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Effects of Range Plant Foliage Removal on Soil Moisture Regime at Two Elevations in Central Utah

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EFFECTS OF RANGE PLANT FOLIAGE REMOVAL ON SOIL MOISTURE REGIME

AT TWO ELEVATIONS IN CENTRAL UTAH

by

John C. Buckhouse

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

of

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John C Buckhouse

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ABSTRACT

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At Two Elevations in Central Utah

by

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Utah State University, 1968

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During 1966 and 1967, a range plant clipping study was conducted at two locations in central Utah's Ephraim Canyon. It was found that extreme clipping treatment resulted in a significant increase in soil moisture due to a presumed decrease in transpiration during 1967. At the lower location, 7,100 feet elevation, a difference of 5.4 inches over a 5 foot soil profile was noted between the extreme and control clipping treatments in 1967. At the upper location, 10,000 feet in elevation, a savings of 3.6 inches soil moisture was observed over the 5 foot soil profile in 1967. Other clipping intensities also showed water savings in terms of reduced depletion values over the control plots, although these differences were not in all cases statistically significant.

(76 pages)

INTRODUCTION

Need for Study

The growing need for water and water conservation is generally recognized, particularly in the Western United States. Our present water resources can not continue to supply the increasing demands placed upon them. It is necessary that we look to all phases of the hydrological cycle for possible solutions to this critical shortage.

The role of soil moisture in the growth and development of plants is well recognized. The relationship of soil moisture response to alteration of range plant foliage is not as well understood. There has been considerable speculation as to the effect of foliage removal on soil moisture regime. Some individuals suggest that removal of foliage by livestock should result in reduced transpiration rates which reduce soil water deficits and thus provide greater opportunities for increased water yields. Others contend that the opposite is true: an apparent lack of soil moisture is attributed to reduced infiltration, increased surface runoff, and evaporation from the soil surface.

When an area is grazed by livestock, several things occur which may affect the amount of moisture in the soil. First, some of the plant foliage is removed. Foliage removal could have a definite effect on the rate of soil moisture extraction by plants, both from the standpoint of reduced transpiration surface and reduced root development. Second, the soil and plants are trampled by the livestock. Trampling often results in a compacted soil surface which tends to restrict the movement of water into the soil (Packer, 1951). Therefore, when attempting to evaluate variations in soil moisture which are attributable to grazing, it is most difficult to determine how much of this variation is caused by foliage removal and how much by trampling. Thus, there is a very definite need to determine the effects of foliage removal, independent of trampling, on soil moisture regime.

Objectives of the Study

The objectives of this study are: (1) to investigate and determine the effects of light, medium, and heavy levels of foliage removal from range plants on soil moisture regime; (2) to determine the effects of season of foliage removal from range plants on soil moisture regime.

As various schemes of grazing periods and intensities are currently in use on public watershed areas, it is desirable to study the effects of the several clipping intensities as well as several frequencies of foliage removal.

It is hoped that this study will contribute toward the knowledge on which sound grazing and watershed management practices are based.

REVIEW OF PREVIOUS WORK

Numerous investigators have reported the effects of grazing or clipping on root response (Weaver, 1930; Parker and Sampson, 1931; Hanson and Stoddart, 1940; Weaver, 1950; Downs and Box, 1964; Mathis, Jaynes, and Thomas, 1965). These investigations, in general, indicate that root growth and development are restricted by intensive foliage removal. Biswell and Weaver (1933) note that in all cases considerable decreases in ground cover accompanied clipping as subsequent weakening of the stand proceeded. They further note that clipped plants failed to produce new rhizomes and many of the old ones died. The length of roots was generally decreased and the relative production of roots was reduced to a greater extent than the tops. Since the root systems are the means by which plants extract moisture from the soil, any reduction or restriction of the root systems would be expected to reduce the ability of the plants to extract moisture from the soil.

A number of studies have been conducted in the realm of tree removal and subsequent effects on soil moisture regime (Bates, 1928; Kittredge, 1937; Hoover, 1944; Wilm and Dunford, 1948; Croft, 1950; Kramer, 1952; Biswell and Schultz, 1958; Marston, 1962). These studies tend to quantify and explain the increased runoff which they have observed in terms of cutting treatments and decreased transpirational draft. For example, Dunford and Fletcher (1947) indicate that complete removal of vegetation could be expected to result in notable gains in water yield because of a reduction in transpiration. Cutting the riparian growth has also been shown to result in an increase in yield sufficient in magnitude to be significant in water-resource management (Biswell and Schultz, 1958).

Several studies have been conducted in terms of soil moisture response under different clipping or grazing intensities. Conflicting evidence is shown by these studies. Zijlstra (1938) reports that evaporation from the ground with no plant cover is less than transpiration of a normal sward, indicating that complete vegetation removal would result in a higher soil moisture content. Dennis, Harrison, and Erickson (1959) report a study in which water consumed, per unit of forage produced, decreased as the cutting interval increased. They further state that less water was used from the deeper soil horizons in the frequently cut plots. Baker and Hunt, (1961) write that plants clipped at 2 inches were more efficient in their use of water than those clipped at 4 inches. They speculate that this is a result of greater transpiring area of the four inch plants. Liacos (1962) suggests that water yield will be many times greater from grassland under protection, when the major part of the rainfall comes during the winter period which coincides with low growth. He further states that the practice of grazing may be a method for regulating runoff. Protection from grazing may reduce the runoff and control the floods in small watersheds. In contrast, he suggests increased grazing may be the correct practice for increased water yield. Madison and Hagan (1962) report a study on a deep clay loam with a 3- and a 4-year old turf. They found the amount of soil moisture extracted to be directly related to height of cutting and length of interval between irrigation. Van Riper and Owen (1964) found that forages cut at a two inch height used less water than those cut at a five inch height. They also speculate that the apparent difference in transpirational area accounts for the difference in moisture use.

Several conflicting views have been published indicating that the question is still open for lively debate. Hagan and Peterson (1953) report a study under irrigated conditions in which the more frequent clipping schedules resulted in greater moisture extraction. Lassen, Lull, and Frank (1952) suggest that water is removed more rapidly in a vegetated soil, but, assuming no addition of moisture to an area, evaporation will eventually remove a greater amount of water because the evaporation process is not governed by the physiological factors which limit transpiration. They acknowledge that removal or killing of vegetation affects transpiration by reducing transpiring surface. They maintain, however, that where only a part of a plant is destroyed, transpiration may not be reduced, depending on whether the rate can be maintained by the remaining leaf surface. Hanks and Anderson (1957) report that 2.5 inches of rain was lost as runoff on burned plots as compared with 0.7 inches of runoff on control plots. Infiltration was also reduced on the burned plots. Houston (1965) found that heavy stocking lowered average moisture stress in a year of normal precipitation; due, at least in part, to some combination of lower transpiration loss from reduced root growth, plant growth, plant vigor, and increased numbers of shallow-rooted species caused by repeated close grazing of the vegetation. He was, however, unable to show significance between light and heavy stocking levels during a drought year. In the same study Houston found heavy stocking in a clayey soil resulted in high soil moisture stress. The author attributes this effect to "a compacting and sealing of the soil surface from livestock trampling, thus reducing soil moisture infiltration and resulting in a drier sub-soil."

It is interesting to note that numerous studies have been conducted concerning the effects of livestock grazing and land condition. Most of these reports are primarily concerned with the effects of trampling and denudation on the infiltration capacity of the soils and subsequent runoff and erosion problems, rather than transpirational requirements (Duley and Domingo, 1949; Osborn, 1952; Liethead, 1959; Rauzi and Smika, 1963). Rauzi (1960) reports that pastures rated in low range condition had less water intake (infiltration) because too heavy use had decreased the amount of standing vegetation and mulch material, which bared the soil to the sealing action of the raindrops. Rich and Reynolds (1963) found that chaparral areas in central Arizona can be properly grazed without detriment to soil stability or water regime. If no more than 40 percent of perennial grass production is removed at the end of the summer growing season, ground cover does not deteriorate and appears sufficient to maintain a stable soil.

The correlation between grazing and flooding and erosion seems to be well substantiated. Forsling (1931) reports the results of treatment of Watersheds A and B in Ephraim Canyon, Utah. His review of 15 years of data shows the importance of herbaceous vegetation in reducing rain-initiated surface runoff, floods, and erosion. He also points out the need for regulating grazing to prevent depletion of the herbaceous cover on sloping lands subject to torrential rainfall. Johnson (1952) states it much more strongly, by reporting that intensive grazing brought about a reduction of soil porosity and permeability, as well as infiltration. He further notes that increased turbidities and silt load contribute to a decline of water quality. Fletcher (1960) warns that the relations between plant cover and infiltration capacity are complex and must be carefully studied at each site if gross errors are to be avoided.

Obviously, the results of studies such as these indicate the complexity and confounded nature of the interaction of foliage removal and livestock trampling.

Stoddart and Smith (1955) speculate on the problem as follows: "in arid regions, it is quite possible that grazing induces better moisture relations since, with removal of herbage, the transpiring surface is reduced and plants may be able to stand more drought." They further state: "Whether or not grazing to reduce foliage may measurably reduce loss of water through transpiration has not been adequately determined. Possibly grazing may increase water yield without impairing stream-flow behavior."

There appears to have been an obvious lack of research related to the effects of foliage removal, either by grazing or clipping, from range plants on soil moisture regime.

STUDY AREA DESCRIPTION

Location and Site Layout

The project study areas are located on the western edge and the crest of the Wasatch Plateau in central Utah. The experimental areas are situated in Ephraim Canyon, San Pete County. The lower plots are located at Major's Flat, elevation 7,100 feet, near the U. S. Forest Service experimental nursery and reseeding areas. The upper plots are located at the head of Ephraim Canyon at an elevation of 10,000 feet. The study areas and site locations are shown in Figure 1.

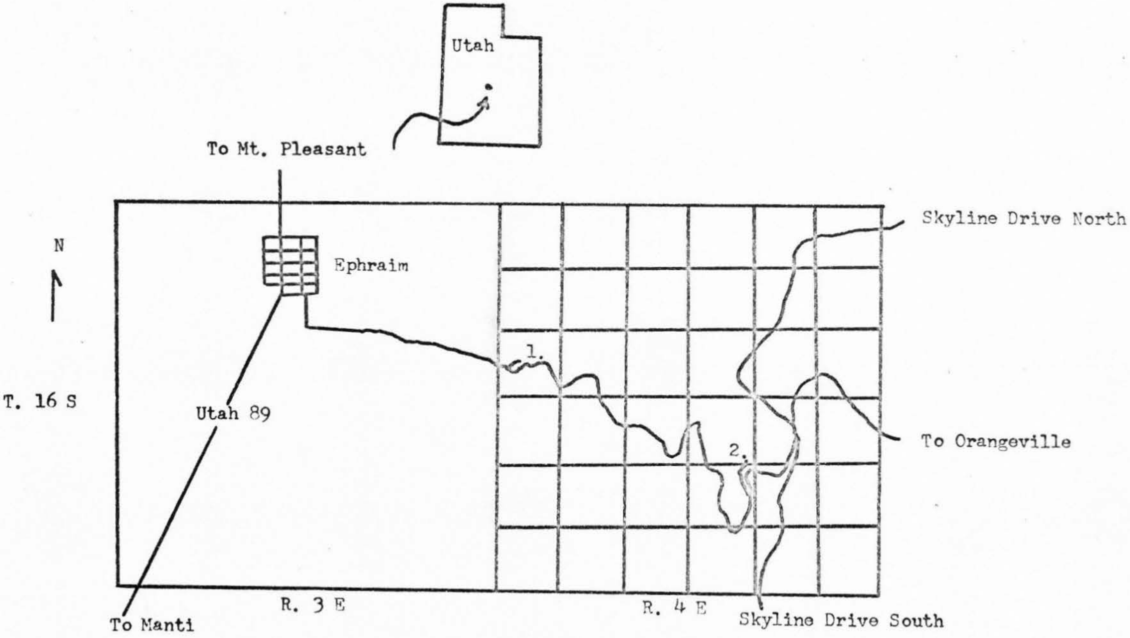
Elevation and Aspect

In order to minimize lateral movement of water into and/or out of the specified areas, the study areas were located on level to moderately sloping land. The lower study site has a west aspect, with a slope of 13-14 percent.

