AGRICULTURAL EXPERIMENT STATION
KANSAS STATE COLLEGE OF AGRICULTURE
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MANHATTAN, KANSAS

EFFECT OF BURNING ON KANSAS BLUESTEM PASTURES

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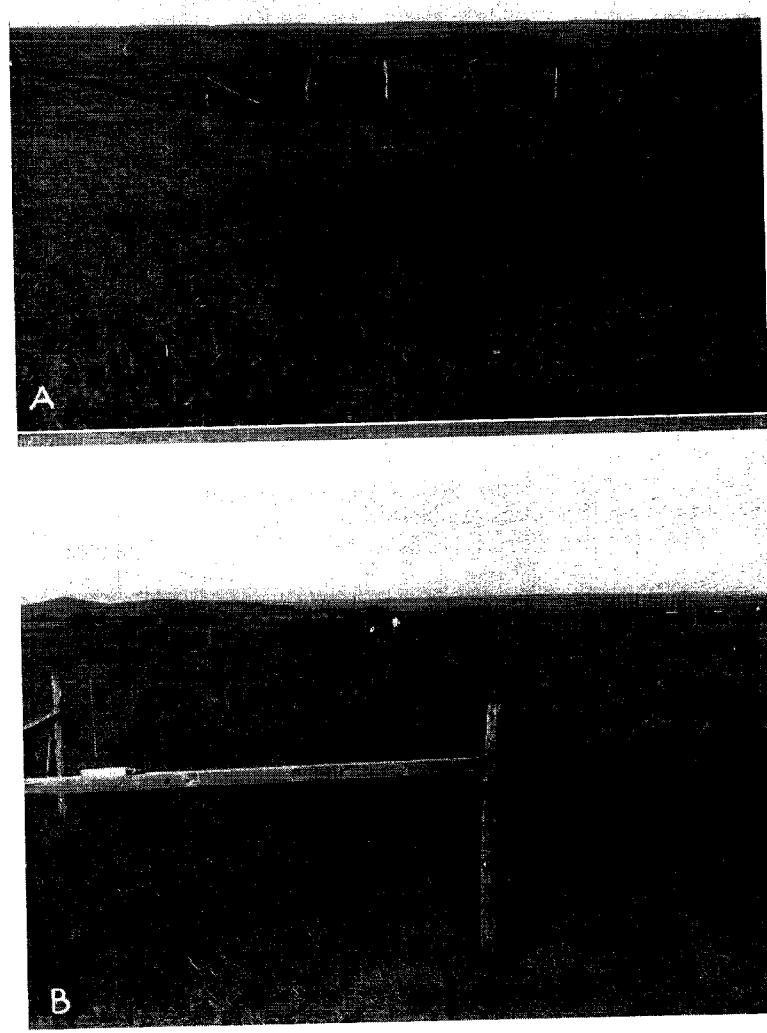

FIG. 1.—Experimental burning areas: (A) Casement pasture, looking southeast. (B) College pasture, looking northeast.

EFFECT OF BURNING ON KANSAS BLUESTEM PASTURES [1]

A. E. ALDOUS

INTRODUCTION

Burning bluestem pastures in the spring is a practice that is generally followed in eastern Kansas. This applies particularly to the Bluestem or Flint Hill region, which occupies about three million acres of pasture land extending north and south across Kansas in the western part of the eastern third of the state.

Pastures are burned to remove the dead grass remaining from the previous year's grazing, which is usually too coarse and low in palatability and nutritive content to have been used for pasturage the previous fall and winter. It is contended by those who practice burning that unless this dead vegetative growth is removed it will result in patchy grazing, with some places, mainly the rocky slopes, undergrazed while the ridge tops are overgrazed. Pastures are also burned to promote earlier growth in the spring. Burning also destroys the dead, unpalatable grass and permits the new growth to be grazed to better advantage. Those who burn their pastures also claim that this practice is effective in controlling weeds.

There has always been considerable difference of opinion regarding the possible benefits and detrimental effects of burning. There has also been much controversy as to the time that pastures should be burned to obtain the greatest benefits with the least damage to the desirable species of vegetation.

