A STUDY OF ROOTS ON NATIVE RANGE UNDER DIFFERENT GRAZING AND BURNING MANAGEMENT

by

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INTRODUCTION

Range burning has been practiced in the vast bluestem range of the Flint Hills. Burning dates may vary widely within a locality even during the same season. A great variation in grazing intensity is often observed on similar ranges. These management differences point out the need for evaluation studies and presentation of results to ranchers in a convincing form.

Extensive research has been conducted on forage production of native range under different management practices. Many range management studies have dealt with vegetation top growth analyses, but root growth has seldom been investigated. Root growth is probably more important to investigate than top growth since plants must have a healthy, vigorous root system to obtain water and nutrients from the soil before they can produce abundant top growth. Improper range management has resulted in depleted grass root systems as well as reduced top growth.

A thorough study of grass roots in pastures managed differently may reveal the relationship of management systems to root growth, forage production, and range condition. A knowledge of the quantity of roots present, their distribution in the soil, and carbohydrate content would be valuable. With these thoughts in mind, this study was undertaken to determine the effect of grazing at three different stocking rates and burning at three different dates on root development in six separate pastures. Volume, weight, and carbohydrate content of roots in the soil profile were measured.

REVIEW OF LITERATURE

Anderson and Fly (1955) stated that bluestem grasslands such as in the Flint Hills, when at or near climax condition, are very productive and are characterized by high stability under grazing, and this condition is not easily disturbed except by repeated burning over dry soil or long continued abusive grazing. Observations on native grassland have revealed that burning and grazing management practices vary widely even in the same area. Many grazing and burning studies need to be evaluated to give a better understanding of the effects of a particular management practice on range condition to determine proper range management for a particular area.

The Flint Hills Grazing Region

The Flint Hills grazing region was described by Anderson and Fly (1955) as an approximately 4,000,000 acre region extending from the Nebraska-Kansas line on the north, into northern Oklahoma where it is known as the "Osage Hills." The terrain is rolling to hilly with relatively smooth, narrow divides bordered by steep slopes and rock outcrops (Fig. 1).

The average annual precipitation ranges from 30 to 38 inches north to south, and the growing seasons vary from 170 to 190 days. According to Anderson and Fly (1955) the native vegetation is classified as true prairie being dominated by mid and tall grasses. As described by Fly (1949) the residual soils have developed from massive limestones, interbedded gray and yellow shales, and highly flinty or cherty limestones of the lower Permian formations. These soils have dark, well-granulated silt loam or silty clay loam surface horizons with abundant rock and chert fragments.

EXPLANATION OF PLATE I

Fig. 1. General view of Flint Hills range in the experimental area.

PLATE I

Anderson and Fly (1955) studied the relationship of the native plant population to soil differences on the Donaldson pastures of the Kansas State University Agriculture Experiment Station, Manhattan, Kansas, and revealed six vegetation-soil units that were recognized as range sites. These six were named: ordinary upland, limestone breaks, clay upland, claypan, very shallow, and lowland range sites. Characteristics of these are summarized as follows:

> OU--Ordinary Upland Site. Lands having sufficient depth of soil with medium or loamy texture and hence with suitable soil plant moisture relations to support the type of vegetation that is climax on the zonal soils of the regional climate.
>
> LB--Limestone Breaks Site. Lands similar to the above but occurring on steeper slopes and therefore subject to somewhat greater loss of moisture by runoff and with less development. The vegetation is like that of the above site in its major features and may be considered climax in nature.
>
> CU--Clay Upland Site. Lands having sufficient depth of soil, but with somewhat less infiltration, slower permeability, and a smaller percentage of water available to plants than ordinary uplands, hence supporting a somewhat preclimax vegetation.
>
> CP--Claypan Site. Lands having sufficient depth of soil, but with even more restrictive water relations than the clay upland sites, thus supporting a preclimax vegetation.
>
> VS--Very Shallow Site. Lands having insufficient depth of soil for normal water storage, hence supporting under proper grazing a distinctly preclimax vegetation.
>
> Ld--Lowland Site. Lands receiving more water than normal and having such moisture relations as to support a postclimax vegetation under proper grazing.

Grass Root Systems

One of the impressive characteristics of the native grasses in the true prairie is their very extensive root systems. This characteristic may contribute considerably to the great stability of these grasses.

In studying the grasses of the true prairie, Weaver (1958) described the root systems of several grasses common to the Flint Hills. He found that the roots of little bluestem (Andropogon scoparius Michx.)[1] often penetrated to a depth of 4 to 5 feet. The root systems of mature plants consisted of a vast network of roots and masses of finely branched rootlets, some more than 30 inches in length and branched to the third order.

Big bluestem (Andropogon gerardi Vitman) roots extended to a depth of 6 to 7 feet on upland true prairie. The roots were abundant and extended downward almost vertically with numerous laterals 2 to 6 inches in length. The main roots were rather coarse measuring 1 to 3 mm. in diameter. Coarse rhizomes 3 to 6 mm. thick and much branched were quite abundant. They generally occurred 1 to 2 inches below the soil surface but were common to a depth of 4 inches. Indiangrass (Sorghastrum nutans (L.) Nash) had roots not so coarse nor quite so deep, although they were often branched more abundantly than those of big bluestem.

Weaver (1958) found that the abundant roots of switchgrass (Panicum virgatum L.) in the lowlands extended downward 8 to 11 feet but branched rather sparingly. These roots were 2 to 4 mm. in diameter. The surface 3 to 6 inches of the soil contained many branched rhizomes. The well-branched roots of sideoats grama (Bouteloua curtipendula (Michx.) Torr.) attained depths of 4 to 5.5 feet. These roots were rather fine and spread laterally 1 to 1.5 feet. Kentucky bluegrass (Poa pratensis L.) had a very well-

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[1]Common and scientific plant names, and taxonomic authorities follow Anderson, K. L. 1961. Common Names of a Selected List of Plants. Tech. Bul. 117 Kans. Agr. Expt. Sta.

developed root system. These roots were fine and thickly branched and formed dense mats in the surface 1.5 to 2 feet of soil but sometimes extended to 3 feet.