The upper study area is located near the plateau crest. This study area is essentially flat, with no directional aspect.

Climate

The upper plots are located in an alpine climatic zone. An 11 year average at the Meadows Climatic Station shows the annual precipitation to be 35.67 inches yearly. While there are occasionally snow flurries as late as July or August, the snow-free season is generally between mid-June and mid-September. Snow melt is generally complte by early July on the study site.



Code: 1. Lower Study Site
2. Upper Study Site

Scale: 1 inch equals 2 miles

Figure 1. Location of upper and lower study sites.

The lower study site experiences slightly milder climatic conditions throughout the year. Major's Flat receives an average of 18.09 inches of precipitation yearly. The snow season is generally about a month shorter at the lower plots than the upper, primarily due to an earlier spring. Table 1 gives average precipitation values by month for each location.

Geology

The upper geologic formation in Ephraim Canyon belongs to the Wasatch Formation, probably of the Eocene period of the Tertiary age. The strata which compose this great uplift or plateau are practically horizontal. They are composed of alternating layers of limestone and clays, with smaller amounts of sandstone, and thin beds of laminated bituminous shale. It is believed that these materials were originally laid in basins of great fresh water lakes.

The Wasatch Plateau breaks abruptly to the west in this area. Ephraim Creek rises at 10,300 feet elevation and drops to 5,900 feet at the San Pete Valley floor, which is about seven miles horizontal distance to the west.

Soils

The soils of this area are derived directly by disintegration and decomposition of the underlying beds of limestone, clay, and thin beds of brownish, finely laminated bituminous shale. A thin bed of calcareous fine sandstone which is present seems to have exerted little influence on the texture of the soil.

The soils at the lower study site are calcareous clay loams, high in organic matter content and highly aggregated under natural conditions (Meeuwig, 1956). At the upper site the soils are mainly clay and clay loam.

Table 1. Average precipitation values for the upper and lower study sites.

Location	Months												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Upper	3.19	4.89	4.94	4.36	3.37	1.45	1.21	1.87	1.99	2.30	2.93	3.17	35.67
Lower	1.59	2.04	2.15	1.95	2.03	0.86	0.89	1.11	1.20	0.89	1.50	1.88	18.09

with variable gravel content. The structure is either loose or friable in the lighter soils or granular or crumbly in the heavy soils. Considerable humus and probably a high percentage of mineral plant food are generally found at this site (Forsling, 1931).

There are moderate infestations of pocket gophers in the vicinity of the upper plots. These rodents dig their tunnels a few inches under the surface and throw up mounds at intervals. Their number was reduced during the 1967 growing season by means of poison grain placed in their runways.

Vegetation, Plant Cover, and Phenology

The lower study location is typical of reseeded sites within a cleared oakbrush type. The brush is Gambel's oak, *Quercus gambelii*. Major forage species are crested wheatgrass, *Agropyron cristatum*; intermediate wheatgrass, *Agropyron intermedium*; smooth brome, *Bromus inermis*; and alfalfa, *Medicago sativa*.

The upper study area is representative of an open, high elevation stipa grassland. The major forage species at this location are Letterman's stipa, *Stipa lettermani*; and yarrow, *Achillea lanulosa* (see appendix, Tables 12, 13, 14, 15).

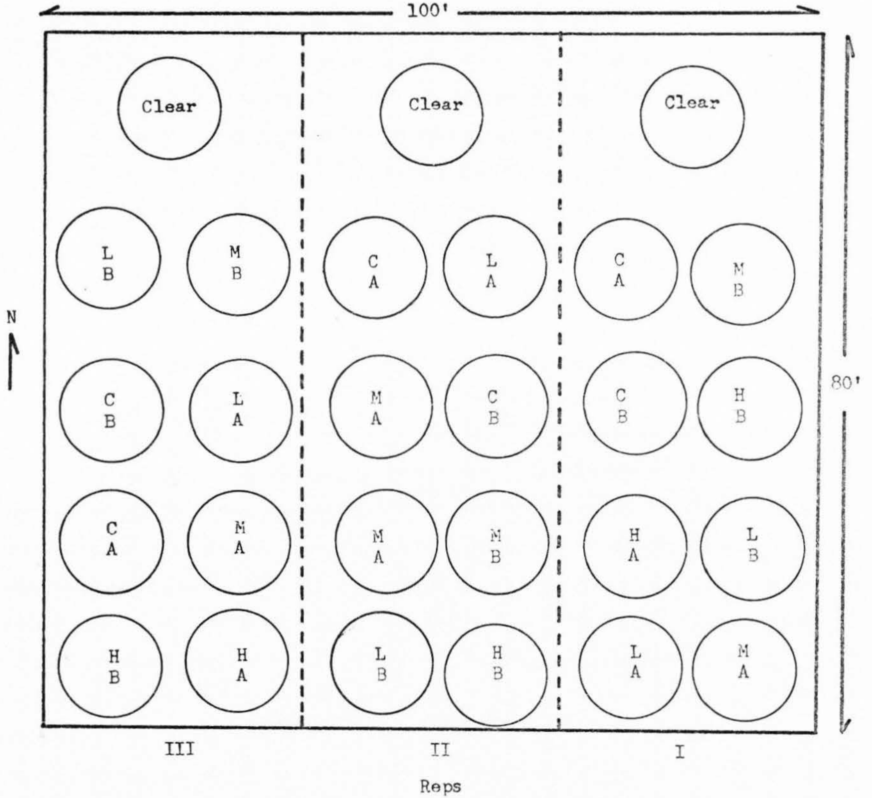
METHODS AND PROCEDURES

Study Area Preparation

Two stands of range grassland were selected as representative of mountainous central Utah range areas. During the latter portion of the summer of 1965, twenty-seven circular plots (3 replications of nine plots), 8 feet in diameter, were established within an area of approximately 80 feet by 100 feet, at each study location. A buffer strip of 4-5 feet was left between plots. A soil moisture access tube, for neutron moisture measurements, was installed at the center of each plot, to a depth of 5.5 feet. The plots were fenced immediately after installation to exclude grazing.

Each plot was assigned a treatment scheme based upon a random selection method (Figure 2 and 3).

The plots were clipped in accordance with the designated scheme, the key being as follows: time or frequency of clipping, monthly (A) or seasonal (B); intensity of clipping, extreme or clear (Cl), heavy (H), medium (M), light (L), or control (C) levels of foliage removal. Forage preferences were eliminated by clipping at 0 (Cl), 4 (H), 8 (M), and 12 (L) inch stubble heights at the lower study area. At the upper site the corresponding stubble heights were 0, 3, 6, and 9 inches. The plots designated as seasonal were clipped at a time corresponding to the grazing season of the federal agencies. Monthly clipping started on the same date as the seasonally clipped plots and proceeded from that date on a calendar basis.



Treatments:
Foliage removal
L = light
M = medium
H = heavy
C = control

Time of Removal
B = clipped once
A = clipped monthly

Figure 2. Plot diagram showing treatment designations - Lower study site.

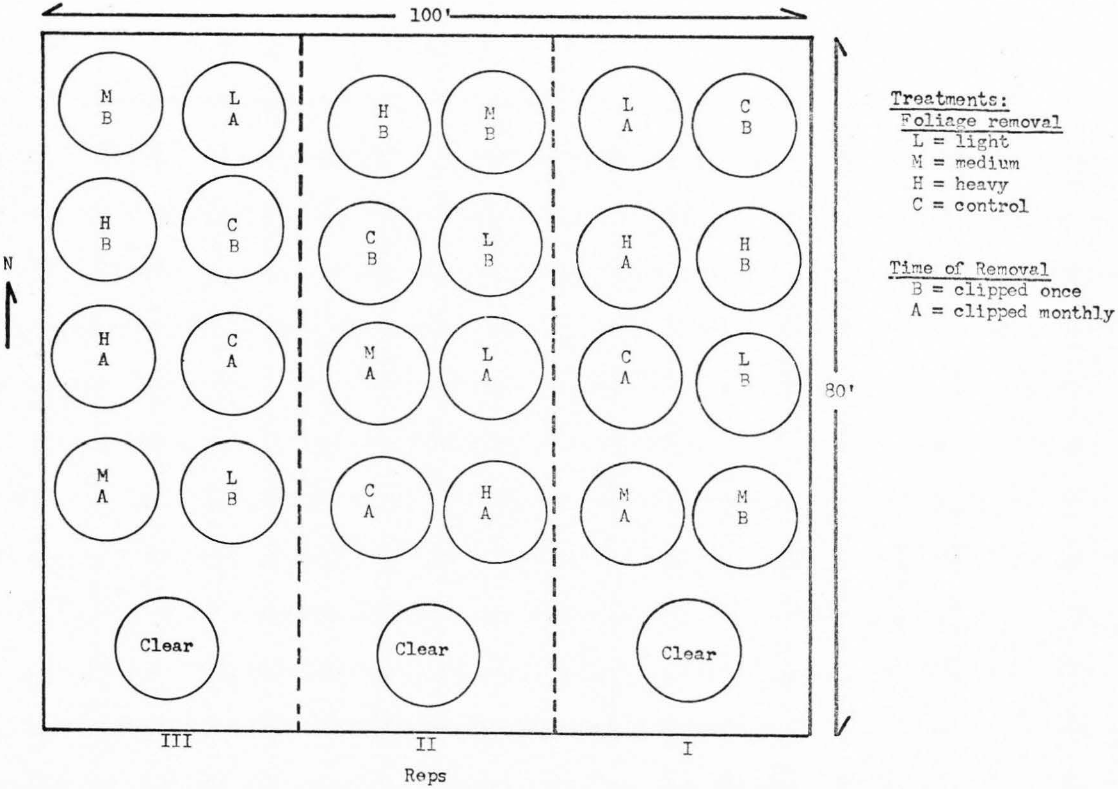


Figure 3. Plot diagram showing treatment designations - Upper study site.

Measurement of soil moisture beneath each treatment was accomplished by means of a neutron scattering device. Measurements were obtained at 0.5, 1.0, 2.0, 3.0, 4.0, and 5.0 feet depths on a semimonthly schedule throughout the latter portion of the 1966 and entire 1967 growing seasons. Whenever soil moisture measurement or clipping was being done a 10 foot aluminum bridge was used to span the plots and thus eliminate any possibility of soil compaction. Figure 4 shows the bridge and equipment used. Figures 5 and 6 are photographs of the lower and upper study areas respectively.

