were generally dominated by low-growing weeds.

In the past, many published evaluations of grasshopper damage in relation to rangeland vegetation losses have been too generalized. Anderson (1972) indicated difficulties in interpreting data from damage studies as follows: changes in density of grasshopper populations, uneven feeding patterns, non-random distribution of

vegetation and grasshoppers, varied food-plant preference and food selectivity within plant species, and a lack of knowledge concerning plant growth phenomena as related to defoliation.

Newton and Esselbaugh (1952) stated that when grasshoppers feed on plant material near the ground they contribute to overgrazing, weakening of the root reserves, and may possibly be providing a way for later soil erosion. New Zealand grasshoppers are basically low-volume grazers but because of their selective feeding habits they can exert high grazing pressure on certain plant species (White, 1974).

Cowan (1958) stated that damage to rangeland vegetation is governed by the grasshopper species, the vegetation complex, the number of grasshoppers, and the weather. Three types of damage are possible: (1) removal of forage in direct competition with livestock, (2) permanent damage to plants due to continued feeding by grasshoppers beyond percent use factors, and (3) destruction of seed heads. However, not all grasshopper damage studies have indicated that a loss of vegetation results from grasshopper grazing. Harris (1974) explained how sometimes no loss, or even an increase in plant yield, may come about due to insect feeding. He stated that defoliated plants may redirect limiting nutrient resources to undamaged tissue and develop a surplus. Also, early removal of apical dominance of growing plants may stimulate tillering.

In a grasshopper damage study on Montana rangelands, Anderson (1961) found little correlation between numbers of grasshoppers per unit area and loss of vegetation. In a summary by Anderson (1972), clipping effects on vegetation suggested that grasshoppers may be responsible for permanent damage to rangeland vegetation, but he also indicated that grasshoppers under certain circumstances may be responsible for increases in forage production over a period of years.

DESCRIPTION OF FIELD STUDY AREA

A study area was selected 12.8 km northeast of Three Forks, Montana in Broadwater County. A 16 ha experimental site was exclosed from livestock grazing in 1973. This site had previously been plowed, approximately 30 years earlier, and later abandoned. The area is located on an upland bench with a two percent slope and a southeast exposure. A small water run-in area traverses the exclosure.

The soil type is classified as a Brocko series in the mixed family Borollic Calciorthid (SCS, National Cooperation Soil Survey, 1972). The texture throughout the profile ranges from very fine sandy loam to silt loam with 8 to 18 percent noncarbonate clay and 1 to 14 percent fine sand to coarser particles. Brocko soils are formed from eolian material which has been deposited over older river terraces.

The climate is cool, semiarid with an annual average precipitation of 30.5 cm in which most of the precipitation occurs during the spring months. Three years of precipitation and temperature data are summarized on Tables 1 and 2 respectively. These data were recorded at Trident, Montana approximately 8 km southeast of the actual study site.

TABLE 1. Three year summary of monthly precipitation (centimeters) near the Three Forks Study Site. Data were taken at Trident, Montana.^{1/}

YEAR		MONTH												TOTAL/YEAR
		JA	FE	MA	AP	MY	JU	JL	AG	SE	OC	NO	DE	
1973	Total Precipitation	.53	.76	.84	1.85	E ^{2/} 1.85	9.17	E .91	2.71	E4.70	E4.93	E2.30	.84	E 29.57
1974	Total Precipitation	.03	.05	1.55	.38	3.81	1.02	1.09	4.42	.48	1.98	.89	.61	16.31
	Deviation from Mean	-.94	-.61	.03	-2.26	-1.14	-5.54	-1.57	1.47	-2.69	.20	-.36	-.22	-13.64
1975	Total Precipitation	1.45	1.30	1.14	3.40	9.30	7.70	7.01	3.12	.99	5.74	.33	.58	42.06
	Deviation from Mean	.48	.64	-.38	.76	4.34	1.14	4.34	.18	-2.18	3.96	-.91	-.25	12.12

^{1/} U. S. Dept. of Commerce Administration, National Oceanic and Atmospheric Administration, Environmental Data Service, Vol: 76,77,78

^{2/} Amount is partially estimated

TABLE 2. Three year summary of monthly temperatures (degrees Celsius) near the Three Forks Study Site. Data were taken at Trident, Montana.^{1/}

YEAR		MONTH											
		JA	FE	MA	AP	MY	JU	JL	AG	SE	OC	NO	DE
1973	Mean/Mo.	- 6.1	- 4.7	3.1	5.9	12.2	17.0	21.4	20.9	13.3	9.2	-0.1	0.2
	Max. Mean	- 0.3	-92.3	9.1	12.8	21.3	25.6	31.5	30.8	20.9	17.2	4.7	5.7
	Min. Mean	-11.9	-11.9	-3.0	- 0.9	2.7	8.3	11.3	11.1	5.6	1.3	-4.8	-6.2
1974	Mean/Mo.	- 6.4	0.1	1.6	8.6	9.9	18.6	21.8	17.0	12.4	8.5	1.6	-3.2
	Max. Mean	- 1.4	5.8	7.6	14.9	16.2	27.8	31.6	25.0	22.6	18.2	7.8	2.2
	Min. Mean	-11.4	- 5.8	-4.6	2.2	3.7	9.4	12.0	8.9	2.3	-1.2	-4.7	-8.6
1975	Mean/Mo.	- 5.3	- 5.9	-9.7	1.6	10.0	14.8	21.7	18.2	13.8	7.9	-0.1	-1.3
	Max. Mean	0.4	0.2	4.3	7.3	17.2	22.8	30.4	26.8	24.1	14.5	6.6	4.3
	Min. Mean	-11.1	-11.9	-5.7	- 4.2	2.8	6.2	12.9	9.4	3.5	1.3	-6.8	-6.9

^{1/} U. S. Dept. of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, Vol: 76, 77, 78

The vegetation is dominated by widely dispersed bunches of needle-and-thread on the relatively level, plowed portions of the study site. Other vegetation occurring in the small run-in area in which plant growth curves were measured was characterized ocularly by the following species in approximate order of descending abundance: western wheatgrass, green needlegrass (Stipa viridula), common dandelion (Taraxacum officinale), blue grama (Bouteloua gracilis), fringed sagewort (Artemisia frigida), cudweed sagewort (Artemisia ludoviciana), and big sagebrush (Artemisia tridentata). Other species present include: death camas (Zygadenus venenosus), threadleaf sedge (Carex filifolia), prairie junegrass (Koeleria cristata), bluebunch wheatgrass (Agropyron spicatum), salsify (Tragopogon dubius), oblongleaf bluebell (Mertensia oblongifolia), Astragalus spp., Hood's phlox (Phlox hoodii), common sunflower (Helianthus annuus), woolly plantain (Plantago purshii), biscuit root (Lomatium spp.), Nuttall violet (Viola nuttallii), Fleabane (Erigeron spp.), white pointloco (Oxytropis sericea), and Rocky Mountain iris (Iris missouriensis).

METHODS AND PROCEDURES

Greenhouse Study -- Needle-and-Thread

A group consisting of approximately equal size (ocularly selected -- basal diameter approximately 5 cm) bunches of needle-and-thread plants was removed from the study area in November of 1973. The tops were trimmed to 2.5 cm level and the roots trimmed to 8 cm. The plants were then placed two each in flat metal pans and stored outdoors in Bozeman, Montana until January 16, 1974. Twelve plants were then placed one each in root boxes filled with a standard greenhouse soil mixture consisting of 75 parts washed sand and 25 parts peat. The root boxes measured 60 x 29 x 23 cm and were constructed of pine wood with a sloping removable glass front as shown in Figure 1.

The greenhouse air temperature ranged from 25⁰ to 30⁰ C and the soil temperature at a depth of 10 cm, measured in one root box, ranged from 18⁰ to 26⁰ C. The photoperiod consisted of natural day length, with the light diffusing through transparent, corrugated, fiberglass paneling.

After 72 days of growth, the 12 plants in the vegetative state were randomly divided into the following three treatments: caged grasshoppers representing a heavy grazing, moderate grazing, and caged plants with no grasshoppers (control). At the initiation