From Weaver's descriptions above, it is evident that grass roots are much more extensive and reach to greater depths than a casual observer might think. The extensiveness of root systems vary depending on such things as the soil characteristics, species, moisture availability, and plant vigor. Roots of some species are very fine and fragile at their deeper depths and could be easily overlooked without careful excavation techniques. Hulbert (1955) noted this when he studied root systems of several Bromus species in Idaho. He was able to trace roots of downy bromegrass (Bromus tectorum L.) to a depth of over 4 feet into a caliche layer when they had been previously described by Tisdale (1947) as having a shallow root system and reaching a depth of 1 foot.

Grazing Management

Anderson (1959) stated that prairie plants are adapted to grazing, and moderate grazing is not detrimental to their development. Still, range is not indestructible and may be abused by livestock grazing too early and too late in the season, or by stocking too heavily.

Duvall and Linnartz (1967) reported that botanical composition remained relatively constant under moderate grazing but changed markedly on ungrazed and heavily grazed range of longleaf pine-bluestem area of Louisiana. Herbage yield and density of cover were greater on both moderately and heavily grazed than on ungrazed range. The fact that heavily grazed range apparently maintained its yield and density of cover in Louisiana, whereas it does not in the Kansas Flint Hills, may be partly explained by the former's higher average rainfall of 58 inches annually. Had the grazing intensity been further increased, a reduction in yield and density of cover probably would have resulted.

Grazing intensity is most noticeably reflected in forage yields. The 1959 to 1965 forage production averages were reported by Owensby (1966) on three different stocking rate pastures of the Donaldson experimental unit, Kansas State University. Total forage production figures from these pastures showed moderately grazed 3216, lightly grazed 4165, and heavily grazed pasture 3240 pounds of air-dry forage per acre. These are the same three grazing intensity pastures included in this thesis.

Different intensities of grazing are reflected in different range conditions. Anderson (1959) stated that grazing use is the major factor affecting range condition. In the Osage rangeland of Oklahoma, Hazell (1967) reported that heavy grazing caused a decrease in range condition, an increase in undesirable grasses and forbs, and a decrease in plant vigor. In his study, little bluestem was by far the most abundant in the moderately grazed pasture while buffalograss (*Buchloe dactyloides* (Nutt.) Engelm) and tall dropseed (*Sporobulus asper* (Michx.) Kunth) were the most abundant in the heavily grazed pasture.

It is less evident that different intensities of grazing are reflected in root systems of range plants than in range condition. Weaver (1950) found great differences when he sampled root systems in soil monoliths from the same soil (Carrington silt loam) in three grades of pasture in south-central Nebraska designated as high, mid, and low-grade. Root samples were chosen according to the average composition of the vegetation in each grade of pasture. The vegetation was mostly little bluestem in the high-grade, about half little bluestem and half bluegrass in the mid-grade, and predominately bluegrass, blue grama (Bouteloua gracilis (H.B.K.) Lag. x Steud.) and weeds in the low-grade sample. Total amounts of underground plant material, expressed as grams of oven-dry weight, were 84.32, 68.39, and 35.07 in the high, mid, and low-grade pastures respectively. The replacement of bluestem grasses by bluegrass, which occurred in the pastures of Weaver's study, has a definite detrimental effect on forage yield. Weaver and Darland (1945) observed a 50% annual loss of yield due to this replacement.

In the mixed prairie of North Dakota, Lorenz and Rogler (1967) compared roots developed under moderately and heavily grazed pastures which had been under that management for 40 years. Although total root weights in a 4-foot profile were about the same for both pastures, there was a larger percentage of root material at each depth below the upper foot in the moderately grazed than in the heavily grazed pasture. Root distribution figures of Lorenz and Rogler (1967) verified similar findings by Weaver (1950).

Close clipping, used to simulate close grazing, has been found to stop root growth. Crider (1955) studied three cool-season and five warm-season grasses under greenhouse conditions, and observed that a single clipping which removed most of the foliage stopped root growth for 6 to 18 days. Continued frequent, close clipping caused complete and prolonged stoppage.

Weaver (1950) made a study of the deterioration of little and big bluestem in high, mid, and low-grade pastures. Little bluestem demonstrated decreased density of the root mass at all soil levels and decreased depth of penetration of roots from the high to the low-grade pasture. The roots were about 5, 4, and 3 feet deep in the high, mid, and low-grade pastures respectively. Similar results were obtained with big bluestem.

A measure of vigor was obtained by Weaver (1950) by taking sods of little bluestem from high, mid, and low-grade pastures and transplanting them into boxes which contained fertile soil where they were adequately watered. After six weeks, the roots and tops were weighed. The dry weights of the new tops were 30.22, 12.89, and 1.87 gm., respectively. Dry weights of new roots below the old sod were 4.70, 1.72, and 0.33 gm. in the high, mid, and low-grade pastures respectively, a ratio of 14 to 5 to 1. Again, these results exemplify the harmful effects of over-grazing.

Weaver (1950) summarized his study well in the following concluding statement:

> A good top that produces much nutritious forage and a good root system that can withstand drought and store much food for early growth in the spring go hand in hand. A depleted range of non-vigorous grasses is usually also one in which the root systems are absorbing water and nutrients only in the upper portion of the soil.

Burning Management

Burning has played an important role in the past management of Flint Hills range and still is common. Increased livestock gains have provided the major incentive for range burning. Increased livestock gains are partially due to an increase in protein content of the forage following burning. Smith and Young (1959) reported the protein content of forage during July, in the mid-spring burned pasture of the Kansas State University experimental area, to be 6.30% compared to 5.70% from a non-burned pasture. In the blue grama-pinyon-juniper vegetation of New Mexico, Dwyer and Pieper (1967) reported protein content in June following an April fire was 16.1% compared to 14.8% on an unburned area.