Data obtained

Periodic semimonthly soil moisture measurements were taken at each depth per plot on each site. Initial measurements were taken in June 1966 and continued through the first of November 1966. The measurements were resumed for the lower study area in April of the 1967 growing season and in early July at the upper study site. Both beginning dates represent the onset of the 1967 growing season at the respective sites. Measurement was continued through the end of October 1967.

Phenology records were regularly kept (see appendix, Tables 16, 17, and 18). Forage yields as determined by the various clipping intensities were also recorded on the basis of oven dried weight measurement (see appendix, Tables 19, 20, 21, and 22).

Rainfall data were obtained through cooperation with the Great Basin Research Station of the Intermountain Forest and Range Experiment Station located at Ephraim. Supplementary rainfall data were obtained at the upper site with a standard 8-inch storage gauge.

Figure 4. Soil moisture measurement equipment and span-bridge.

Figure 5. Vegetation and terrain at the lower study location.

Figure 6. Vegetation and terrain at the upper study location.

Soil samples were saved when the holes for the neutron access tubes were augered. These samples were later analyzed by means of a pressure membrane system to determine moisture values at 1/3 and 15 atmospheres of tension for each sampling depth (see appendix, Table 23).

During the 1967 season small areas adjacent to the metered areas were also clipped at the prescribed treatment intensities. Soil pits were dug at the end of the season to determine root development under the clipping treatments (see appendix, Tables 24 and 25).

Analysis of Data

An analysis of pre-treatment soil moisture variation was made in order to determine natural variability at each study location (see appendix, Tables 26 and 27).

A 2 x 4 (frequency X intensity) factorial computer program was designed to analyze each year's data. An analysis of variance was thus made and statistical significance determined by means of a standard F test. In addition, the 1967 data were analyzed in terms of a completely randomized block design with nine treatments. Again a standard F test was used. The 1967 data were further analyzed by the Newman-Keuls mean comparison method (Ostle, 1964) in order to determine differences between treatment means.

RESULTS AND DISCUSSION

Lower Study Site

The 1966 field season was begun in mid-July, thus allowing less than a full growing season for data collection. During the remainder of the 1966 season the plots were metered and clipped according to the prescribed treatments. The analysis of variance for the 1966 season is shown in Table 2. It is speculated that the lack of high significance during this period is due to late treatment initiation, lack of sufficient root growth retardation after one partial season of treatment, confounding due to a lack of growing season precipitation and high natural variability in terms of moisture in the soil profile. It is appropriate to point out that despite lack of significance due to treatment, the lower study site ended the season indicating graphically that control plots depleted more water from the soil profile than any of the clipped plots (Figure 7). Extreme clipping, on the other hand, resulted in the least depletion.

Data collection for the 1967 field season was begun at the onset of the growing season. The higher degree of significance that is shown for this year can be attributed to the reduced root production on the clipped plots due to the previous year's treatment and to more favorable moisture conditions for the water year. The 2 X 4 factorial analysis of variance is shown in Table 3. A greater degree of significance can be shown by analyzing the data by means of a randomized block design analysis of variance, thus including the extreme clipping treatments. Table 4 shows the lower study site randomized block design (RBD) analysis of variance.

Table 2. 2 X 4 Factorial analysis of variance - 5 foot profile soil moisture values at the Lower Site, 1966.

Source	DF	SS	F calc	F.05
Intensity (I)	3	2220.896	1.936	3.36
Frequency (F)	1	0.667	0.002	4.42
I x F	3	560.104	0.488	3.36
Error (A)	14	5354.286		
Depth (D)	5	3508.145	11.725	2.22*
D x I	15	361.080	0.402	1.73
D x F	5	436.399	1.459	2.22
D x I x F	15	405.580	0.452	1.73
Error (B)	80	4787.074		
Date (Da)	5	1139.461	122.866	2.21*
Da x I	15	21.958	0.789	1.67
T x F	5	45.194	4.873	2.21*
T x I x F	15	65.840	2.367	1.67*
T x D	25	985.501	21.253	1.51*
T x D x I	25	109.524	0.787	1.29
T x D x F	25	49.615	1.070	1.51
T x D x I x F	75	146.351	1.052	1.29
Error (C)	480	890.306		
Total	863	22590.482		

*Indicates significance at the .05 level

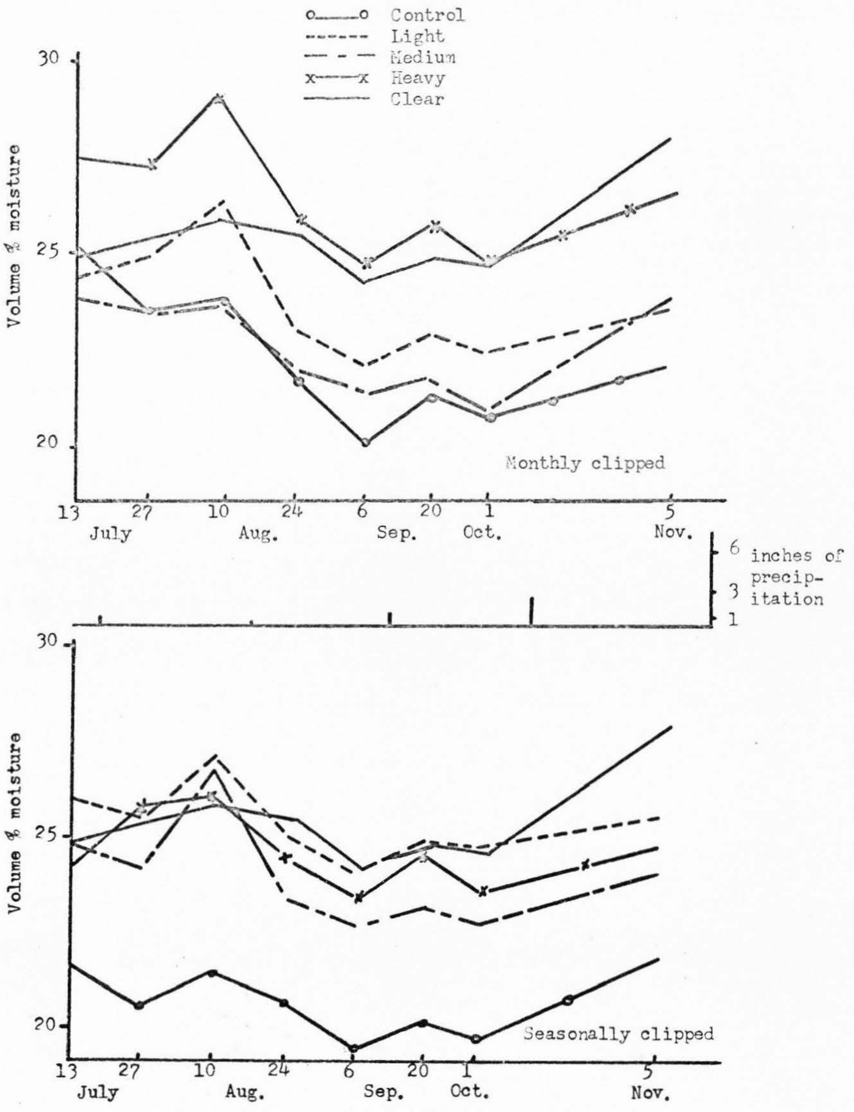


Figure 7. Soil moisture regime 0-60" - Lower study site - 1966.

Table 3. 2 X 4 Factorial analysis of variance - 5 foot profile soil moisture values at the Lower Site, 1967.

Source	DF	SS	F calc	F.05
Intensity (I)	3	4586.812	3.599	3.36*
Frequency (F)	1	11.563	0.027	4.42
I x F	3	525.000	0.412	3.36
Error (A)	14	594.756		
Depth (D)	5	12762.440	25.530	2.22*
D x I	15	1121.500	0.748	1.73
D x F	5	879.313	1.759	2.22
D x I x F	15	398.313	0.266	1.73
Error (B)	80	7998.437		
Date (Da)	9	33114.560	769.570	1.88*
Da x I	27	380.375	2.947	1.49*
Da x F	9	153.000	3.556	1.88*
Da x I x F	27	370.438	2.870	1.49*
Da x D	45	3515.250	16.339	1.37*
Da x D x I	135	838.313	1.299	1.26*
Da x D x F	45	267.063	1.241	1.37
Da x D x I x F	135	482.938	0.748	1.26
Error (C)	864	4130.875		
Total	1439	79893.750		

*Indicates significance at the .05 level

Table 4. RBD analysis of variance - 5 foot profile soil moisture values at the Lower Site, 1967.

Source	DF	SS	F calc	F.05
Treatment (T)	8	11967.000	3.829	2.59
Error (A)	16	6250.000		
Depth (D)	5	14305.000	29.630	2.31
D x T	40	2993.000	0.775	1.53
Error (B)	90	8689.000		
Date (Da)	9	35334.000	85.420	1.89
Da x D	45	3437.000	16.619	1.39
Da x T	72	1231.000	3.720	1.30
Da x D x T	360	2003.000	1.211	1.18
Error (C)	972	4467.000		
Total	1619	94034.000		

*Indicates significance at the .05 level

Treatment mean comparisons (Newman-Keuls method) were made in order to determine differences between treatments. The mean comparisons for treatments at the lower plots are shown in Table 5.

At the lower site it becomes obvious that the extremes of complete foliage removal and no foliage removal are significant practices in altering the amount of water present in the soil profile. By observing the graphs (Figure 8) the relative positions of each of the treatments can be noted. In general, the relative order of decreasing soil moisture within the 5 foot profile is from extreme to heavy to medium and light to no foliage removal. While these treatments are not in all cases significantly different from the preceeding treatment, such a relative order is important in determining trends. It should be noted that the medium and light clipping treatments were reversed, though not statistically different, from what would be expected based on the general model. It is speculated that the clipping treatments were such that plants under light intensity foliage removal were able to mature and consequently slow their water uptake. Medium clipping intensity, however, was not severe enough to fully retard transpiration, though sufficient to prevent the plant from reaching maturity.

Season of foliage removal, under these clipping intensities, was not found to be significant at the lower study site. Nevertheless, it can be graphically shown that, at the lower site, frequent low intensity (light and medium) clipping apparently induced plants to use more water than companion plants that were only clipped once and then allowed to mature. Heavy intensity clipping caused the reverse phenomena. It is quite probable that the plant is able to grow and reach maturity under the low intensity-clipped once scheme, while low intensity-frequently clipped plants were

Table 5. Treatment mean comparisons - average soil moisture percentage within the 5 foot soil profile.

Range	Trt	CB	CA	MA	LA	MB	LB	HB	HA	CL
9	32.40 (Cl)	9.57*	8.45*	7.67*	6.41*	6.33*	0.577*	4.95*	2.26*	0.00
8	29.14 (HA)	6.31*	5.21*	4.41*	3.15*	3.08*	2.51*	1.60	0.00	
7	27.14 (HB)	4.72*	3.62*	2.82*	1.56	1.48	0.91	0.00		
6	26.63 (LB)	3.80*	2.70	1.90	0.64	0.57	0.00			
5	26.07 (MB)	3.23*	2.14	1.33	0.08	0.00				
4	25.99 (LA)	3.16*	2.06	1.26	0.00					
3	24.73 (MA)	1.90	0.80	0.00						
2	23.93 (CA)	1.10	0.00							
1	22.83 (CB)	0.00								

$$Q\sqrt{\frac{MSE}{M}} = Q\sqrt{0.5106} = .715$$

Range	Q
2	2.77 x .715 = 1.98
3	3.31 x .715 = 2.37
4	3.63 x .715 = 2.60
5	3.86 x .715 = 2.76
6	4.03 x .715 = 2.88
7	4.17 x .715 = 2.98
8	4.29 x .715 = 3.04
9	4.39 x .715 = 3.14

*Indicates statistical significance at the .05 level.