The practice of burning grass is an old one, and was extensively used by the Indians before the advent of the white man to attract game animals in the early spring so that hunting would be made easier. Apparently no great change resulted from this practice during this long period of years or it would have caused noticeable change in the vegetative composition of the prairies. It is also highly probable that a large portion of the prairie was burned periodically during very dry years from natural causes. At these times the ground was extremely dry and burning would have been much more harmful to the vegetation than burning in the early spring or late winter when the grasses are dormant and the soil contains more moisture.

Many persons have considered burning a harmful practice. This conclusion is reached from the fact that fire is usually associated with destruction, and it is only natural to assume that there would be some loss in fertility as well as a decrease in the density and vigor of the desirable pasture plants.

REVIEW OF LITERATURE

The investigations conducted to obtain information on burning pastures show varying results. Hensel *(9)* in some preliminary studies on the effect of burning on the vegetation in Kansas pastures reported a slight decrease in the yield of the vegetation, but an increase in the population of grasses.

Acknowledgment.—The author wishes to acknowledge the excellent coöperation of Mr. Dan D. Casement for permitting a part of the experiments to be conducted in his pastures. Valuable assistance was also given by Dr. F. D. Keim, chairman of the Department of Agronomy, and Dr. J. E. Weaver, professor of plant ecology, of the University of Nebraska.

1. Contribution No. 234 from the Department of Agronomy.

There was little difference in the vegetation on the burned and unburned area. This led him to conclude that burning had not been injurious.

In Natal, South Africa, Staples *(13)* found that burning during the dormant season encouraged the growth of red grass, *Thermeda triandra* var. *burchellii,* the most desirable native pasture grass. Where the pasture was protected and not burned this grass was gradually replaced by less desirable species. When the vegetation was mowed there was also a gradual succession to less palatable species. Burning in alternate years resulted in a very slight decrease in red grass, but provided a good mixture of native species that gave early grazing in the spring.

Camp *(3),* in a study of range cattle management in Alachua county, Florida, reports that range is burned in that section (1) to stimulate early growth in the spring, (2) to remove dead grass, and (3) to control brush and weeds. Burning the flatwoods under proper moisture conditions injured the turf very little. It is considered, however, that bunch grasses such as broom sedge and wire grass predominate on burned ranges, because they are better able to withstand burning, and are affected less by heavy grazing owing to their lower palatability.

Neal and Becker *(10)* made an analysis of wire grass, mainly *Aristida striata,* the principal grass on the open ranges in Florida, which showed the green grass from burned areas to have a higher mineral and protein content than grass taken from adjacent unburned areas. Wire grass is resistant to burning and immediately puts out new growth. Where it is not burned the proportion of dead grass increases progressively, which not only affects the palatability of the forage but interferes with easy grazing.

Hart *et al. (8)* made chemical analyses of vegetation in California at different stages of growth to try to ascertain why the live stock grazed burned areas in preference to adjoining unburned ones. There was very little difference in the protein content of the samples collected from burned and unburned land. There was, however, an increase in the phosphorus content of the vegetation from the burned area. This was not substantiated by the results from a limited number of samples taken from two other areas having a more fertile soil.

To determine the effect of burning on bluegrass pastures in Wisconsin, Graber *(4)* burned bluegrass sod in the late winter when it was completely frozen and in the late spring after growth had started. There was a 71 per cent decrease in yield from the late burning, and a 52 per cent decrease from the early burning. The burning caused a 34 per cent decrease in the number of rhizomes. Late burning greatly increased the weeds. The area burned in the late winter produced more vigorous grass with few weeds.

Hanson *(7)* found that forage grasses in the Laramie river valley, Colorado, were greatly increased by grubbing and burning off the sage brush. Burning was more effective in removing the sage brush than grubbing.

Observations of Pickford *(11)* on foothill range in Utah indicated that the total plant density was about the same on the protected, burned area as on the protected, unburned one. The burning had a tendency to decrease the density of the perennial grasses and increase the annual grasses. The sage brush was destroyed by burning, but the grazing capacity was slightly decreased by burning.