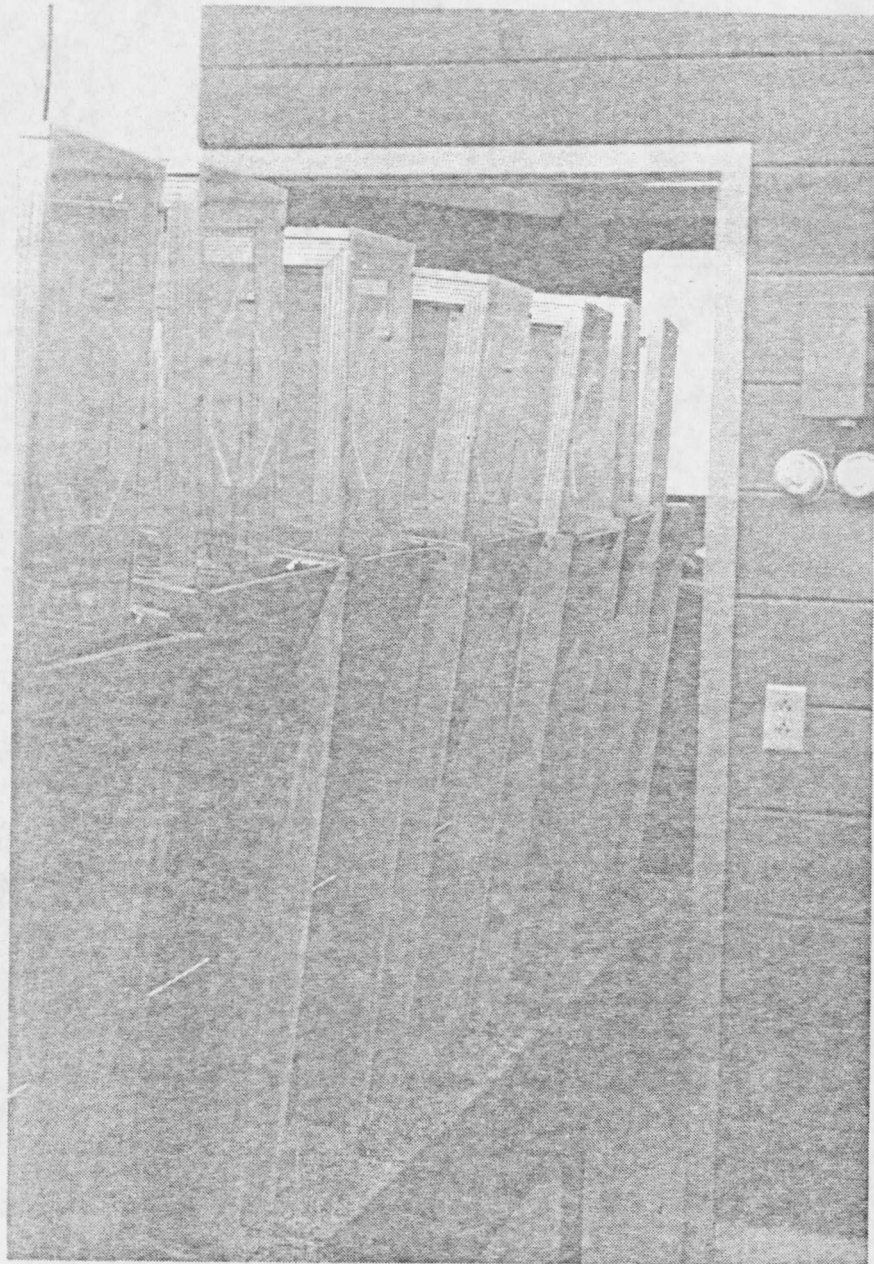


FIGURE 1. Root boxes used in greenhouse studies

of the treatments 3rd instar Melanoplus sanguinipes were placed at the rates of 12, 3 and 0 grasshoppers per cage representing the three treatments. A group of the equal age grasshoppers was used as replacements to maintain the grass defoliation levels. The grasshopper densities in each cage were periodically adjusted to establish equal defoliation within each treatment.

One week before grasshopper introduction onto the 72-day plants, an additional 12 plants were started in root boxes to determine the effects of grasshopper grazing on new green-up growth. These 12 plants were randomly divided into three treatments of 3, 1, and 0 M. sanguinipes in an attempt to duplicate the previously mentioned grazing intensities. No root growth measurements were made in this phase of the study.

On May 16, 1974, the test was ended and the plants were washed from the root boxes and divided into root, crowns, and top growth. Later they were oven-dried at 60⁰ C and weighed. In this phase of the study, crown consisted of the very basal area of the culm through 8 cm of roots.

Greenhouse Study -- Western Wheatgrass

Approximately 400 western wheatgrass (A. smithii var. rosana) seeds were placed on wet blotter paper in four petri dishes on March 1, 1975. Within five days the seeds germinated. Germination

day was day one in the experiment. On day two, 100 seedlings of uniform size and vigor were transferred into 25 of the glass faced root boxes. The four seedlings per box were placed one cm from the slanting glass.

The soil used in this experiment was mixed by hand using $\frac{1}{2}$ washed sand and $\frac{1}{2}$ Bozeman silt loam. The loam was sterilized by steam for 24 hours. The root boxes were laid on their sides and filled with the mixed soil. Sifted soil was placed next to the glass and formed the top layer of each root box. The root boxes were heavily watered and left until the soil was settled on the glass. Care was taken not to push the soil against the glass because this causes a muddy smearing effect. Small soil and sand particles should just rest on the glass for the best view of the root systems.

On day 31, the 25 root boxes each containing the four western wheatgrass plants were randomly divided into five treatments, each having five replications. A die was used to randomly assign treatments. This represented a complete randomized block design. The five treatments were as follows:

1. Clipping at one time on day 31
2. Heavy grazing by grasshoppers (80 percent removal by weight of top growth)
3. Moderate grazing by grasshoppers (50 percent removal)

4. Light grazing by grasshoppers (20 percent removal)
5. Un-grazed

The grazing levels were maintained for a period of 16 days by the grasshopper Melanoplus bivitattus. The grasshopper densities were periodically changed to establish equal levels of defoliation within a treatment. This allowed the grasshoppers to slowly establish the defined levels of defoliations. The clipping treatment removed all portions of the plant above the first leaf, leaving a stubble height of about 2.5 cm. The grazing treatment ended on day 48, after which the plants continued to grow until day 93.

Data were collected periodically on height of top growth along with air and soil temperatures. Daily root growth measurements were made just prior to and during the treatment period. The number of tillers and shoots from rhizomes was recorded for each root box. On day 93 the plants were separated into tops, crowns, roots, and rhizomes and were oven dried at 60⁰ C and weighed. The crown consisted of the immediate basal portion of the culm and small (5 mm) portions of the roots.

Field Study -- Needle-and-Thread

A field study comparing needle-and-thread plants subjected to grasshopper grazing and plants left ungrazed was conducted at the study site near Three Forks, Montana. Ten somewhat isolated plants

of approximately the same size (basal diameter approximately 5 cm) were selected and excavated on June 20, 1974. The root system was cut 8 cm below the surface level, and the flag leaf and sheath containing the inflorescence were removed. These plants were then replanted in their original spot and caged as shown in Figure 2. Five randomly selected caged plants were then infested, each with six 3rd and 4th instar grasshoppers (Aulocara ellioti). The five remaining caged plants were used as controls. During this test, the grasshoppers were maintained at a level of at least two grasshoppers per cage.

A other group of ten needle-and-thread plants was similarly selected although not excavated. These plants were caged and infested with A. ellioti at the same level as the above.

After 48 days there were no grasshoppers remaining on the treated plants. The plants were then excavated with a shovel in approximately equal size blocks (15 x 15 x 30 cm), labeled, and brought into the laboratory for soil removal. After presoaking the plants in a large tub of water, the soil was gently agitated with running water to remove the remaining soil particles. The plants were then separated into tops, crowns, and roots and weighed following oven-drying for 24 hours. The crowns in this phase of the study consisted of the immediate basal portion, the culm, and approximately 8 cm of the roots.



FIGURE 2. Caged needle-and-thread plant

Plant and Grasshopper Growth Curves

On the study site near Three Forks, Montana, four glass panes were buried on May 2, 1975. The panes were adjusted at a slight angle in a bank of the small flow-in area which runs through the exclosure. Two panes had sifted soil placed against the glass. One was planted with one western wheatgrass plant and the other with one needle-and-thread plant. The third glass pane was placed under a naturally occurring western wheatgrass plant and the fourth under a needle-and-thread plant. Some of the older parts of the root system of these latter grasses were cut away to accommodate the glass.

The range and mean of the maximum height of leaves held vertically, leaf stage, apical meristem location, root growth, and phenology were recorded bi-weekly from May to September for the two grass species studied.

Weekly climatic data were also recorded. Soil moisture was tabulated using a gypsum block which was placed 20 cm below the surface in one of the buried glass panes.

Grasshoppers were collected with a sweep net each week from the same sampling area. They were stored in a freezer and later identified and tabulated into developmental stages.

RESULTS AND DISCUSSION

Needle-and-Thread Defoliation

Greenhouse

The two defoliation treatments of the older group of needle-and-thread plants studied in the greenhouse had 48 days of grasshopper grazing. This resulted in approximately 50 and 70 percent removal by weight of the top growth which are referred to as moderate and heavy grazing respectively (Figure 3). The oven dry weights of top growth are given in Table 3 along with the analysis of variance.

The root growth in response to both grazing treatments was reduced approximately 50 percent as compared to the un-grazed plants (Figure 3). However, an analysis of variance of root weight (Table 4) indicated there were no significant differences among the treatments at the five percent level.

The crown weight represented by the crown and eight cm of old roots did not show any significant treatment effect (Table 5). This was probably due to the unequal size of the plants selected in the field. The average crown weight of the heavily grazed plants was nearly twice as much as that of either the moderate or the un-grazed plants. This may be responsible for much of the variation in the root weights.

The defoliation of the green-up phase of this study suggested that any grasshopper grazing of one week (new growth) of needle-and-thread plants was considered too detrimental. All grazed plants in this study died back within a few days due to the grasshopper defoliation. The method by which the plant root system was collected in the field is thought to cause a great amount of stress on these plants. The root system was too weak to allow any defoliation at this stage of development.