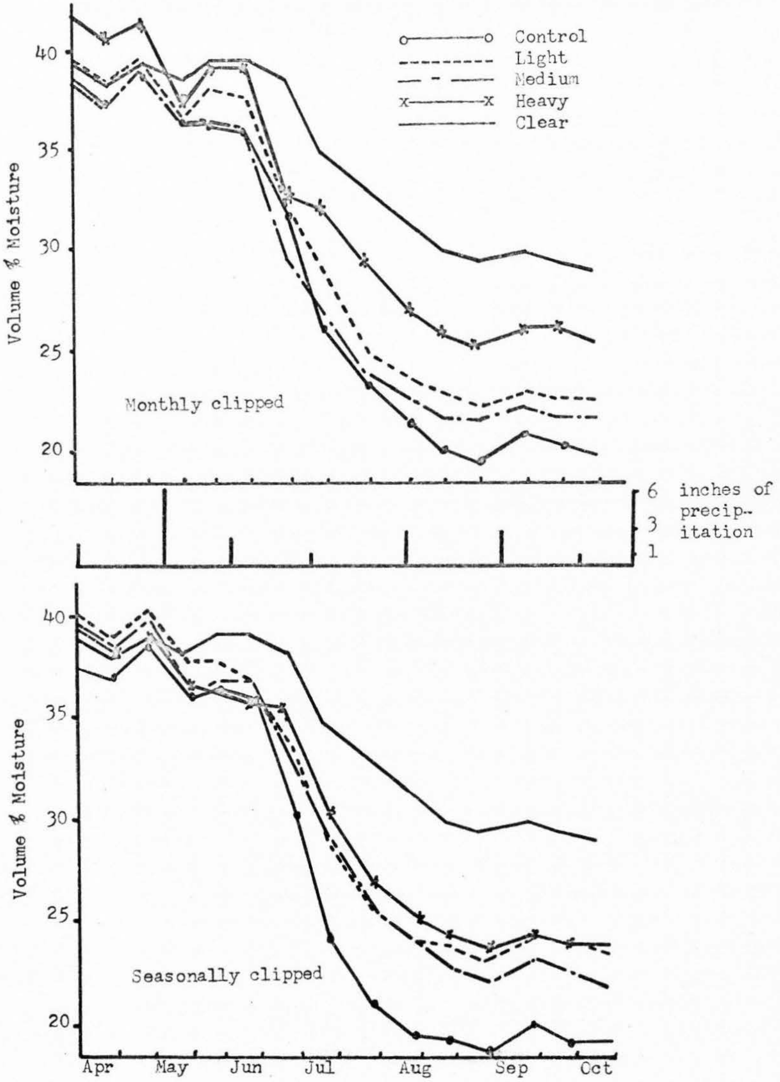


Figure 8. Soil moisture regime 0-60" - Lower study site - 1967

prevented from reaching maturity, yet were not seriously affected in terms of transpiring surface. The heavy intensity-frequently clipped plants were, however, severely affected in terms of transpiring area, while heavy intensity-seasonally clipped plants were not as affected due to their recovery potential.

An alternate way of studying the phenomena involved in this investigation would be to adjust each curve to a common starting point and observe the relative amount of water depletion under each treatment. Figure 9 shows such a representation for the lower study site. This also substantiates the observation that at this elevation the soil profile will retain more water throughout the growing season under clipping than under no foliage removal. Though the intermediate clippings are not all statistically different, it is graphically evident that the amount of water to be found in the soil profile underlying these plots is in proportion to the extent of transpirational material removed.

In terms of inches of moisture used under each treatment one observes the same general patterns of moisture use (Table 6). By September 14 the control plots had depleted approximately 25.6 inches of water from its 5 foot soil profile by means of evapotranspiration. The bare plots on the other hand indicate a soil moisture loss of only 20.2 inches over the entire soil profile, due entirely to evaporation from the soil directly. At this elevation a 47 percent saving of soil moisture was found under the extreme clipping treatment.

Table 6. Inches of soil moisture depletion by treatment during the 1967 growing season as of September 14 - Lower Study site.

Treatment	CA	CB	LA	LB	MA	MB	HA	HB	CL
Inches of depletion	25.3	25.8	24.6	24.4	24.5	25.1	24.4	24.4	20.2

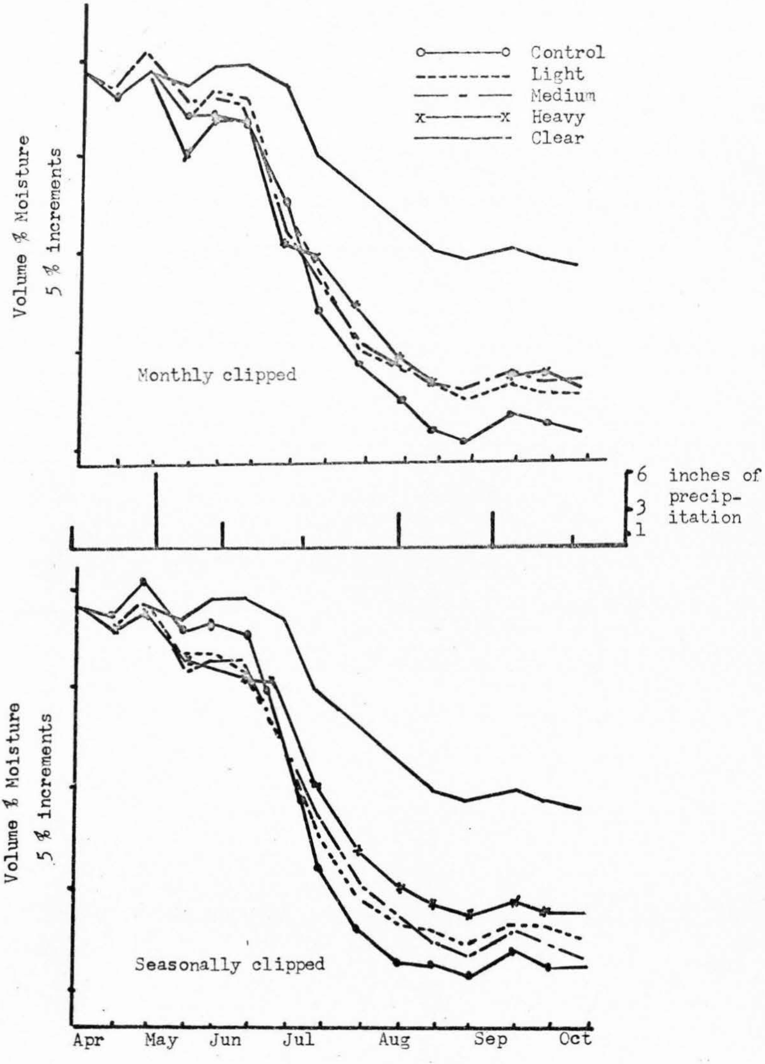


Figure 9. "Adjusted" soil moisture regime 0-60" - Lower study site - 1967

Post treatment depletion curves are also shown by depth in Figure 10. The control and extreme clipping treatments are contrasted in this series. At the lower location one notices that the control plot is subject to serious depletion throughout the entire five foot profile. The rooting habits of some of the overlying vegetation, primarily the alfalfa, makes this possible. The bare plots are noted to deplete most rapidly in the surface layers, tapering to a gradual decline at the deeper depths as the season progressed. This series indicates that at all depths the lower plots are subjected to more intense soil moisture depletion under no foliage removal than under complete foliage removal. It is expected that the intermediate levels of vegetation removal will fall somewhere between.

Upper Study Location

The 1966 field season was begun in mid-July at the upper site, also. While mid-July did not represent the onset of the 1966 growing season, it was not as late, relatively speaking, as the lower site treatment initiation. The 1966 analysis of variance is shown in Table 7. It is thought that the lack of treatment significance during this period at this location is due to a combination of natural soil moisture variability and insufficient retardation of root growth, compounded by little soil moisture stress at this elevation. When viewed graphically, one notices that at the end of the growing season more water remained (less was depleted) in the 5 foot soil profile under extreme clipping than under any other treatment. At the same time, control conditions show a tendency toward less soil moisture remaining in the profile at the end of the season (Figure 11).

Data collection for the 1967 field season was begun in early July, 1967, which was the onset of the growing season. Again the 2 X 4 factorial

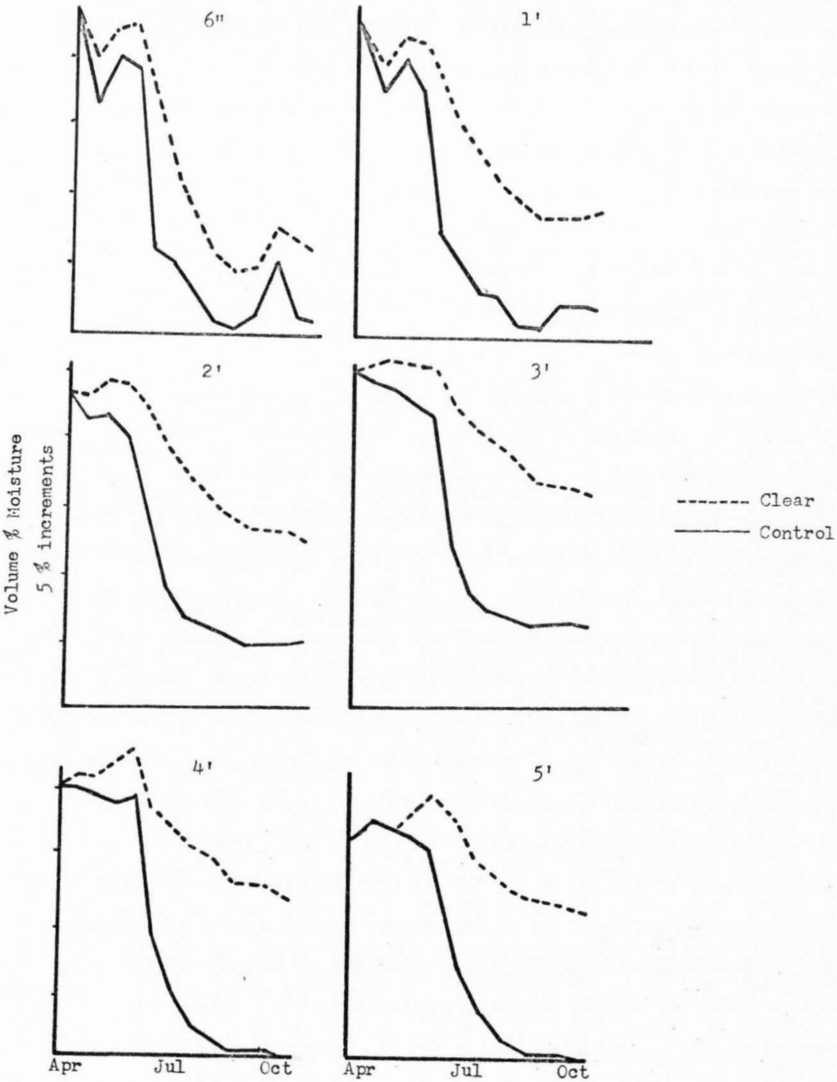


Figure 10. "Adjusted" soil moisture regime by depth contrasting complete vegetative removal and control plots - Lower study site - 1967

Table 7. 2 X 4 factorial analysis of variance - soil moisture at Upper Site - 1966.