Rice *(12)* studied the subclimax type of high prairie along the Illinois Central railroad in east central Illinois. She reports that the vegetation upon a burned area is earlier and grows more rapidly for a time and that certain broad-leaf plants appear abundantly on places left bare by fire. Repeated burning also produces a community in which herbs partially suppress the grasses. The temperature of the soil was more constant under the unburned

area which remained frozen until after March 23, while in the burned area the soil froze at night and thawed during the day.

Greene *(5)* reports that burning is beneficial to the survival of long-leaf pine because the accumulation of grass harbors a fungus that attach the seedlings He states that long-leaf pine produces a large root which contains considerable reserve food, making a rapid top growth possible when the pine seedling has made sufficient root development.

The effect of burning on the fertility of the soil is a very important consideration.

Barnette and Hester *(2)* investigated the effect of burning on forest soil in Florida and found that yearly burning over a period of 42 years caused a decrease of 121,289 pounds of organic matter per acre to a depth of 45 inches. This amounted to a total loss of nitrogen of 1,126 pounds or an annual loss of 27 pounds of nitrogen per acre.

Alway and Rost *(1)* investigated the effect of extensive forest fires in Minnesota on the nitrogen content of the surface 6 inches of the mineral soil and found little difference in the burned and unburned soil on pasture land.

In southern Mississippi, Greene *(6)* reports that soil on rolling long-leaf-pine land burned yearly contained more organic matter and nitrogen than soil that had been protected from burning eight years. This increase was attributed to the greater quantity of plant roots and legumes on the burned areas.

EXPERIMENTAL CONDITIONS

Since burning is generally practiced in eastern Kansas on the bluestem pastures it appeared desirable to obtain definite information on its effect upon the pastures. Experiments in burning, therefore, were started in 1918, in connection with other grazing investigations that were being conducted at the Casement pasture, located 9 miles north of Manhattan on a typical bluestem or flint-hill type of pasture land. (Fig. 2.) The experiments were continued until 1922, when they were discontinued until work on the pasture project was resumed in 1926.

DESCRIPTION OF EXPERIMENTAL AREAS

It was realized shortly after resuming work on the project in 1926 that it was impossible to take comparable soil samples at various depths in the Casement pasture experimental area, because of the cherty rock in the soil. It was, therefore, impossible to obtain information on the effect of burning on the fertility of the soil, which is a very important question that should be investigated. The soil on the Casement area also lacked uniformity, although it was about as uniform as any similar-sized area of the flint-hill type of pasture land. Therefore, in 1927 work was started in another experimental area of a little over an acre in one of the pastures of the Department of Animal Husbandry about one-half of a mile due north of the Kansas State College campus.

An area 112 feet square, located on one of the ridges in the Casement pasture, was fenced in 1918 at the time the burning experiment was started. (Fig. 1, A,) This area, which is typical of flint-hill pasture land, has a black loam soil with a subsoil of clay, classified by the Bureau of Chemistry and Soils of the United States Department of Agriculture as a Summit, stony loam.

The surface is covered with loose, cherty rock. The experimental area slopes gradually to the southwest. It is somewhat lacking in uniformity, but is much more uniform than the entire pasture unit of 1,200 acres, which is rolling to hilly, and nontillable because of the topography and the presence

of limestone outcroppings and loose, cherty rock. The altitude of the pasture ranges from 1,200 to 1,400 feet above sea level. The altitude of the experimental area is approximately 1,330 feet.

This area had been pastured for a great many years, and while it had been conservatively used there is a tendency for live stock to overgraze the ridge tops slightly and undergraze the more rocky slopes. The grazing had not been heavy enough, however, to injure the sod to any marked extent. The area had also been burned at least every alternate year, but it had all received similar burning treatment.