Aldous (1934) found that the protein content of forage following burning increased with later spring burning dates on plots at Kansas State University. He reported 8.50, 9.31, and 12.37% protein content of forage during early June in early, mid, and late-spring burned plots respectively. Smith et al. (1965) reported the 15-year average of beef gains in mid and late-spring burned Donaldson pastures to be 20 and 23 pounds per steer higher than gains on an adjacent unburned pasture.

One of the big questions about burning is its effect on forage yields. Aldous (1934), McMurphy and Anderson (1963), Owensby and Anderson (1967), and Dwyer and Pieper (1967) found a definite decrease in forage yields following burning. McMurphy and Anderson (1963) summarized the long term forage yield from 1928 through 1960 on plots at Kansas State University. Production figures from these plots resulted in yields of 3960 pounds of air-dry forage per acre from the check plots, 3449 pounds from the mid-spring burned plots, and 3536 pounds from the early-spring burned plots.

Forage production from the grazed Donaldson pastures of the Kansas State University experimental area has followed the same general trend, the unburned pasture producing the greatest, and the early-spring burned the smallest yield. Owensby and Anderson (1967) reported the average forage production from 1959 to 1965 on three of the Donaldson experimental pastures (which are the burning date pastures involved in one portion of this root study). These forage production figures from an ordinary upland range site, expressed as pounds per acre of air-dry forage, were 3919 from the unburned, 3529, 3238, and 2612 pounds from the late, mid, and early-spring burned pastures respectively. All of these yield reductions were significant at the 0.05 probability level except those of the late-spring burned pasture. The late-spring burned pasture had significantly lower weed yields than in the unburned check at the 0.05 confidence level.

In contrast to the work reported in Kansas, Duvall (1962) in central Louisiana found no difference in 8-year tests in herbage yield between areas burned in January and those burned in March. The differences in these findings may be partly explained by differences in precipitation in the two areas; an annual average of 58 inches in central Louisiana compared to 32 inches annually in the Flint Hills. Reduced soil moisture is one of the biggest drawbacks to range burning and in areas of high precipitation this effect would not be as noticeable.

Duvall (1962) stated that a key to good forage production in the slender bluestem area of central Louisiana is preventing large accumulations of herbaceous litter from building up. In a study on southern bluestem range, Grelen and Epps (1967) reported that yield and nutrient content of herbage on burned plots differed little from plots that were closely mowed and raked. Thus, they attributed the beneficial effects of burning mainly to litter removal. In contrast to the statements by Duvall (1962) and Grelen and Epps (1967), Duvall and Linnartz (1967) reported that during a 12-year test, litter was little affected by burning.

A change in botanical composition following fire has been observed in several studies. In the Flint Hills, juniper (Juniperus virginiana L.) is quite satisfactorily controlled where burning occurs.

Dwyer and Pieper (1967) stated that 24% of the juniper (Juniperus monosperma (Engelm) Sarg.) and 13.5% of pinyon pine (Pinus edulis Engelm.) were killed by a wild fire in south-central New Mexico. In contrast to finding a switch in botanical composition, Duvall and Linnartz (1967) reported no change in species composition during a 12-year study in the longleaf pine-bluestem range of Louisiana.

McMurphy and Anderson (1963) stated that reduced soil moisture brought about by burning appeared to be the major cause of herbage yield reduction. Aldous (1934) found a close relationship between soil moisture and forage yields. He attributed difference in yields primarily to differences in soil moisture content.

Burning may influence the intake of water by the soil and evaporation of water from the soil. Hanks and Anderson (1957) found that burning at any time greatly decreased water intake. They also stated that more water was lost by evaporation as the time interval from burning to the initiation of growth in the spring increased. Reduced water loss by burning late in the spring or not burning at all will increase forage yields and water use efficiency.

McMurphy and Anderson (1965) concluded that all dates of range burning reduced soil moisture, but late-spring burning reduced it least. They reported that this reduction was largely due to decreased infiltration and that this caused a shortage of moisture in the lower part of the soil profile which was critical to plants during dry seasons.

Since late-spring burning appeared to be the least detrimental, McMurphy and Anderson (1965) narrowed the question to a comparison of late-spring burning and no burning.

The advantages of late-spring burning over not burning in the Flint Hills appeared to be: (1) an increase in big bluestem, (2) control of Kentucky bluegrass, Japanese brome (*Bromus japonicus* Thumb.) and buckbrush (*Symphoricarpos orbiculatus* Moench), and (3) more rapid beef gains. The disadvantages of late-spring burning were: (1) reduced infiltration rate, (2) reduced soil moisture, (3) reduced forage yield, and (4) increases of smooth sumac (*Rhus glabra* L.) and possibly other undesirable species that may be favored by fire (McMurphy and Anderson, 1965).

MATERIALS AND METHODS

The field research was conducted the summer of 1967 on Kansas State University rangeland. The study area is 5 miles northwest of Manhattan, Kansas, in the Flint Hills region of the True Prairie. The average annual precipitation for Manhattan is 32.0 inches. Nearly 3/4 of it occurs from April through September.

The vegetation of the area is largely warm-season perennial grasses, i.e., big bluestem, little bluestem, indiangrass, switchgrass, and sideoats grama. Buffalo grass and blue grama are abundant only on sites having less favorable moisture relations.

Six pastures were selected which have each been under different management treatments continuously since 1950 (Table 1). Three 44-acre pastures have been burned annually at three different dates termed early, mid, and late-spring burn. These three pastures were moderately stocked. The other three 60-acre pastures, which were not burned, have been stocked at three different stocking rates termed light, moderate, and heavy. Yearling steers and heifers grazed all pastures from May 1 to about October 1 each year.

Table 1. Pasture number, name, and treatment.