Source	DF	SS	F calc	F.05
Intensity (I)	3	337.906	0.595	3.36
Frequency (F)	1	418.753	2.213	4.42
I x F	3	1279.834	2.255	3.36
Error (A)	14	2648.901		
Depth (D)	5	3335.054	6.054	2.22*
D x I	15	1236.367	0.748	1.73
D x F	5	2206.871	4.006	2.22*
D x I x F	15	2645.605	1.601	1.73
Error (B)	80	8813.806		
Date (Da)	5	1524.859	83.415	2.21*
Da x I	15	81.519	1.486	1.67
Da x F	5	55.885	3.057	2.21*
Da x I x F	15	93.105	1.698	1.67*
Da x D	25	1067.945	11.684	1.51*
Da x D x I	75	214.656	0.783	1.29
Da x D x F	25	125.628	1.374	1.51
Da x D x I x F	75	262.445	0.957	1.29
Error (C)	480	1754.917		
Total	863	29158.597		

*Indicates significance at .05 level

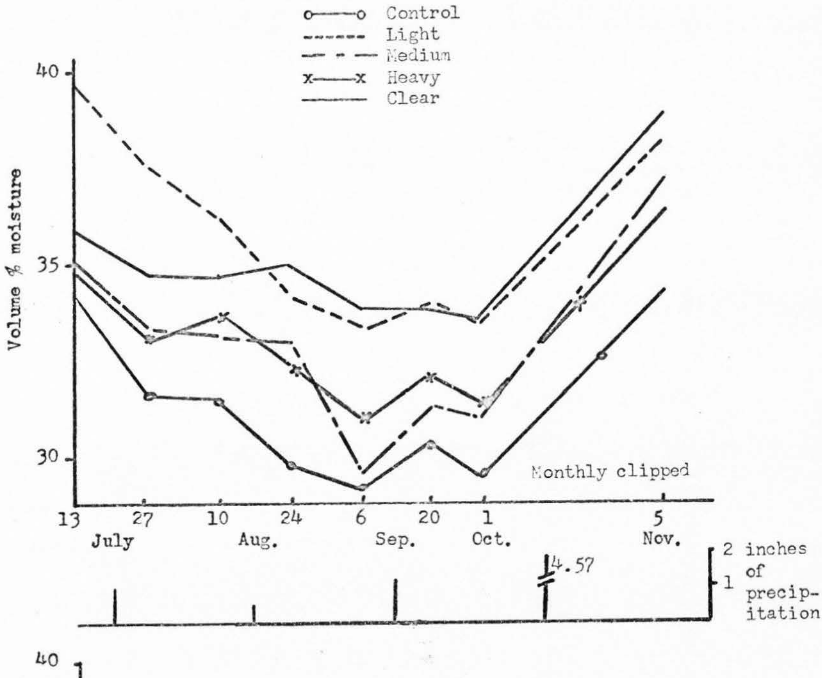


Figure 11. Soil moisture regime 0-60" - Upper study site - 1966.

and RMD analyses of variance did not show significance in terms of treatment differences (Tables 8 and 9). It follows that results at the upper collection site are obscured because of a high natural soil variation, short growing season, and high soil moisture values due to low evapotranspiration. Ellison (1954) reported a 16 year study conducted in this area at similar elevations in which soil moisture remained above wilting point in the surface 6 inches throughout the entire summer in 6 of the 16 years. Thus with high residual soil moisture conditions only extreme clipping treatments will indicate changes in the soil moisture throughout the profile. Examination of the treatment mean comparisons (Table 10 and Figure 12) shows that the extreme treatment of complete foliage removal resulted in higher soil moisture values at the end of the growing season than any of the other levels of foliage removal.

By adjusting the depletion curves for each treatment to a common starting point one can observe relative trends in the depletion phenomena (Figure 13). It is well to note that the bare plots exhibited less soil moisture depletion throughout the season than any of the other treatments. Heavy, medium, and light foliage removal followed by the control plots, complete the order of soil moisture storage, from most to the least, in the monthly clipped plots.

Relative depletion under the seasonal foliage removal scheme is similar, but one notes that the control plots are out of order from what would be expected from the general model. These differences are not statistically significant, and are reflections of the high initial variations in soil moisture characteristics.

When adjusted depletion curves are observed by contrasting the bare (extreme clipping) and control plots one notes that the bare plot indicates

Table 8. 2 X 4 factorial analysis of variance - 5 foot profile soil moisture values at the Upper Site - 1967.

Source	DF	SS	F calc	F.05
Intensity (I)	3	341.563	0.440	3.36
Frequency (F)	1	1070.750	4.140	4.42
I x F	3	1592.000	2.053	3.36
Error (A)	14	3618.562		
Depth (D)	5	3154.375	4.763	2.22*
D x I	15	2111.687	1.063	1.73
D x F	5	3065.562	4.629	2.22*
D x I x F	15	2261.812	1.138	1.73
Error (B)	80	10596.560		
Date (Da)	6	5024.687	252.906	2.10*
Da x I	18	57.438	0.964	1.61
Da x F	6	42.938	2.161	2.10*
Da x I x F	18	78.125	1.311	1.61
Da x D	30	4964.875	49.979	1.46*
Da x D x I	90	126.750	0.425	1.28
Da x D x F	30	63.938	0.644	1.46
Da x D x I x F	90	123.063	0.413	1.28
Error (C)	576	1907.312		
Total	1007	40596.940		

*Indicates significance at .05 level

Table 9. RBD analysis of variance - 5 foot profile soil moisture values at the Upper Site - 1967.

Source	DF	SS	F calc	F.05
Treatment (T)	8	3670.000	1.609	2.59
Error (A)	16	4562.000		
Depth (D)	5	4399.000	6.456	2.31*
D x T	40	7130.000	1.308	1.52
Error (B)	90	12264.000		
Date (Da)	6	5237.000	266.160	2.11*
Da x D	30	4946.000	50.270	1.48*
Da x T	48	189.000	1.201	1.37
Da x D x T	240	500.000	0.635	1.21
Error (C)	648	2125.000		
Total	1133	45730.000		

*Indicates significance at the .05 level

Table 10. Treatment mean comparisons - average soil moisture percentage within the 5 foot soil profile.

Range	Trt	MA	CA	HA	CB	LB	MB	LB	HB	Cl
9	34.13 (Cl)	5.67*	5.50*	5.29*	4.73*	4.32*	3.23*	2.29*	2.25*	0.00
8	31.88 (HB)	3.42*	3.25*	3.04*	2.48*	2.07	0.98	.04	0.00	
7	31.84 (LB)	3.38*	3.21*	3.00*	2.44*	2.03*	0.94	0.00		
6	30.90 (MB)	2.44*	2.27	2.06	1.50	0.09	0.00			
5	29.81 (LB)	1.35	1.22	0.97	0.41	0.00				
4	29.40 (CB)	0.94	0.77	0.56	0.00					
3	28.84 (HA)	0.38	0.21	0.00						
2	28.63 (CA)	0.17	0.00							
1	28.46 (MA)	0.00								

$$Q\sqrt{\frac{3.279}{9}} = \sqrt{.364} = .603$$

Range	Q
2	2.77 x .603 = 1.67
3	3.31 x .603 = 1.99
4	3.63 x .603 = 2.19
5	3.86 x .603 = 2.33
6	4.03 x .603 = 2.43
7	4.17 x .603 = 2.52
8	4.29 x .603 = 2.59
9	4.39 x .603 = 2.65

*Indicates significance at the .05 level

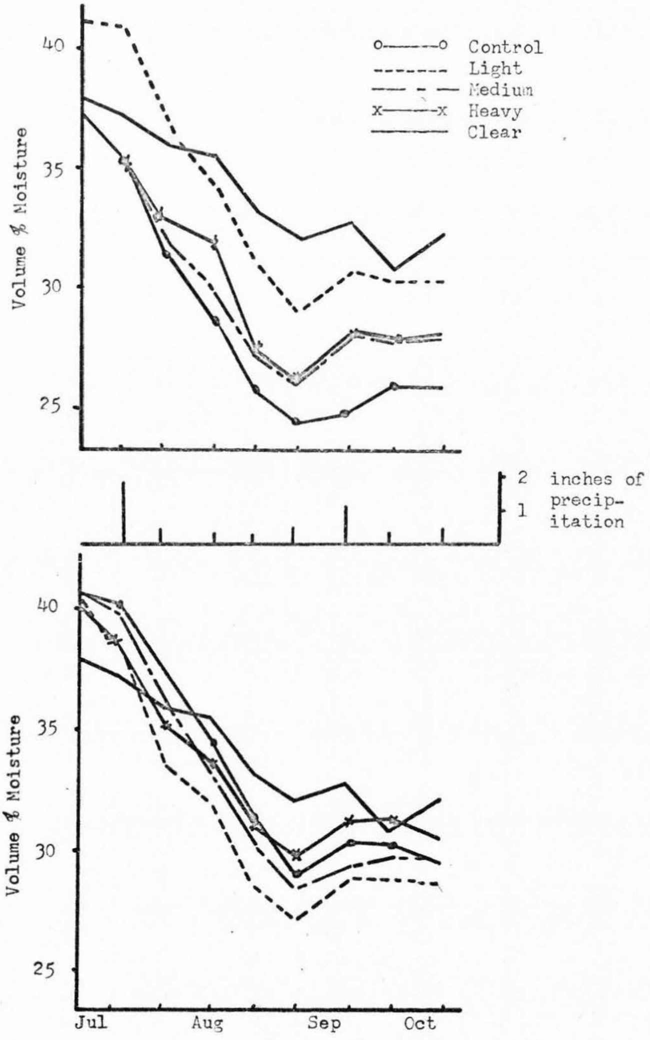


Figure 12. Soil moisture regime 0-60" - Upper study site - 1967

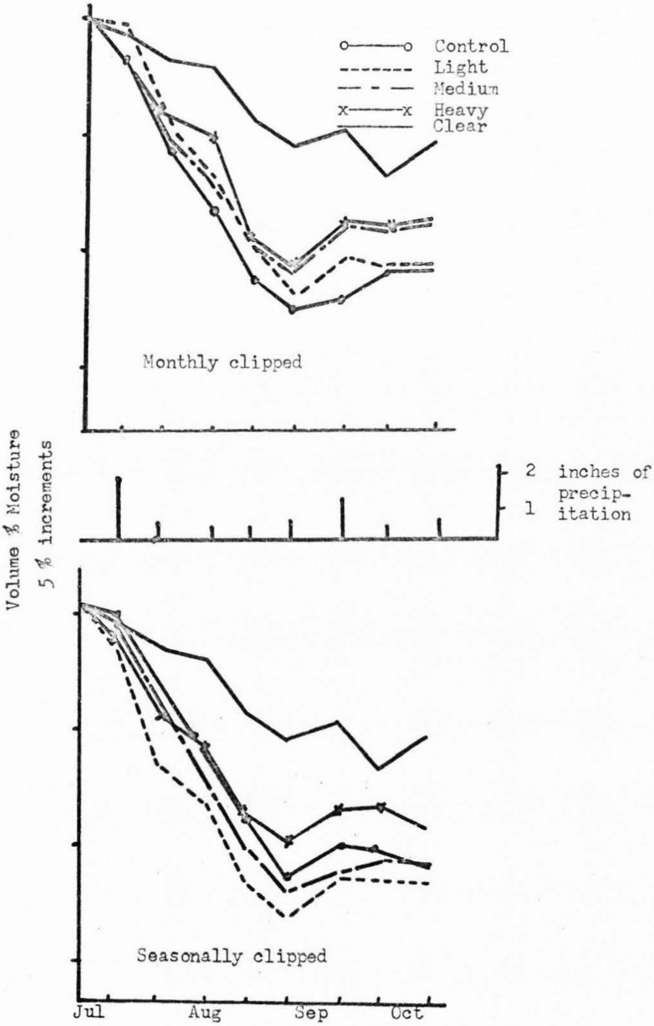


Figure 13. "Adjusted" soil moisture regime 0-60" - Upper study site - 1967

less water loss from evaporation in the surface layers than the losses due to evapotranspiration from the control. At the lower depths (below 3 feet) roots are influencing the removal of water to only a slight extent. It is therefore speculated that the soil water (which is being held near field capacity) is moving slowly downward by means of deep percolation at approximately the same rate under each plot. Figure 14 is the representation of this series of values.