The experimental area in the college pasture (fig. 1, B) is located on a broad, comparatively level ridge top. The soil is the type classified by the Bureau of Chemistry and Soils as a Derby silt loam, described as a brown to dark, grayish-brown silt loam to a depth of 9 inches, with a subsoil of heavy,

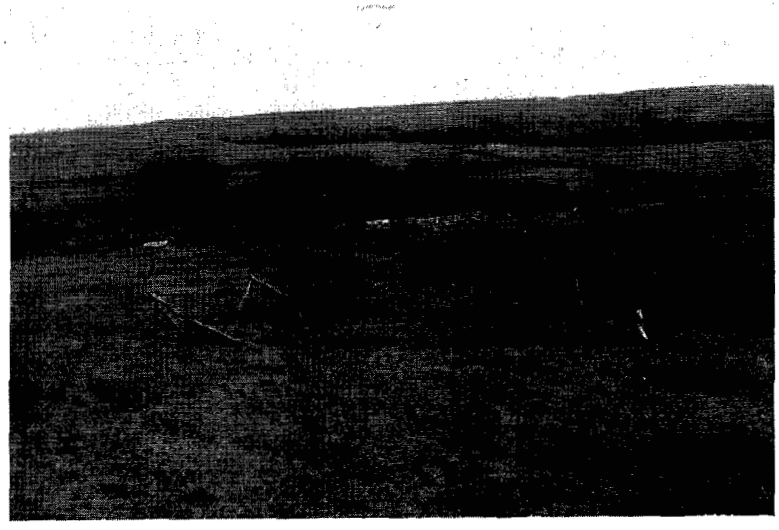

FIG. 2.—Bluestem or flint-hill type of pasture land.

reddish-brown silty loam to a depth of 36 inches. The area is readily tillable, but has never been plowed.

The experimental area had been used for cutting native hay before it became the property of the college about 20 years ago. Since that time it has been pastured by beef cattle. The pasturing has been very moderate, so much so that burning has been necessary every spring to remove the excess dead grass. The burning was usually done in the early spring before growth of the bluestem grasses had started. The previous treatment as to grazing and burning was the same for the entire area.

CLIMATE

The mean annual precipitation at Manhattan for a 73-year period is 31.49 inches. About three-fourths of this precipitation falls during the growing season of the year, that is, from April to September, inclusive. The precipitation for the years that the experiments were in progress is recorded in Table I. The mean for these years was slightly less than the mean for the 73-year period. The years 1932 and 1933 were very dry and abnormally hot. The

TABLE I.—MONTHLY PRECIPITATION AT MANHATTAN, FROM 1918 TO 1921 AND FROM 1927 TO 1933; AND THE 73-YEAR MEAN

MONTH.	Precipitation (inches).											Mean.	Mean.
	1918.	1919.	1920.	1921.	1927.	1928.	1929.	1930.	1931.	1932.	1933.	11 years.	1858-1930 73 years.
January	0.65	0.26	0.12	1.08	0.33	Trace	1.95	0.85	0.12	1.03	0.12	0.65	0.77
February	.52	1.24	.57	.36	1.39	1.58	.82	.37	1.18	.85	.08	.81	1.19
March	.76	5.03	.61	.16	3.88	1.06	.94	.52	1.64	1.40	1.82	1.53	1.50
April	4.60	3.40	4.17	2.95	5.48	1.77	5.49	6.72	2.79	1.91	2.86	3.83	2.78
May	5.17	3.15	1.75	3.32	1.67	2.21	3.35	5.25	3.28	2.67	1.57	3.05	4.33
June	1.56	4.66	2.24	6.26	7.59	4.99	7.96	6.39	2.80	4.88	.69	4.55	4.62
July	1.98	1.45	4.83	4.21	3.42	7.38	5.05	.57	1.52	1.91	4.68	3.18	4.53
August	3.34	1.40	6.76	4.65	6.65	5.29	2.51	4.99	10.52	4.11	4.07	4.95	3.74
September	2.55	2.65	4.39	3.17	4.00	2.19	1.39	2.43	7.21	4.03	4.13	3.45	3.39
October	4.87	.68	.90	1.38	2.31	1.33	5.07	2.86	2.04	.60	1 03	2.10	2.29
November	1.55	2.62	2.20	Trace	.09	5.79	1.10	3.14	5.12	.24	.20	2.00	1.49
December	2.40	.08	1.35	.34	.64	.60	Trace	.11	.53	1.32	.69	.73	.86
Totals	29.84	26.62	29.89	27.87	37.45	34.19	33.63	34.19	38.75	23.93	21.94	30.79	31.49