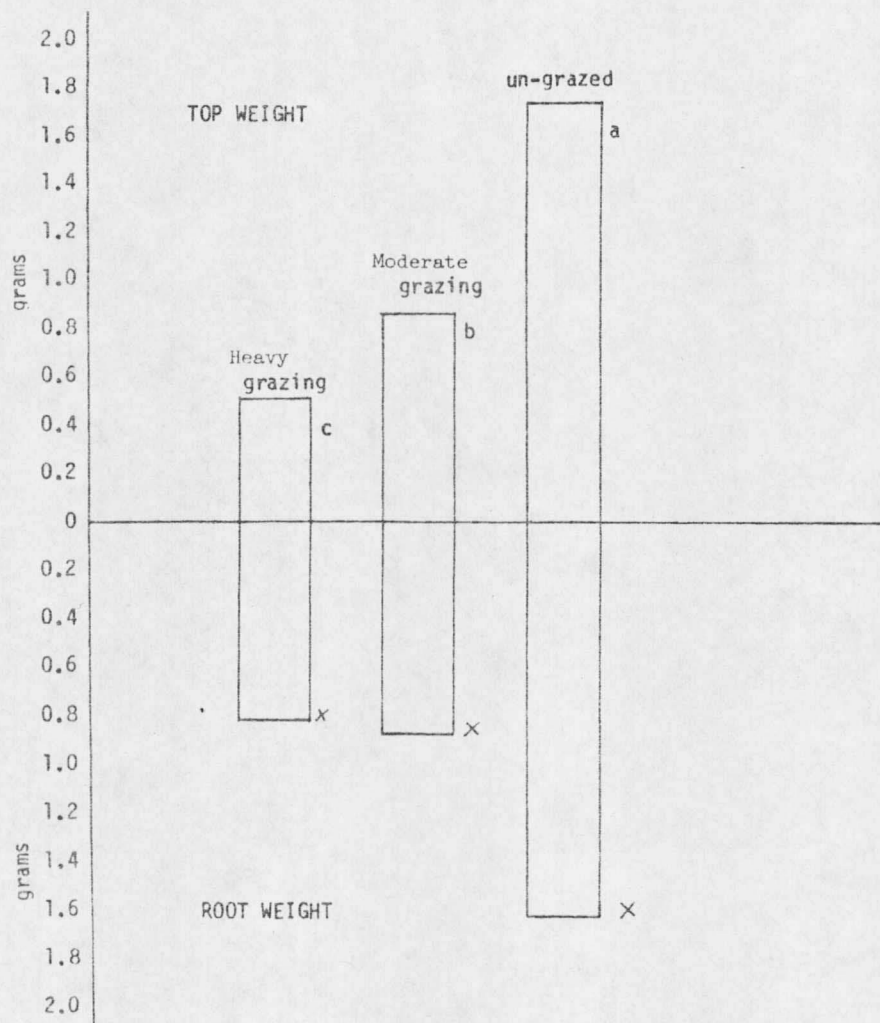


FIGURE 3. Top and root weights of needle-and-thread grass following 48 days of grasshopper defoliation. Bars having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test (greenhouse data)

TABLE 3. Dry weights (gm/plant) of needle-and-thread top growth remaining after 48 days of grasshopper defoliation (greenhouse).

TREATMENT	REPLICATE				TOTAL	MEAN
	1	2	3	4		
Heavy grazing	0.605	0.480	0.465	0.476	2.026	0.506
Moderate grazing	0.898	0.977	0.826	0.826	3.527	0.881
Un-grazed	1.829	1.414	1.746	1.904	6.893	1.723

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	11	3.275	
REPS	3	4.031E-02	
TREATMENTS	2	3.106	1.553
ERROR	6	.128	2.138E-02

$F=72.622^{**1/}$

TREATMENT	MEAN
Un-grazed	1.723a ^{2/}
Moderate grazing	0.881b
Heavy grazing	0.506c

^{1/} Highly significant (P .01)

^{2/} Means having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test.

TABLE 4. Dry weights (gm/plant) of needle-and-thread root growth in response to grasshopper defoliation (greenhouse).

TREATMENT	REPLICATE				TOTAL	MEAN
	1	2	3	4		
Heavy grazing	1.314	1.083	0.382	0.509	3.288	0.822
Moderate grazing	0.688	0.500	1.543	0.833	3.564	0.891
Un-grazed	2.091	1.170	1.646	1.560	6.467	1.616

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	11	3.204	
REPS	3	.385	
TREATMENTS	2	1.551	.775
ERROR	6	1.267	.211

F=3.671^{1/}

^{1/} Not significant (P .05)

TABLE 5. Dry weights (gm/plant) of needle-and-thread crown (base plus 7.5 cm old roots) growth as related to grasshopper defoliation (greenhouse).

TREATMENT	REPLICATE				TOTAL	MEAN
	1	2	3	4		
Heavy grazing	16.492	10.088	8.634	6.393	41.607	10.401
Moderate grazing	4.799	6.576	5.510	6.422	23.307	5.826
Un-grazed	6.329	7.263	5.325	6.130	25.047	6.261

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	11	111.371	
REPS	3	16.692	
TREATMENTS	2	51.013	25.506
ERROR	6	43.667	7.278

$F=3.505$ ^{1/}

^{1/} Not significant (P .05)

Field

The treatment period for the field study with needle-and-thread grass ended August 6, 1974, 48 days after the initial infestation with grasshoppers. By this time no grasshoppers remained alive within the treated cages. The defoliation period occurred between the emergence of inflorescence and seed shatter at which time the grasshoppers removed 83 and 88 percent (weight estimate) of the top growth of the pre-excavated and non-excavated plants respectively (Figure 4). Dry weights of the remaining top growth are given in Table 6 along with the analysis of variance.

The response of the root growth to this defoliation is also shown in Figure 4. Needle-and-thread roots of the grazed pre-excavated plants were 63 percent less by weight than the un-grazed pre-excavated plants. The roots of the non-excavated plants were reduced 38 percent by grazing. This reduction in root growth is significant at the five percent level (Table 7).

The difference between percent root reduction of the pre-excavated and non-excavated plants is probably due to excavating the plants before the grazing period. The root system under the non-excavated plants would include both old and new active roots. The roots of the excavated plants would include primarily the newer active roots. However, the roots of the pre-excavated un-grazed plants were greater in weight than those of the non-excavated

un-grazed plants. The sampling method employed could account for much of the variations found here.

Table 8 indicates that crown weights were not significantly affected by grasshopper defoliation. As previously indicated, in the greenhouse study, crown weight differences were probably due to selecting unequal size plants.

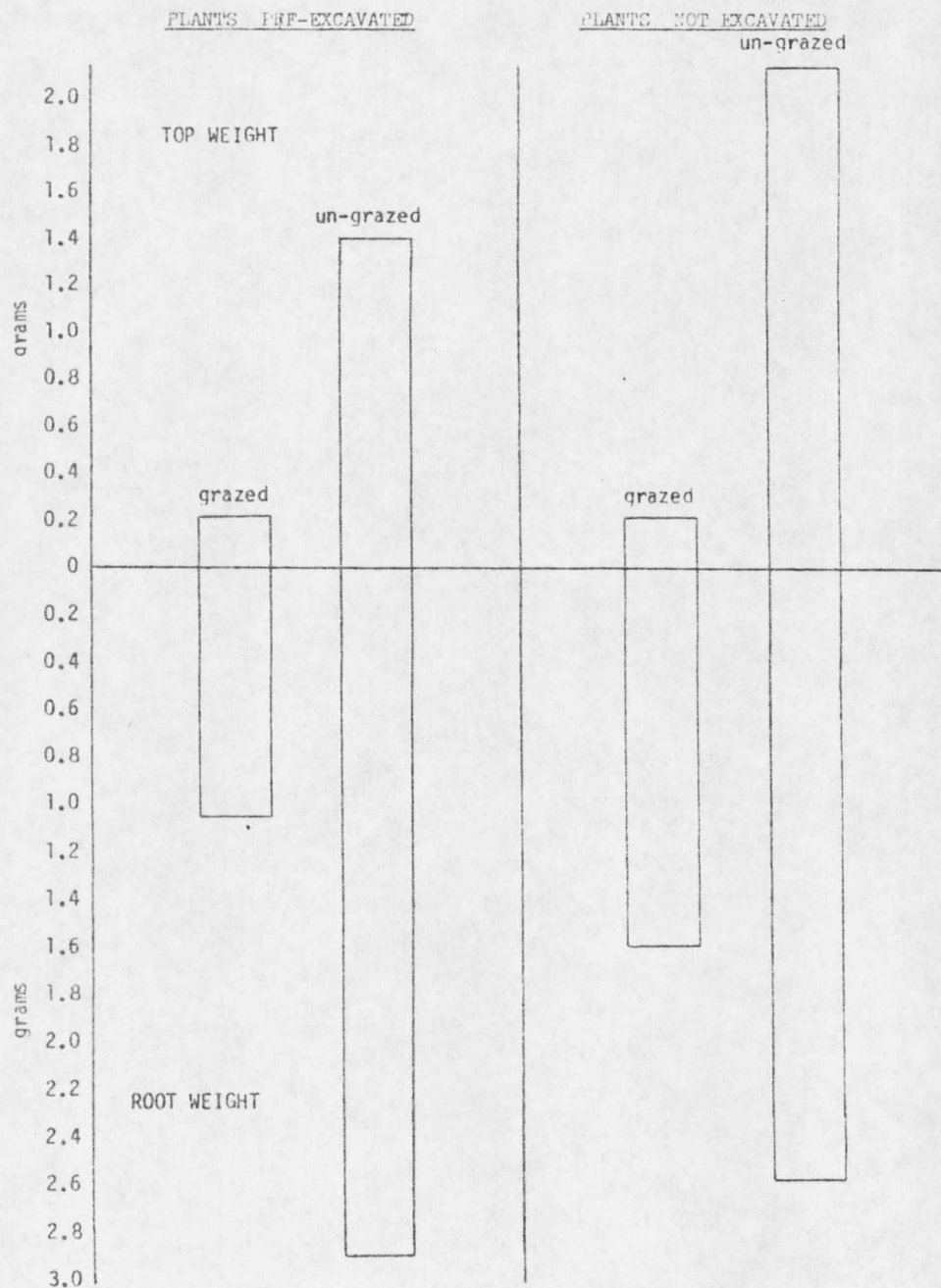


FIGURE 4. Top and root weights of needle-and-thread following approximately 40 days of grasshopper defoliation (field data)

TABLE 6. Weights (gm/plant) of needle-and-thread top growth remaining after approximately 40 days of grasshopper defoliation (field data).