One notes that inches of water use throughout the profile at the upper study area reflects the conditions noted earlier (Table 11). The control plots depleted an average of 10.6 inches of soil moisture during the 1967 growing season as of September 14, while the bare plots depleted only 7.0 inches. The intermediate levels of foliage removal reflect plant growth under moist conditions, as well as the high natural variability of the site. Nevertheless, a 50 percent saving of soil moisture was noted under extreme clipping treatment at this site.

Table 11. Inches of soil moisture depletion by treatment during the 1967 growing season as of September 14. Upper study site.

Treatment	CA	CB	LA	LB	MA	MB	HA	HB	Cl
Inches of depletion	10.8	10.5	10.7	11.4	9.9	10.9	9.8	9.6	7.0

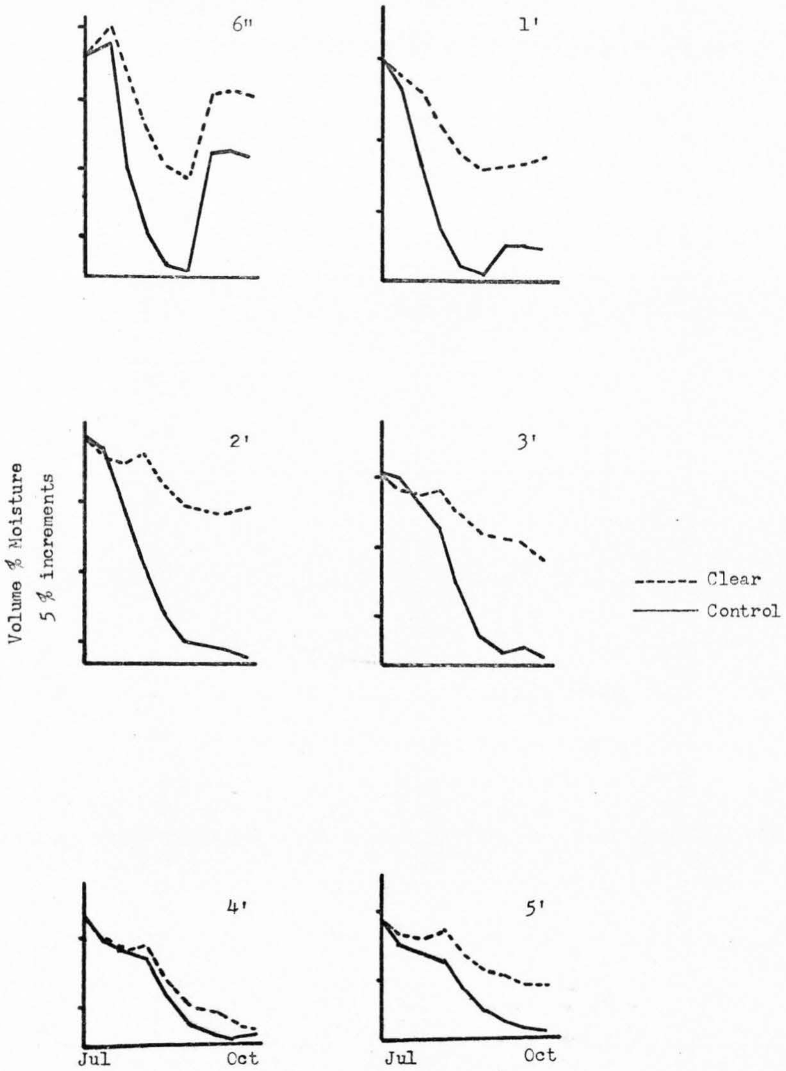


Figure 14. "Adjusted" soil moisture by depth contrasting complete vegetative removal and control plots - Upper study site - 1967

SUMMARY AND CONCLUSIONS

During 1966 and 1967 a range plant clipping study was conducted at two locations in central Utah's Ephraim Canyon. It was found that extreme clipping treatment, i.e. complete denudation, resulted in significantly less soil moisture withdrawal than the control condition. At the lower location, 7,100 feet elevation, a difference of 5.4 inches was noted between the cleared plots and control plots in 1967. At the upper location, 10,000 feet in elevation, a savings of 3.6 inches soil moisture was observed during the 1967 growing season. Other clipping intensities also showed water savings in terms of reduced depletion values over the control plots, although these differences were not in all cases statistically significant.

It may appear from this study that the stockman's claim that heavy grazing promotes increased water yield has some validity at these elevations; however, no watershed manager would advocate complete denudation of the watersheds, because of past experience with floods, mudrock flows, decreased water quality, and poor seasonal control of the water. It would seem, then, that moderate or light levels of foliage removal will yield the benefits of increased livestock use and increased water yield over and above those of ungrazed conditions. It must be remembered that this study dealt with foliage removal, independent of trampling. Therefore, until the additional effects of the animals' hooves are fully explored direct implications between this study and the absolute response of soil moisture to livestock grazing cannot be drawn.

While it is evident that further research is necessary in this field, it is hoped that this study has contributed to the knowledge on which good grazing and water management can be based. It is also hoped that this study will stimulate further research in the realm of livestock use and water yield.

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APPENDIX

Table 12. Vegetation inventory - Lower Plots - 1966

Plot number and treatment	AG CR	ME SA	AG IN	AS SPP	SO MU	BR IN	TA OF	CU SPP	BR TE	LA SE	CO PA	VIOLA
						Species						
I/1 (MA)	3	1	1									
2 (LB)	3	2	1									
3 (HB)	2	1	1			1						
4 (MB)	2	1	1			1						
5 (CA)	3	2				1						
6 (CB)	2	1										
7 (HA)	2	2	1			1						
8 (LA)	2	1				1						
Cl	2	1	1	1	1	1						
II/1 (HB)	2	1	1			1						
2 (MB)	2	2	1									
3 (CB)	2	1	1			2						
4 (LA)	2	2	1									
5 (CA)	2	2				1	1					
6 (HA)	2	1	1			1						
7 (MA)	2	2	1									
8 (LA)	3	1	1			1						
Cl	2	1	1		1	1						
III/1 (HA)	2	1	1			1						
2 (MA)	3	1										
3 (LA)	2	1	1			1		1				
4 (MB)	2	1	1									
5 (LB)	2	2										
6 (CB)	2	1										
7 (CA)	2	1	1									
8 (HB)	2	2										
Cl	2	1										

Key:

Ag Cr - Agropyron cristatum
Me Sa - Medicago sativa
Ag In - Agropyron intermedium
As Spp - Astragalus spp.
So Mu - Solidago multiradiata
Br In - Bromus inermis
Ta Of - Taraxacum officinale
Cu Spp - Cuscuta spp.
Br Te - Bromus tectorum
La Se - Lactuca serriola
Co Pa - Collinsia parviflora
Viola - Viola spp.

Coverage Class	Estimation Range
0	0%
T	Trace
1	1-5%
2	6-25%
3	26-50%
4	51-75%
5	76-95%
6	96-100%

Table 13. Vegetation inventory - Upper Plots - 1966

Plot number and treatment	CA SPP	PE CY	ST LE	VI SPP	GE SPP	SO MU	AR LU	AC LA	DE PI	ER SP	TA OF	SM RA	TR SP	BR IN	ER SP	AG TR
								Species								
I/1 (MB)			3				1	1		1	1		1			1
2 (LB)		1	3	1			1	1		1	1					1
3 (HB)		2	2					1	1	1	1	1				1
4 (CB)			2				1	2	1		2					1
5 (LA)			2			1	1	1	1	1	1					1
6 (HA)		2	2				1	1	1	1	1					1
7 (CA)		2	2		1	1	1	1			1					1
8 (MA)		1	3				1	1	1		1					1
C1			3				1	1	1	1						1
II/1 (HA)			3				1	1	1		1					1
2 (LA)		2	2				1	1		1						
3 (LB)		1	2				1	1	1	1	1					1
4 (MB)		2	2				1	2	1	1	1					1
5 (HB)			2				1	2	1	2	1			1	1	1
6 (CB)			2					1	1	1	1					1
7 (MA)			3				1	1		1	1					
8 (CA)		1	3				2	1	1	1	1					1
C1	1		3				2	1	1	1	1					1
III/1 (LB)			2			1	2	2		1			1			
2 (CA)		1	2				1	1	1	2	1				1	1
3 (CB)			3				1	1	1	2	1					1
4 (LA)			1				2	2	1	1	1					2
5 (MB)			1				1	2	1	1	1					2
6 (HB)			2				2	2		1	1					1
7 (HA)			3				1	1		1	1					
8 (MA)			3			1	1	2	1	2						
C1		2	2			1	1	2	1	2	1					1

Key:

- Ca Spp - Carex Spp.
- Pe Cy - Penstemon cyananthus
- St Le - Stipa lettermani
- Vio Spp - Viola Spp.
- Ge Spp - Geranium Spp.
- So Mu - Solidago multirodiata
- At Tr - Artemisia ludoviciana
- Ac La - Achillea lanulosa
- De Pi - Descurainia pinnata
- Er Sp - Erigeron speciosus
- Ta Of - Taraxacum officinale
- Sm Ra - Smilacina racemosa
- Tr Sp - Trisetum spicatum
- Br In - Bromus inermis
- Er Sp - Erigeron speciosus
- Ar Tr - Agropyron Trachycaulum
- Vic Spp - Vicia species
- Me Bu - Melica bulbosa

Coverage Class	Estimation Range
0	0%
T	Trace
1	1-5%
2	6-25%
3	26-50%
4	51-75%
5	76-95%
6	96-100%

Table 14. Vegetation inventory - Lower Plots - 1967

Plot number and treatment	AG CR	ME SA	AG IN	AS SPP	SO MU	BR IN	TA OF	CU SPP	BR TE	LA SE	CO PA	VIOLA
	Species											
I/1 (MA)	2	2	1			1			T		T	
2 (LB)	2	3	1						T			
3 (HB)	1	1				2						
4 (MB)	2	1	1			1						
5 (CA)	2	2	T			T						
6 (CB)	1	2+	1									
7 (HA)	2	2	1			1				T		
8 (LA)	2	2				1	T		T	T	T	T
II/1 (HB)	1	1	1			1			T			
2 (MB)	2	3	1									
3 (CB)	2-	2	1			1						
4 (LA)	1	2	1			1						
5 (CA)	2	2	T			1						
6 (HA)	2	1	1			1						
7 (MA)	2	2	2								T	
8 (LB)	2	1	1			1						
III/1 (HA)	2	1				1	T		T	T		
2 (MA)	3	1				1					T	
3 (LA)	2	1	1			1						T
4 (MB)	1	1	1									
5 (LB)	1	2										
6 (CB)	2	2				1						
7 (CA)	2	1	1			T						
8 (HB)	2	1	1			1						

Key:

- Ag Cr - Agropyron cristatum
- Me Sa - Medicago sativa
- Ag In - Agropyron intermedium
- So Mu - Solidago multiradiata
- As Spp - Astragalus spp.
- Br In - Bromus inermis
- Ta Of - Taraxacum officinale
- Cu Spp - Cuscuta spp.
- Br Te - Bromus tectorum
- La Se - Lactuca serriola
- Co Pa - Collinsia parviflora
- Viola - Viola spp.