Pasture no.	Pasture name	Pasture treatment
1	Moderately stocked	Stocked season-long at 5.00 A/AU[1]; not burned
2	Heavily stocked	Stocked season-long at 3.75 A/AU; not burned
3	Lightly stocked	Stocked season-long at 7.50 A/AU; not burned
9	Early-spring burned	Stocked season-long at 5.00 A/AU; burned annually March 20
10	Mid-spring burned	Stocked season-long at 5.00 A/AU; burned annually April 10
11	Late-spring burned	Stocked season-long at 5.00 A/AU; burned annually May 1

1. Acres per animal unit.

All pastures sampled contained ordinary upland and limestone breaks range sites. In addition, pastures 1, 2, and 3 contained clay upland and pastures 9, 10, and 11 contained claypan sites. Two range sites were selected from each of the six pastures. These sites were ordinary upland in all six pastures, clay upland in pastures 1, 2, 3, and claypan in pastures 9, 10, and 11, resulting in a total of 12 collecting sites.

A Gidding's hydraulic soil probe mounted on a Jeep truck was used to collect soil-root cores from these sites in early July, 1967 (Fig. 2). Aerial photos, with range site boundaries drawn in, were used to locate the approximate collecting areas. All of these areas were of similar distance from water so that grazing distribution was nearly uniform.

Three soil-root cores were collected at each range site with each core

EXPLANATION OF PLATE II

Fig. 2. The hydraulic soil probe used to collect the soil root cores.

PLATE II

considered as a sub-sample. The driver could not see the vegetation under the probe when he stopped the truck, and it was felt that this gave an unbiased method of collecting the sub-samples.

Plans in the original experimental design were to use a 3-inch diameter probe on all range sites and collect to a depth of 60 inches. However, because of a predominance of rocks or a very tight clay layer, cores were collected to a depth of 30 inches with a $1\frac{1}{2}$-inch diameter probe in the clay upland and claypan range sites, and to a depth of 54 inches with a 3-inch diameter probe in the ordinary upland site.

The soil-root cores were separated into depth increments so that root distribution could be studied. Immediately after extracting, the soil-root cores were laid on a 1 by 4 board and cut at 4, 8, 12, 18, 24, 30,[2/] 36, 48, and 54 inches. This resulted in eight increments per core in the ordinary upland range sites and six increments per core in the clay upland and claypan sites. Each soil-root increment was placed in a labeled paper bag.

After the field collecting was completed, the samples were placed in 1-gallon cans where they were soaked in water for a minimum of 24 hours. A sieve was constructed for washing the soil from the roots by making a 2 by 4 foot frame from 1 by 4 lumber and attaching a copper window screen to the bottom. The frame was partitioned to produce eight, one square foot compartments (Fig. 3). The soaked soil-root samples were transferred into separate compartments and painstakingly washed with a small stream of water from a hose (Figs. 4 and 5). No attempt was made to separate dead plant material from live roots.

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[1]A cut was made at 30 inches in the clay upland and claypan range sites only.

EXPLANATION OF PLATE III

Fig. 3. General view of the washing bin and the washing process.

PLATE III

EXPLANATION OF PLATE IV

Fig. 4. View of pouring a soaked soil-root sample into a compartment of the washing bin.

PLATE IV

EXPLANATION OF PLATE V

Fig. 5. Completing the washing of a root sample with a small stream of water.

PLATE V

The roots were air-dried and then analyzed volumetrically by water displacement in either a 10 or 100 ml. graduated cylinder, depending on the amount of roots contained in the particular sample.

The roots were then placed in labeled paper bags and oven dried for three days. After drying, the roots were weighed on a Mettler mg. scale. The roots from the moderately stocked and the late-spring burned pastures were ground in an intermediate Wiley mill. The resulting material was analyzed for total available carbohydrates (Weinmann, 1947). The sub-samples and some of the increments were combined in some instances because of the small amount of roots available.

The root weight data were statistically analyzed according to range sites within the stocking rate pastures and within the burning date pastures. This was done because the rocky, or tight clayey condition of the sub-soil prevented the hydraulic soil probe from penetrating to the desired depths in two range sites. As a result, there were no samples collected from 18 to 30 inches in the claypan range site of the late-spring burned pasture, and from 48 to 54 inches in the ordinary upland site of the lightly grazed pasture. Because some samples were missing, data were analyzed as follows: (1) claypan range sites of burning date pastures to a depth of 18 inches, and (2) ordinary upland sites of grazing intensity pastures to a depth of 48 inches, (3) clay upland range sites of grazing intensity pastures to the planned depth of 30 inches, and (4) ordinary upland sites of burning date pastures to the planned depth of 54 inches.

An analysis of variance was conducted on each of the resulting four groups of root weight data. Least significant difference (LSD) tests were conducted on the root weight means of the depth increments to determine which depths displayed significant differences in root accumulation. A determination was made of the percentage of total oven-dry root weight from each pasture contained in each depth increment.

Since the question of primary concern is a comparison of moderately grazed unburned and moderately grazed late-spring burned pastures, root carbohydrates were determined in these two pastures only. An analysis of variance was conducted on the carbohydrate content of the roots between the two pastures, and a LSD test was used to determine which increments within each pasture were significantly different in carbohydrate content.

RESULTS AND DISCUSSION

Results

At the beginning of this study, it was hypothesized that past range management had an effect on the quantity and distribution of range plant roots in the soil. It was speculated that range plants in properly managed pastures (considered to be unburned moderately stocked and late-spring burned) may have a greater root accumulation, and a different distribution of roots than plants in improperly managed pastures.

Analyses of variance of the root weight data revealed no significant difference, at the 0.05 level of probability, in the amount and distribution of roots between differently managed pastures (pastures and pastures x depths). A correlation coefficient between root weight and volume was determined to be +0.97 ($C.I._{95}$ $.965 \leq P \leq .982$). Since root weight and volume were highly correlated, the volume data were not included in further statistical analyses.

F-tests on the analyses of variance data, revealed that in every instance, depths were the only source that had a significant difference, and they were different even at the 0.005 level of probability (Tables 2, 4, 6, and 8). LSD tests on the root weight means of the depth increments revealed that in every instance, the 0 to 4 inch increment contained a significantly greater amount of roots than any other depth increment at the 0.05 level of probability (Tables 3, 5, 7, and 9). In the claypan and clay upland range sites, the 0 to 4 inch increment was the only increment that contained a significantly greater amount of roots than greater depth increments.