PLANTS NOT EXCAVATED

TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Un-grazed	1.713	1.698	2.818	3.570	2.360	12.159	2.431
Grazed	0.279	0.356	0.246	0.434	0.105	1.420	0.284

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	9	14.098	
REPS	4	1.403	
TREATMENTS	1	11.533	11.533
ERROR	4	1.163	.291

$F=39.651^{**1/}$

PLANTS PRE-EXCAVATED

TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Un-grazed	1.085	1.558	1.420	1.404	1.544	7.011	1.402
Grazed	0.182	0.455	0.162	0.376	0.010	1.185	0.237

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	9	3.667	
REPS	4	.154	
TREATMENTS	1	3.394	3.394
ERROR	4	.118	2.951E-02

$F=115.026^{**1/}$

1/ Highly significant (P .01)

TABLE 7. Weights (gm/plant) of needle-and-thread roots in response to grasshopper defoliation (field data).

PLANTS NOT EXCAVATED

TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Un-grazed	1.950	2.035	2.904	3.562	2.493	12.944	2.588
Grazed	1.388	1.953	2.008	1.471	1.155	7.975	1.595

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	9	4.790	
REPS	4	1.146	
TREATMENTS	1	2.469	2.469
ERROR	4	1.175	.294

$$F=8.406*\frac{1}{1}$$

PLANTS PRE-EXCAVATED

TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Un-grazed	3.568	3.221	3.613	2.825	1.380	14.607	2.921
Grazed	1.158	1.055	1.149	0.996	1.018	5.376	1.075

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	9	11.915	
REPS	4	1.891	
TREATMENTS	1	8.521	8.521
ERROR	4	1.502	.376

$$F=22.685*\frac{1}{1}$$

1/ Significant (P .05)

TABLE 8.. Weights (gm/plant) of needle-and-thread crowns in response to grasshopper defoliation (field data).

PLANTS NOT EXCAVATED

TREATMENT	1	2	REPLICATE			TOTAL	MEAN
			3	4	5		
Un-grazed	10.830	8.536	14.447	15.905	24.200	73.918	14.783
Grazed	8.725	7.140	6.780	11.200	3.523	37.368	7.473

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	9	309.945	
REPS	4	52.526	
TREATMENTS	1	133.590	133.590
ERROR	4	123.829	30.957

F=4.315^{1/}

PLANTS PRE-EXCAVATED

TREATMENT	1	2	REPLICATE			TOTAL	MEAN
			3	4	5		
Un-grazed	5.800	13.915	11.745	13.105	9.035	53.600	10.720
Grazed	8.790	15.237	10.073	3.805	9.185	47.090	9.418

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	9	114.475	
REPS	4	64.477	
TREATMENTS	1	4.238	4.238
ERROR	4	45.760	11.440

F=.370^{1/}

^{1/} Not significant (P .05)

Western Wheatgrass Defoliation

Greenhouse

In the three grazing treatments studied, western wheatgrass seedlings were subjected to grasshopper defoliation. The grasshoppers removed 20, 50, and 80 percent (ocular estimate) of the top growth as compared to the un-grazed plants. These grazing treatments are referred to as light, moderate, and heavy grazing respectively.

The clipping treatment occurred only on day 31, at which time 90 percent (ocular estimate) of the top growth was removed.

The top regrowth response of western wheatgrass to defoliation is illustrated by the bar graph in Figure 5. The weight data were taken 46 days after the end of the treatment period. The oven-dry top weights and statistical tests are given in Table 9. No significant difference in top growth existed between the light grazing and clipping, between the clipping and moderate grazing, and between the control and light grazing. The heavy grazing differed significantly from all other treatments.

The root weight responses to all five treatments are illustrated in Figure 5. The data given in Table 10 show there were no significant differences in root weights between the light grazing and un-grazed, and between the clipping and moderate grazing. The roots of the clipping and moderately grazed plants were reduced 60 and 70 percent respectively. The roots of the heavily grazed plants were reduced

85 percent compared to those of the un-grazed plants. The oven-dry weights are given in Table 10 along with the analysis of variance and Duncan's new multiple range test.

These data indicate that grasshopper defoliation of young actively growing western wheatgrass plants in the greenhouse at moderate and heavy grazing intensities will significantly reduce the mass of roots produced, even after 46 days of rest following treatment. The clipping and moderate grazing treatments in this experiment responded similarly. The light grazing treatment had no significant effect on root growth.

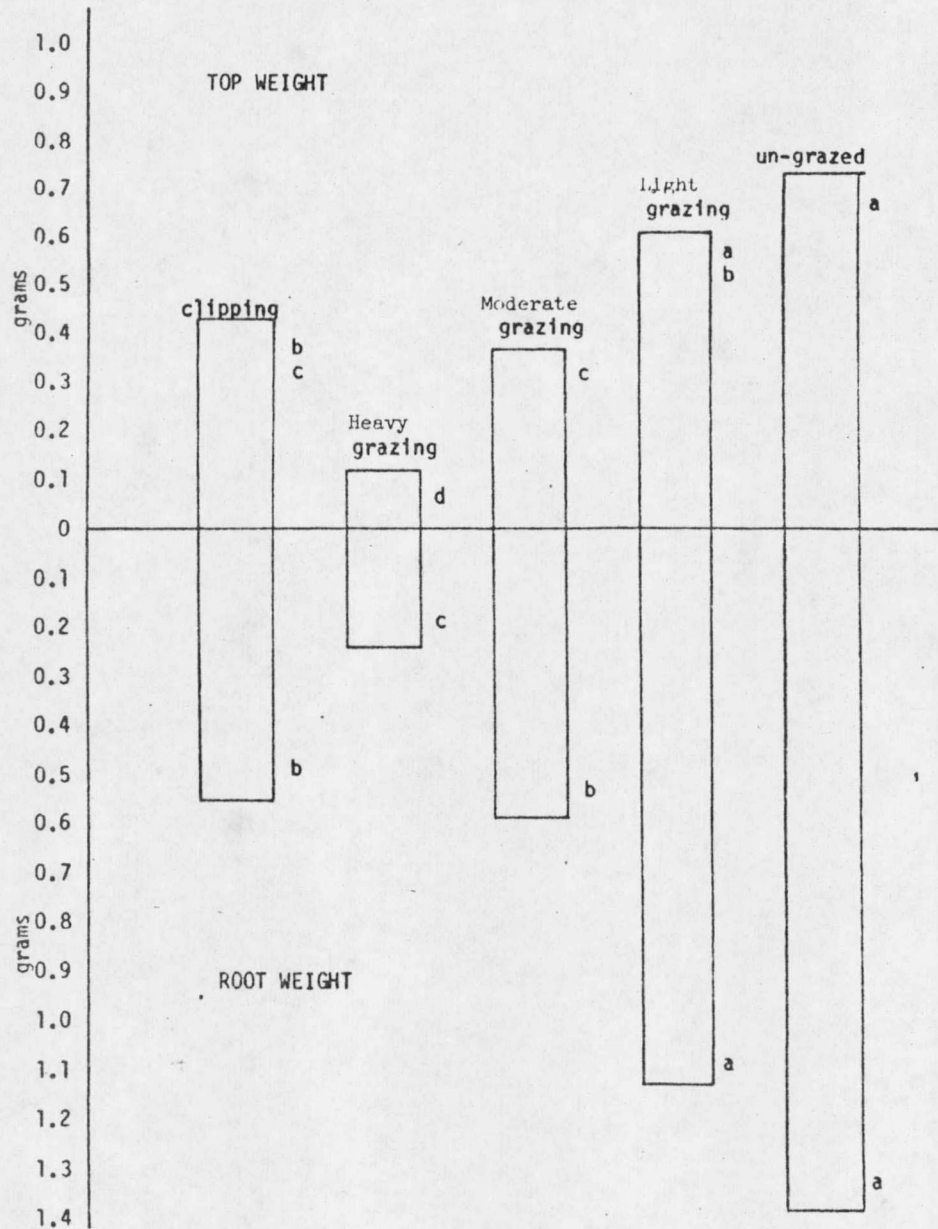


FIGURE 5. Top and root weights of western wheatgrass in relationship to clipping and grasshopper defoliation. Bars having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test.

TABLE 9. Weights (gm/4 plants) of western wheatgrass top growth
as related to grasshopper defoliation and clipping

TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Clipping	0.769	0.435	0.335	0.272	0.391	2.203	0.440
Heavy grazing	0.110	0.115	0.203	0.133	0.104	0.667	0.133
Moderate grazing	0.427	0.153	0.573	0.354	0.330	1.838	0.367
Light grazing	0.632	0.708	0.433	0.584	0.687	3.045	0.609
Un-grazed	0.810	0.720	0.517	0.700	0.999	3.748	0.749

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	24	1.530	
REPS	4	7.967E-02	
TREATMENTS	4	1.108	.277
ERROR	16	.342	2.136E-02

$F=12.973^{**1/}$

TREATMENT	MEAN
Un-grazed	0.749a ^{2/}
Light grazing	0.609ab
Clipping	0.440bc
Moderate grazing	0.367c
Heavy grazing	0.133d

1/ Highly significant (P<.01)

2/ Means having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test.

TABLE 10. Weights (gm/4 plants) of western wheatgrass roots in response to grasshopper defoliation and clipping.

TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Clipping	0.979	0.567	0.415	0.280	0.519	2.760	0.552
Heavy grazing	0.315	0.149	0.286	0.130	0.173	1.053	0.210
Moderate grazing	0.762	0.184	1.184	0.298	0.542	2.970	0.594
Light grazing	1.280	1.298	0.924	0.965	1.113	5.580	1.116
Un-grazed	1.877	1.169	1.280	0.704	1.883	6.913	1.382

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	24	6.502	
REPS	4	.892	
TREATMENTS	4	4.432	1.108
ERROR	16	1.178	7.365E-02

F=15.047**^{1/}

TREATMENT	MEAN
Un-grazed	1.382a ^{2/}
Light grazing	1.116a
Moderate grazing	0.594b
Clipping	0.551bc
Heavy grazing	0.210c

^{1/} Highly significant (P .01)

^{2/} Means having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test.