Coverage Class	Estimation Range
0	0%
T	Trace
1	1-5%
2	6-25%
3	26-50%
4	51-75%
5	76-95%
6	96-100%

Table 15. Vegetation inventory - Upper Plots - 1967

Plot number and treatment	CA SPP	PE CY	ST LE	VIO SPP	GE SPP	SO MU	AR LU	AC LA	DE PI	ER SP	TA OF	SM RA	TR SP	BR IN	ER SP	AG TR	VIC SPP	ME BU
									Species									
I/1 (MB)			3				1	1		1	T		T			T		
2 (LB)			2+				T	1		2	1					1		
3 (HB)		1	3-					1		2	1					1		
4 (CB)			2				1	2			1							
5 (LA)			2			1	1	1	1	1	1					1		
6 (HA)		1	1				T	1		1	1					1		
7 (CA)			2+		1		1	1			1				1			
8 (MA)		1	2+				1	1	T	1						1		1
Cl																		
II/1 (HA)			2				1	1	T	1	1					1		
2 (LA)		1	2				1	1		1								
3 (LB)			1+				1	2		1	1					1		
4 (MB)			2+				1	1		2+	1					1	T	1+
5 (HB)			1				T	1		1	1					1		
6 (CB)			2					1			1							
7 (MA)			2	T			1	1		1	1							
8 (CA)			2+				1+	1			T				1			1
Cl																		
III/1 (LB)			2				2+	2			T		1		1			
2 (CA)			2+				1	1			1							T
3 (CB)			2				2-	1			1							
4 (LA)			1				1	1	1	1	1							
5 (MB)			1	T			T	2			1				2			
6 (HB)			2	T			2	1			1				1			
7 (HA)			2				1	1		1	1							
8 (MA)			2			1	1	2	1	1								
Cl																		

Key:

Ca Spp - Carex Spp.
Pe Cy - Penstemon cyananthus
St Le - Stipa lettermani
Vio Spp - Viola Spp.
Ge Spp - Geranium Spp.
So Mu - Solidago multirodiata
At Tr - Artemisia ludoviciana
Ac La - Achillea lanulosa
De Pi - Descurainia pinnata
Er Sp - Erigeron speciosus
Ta Of - Taraxacum officinale
Sm Ra - Smilacina racemosa
Tr Sp - Trisetum spicatum
Br In - Bromus inermis
Er Sp - Erigeron speciosus
Ar Tr - Agropyron trachycaulum
Vic Spp - Vicia species
Me Bu - Melica bulbosa

Coverage Class	Estimation Range
0	0%
T	Trace
1	1-5%
2	6-25%
3	26-50%
4	51-75%
5	76-95%
6	96-100%

Table 16. Grass Phenology Key

Dormancy	0
Growth Initiation	10
2 leaf stage	30
4 leaf stage	40
5 leaf stage	50
Boot	60
Head	70
Hard seed	80
Seed scatter	90
Dormancy	100

When possible make notes on time and position on rachis of:

a. anthesis

b. milk

c. soft dough

d. hard dough

e. dimensions of leaf and culm growth

Table 17. Phenology by Date - Lower Site - 1967

7 June 67	Me Sa:	10" high, no bloom, insect damage	
	Ag Cr:	4-5 leaf stage, 10" high, Code 45	
	Br In:	4-5 leaf stage, 10" high, Code 45	
	Ag IN:	4-6 leaf stage, 10" high, Code 45	
21 June 67	Me Sa:	15-18" high, leaf 1" x 3/8", no bloom, insect damage	
	Ag Cr:	12-15" high, leaf width 1/4", Code 65	
	Br In:	13-16" high, leaf width 3/8", Code 60+	
	Ag In:	12-15" high, leaf width 1/4", Code 65-	
5 July 67	Me Sa:	20-25" tall, growing vigorously, budding (no bloom), no apparent new insect damage	
	Ag Cr:	19-22" tall, growing vigorously, headed, Code 70	
	Br In:	26-30" tall, growing vigorously, headed, Code 70	
	Ag In:	26-30" tall, growing vigorously, headed, Code 70	
18 July 67	Me Sa:	25+" tall, good vigor, nearly full bloom	
	Ag Cr:	25" tall, good vigor, full anthesis, Code 70	
	Br In:	30" tall, good vigor, full anthesis, Code 70	
	Ag In:	30" tall, good vigor, full anthesis, Code 70	
4 Aug. 67	Me Sa:	30" tall, begin seed set	
	Ag Cr:	26" tall, soft dough, Code 72	beginning to dry-
	Br In:	36" tall, hard dough, Code 77	showing some signs
	Ag In:	36" tall, soft dough, Code 72	of stress
17 Aug. 67	Me Sa:	30" tall, green seed	
	Ag Cr:	35" tall, hard seed, Code 80	
	Br In:	39" tall, hard seed, Code 80	slowly turning
	Ag In:	39" tall, hard dough, Code 77	and drying
31 Aug. 67	Me Sa:	30" tall mature seed	
	Ag Cr:	35" tall, seed shatter, Code 90	quite dry
	Br In:	40" tall, seed shatter, Code 90	
	Ag In:	40" tall, seed shatter, Code 90	
14 Sept 67	Me Sa:	30" tall, shattering, few leaves	
	Ag Cr:	35" tall, shatter, Code 90	
	Br In:	40" tall, shatter, Code 90	quite dry
	Ag In:	40" tall, shatter, Code 90	
1 Oct. 67	Me Sa:	shatter	
	Ag Cr:	Code 90	beginning to re-green from base up to about 15"
	Br In:	Code 90	
	Ag In:	Code 90	
15 Oct. 67	All Code 90		Green to 10" from base
28 Oct. 67	All Code 90.		Dry

Table 18. Phenology by Date - Upper Site - 1967

5 July	St Le:	4-5 inches tall, 3 leaf stage, code 35
18 July	St Le:	8" tall, 3 leaf stage, code 35
	Melic:	10" tall, 3 leaf stage, code 35
4 Aug.	St Le:	18" tall, beginning anthesis, code 65
	Melic:	18-20" tall, anthesis, code 65
	Ag Tr:	16-18" tall, anthesis, code 65
	Ac La:	18" tall, nearly full flower
17 Aug.	St Le:	34" tall, soft dough, code 70
	Melic:	26" tall, soft dough, code 70
	Ag Tr:	25" tall, soft dough, code 70
	Ac La:	16-18" tall, full flower
31 Aug.	St Le:	16" tall, hard dough, code 75
	Melic:	18" tall, seed scatter, code 90
	Ag Tr:	26" tall, hard dough, code 75, full flower
	Ac La:	full flower
14 Sept.	St Le:	24" tall, hard seed, code 80+
	Melic:	22" tall, shatter, code 90
	Ag Tr:	hard seed, code 80+
	Ac La:	mature seed
30 Sept.	St Le:	Code 90
	Melic:	Code 90 very little green, but slight
	Ag Tr:	Code 90 amounts at very base
	Ac La:	mature and shattering
15 Oct.	All Code 90	
29 Oct.	All Code 90	

Table 19. Average amounts of foliage removed/treatment - Lower site - 1966

Clipping dates	Treatment						
	LA	LB	MA	MB	HA	HB	Cl
12 July #/A	174.8	107.0	667.5	382.5	1136	856.6	1876
10 Aug. #/A	16.8		34.5		36.2		86.1
24 Aug. #/A							33.3
7 Sept. #/A	0.9		10.7		22.5		26.3
20 Sept. #/A							35.7
1 Oct. #/A							46.1
5 Nov. #/A							66.4

Key:

L = Light intensity, 12"
M = Medium intensity, 8"
H = Heavy intensity, 4"

A = Clipped monthly
B = Clipped seasonally
Cl = Complete removal

Table 20. Average amounts of foliage removed/treatment - Upper site - 1966

Clipping dates	Treatment						
	LA	LB	MA	MB	HA	HB	Cl
12 July #/A	55.1	97.5	275.5	316.7	506.7	502.8	1803.7
10 Aug. #/A	102.4		51.3		41.6		190.9
24 Aug. #/A							24.3
7 Sept. #/A	4.1		1.7		2.6		44.5
20 Sept. #/A							18.6
1 Oct. #/A							---
5 Nov. #/A							---

Key:

L = Light intensity, 9"
M = Medium intensity, 6"
H = Heavy intensity, 3"

A = Clipped monthly
B = Clipped seasonally
Cl = Complete removal

Table 21. Average amounts of foliage removed/treatment - Lower site - 1967

Clipping dates	Treatment						
	LA	LB	MA	MB	HA	HB	Cl
15 Apr. #/A							123.7
13 May #/A							309.4
27 May #/A							323.6
7 June #/A	26.6		253.3		409.6		125.8
21 June #/A		348.6		607.6		1162.1	112.7
5 July #/A	530.1		1474.6		896.8		207.8
18 July #/A							83.2
3 Aug. #/A	95.2		149.0		49.3		41.6
17 Aug. #/A							12.1
30 Aug. #/A	52.8		21.6		13.3		0.3
14 Sept. #/A							----
30 Sept. #/A	----		----		----		1.1
14 Oct. #/A							25.3
28 Oct. #/A	----		----		----		5.8

Table 22. Average amounts of foliage removed/treatment - Upper site - 1967

Clipping dates	Treatment						
	LA	LB	MA	MB	HA	HB	Cl
7 July #/A							531.6
18 July #/A	71.9		276.9		419.1		264.7
4 Aug. #/A		403.4		518.7		648.6	291.9
18 Aug. #/A	296.7		299.9		287.9		134.7
30 Aug. #/A							73.9
13 Sept. #/A	8.3		32.8		16.0		32.7
30 Sept. #/A							----
14 Oct. #/A	----		----				----
28 Oct. #/A							----

Table 23. Soil moisture constants

	Depth	Volume % moisture Replications I	II	III
Upper study location				
1/3 atmosphere[a]	6"	47.6[b]	47.5	47.9
	1'	39.5	35.5	38.7
	2'	33.5	37.8	46.3
	3'	28.6	32.8	43.7
	4'	21.9	20.1	21.4
	5'	16.1	17.9	20.4
Upper study location				
15 atmospheres	6"	25.8	25.5	25.6
	1'	20.9	21.8	21.0
	2'	19.5	19.7	24.4
	3'	14.3	16.0	21.9
	4'	9.1	9.3	7.1
	5'	6.4	7.2	5.8
Lower study location				
1/3 atmosphere	6"	40.8	33.7	38.0
	1'	39.2	34.6	38.0
	2'	44.4	39.8	37.1
	3'	45.5	46.6	43.0
	4'	48.5	42.9	41.4
	5'	47.3	44.7	----
Lower study location				
15 atmospheres	6"	19.1	18.2	18.6
	1'	18.0	18.8	18.4
	2'	19.8	20.8	17.9
	3'	19.7	20.8	21.3
	4'	23.3	18.7	24.9
	5'	22.3	22.0	----

[a]Determined by means of pressure membrane apparatus and gama probe bulk density measurements

[b]Average of 9 plots

Table 24. Root observations - Lower site - 1 October 1967.