Table 2. Analysis of variance of root weights[1] in the ordinary upland range sites of the grazing intensity pastures.

Source	Analysis of Variance D. F.	M. S.	F-test[2]
Cores	2	0.0957	0.11 n.s.
Pastures	2	0.4174	0.46 n.s.
Error a	4	0.9100	
Depths	6	21.2274	37.36*
P x D	12	0.1411	0.25 n.s.
Error b	36	0.5690	

1. The root weights were converted to grams per inch of depth before the analyses were made so that the unequal lengthed increments could be fairly compared by the LSD test.

2. The asterisk (*) indicates significance at the 0.005 probability level; "n.s." denotes non-significance at the 0.05 probability level.

Table 3. Oven-dry root weights, expressed as grams per inch of depth, in each of the grazing intensity pastures on the ordinary upland range sites; weights represent sums of three cores per pasture.

Depth (in.) increment	Heavily grazed	Moderately grazed	Lightly grazed	Mean[1]
0-4	1.379	1.123	1.431	0.437a
4-8	0.274	0.212	0.263	0.083b
8-12	0.209	0.112	0.122	0.049bc
12-18	0.192	0.067	0.073	0.037bc
18-24	0.138	0.083	0.056	0.031bc
24-36	0.024	0.037	0.024	0.009c
36-48	0.029	0.021	0.025	0.008c

1. Values which are followed by the same letter are not significantly different at the 0.05 level of probability. The largest value, and all not statistically different from it, is always followed by the letter "a". LSD (0.05) =0.069

Table 4. Analysis of variance of root weights in the ordinary upland range sites of the burning date pastures.

Source	D. F.	M. S.	F-test 1/
	Analysis of Variance		
Cores	2	0.0320	0.05 n.s.
Pastures	2	0.0954	0.15 n.s.
Error a	4	0.6196	
Depths	7	19.7870	31.92*
P x D	14	0.1047	0.17 n.s.
Error b	42	0.6199	

1. The asterisk (*) indicates significance at the 0.005 probability level; "n.s." denotes non-significance at the 0.05 level.

Table 5. Oven-dry root weights, expressed as grams per inch of depth, in each of the burning date pastures on the ordinary upland range sites; weights represent sums of three cores per pasture.

Depth (in.) increment	Early burned	Mid burned	Late burned	Mean 1/
0-4	1.197	1.450	1.373	0.447a
4-8	0.258	0.247	0.252	0.084b
8-12	0.155	0.140	0.191	0.054bc
12-18	0.143	0.055	0.179	0.042cd
18-24	0.129	0.033	0.117	0.031cd
24-36	0.023	0.041	0.059	0.014d
36-48	0.014	0.018	0.037	0.008d
48-54	0.012	0.024	0.015	0.006d

1. Values which are followed by the same letter are not significantly different at the 0.05 level of probability. The largest value, and all not statistically different from it, is always followed by the letter "a". LSD (0.05) = 0.040

Table 6. Analysis of variance of root weights in the clay upland range sites of the grazing intensity pastures.

Source	Analysis of Variance D. F.	M. S.	F-test 1/
Cores	2	0.4894	0.32 n.s.
Pastures	2	0.8930	0.59 n.s.
Error a	4	1.5263	
Depths	5	9.3182	7.85*
P x D	10	0.5924	0.43 n.s.
Error b	30	1.1867	

1. The asterisk (*) indicates significance at the 0.005 probability level; "n.s." denotes non-significance at the 0.05 level.

Table 7. Oven-dry root weights, expressed as grams per inch of depth, in each of the grazing intensity pastures on the clay upland range sites; weights represent sums of three cores per pasture.

Depth (in.) increment	Heavily grazed	Moderately grazed	Lightly grazed	Mean 1/
0-4	1.123	0.742	0.543	0.268a
4-8	0.272	0.063	0.141	0.053b
8-12	0.027	0.034	0.100	0.018b
12-18	0.111	0.016	0.056	0.020b
18-24	0.031	0.017	0.039	0.010b
24-30	0.025	0.009	0.030	0.007b

1. Values which are followed by the same letter are not significantly different at the 0.05 level of probability. The largest value, and all not statistically different from it, is always followed by the letter "a". LSD (0.05) = 0.107

Table 8. Analysis of variance of root weights in the claypan range sites of the burning date pastures.

Source	Analysis of Variance D. F.	M. S.	F-test 1/
Cores	2	1.4275	2.84 n.s.
Pastures	2	1.7108	3.07 n.s.
Error a	4	0.5571	
Depths	3	3.5972	6.62*
P x D	6	0.6871	1.37 n.s.
Error b	18	0.5346	

1. The asterisk (*) indicates significance at the 0.005 probability level; "n.s." denotes non-significance at the 0.05 level.

Table 9. Oven-dry root weights, expressed as grams per inch of depth, in each of the burning date pastures on the claypan range sites; weights represent sums of three cores per pasture.

Depth (in.) increment	Early burned	Mid burned	Late burned	Mean 1/
0-4	0.534	0.605	0.367	0.167a
4-8	0.088	0.163	0.132	0.043b
8-12	0.055	0.100	0.076	0.026b
12-18	0.044	0.580	0.041	0.073b

1. Values which are followed by the same letter are not significantly different at the 0.05 level of probability. The largest value, and all not statistically different from it, is always followed by the letter "a". LSD (0.05) = 0.082

The ordinary upland range sites displayed more variation in the distribution of the roots than did the clay upland and the claypan sites. In the grazing intensity pastures, the 4 to 8 inch increment contained significantly more roots than the 24 to 36 and 36 to 48 inch increments. In the burning date pastures, the 4 to 8 inch increment had a significantly greater root accumulation than all depth increments from 12 to 54 inches. The 8 to 12 inch increment contained significantly more roots than the increments included in the 24 to 54 inch depth.