The crown and rhizome weight data are presented in Figure 6. These data indicate that although there was no significant difference in the crown weights between the light grazing and the un-grazed treatments, both the one time clipping and moderate grazing intensities significantly reduced crown weights by 49 percent. The heavy grazing treatment reduced crown weight by 80 percent. The crown weights and statistical tests are given in Table 11.

Both the heavy and moderate grazing intensities significantly reduced rhizome weights (approximately 90 and 100 percent respectively) from those of the un-grazed plants. However, these treatments were not significantly different from the light grazing or clipping treatments (Table 12). There were no significant differences in rhizome weights between the un-grazed, the lightly grazed, and the clipping treatments.

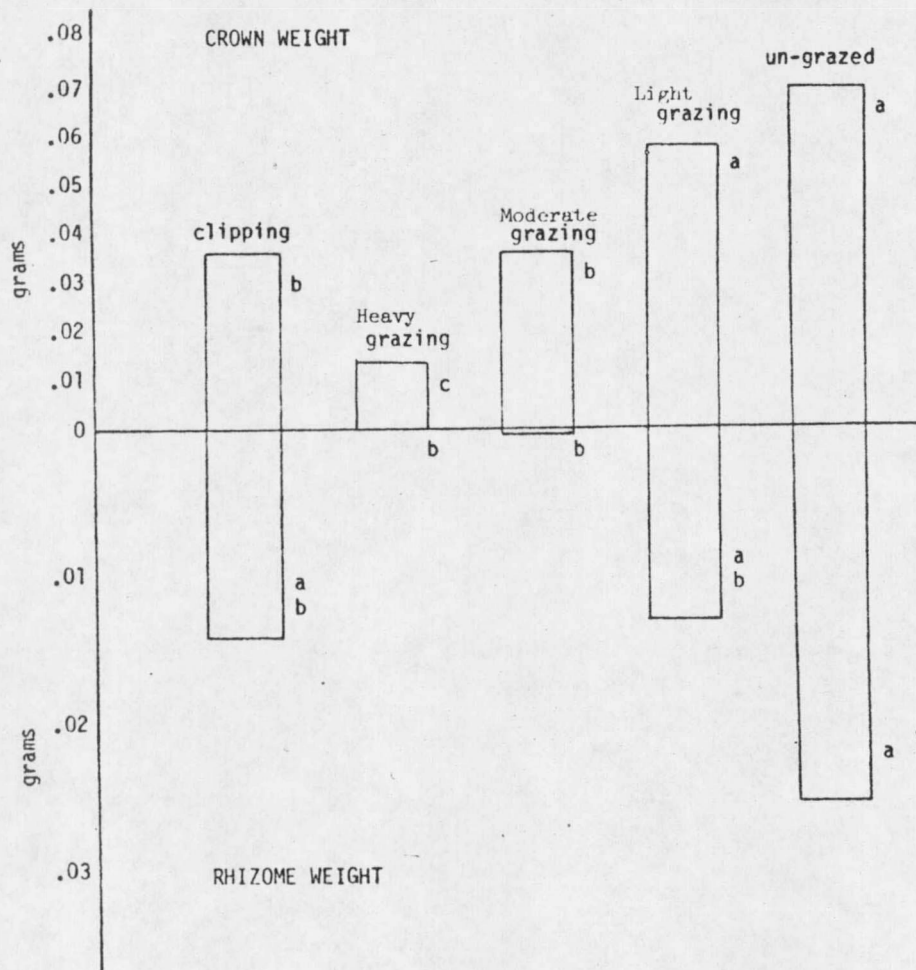


FIGURE 6. Crown and rhizome weight response of western wheatgrass to clipping and grasshopper defoliation. Bars having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test.

TABLE 11. Weights (gm/4 plants) of western wheatgrass crowns in response to grasshopper defoliation and clipping.

TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Clipping	0.048	0.039	0.040	0.024	0.034	0.185	0.037
Heavy grazing	0.010	0.014	0.022	0.013	0.012	0.071	0.014
Moderate grazing	0.056	0.015	0.059	0.029	0.030	0.189	0.037
Light grazing	0.047	0.070	0.062	0.056	0.064	0.299	0.059
Un-grazed	0.075	0.073	0.059	0.073	0.082	0.362	0.072

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	24	1.258E-02	
REPS	4	2.886E-04	
TREATMENTS	4	1.016E-02	2.539E-03
ERROR	16	2.131E-02	1.332E-04

$F=19.065^{**1/}$

TREATMENT	MEAN
Un-grazed	0.072a ^{2/}
Light grazing	0.059a
Moderate grazing	0.037b
Clipping	0.037b
Heavy grazing	0.014c

1/ Highly significant (P .01)

2/ Means having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test.

TABLE 12. Weights (gm/4 plants) of western wheatgrass rhizomes in response to grasshopper defoliation and clipping.

TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Clipping	0.019	0.000	0.033	0.001	0.025	0.079	0.015
Heavy grazing	0.000	0.000	0.002	0.000	0.000	0.002	0.000
Moderate grazing	0.016	0.000	0.000	0.000	0.000	0.016	0.003
Light grazing	0.014	0.021	0.012	0.017	0.005	0.071	0.014
Un-grazed	0.036	0.038	0.000	0.014	0.042	0.132	0.026

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	24	4.773E-03	
REPS	4	3.555E-04	
TREATMENTS	4	2.191E-03	5.477E-04
ERROR	16	2.227E-03	1.392E-04

F=3.935*^{1/}

TREATMENT	MEAN
Un-grazed	0.026a
Clipping	0.015ab
Light grazing	0.014ab
Moderate grazing	0.003b
Heavy grazing	0.000b

^{1/} Significant (P .05)

^{2/} Means having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test.

The total depth of penetrations of the actively growing roots on day 64 are illustrated by the bar graph in Figure 7. Data were recorded on this day because by this time some of the roots had reached the bottom of the box. The clipping and moderate grazing responded similarly with a reduction in depth root penetration of 26 and 22 percent respectively. No significant difference occurred between the light grazing and the un-grazed treatments. The heavy grazed treatment reduced the length of root penetration by 49 percent when compared to the un-grazed plants. Table 13 lists the root length in centimeters of the five treatments and the statistical test.

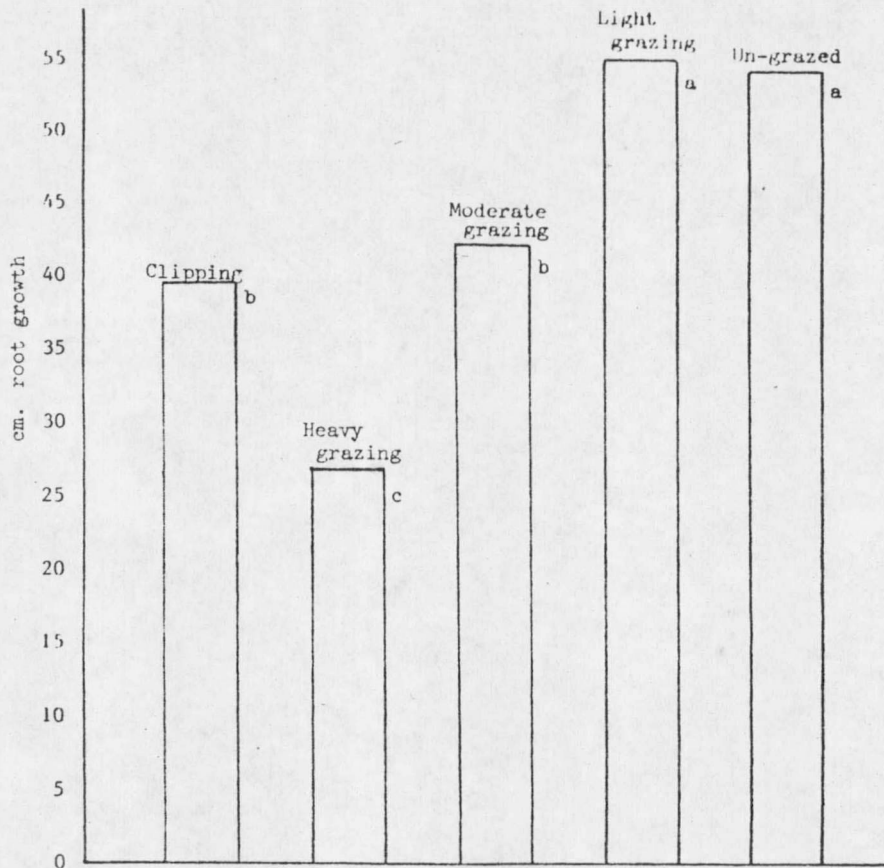


FIGURE 7. Maximum root depth response of western wheatgrass to grasshopper defoliation and clipping. Bars having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test.

TABLE 13. Maximum depth of penetration (cm) of western wheatgrass roots in response to grasshopper defoliation and clipping.

TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Clipping	52.8	34.3	37.7	36.0	38.7	199.5	39.90
Heavy grazing	24.6	25.3	28.3	30.2	30.1	138.5	27.70
Moderate grazing	47.5	37.8	50.0	32.1	42.9	210.3	42.06
Light grazing	58.0	55.6	54.3	49.9	56.0	273.8	54.76
Un-grazed	54.1	58.0	51.5	47.4	58.0	269.0	53.80

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	24	3063.122	
REPS	4	197.050	
TREATMENTS	4	2487.238	621.809
ERROR	16	378.834	23.677

F-26.262**^{1/}

TREATMENT	MEAN
Light grazing	54.76d
Un-grazed	53.80a
Moderate grazing	42.06b
Clipping	39.90b
Heavy clipping	27.70c

^{1/} Highly significant (P .01)

^{2/} Means having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test.

The rate of root growth of all five treatments from day 28 through day 55 is represented in Figure 8. The grazing treatment period occurred from day 31 through day 47.

The clipping treatment stopped all root growth for a period of five days during which time there was an increase in rate of top growth of the clipped plants when compared to the un-grazed plants (Figure 9). By the end of the testing period the average height of the clipped and the un-grazed plants was equal.

The grazing treatments did not have the immediate effect that occurred in the clipping treatment, but as the defoliation intensity increased with time and the grasshoppers increased in size, the daily root elongation gradually decreased. The heavy grazing treatment on day 42 nearly stopped any further root elongation during the time measured. It was felt that if heavy grazing had been continued the western wheatgrass plants would have died.

As previously indicated by root weights at the end of this study period and the rate of root growth, the un-grazed and lightly grazed plants responded similarly. The moderate grazing and clipping treatments were nearly on the same incline of rate of root elongation (Figure 8). The data showed roots of the heavily grazed plants were affected most detrimentally.

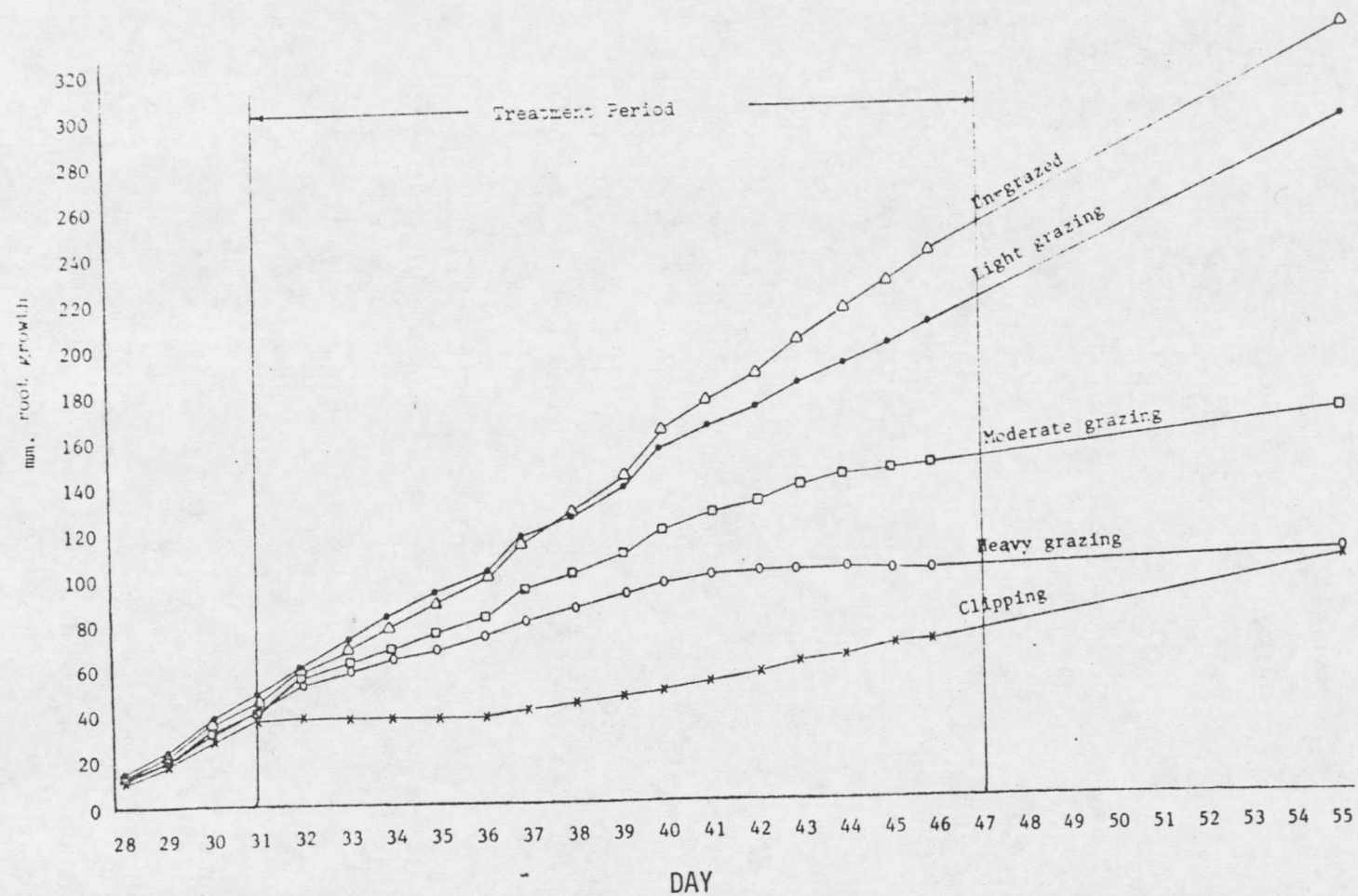


FIGURE 8. Root growth rate of western wheatgrass in response to grasshopper defoliation and clipping.

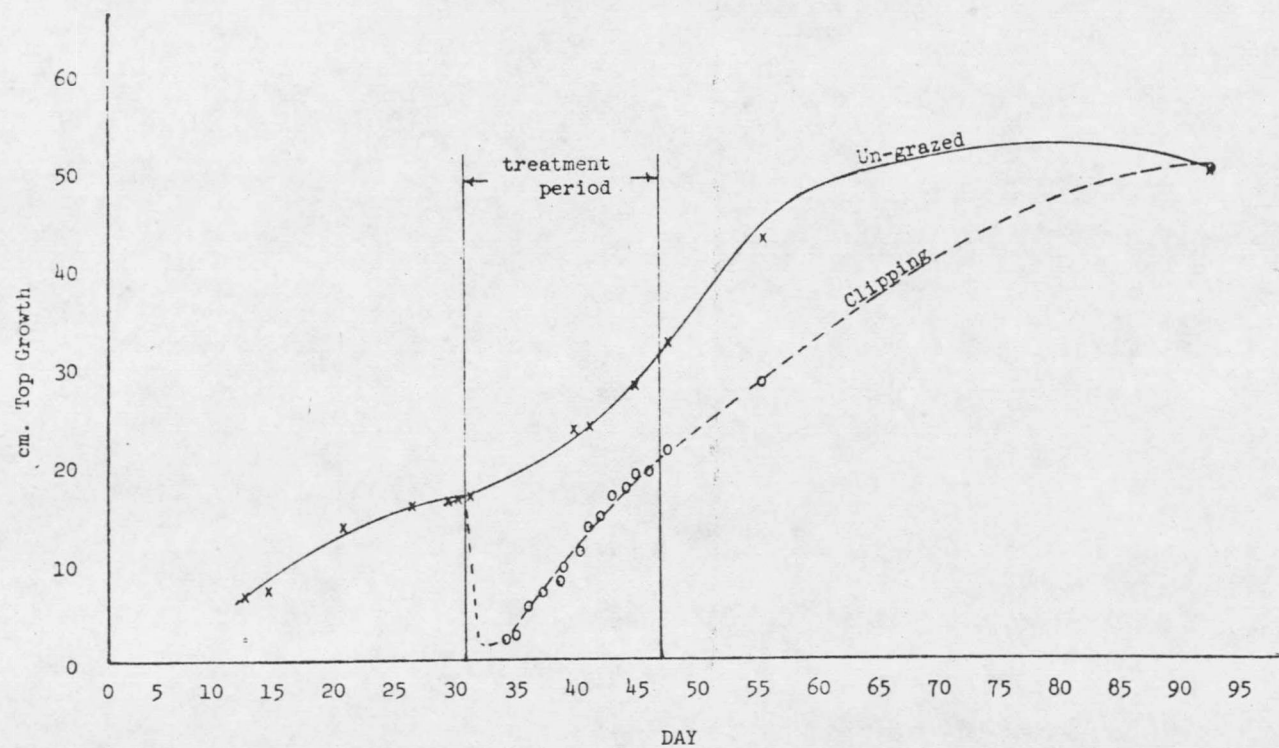


FIGURE 9. Top growth response of western wheatgrass to clipping.

The numbers of new shoots produced by western wheatgrass in response to four of the five treatments is shown in Figure 10. The heavy grazing treatments is not represented because no new shoots were produced. There was no significant difference between the un-grazed, lightly grazed, and clipping treatments (Table 14). However, the moderately grazed plants had significantly 35 percent fewer new shoots than the un-grazed plants.