Control Site (S. side of fence)

+½-0"	AO	- Litter
0-4"	A1	- Grey brownish
4-25"	B	- Brown (clay movement)
25"	C	- Grey brown clay - very hard (Caleche layer?)

Grass:

0-4"	85% of roots
4-18"	10% of roots
18-25"	5% of roots

Alfalfa:

Tap root 3/8" Diameter at five feet

12" Clipping (Light)

depth	Root conc.		
0-2"	90%		
3-12"	7%	Grass	3/8" Alf. root at 48"
12+"	3%		

30" deepest root

8" Clipping (Medium)

depth	Root conc.		
0-3"	90%		
3-10"	5%	Grass	1/4" Alf. root at 48"
10+"	5%		

24" deepest root

4" Clipping (Heavy)

depth	Root conc.	
0-3"	90%	
3-6"	5%	3/16" Alf. root at 48"
6+"	5%	

18" deepest root

Table 25. Root observations - Upper site - 30 September 1967.

Control Site (E. side of fence)

0-18"	Zone of root concentration	Reasonable hardness.
26-31"	Rock layer	No restricting layers
31-60"	Sand	to roots.

+½-0"	A0	(Litter)
0-12"	A1	Brownish - even texture
12-20"	A2	Brownish - Some pea gravel
20-30"	C	
30"	Sandy	

Estimated root conc.

0-3"	89%
3-11"	7%
11-20"	3%
20"	1%

Deepest root at 55". Diameter of hair.
Apparently less than 1 ft. Lateral extent.

9" Clipping (Heavy)
Few roots deeper than 6"

6" Clipping (Medium)
Few roots deeper than 4"

3" Clipping (Light)
Few roots deeper than 4"

Table 26. Areal variability of soil moisture content (pre-treatment) - Lower site.

	Replication								
	I			II			III		
Depth	$\bar{x}$[a]	s[b]	c.v[c]	$\bar{x}$	s	c.v	$\bar{x}$	s	c.v
				11 November 1965					
1'	24.1	5.89	24.44	22.7	3.34	14.71	21.2	3.72	17.55
2'	26.4	2.87	10.87	26.5	3.35	12.64	22.2	3.22	14.50
4'	27.5	2.71	9.85	23.1	5.30	22.94	21.9	3.59	16.39
				10 June 1966					
1'	21.8	3.84	17.60	21.8	2.33	10.70	20.9	2.46	11.77
1.5'	25.8	3.45	13.71	27.3	1.66	6.75	23.5	3.90	16.59
2'	27.7	3.24	11.69	29.4	2.27	7.72	24.8	3.96	15.95
4'	33.6	5.98	17.80	32.8	7.35	22.40	30.6	7.45	24.35
5'	34.2	3.84	8.91	34.9	8.45	24.20	33.0	8.42	25.81
				12 July 1966					
1'	23.4	2.74	11.71	25.4	3.17	12.45	20.5	3.01	14.65
2'	26.3	2.01	7.65	28.0	3.61	15.27	23.6	3.46	14.67
3'	27.5	2.29	8.34	26.5	5.08	19.15	23.5	4.02	17.80
4'	29.4	5.00	17.00	28.2	7.36	26.10	21.9	4.91	22.40
5'	30.6	5.65	18.45	30.6	7.30	23.84	25.6	7.36	28.78

[a]Soil moisture (% by volume): represents the average value for 8 plots

[b]Standard deviation

[c]Coefficient of variation

Table 27. Areal variability of soil moisture content (pre-treatment) - Upper site.

	Replication								
	I			II			III		
Depth	$\bar{x}$[a]	s[b]	c.v[c]	$\bar{x}$	s	c.v	$\bar{x}$	s	c.v
				11 November 1965					
1'	43.9	3.94	8.97	43.7	2.95	6.75	44.2	3.37	7.62
1.5'	45.4	4.02	8.85	44.5	3.49	7.84	47.1	3.11	6.60
2'	46.6	3.82	8.20	45.6	3.62	7.94	48.4	2.31	4.77
4'	29.4	3.98	13.54	34.6	6.65	19.22	34.7	8.11	23.37
				10 June 1966					
1'	40.6	7.08	17.43	42.3	2.37	5.60	41.1	3.70	9.00
1.5'	43.3	7.52	17.34	44.3	3.13	7.04	44.6	3.86	8.66
2'	46.9	2.65	5.65	43.2	3.45	8.20	47.5	2.12	4.47
4'	32.4	6.36	19.62	36.1	7.78	20.04	34.2	4.55	13.60
5'	32.4	4.15	12.61	38.0	5.23	14.51	37.4	6.54	17.41
				12 July 1966					
1'	30.5	7.00	22.95	29.2	4.38	14.95	28.8	3.98	13.50
2'	36.4	4.23	11.61	35.6	4.76	13.35	39.1	5.39	13.79
3'	35.2	4.76	13.41	35.9	4.77	13.29	36.9	8.07	21.83
4'	29.2	2.67	9.15	32.3	3.67	11.35	31.1	3.34	10.75
5'	29.4	4.35	14.70	36.0	5.06	14.05	35.6	6.40	17.98

[a] Soil moisture (% by volume): represents the average value for 8 plots

[b] Standard deviation

[c] Coefficient of variation

Table 28. Soil moisture regime 0-60" - Lower location - 1966

Measurement date	Treatment								
	CA	CB	LA	LB	MA	MB	HA	HB	C1
13 July	25.1	21.6	24.6	26.0	23.9	24.8	27.5	24.3	24.9
27 July	23.5	20.6	25.0	25.5	23.4	24.2	27.3	25.8	25.5
10 Aug.	23.9	21.5	26.4	27.1	23.9	26.7	29.3	26.1	25.8
24 Aug.	21.7	20.7	23.2	25.0	22.0	23.4	26.0	24.4	25.5
7 Sept.	20.6	19.5	22.2	24.1	21.4	22.7	24.8	23.4	24.4
20 Sept.	21.3	20.2	22.9	24.9	21.8	23.2	25.9	24.6	24.8
1 Oct.	20.7	19.7	22.5	24.7	21.0	22.7	24.8	23.6	24.7
5 Nov.	22.0	21.9	23.6	25.6	23.7	24.1	26.5	24.7	27.8

Code:

A = Clipped monthly

B = Clipped seasonally

C = Control

L = Light intensity foliage removal

M = Medium intensity foliage removal

H = Heavy intensity foliage removal

Table 29. Soil moisture regime 0-60" - Lower location - 1967

Measurement date	Treatment								
	CA	CB	LA	LB	MA	MB	HA	HB	Cl
15 Apr.	38.8	37.4	39.7	40.3	38.7	40.5	42.4	40.9	39.5
29 Apr.	37.3	36.8	38.4	39.1	37.3	38.5	40.9	38.1	38.4
13 May	38.8	38.7	39.6	40.4	39.1	39.7	41.8	39.3	39.5
27 May	36.5	36.0	36.8	37.9	36.5	36.4	37.2	36.6	38.6
7 June	37.9	36.4	37.5	37.7	36.6	36.9	39.3	36.4	39.6
20 June	35.8	36.0	37.1	36.8	36.1	36.6	39.6	35.8	39.6
5 July	31.8	30.2	32.1	33.2	29.8	32.1	32.8	35.6	38.5
19 July	26.1	24.1	29.1	28.8	26.8	28.9	32.2	30.3	34.8
3 Aug.	23.2	21.0	25.1	25.2	23.7	25.4	29.4	26.9	33.1
16 Aug.	21.6	19.5	23.8	24.2	22.6	24.0	27.0	25.3	31.5
31 Aug.	20.0	19.3	23.1	23.7	21.5	22.7	25.8	24.3	29.8
13 Sept.	19.3	18.7	22.3	23.1	21.4	22.2	25.2	23.7	29.4
1 Oct.	20.7	20.1	23.0	24.0	22.1	23.2	26.0	24.4	29.8
14 Oct.	20.3	19.2	22.6	24.0	21.6	22.6	26.1	23.9	29.4
28 Oct.	19.8	19.1	22.4	23.4	21.5	21.8	25.4	23.7	28.9

Code:

A = Clipped monthly

B = Clipped seasonally

C = Control

L = Light intensity foliage removal

M = Medium intensity foliage removal

H = Heavy intensity foliage removal

Table 30. Soil moisture regime 0-60" - Upper location - 1966

Measurement date	Treatment								
	CA	CB	LA	LB	MA	MB	HA	HB	Cl
13 July	29.2	33.6	34.6	32.4	30.1	33.5	29.8	32.9	30.9
27 July	26.6	21.4	32.6	30.4	28.4	29.5	28.1	32.1	29.8
10 Aug.	26.5	31.4	31.3	29.6	28.2	29.9	28.6	32.0	29.7
24 Aug.	24.8	29.2	29.2	26.2	28.0	26.5	27.4	30.0	29.0
7 Sept.	24.1	27.9	28.4	25.8	24.6	26.7	26.0	28.4	29.0
20 Oct.	25.4	28.1	29.0	26.4	26.3	26.9	27.0	29.1	28.9
1 Oct.	24.5	27.6	28.4	26.1	26.0	27.7	26.2	28.7	28.4
5 Nov.	29.3	32.7	33.1	31.7	32.2	31.6	31.5	33.2	33.9

Code:

A = Clipped monthly

B = Clipped seasonally

C - Control

L = Light intensity foliage removal

M = Medium intensity foliage removal

H = Heavy intensity foliage removal

Table 31. Soil moisture regime 0-60" - Upper location - 1967

Measurement date	Treatment								
	CA	CB	LA	LB	MA	MB	HA	HB	Cl
6 July	36.9	40.8	41.4	40.4	37.1	40.9	37.2	40.1	38.0
19 July	35.5	40.3	41.4	38.5	35.4	39.9	35.4	38.5	37.3
3 Aug.	31.5	37.1	36.5	34.7	31.9	36.1	33.0	35.7	36.1
16 Aug.	28.8	34.4	34.3	31.9	30.4	33.3	32.0	33.7	35.6
30 Aug.	25.8	31.3	31.1	28.4	27.3	30.1	27.4	30.9	33.2
14 Sept.	24.6	29.0	29.2	27.1	26.3	28.4	26.5	29.7	32.1
30 Sept.	26.0	30.4	30.8	28.7	28.1	29.4	28.2	31.3	32.8
14 Oct.	26.1	30.1	30.5	28.8	27.8	29.7	28.3	31.3	30.9
28 Oct.	26.0	29.3	30.5	28.6	27.9	29.5	28.3	30.5	32.4

Code:

A = Clipped monthly

B = Clipped seasonally

C = Control

L = Light intensity foliage removal

M = Medium intensity foliage removal

H = Heavy intensity foliage removal

VITA

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