Tables 11 and 13 show the total weight of oven-dry roots in the grazing intensity and burning date pastures respectively. The figures are rather erratic and as previously stated there was not a significant difference in total root accumulation between pastures. The percentage of total oven-dry root weight from each grazing intensity pasture contained in each depth increment is given in Table 10, and of the burning date pastures in Table 12. With these percentage tables, care should be taken in making comparisons between depth increments since they were not all equal in length. However, the results of the statistical tests applied to the root weights expressed in grams would also apply to the root weights expressed as percentages.

An analysis of variance determination revealed no significant difference in the carbohydrate level of roots in the moderately grazed and late-spring burned pastures at the 0.05 level of probability. There was a significant difference at the 0.005 level in the carbohydrate distribution at various depths (Table 14). The LSD test showed that the carbohydrate content in the 0 to 4 inch increment was significantly greater, at the 0.05 level, than any other increment. The 4 to 12 inch increment contained a significantly higher carbohydrate content than any deeper increment (Table 15).

Table 10. Percentage of total oven-dry root weight in each increment of the grazing intensity pastures; average of three cores per pasture.

Range site	Depth (in.) increment	Heavily grazed	Moderately grazed	Lightly grazed
Ordinary upland	0-4	54.81	56.54	65.43
	4-8	11.71	11.80	12.72
	8-12	08.44	06.52	05.96
	12-18	11.14	06.66	04.89
	18-24	07.93	07.68	03.89
	24-36 1/	02.89	06.94	03.42
	36-48	03.08	03.86	03.69
Clay upland	0-4	54.39	80.32	56.29
	4-8	19.31	07.18	14.01
	8-12	02.35	04.32	10.32
	12-18	16.04	03.01	08.70
	18-24	03.82	03.09	05.85
	24-30	04.09	02.08	04.82

1. Refer to (1) below table 11.

Table 11. Total weight in grams of oven-dry roots in each of the grazing intensity pastures; three cores per pasture are combined.

Range site	Depth (in.) increment	Heavily grazed	Moderately grazed	Lightly grazed
Ordinary upland	0-48 1/	10.066	07.350	08.619
Clay upland 2/	0-30	06.700	03.610	03.884

1. Root weights were included to a depth of 48 inches only on the ordinary upland site of grazing intensity pastures because of some missing data at a deeper depth in one pasture.

2. Since the soil-root cores were about one-half the diameter on clay sites as on ordinary upland, comparisons of these sites should not be made directly in this table.

Table 12. Percentage of total oven-dry root weight in each increment of the burning date pastures; average of three cores per pasture.

Range site	Depth (in.) increment	Early burned	Mid burned	Late burned
Ordinary upland	0-4	56.09	65.50	51.50
	4-8	12.45	12.14	10.00
	8-12	07.54	06.91	07.91
	12-18	08.81	04.00	10.77
	18-24	09.05	02.35	06.80
	24-36	03.38	05.18	07.34
	36-48	01.87	02.23	04.58
	48-54	00.81	01.69	01.10
Claypan	0-4	73.63	46.72	55.68
	4-8	10.99	13.69	21.47
	8-12	07.30	08.04	12.02
	12-18 1/	08.08	31.55 2/	10.83

1. Refer to (1) below table 13.

2. Exceptionally large due to a _Liatris_ taproot.

Table 13. Total weight in grams of oven-dry roots in each of the burning date pastures; three cores per pasture are combined.

Range site	Depth (in.) increment	Early burned	Mid burned	Late burned
Ordinary upland	0-54	08.504	08.598	10.282
Claypan 2/	0-18 1/	02.959	06.947	02.537

1. Root weights were included to a depth of 18 inches only on the claypan site of the burning date pastures because of missing data at deeper depths in one pasture.

2. Since the soil-root cores were about one-half the diameter on clay sites as on ordinary upland, comparisons of these sites should not be made directly in this table.

Table 14. Analysis of variance of total available carbohydrates in the ordinary upland range sites of the moderately grazed and late-spring burned pastures.

Source	D. F.	M. S.	F-test 1/
	Analysis of Variance		
Depths	4	.0003200	32.00*
Pastures	1	.0000100	n.s.
Error	4	.0000025	

1. The asterisk (*) indicates significance at the 0.005 probability level; "n.s." denotes non-significance at the 0.05 probability level.

Table 15. Total available carbohydrates, expressed as grams per inch of depth, in the ordinary upland range sites of the moderately grazed and late-spring burned pastures.

Depth (in.) increment	Moderately grazed unburned	Late burned	Mean 1/
0-4	0.0288	0.0340	0.0314a
4-12	0.0052	0.0075	0.0064b
12-24 2/	0.0027	0.0043	0.0035bc
24-36	0.0021	0.0020	0.0020c
36-54	0.0008	0.0009	0.0008c

1. Values which are followed by the same letter are not significantly different at the 0.05 level of probability. The largest value, and all not statistically different from it, is always followed by the letter "a". LSD (0.05) = 0.0040

2. Some of the increments were combined before the carbohydrate determination in order to have a sufficient sample size.

Table 16 shows that, although not significant, there appeared to be some trends in the percent total available carbohydrates between the two pastures. The roots in the moderately grazed unburned pasture contained a noticeably higher percentage of carbohydrates than those in the late-spring burned pasture.

Discussion

The root weight data were analyzed in four groups because some uncontrollable factors caused nonuniformity in the data. Analyses of variance and LSD tests conducted on data from the ordinary upland range sites of the grazing intensity and burning date pastures are contained in Tables 2, 3, 4, and 5, from the clay upland range sites of the grazing intensity pastures in Tables 6 and 7, and from the claypan range sites of the burning date pastures in Tables 8 and 9.

The analyses of variance were conducted on the root weight data after they had been converted to grams per inch of depth. This conversion was necessary before comparisons could be made between depth increments since the increments were not all the same length.