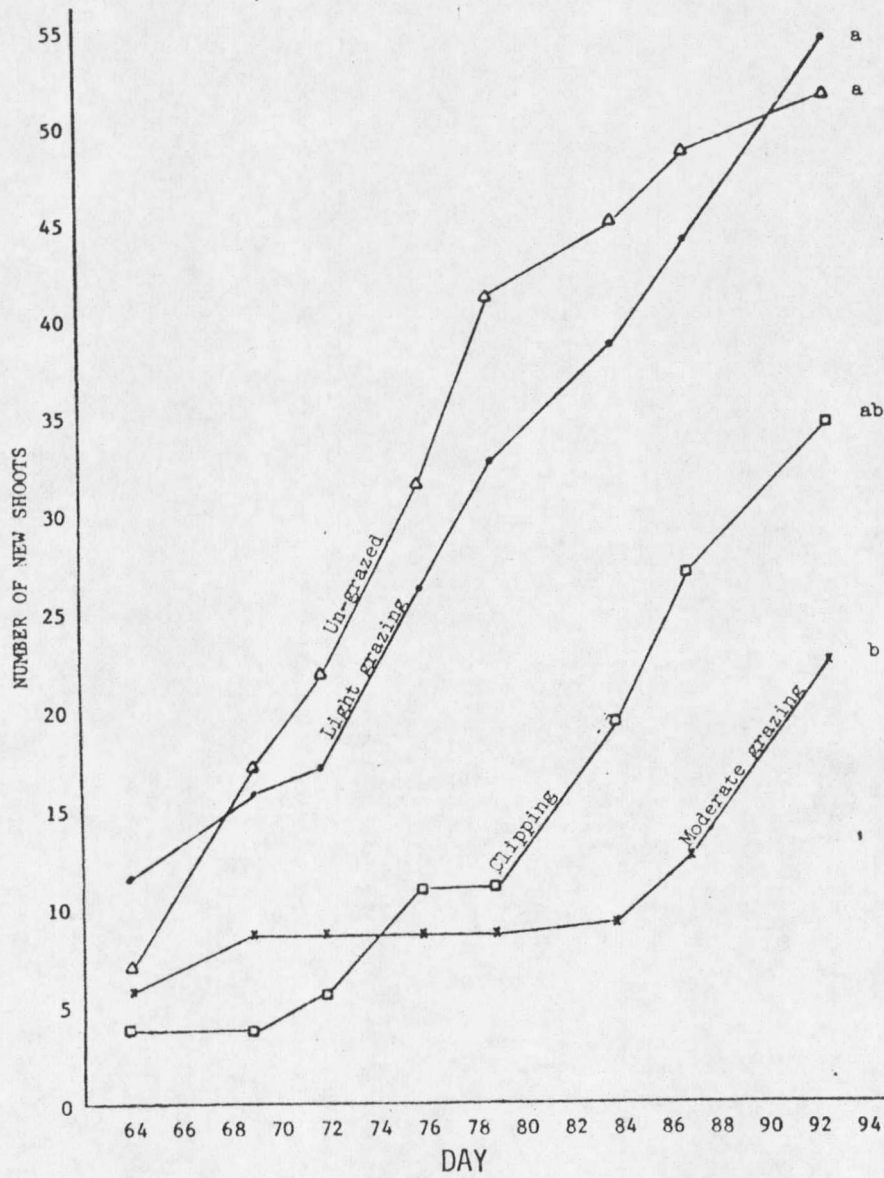


FIGURE 10. The total new shoots produced by western wheatgrass in response to clipping and grasshopper defoliation. Lines having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test.

TABLE 14. Number of new shoots produced by western wheatgrass in response to grasshopper defoliation and clipping.

TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Clipping	18	3	4	2	7	34	6.8
Heavy grazing	0	0	0	0	0	0	0.0
Moderate grazing	9	0	0	2	2	22	4.4
Light grazing	10	13	12	0	11	55	11.0
Un-grazed	10	10	8	0	15	52	10.4

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	24	694.24	
REPS	4	73.84	
TREATMENTS	4	411.04	102.75
ERROR	16	209.36	13.085

$F=7.853^{**1/}$

TREATMENT	MEAN
Light grazing	11.0a
Un-grazed	10.4a
Clipping	6.8ab
Moderate grazing	4.4bc
Heavy grazing	0.0c

1/ Highly significant (P .05)

2/ Means having the same lower case letters are not significantly different at the .05 level using Duncan's new multiple range test.

Plant and Grasshopper Development in the Field

The height of the culm development is expressed graphically for western wheatgrass and needle-and-thread grass in Figures 11 and 12 respectively. The range and mean are given for each week sampled. Also indicated on these figures are the general developmental curves of the grasshoppers collected at the site. As indicated in Figures 11 and 12, the development period for the later instars and adult stage of the grasshoppers collected on the site occurred after the active growth period for the two cool season grass species studied.

Table 15 lists some of the grasshopper species collected and their respective developmental period. Most of the adult portion of the grasshoppers life span occurred during the latter part of July through September. An exception to this is Psoloessa delicatula which overwinters in the nymphal stage. This grasshopper could possibly graze plant parts during the active growing season of cool season grasses. However, from personal observations this grasshopper does not usually occur in relatively high numbers.

It was observed that the year under consideration was atypical. The spring of 1975 was unusually cool with high precipitation (Table 1, page 11). The effect of this weather difference on grasshopper development is unknown.

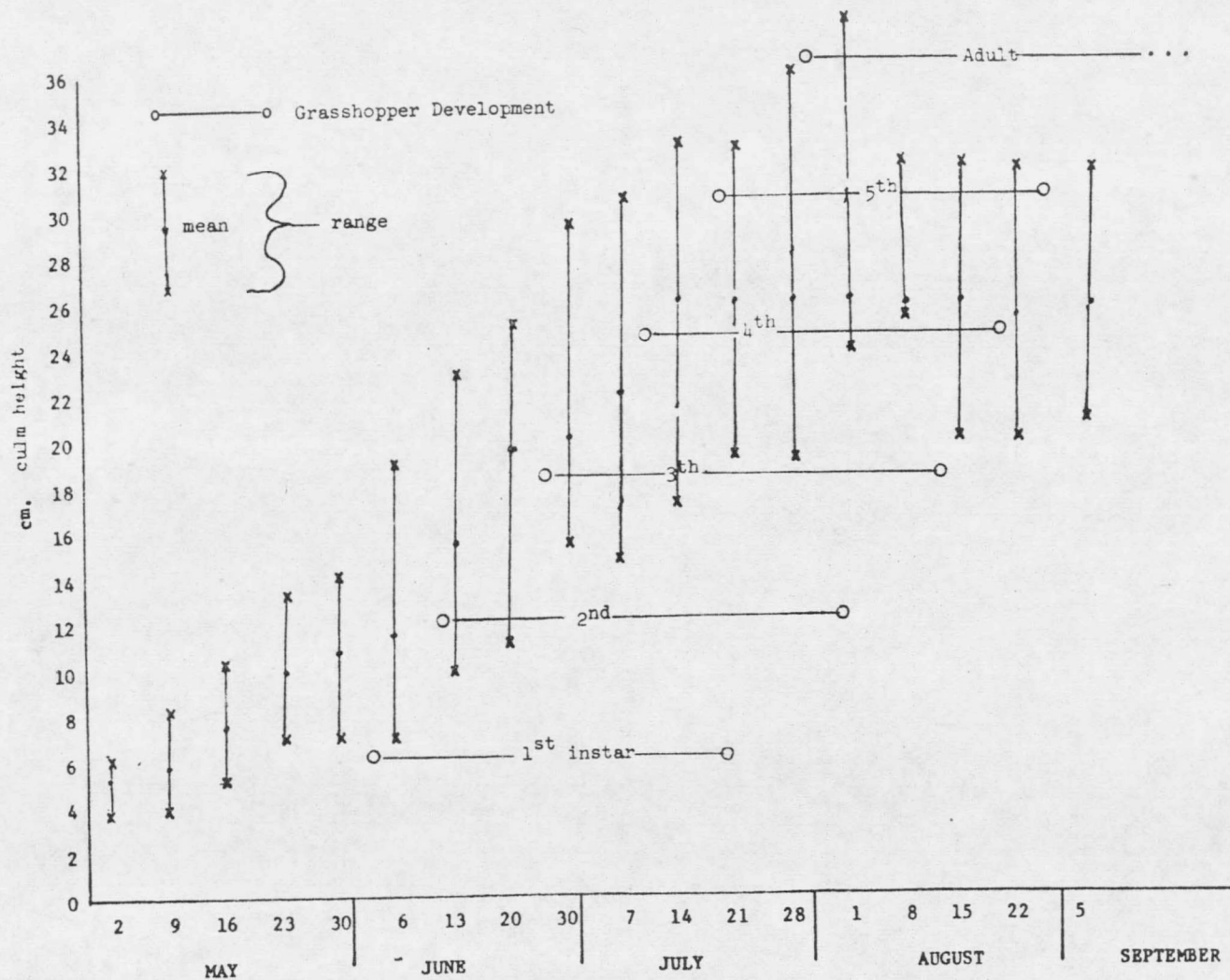


FIGURE 11. Average and range of culm height for western wheatgrass as related to grasshopper development.

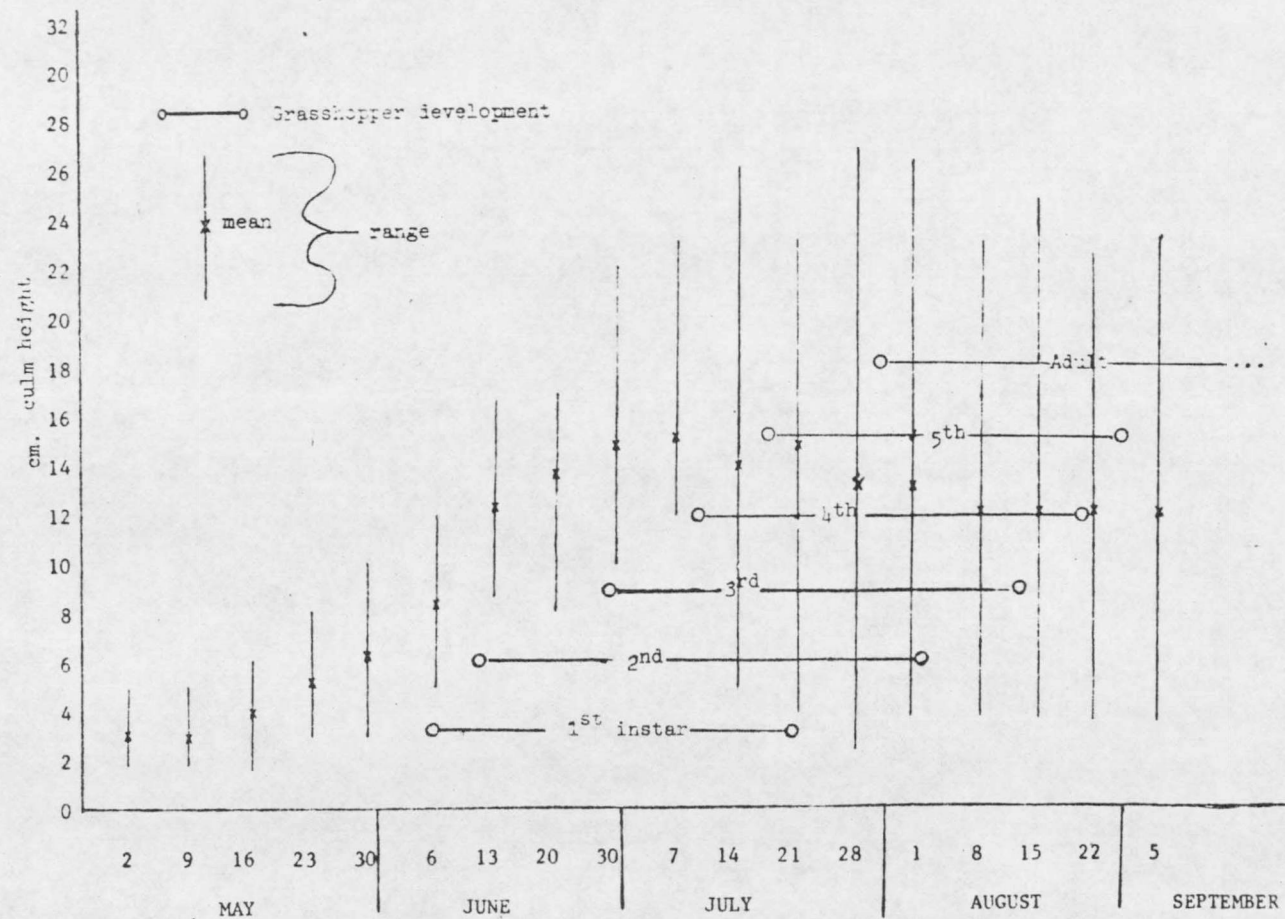
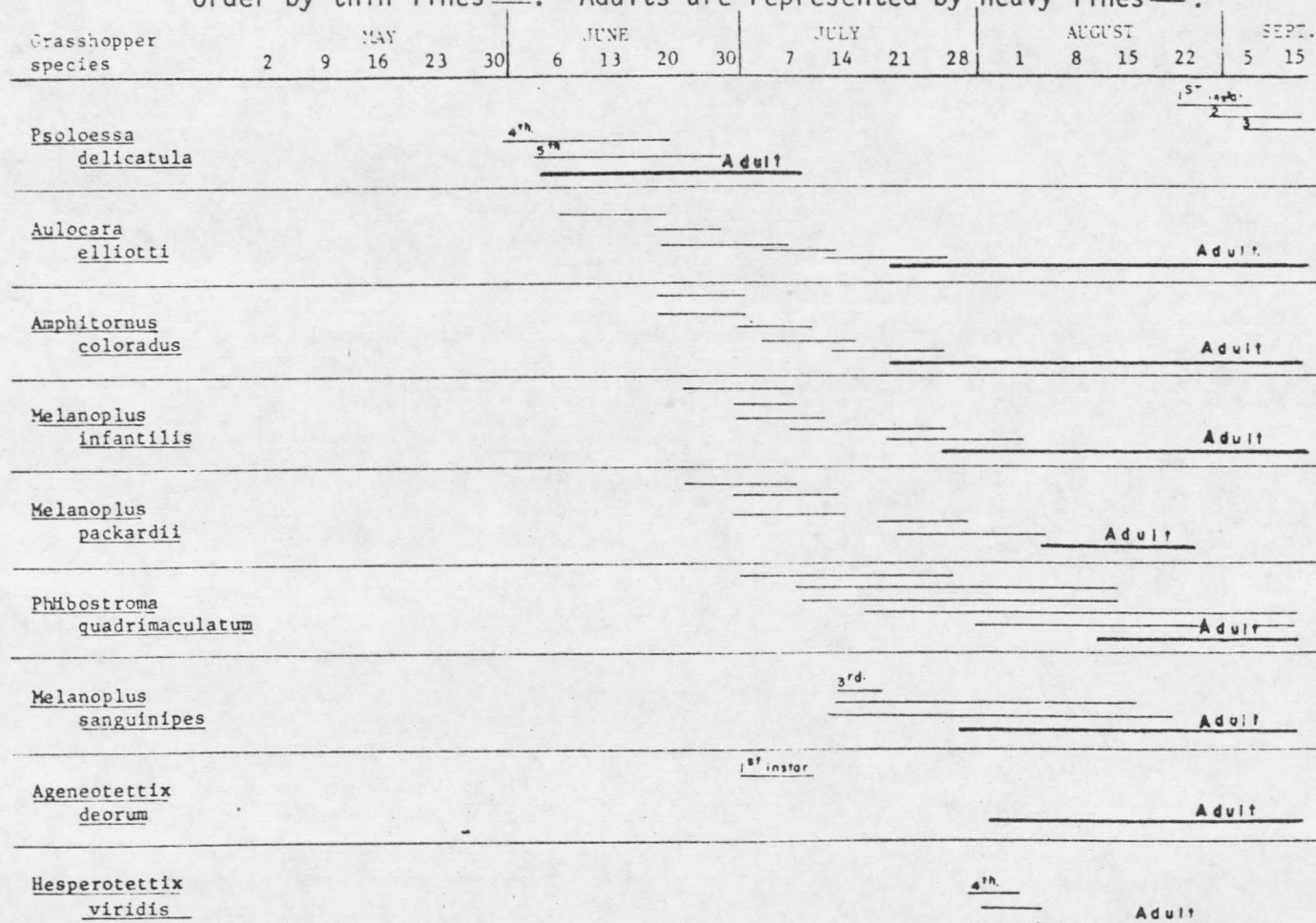


FIGURE 12. Average and range of culm height for needle-and-thread as related to grasshopper development.

TABLE 15. Developmental period of grasshopper species from the Three Forks, Montana study site - 1975. Instars are represented in descending order by thin lines —. Adults are represented by heavy lines —.



Field root elongation for western wheatgrass and needle-and-thread was highly variable. The data collected by the method employed were thought to be unreliable. The roots would grow against the glass for a short period of time and then die back or turn away from the glass. The weekly measurements indicated an average daily root growth of 10 mm per day. However, this is a highly variable figure.

During mid July the roots of both grass species nearly stopped growing against the glass panes at the time of anthesis. Only occasional elongation was observed after this date. No estimation of early spring (May) root growth was made; however, some rhizome activity was noted during September.

SUMMARY AND CONCLUSIONS

Grazing grasshoppers exert an influence upon the productive rangeland ecosystem by their defoliation of plants through eating and dislodging plant material. This grazing includes four aspects of defoliation: intensity, frequency, seasonality, and selectivity. This study deals mainly with intensity and frequency, although seasonality was investigated on a very limited basis.

Greenhouse and field observation data were recorded for two years on various phases of grasshopper grazing of Agropyron smithii (western wheatgrass) and Stipa comata (needle-and-thread). Based on this study the following conclusions were formulated:

1. Both greenhouse and field data of needle-and-thread grass indicated that as grasshopper grazing intensity increased there is a general reduction in total root weight.
2. A greenhouse study of western wheatgrass indicated that heavy grazing (80 percent removal of top growth) for a 16 day period was the most detrimental of all treatments studied. Observation and data found that moderate rates of grazing (50 percent removal of top growth) and a one-time clipping (to a 2.5 cm level) responded similarly. Western wheatgrass responded to an increase in grasshopper grazing intensity by (1) a reduction in total root, crown, and rhizome weight, (2) reduction in maximum depth of root penetration, and (3) reduction

of the number of new shoots produced. There were no significant differences between the light grazing and un-grazed treatments.

3. It was observed and recorded that on one site located in south central Montana the majority of the grasshopper defoliation period occurred after the active growth period for the two cool season grass species studied.

Grasshopper grazing can reduce the amount of new roots produced during certain growing stages of grass species. However, from this brief investigation, it appears grasshopper grazing occurs late enough in the developmental stages of cool season grasses that the influence of this defoliation is less drastic than if defoliation had occurred earlier.

TABLE 8. Weights (gm/plant) of needle-and-thread crowns in response to grasshopper defoliation (field data).

PLANTS NOT EXCAVATED							
TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Un-grazed	10.830	8.536	14.447	15.905	24.200	73.918	14.783
Grazed	8.725	7.140	6.780	11.200	3.523	37.368	7.473

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	9	309.945	
REPS	4	52.526	
TREATMENTS	1	133.590	133.590
ERROR	4	123.829	30.957

$$F=4.315^{1/}$$

PLANTS PRE-EXCAVATED							
TREATMENT	REPLICATE					TOTAL	MEAN
	1	2	3	4	5		
Un-grazed	5.800	13.915	11.745	13.105	9.035	53.600	10.720
Grazed	8.790	15.237	10.073	3.805	9.185	47.090	9.418

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS
TOTAL	9	114.475	
REPS	4	64.477	
TREATMENTS	1	4.238	4.238
ERROR	4	45.760	11.440

$$F=.370^{1/}$$

^{1/} Not significant (P .05)

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