Although there was not a significant difference in the distribution of roots throughout the soil profile between pastures, there appeared to be noticeable trends. There was a higher percentage of roots at depths below 24 inches in the ordinary upland range site of the moderately grazed pasture than in the heavily and lightly grazed pastures. Previous soil moisture measurements have shown that the soil moisture level was lower in the moderately grazed pasture than in the heavily and lightly grazed pastures. In the grazing intensity pastures, plant usage is probably the primary

Table 16. Percent total available carbohydrates in the moderately grazed unburned and late-spring burned pastures.

Range site	Depth (in.) increment	% total available carbohydrates	
		Moderately grazed unburned	Moderately grazed late-spring burned
Ordinary upland	0-4	02.592	02.482
	4-12	03.192	03.429
	12-24	03.558	02.886
	24-36	05.851	03.278
	36-54	04.252	02.862
Claypan and clay upland1/	0-12	07.823	03.444

1. Claypan range site in the late-spring burned and clay upland in the moderately grazed pasture.

factor controlling the soil moisture level. The fact that the moderately grazed pasture contained the highest percentage of roots at deeper depths is probably the main reason soil moisture level is lowest in that pasture.

In the grazing intensity pastures, root distribution and accumulation were expected to result partly from the response of range plant roots to grazing intensity. The percentage of roots that stopped growth was expected to vary in proportion to the percentage of the foliage that was removed (Crider, 1955). If the plant roots in this study were responding to grazing intensity, it was not reflected in the results. Root accumulations at the deeper depths were just as great in the heavily grazed pasture as in the lightly and moderately grazed pastures.

As the burning date became later, there was an increase in percentage of roots at depths below 24 inches in the ordinary upland range sites, and below 6 inches in the claypan sites (disregarding the high percentage at the 12 to 18 inch depth attributed to a dotted gayfeather (Liatris punctata Hook.) taproot). Previous soil moisture readings have revealed that the soil moisture level increased as the burning date became later in the spring. In the burning date pastures, infiltration and evaporation are probably the biggest factors controlling the soil moisture level. The early spring burned pasture probably loses the most moisture from evaporation and reduced infiltration. The increase in percentage of roots at deeper depths as the burning date became later, may have resulted from range plants responding to the higher soil moisture level in these pastures.

It is probable that the reason for not finding any real differences in root distribution and accumulation between pastures, was that the samples were not sufficiently large or numerous enough. Having an adequate sample size has often been a problem in root studies. There are several reasons why root samples need to be especially extensive when they are collected from native grassland. Numbers of plant species are large in the Flint Hills, even in the same pasture. Over 200 species have been collected in the Donaldson pastures of this study area, and different species have different root characteristics. Species are quite similar within an area when grouped by range sites and grazing intensity, but it is very possible to have a large forb taproot in an occasional sample. This was demonstrated by the extremely large percentage of root weight in the 12 to 18 inch increment in the claypan site of the mid-spring burned pasture (Table 12), which was attributed to a dotted gayfeather taproot in one soil-root core.

Also, more samples are needed due to selective and unequal grazing by livestock even when attempts are made to minimize this effect, such as collecting at approximately equal distances from water as was done in this study. There was always a possibility of collecting some root samples with variation in soil characteristics between the pastures even on the same range site. For example, the samples from the clay upland range site in the moderately grazed pasture appeared to be exceptionally clayey from the 12 to 30 inch depth. This characteristic of the soil was also observed from the 18 to 48 inch depth on the ordinary upland range site in the lightly grazed pasture. The percentage of the root systems contained at the depths of high clay content in the examples cited were especially small (Table 10). The tightness of the soil possibly had a limiting effect on root penetration. The fine, fragile roots were difficult to recover from these samples during the washing operation.

It was also possible that the heavily grazed pasture was not grazed intensely enough to cause significant differences in root distribution and accumulation from that in the moderately and lightly grazed pastures.

Although not significant, a somewhat higher percentage of root carbohydrates was found in the moderately grazed unburned pasture than in the moderately grazed late-spring burned pasture. The apparent difference was especially noticeable between the claypan and clay upland range sites where a test of significance was not conducted on the samples because of insufficient root material. Even late-spring burning may have some detrimental effect on the root carbohydrate level of range plants. The percent total available carbohydrates measured was lower than has often been reported, but the root material contained very few plant crowns since the cores were cut off at the soil level when they were collected. The crowns normally contain the largest concentration of carbohydrates. No attempt was made to separate dead material from live roots and this may have further lowered the carbohydrate percentages reported.

It would appear that a study of the amount and distribution of range plant roots in the soil and their carbohydrate content, cannot by itself, present enough information on which to base a total evaluation of past range management. It is important to consider all available information when making an evaluation of past range management, and range condition is one of the most important considerations since it takes into account several important factors such as botanical composition, plant vigor, and forage yield.

Do not discount the value of a root study since it is probable that if there had been more severe differences in grazing intensities and more soil-root cores collected, preferably during more than one growing season, a significant difference in root weight between pastures would have been found.

SUMMARY AND CONCLUSIONS

This study was initiated to determine what influence, if any, grazing and burning have on the roots of native range plants in the Flint Hills. Root volume, weight, distribution, and carbohydrates were determined. The effects of light, moderate, and heavy stocking rates on plant roots were compared, as well as the effects of early, mid, and late-spring burning. Three soil-root cores were collected from two range sites in each pasture. These sites were ordinary upland in all six pastures, clay upland in the three stocking rate pastures, and claypan in the three burning date pastures.

The correlation coefficient between root weight and volume was determined to be +0.97. Since they were highly correlated, the volume data were not included in any further statistical analyses. The root weight data were subjected to an analysis of variance according to range sites within the grazing intensity pastures and within the burning date pastures. Analyses of variance conducted on each of the resulting four groups of root weight data indicated the following:

1. No significant difference in the amount of roots between pastures at the 0.05 level of confidence.

2. No significant difference in the amount of roots between cores or sub-samples at the 0.05 level of confidence.

3. No significant difference in the distribution of roots throughout the soil profile between pastures at the 0.05 level of confidence.

4. Highly significant difference in depth of root penetration and distribution throughout the soil profile in each pasture at the 0.005 level of confidence.

LSD tests were conducted on the root-weight means of the depth increments to determine which increments displayed significant difference in root accumulation (0.05 level). In every instance, the 0 to 4 inch increment contained a significantly greater amount of roots than any other depth increment. The 0 to 4 inch depth was the only increment that indicated a significant difference in the claypan and clay upland range sites. The ordinary upland range sites showed more variation in root distribution than the claypan and clay upland sites.

Although there was not a significant difference in the distribution of roots throughout the soil profile between pastures, there appeared to be noticeable trends. There appeared to be a decrease in the amount of roots as the burning date became earlier, at depths below 24 inches in the ordinary upland range site and below 8 inches in the claypan site. The late-spring burned pasture appeared to contain more roots than the other burning date pastures in the ordinary upland range site. This may have been a response to soil moisture since previous measurements in the burning date pastures have shown that soil moisture levels were lowest in the early-spring burned and highest in the late-spring burned pastures. There were more roots below 24 inches in the moderately grazed pasture than in the heavily and lightly grazed pastures in the ordinary upland range site. Previous soil moisture measurements taken in the stocking rate pastures have shown that the moderately grazed pasture had the lowest soil moisture level, and the fact that this pasture had more roots at deeper depths than did the heavily and lightly grazed pastures may explain the lower soil moisture level in the moderately grazed pasture. The total weight of roots was greater in the heavily grazed pasture, on both range sites, than in the moderately and lightly grazed pastures indicating no root growth stoppage response by plants to grazing intensity in these samples.

Total available carbohydrates in the roots were determined and compared in the moderately grazed and late-spring burned pastures. No significant difference, at the 0.05 level, was found in the carbohydrate content of roots between these pastures on the ordinary upland range site. The percent total available carbohydrates in the roots was greater in the moderately grazed unburned pasture than in the late-spring burned pasture. This was especially noticeable between the clay upland and claypan range sites where a test of significance was not conducted because of only one observation in each pasture on these sites. The carbohydrate data indicated that even late-spring burning may lower carbohydrate levels. There was a significant difference, at the 0.005 level, in the root carbohydrate content throughout the various depth increments. The LSD test revealed that the root carbohydrate content in the 0 to 4 inch increment was significantly larger, at the 0.05 level, than any other increment.

It is probable that the reason there was no statistical difference in the amount of roots between the differently managed pastures was that samples were not large and numerous enough. It was also possible that the heavily grazed pasture was not grazed intense enough to cause differences in root distribution and accumulation from the moderately or lightly grazed pastures.

It would appear that a study of the amount and distribution of range plant roots in the soil and their carbohydrate content, cannot by itself, present enough information on which to base a total evaluation of past range management. It is important to consider all available information when making an evaluation of past range management, and range condition is one of the most important considerations since it takes into account several important factors such as botanical composition, plant vigor, and forage yield.

Do not discount the value of a root study since it is probable that if grazing intensity differences were great enough and sufficient soil-root cores were collected, preferably during more than one growing season, a significant difference in root weight between pastures would have been found.

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A STUDY OF ROOTS ON NATIVE RANGE UNDER DIFFERENT GRAZING AND BURNING MANAGEMENT

by

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The widespread practice of pasture burning in the Flint Hills at differing dates and the variation in grazing intensity observed on similar ranges have provided a stimulus for continued research on these subjects. This study was designed to evaluate the effects of different burning and grazing treatments on the roots of native range plants in six pastures which had each been under different management treatments continuously since 1950. Root volume, weight, distribution, and carbohydrates were determined from soil-root cores collected with a Gidding's hydraulic probe. The effects of light, moderate, and heavy stocking on plant roots were compared, as were the effects of early, mid, and late-spring burning. Yearling steers and heifers grazed all pastures from May 1 to about October 1.

Three soil-root cores were collected from two range sites in each pasture. These sites were ordinary upland in all six pastures, clay upland in the three stocking rate pastures, and claypan in the three burning date pastures. The soil-root cores were divided into depth increments so that root distribution could be analyzed. The soil-root increments were soaked in water in 1-gallon cans and soil was washed from the roots using a water hose and a screen-bottomed box.

The correlation coefficient between root weight and volume was quite high, with a value of +0.97. The root weight data were subjected to an analysis of variance according to range sites within the stocking rate pastures and within the burning date pastures. Analyses of variance conducted on each of the resulting four groups of root weight data showed, at the 0.05 probability level, no significant difference in the amount of roots between cores. Unexpectedly, there was no significant difference in the total amount of roots between pastures. No significant difference was shown in the distribution of roots throughout the soil profile between pastures (pasture x depth).

Depth or root distribution within each pasture was the only source that was significantly different and it was significant even at the 0.005 level. LSD tests were conducted on the root weight means of the various depth increments to determine which increments exhibited significant difference in root accumulation (0.05 level). In every instance, the 0 to 4 inch depth contained a significantly greater amount of roots than any other depth increment.

Although there was not a significant difference in the distribution of roots between pastures, there appeared to be noticeable trends. As the burning date became later, there appeared to be an increase in the amount of roots at depths below 24 inches in the ordinary upland range site, and below 8 inches in the claypan site. There appeared to be a greater amount of roots below 24 inches in the moderately grazed pasture than in the heavily and lightly grazed pastures, in the ordinary upland range site, although not in the clay upland site. These trends may have been a response to soil moisture. Previous measurements taken in the burning date pastures have shown that soil moisture levels were lowest in the early-spring burned and highest in late-spring burned pastures. Soil moisture measurements taken in the stocking rate pastures have shown that the moderately grazed pasture had the lowest soil moisture level.

Total available carbohydrates in the roots were determined and compared in the moderately grazed and late-spring burned pastures. No significant difference, at the 0.05 level, was found in the carbohydrate content of roots between these pastures on the ordinary upland range site. There was a significant difference, at the 0.005 level, in the carbohydrate content throughout the depth increments. A LSD test revealed that the carbohydrate content in the 0 to 4 inch increment was significantly larger than any other increment at the 0.05 level.