average date of the last killing frost in the spring at Manhattan is April 24, and the average date for the first killing frost in the fall is October 13, making the average length of the growing season 172 days. The bluestem grasses are very sensitive to frost, making little growth before the middle of April in the average year. The major part of their growth is made in May and June.

While the greater part of the precipitation falls during the frost-free season, there are very few years that growth is not checked during the summer by lack of moisture. These dry periods in July and August are usually accompanied by abnormally high temperatures.

VEGETATION

According to Weaver *(16)* the two experimental areas are the upland type of prairie grassland. On the Casement pasture area the vegetation is more than one-half big bluestem *(Andropogon furcatus)* and little bluestem *(Andropogom scoparius)* about equally divided. Other species of grasses growing on the area are as follows: Indian grass *(Sorghastrum nutans),* side oats grama *(Boutelom curtipendula),* prairie dropseed *(Sporobolus heterolepis),* Scribner's panic grass *(Panicum scribnerianum),* Kentucky bluegrass *(Poa pratensis),* sand dropseed *(Sporobolus cryptandrus),* switch grass *(Panicum virgatum),* and prairie June grass *(Koeleria cristata).* There are two species of sedges that occur very commonly in the vegetation, *Carex madii* and *Carex pennsylvanica.* There are several species of forbs, or broad-leafed plants. In pastures most of these are considered as weeds and will be designated as such. These forbs fluctuate in abundance from year to year. The most abundant ones include perennial ragweed *(Ambrosia psilostachya),* many-flowered aster *(Aster multiflorus),* pasture sage *(Artmesia gnaphalodes),* whorled milkweed *(Asclepias verticillata),* prairie cat's-foot: *(Antennaria campestris),* Missouri goldenrod *(Solidago glaberrima),* stiff goldenrod *(Solidago rigida),* blue-eyed grass *(Sisyrinchium cumpestre),* and about half a dozen other species of minor importance.

In the college pasture area little bluestem constitutes over half of the vegetative cover. The other species of grasses in order of their importance are big bluestem, Indian grass, side oats grama, prairie June grass, hairy grama *(Bouteloua hirsuta),* Scribner's panic grass, Kentucky bluegrass, sand dropseed and prairie dropseed, and the two sedges, *Carex meadii* and *Carex pennsylvanica.* The area contains several weeds which vary in abundance from year to year. The most common ones are many-flowered aster, perennial ragweed, Missouri goldenrod, blue-eyed grass, wild flax *(Linum rigidum),* prairie cat's-foot, and stiff goldenrod.

Buffalo grass *(Bulbilis dactylodides)* is common in both pastures on thinner soil where it has little or no competition from the tall grasses. In the protected areas the buffalo grass is soon excluded by shading from the tall prairie grasses.

EXPERIMENTAL METHODS

The experiments on the effect of burning on bluestem grasses were begun at the Casement pasture in 1918 to obtain information on the effect of burning on (1) yield of grasses and weeds, (2) starting growth in the spring, and (3) temperature of the soil. The entire plan of the experiment was revised in 1926 when the pasture experiments were resumed. Except for the soil temperatures, only the results obtained since 1926 are reported in this bulletin. The yields obtained from 1918 to 1921 were from random samples, the area of which was too small to be representative. The data on the successional changes obtained in these earlier years were taken from plots also believed to be too small to be characteristic of the larger areas in which they were taken.

The experiments started in 1926 were outlined to obtain data on the effect of burning on (1) yield of vegetation, (2) controlling weeds and brush, (3) quality of vegetation, (4) soil moisture, (5) composition and succession of vegetation, (6) soil temperature, (7) starting growth in the spring, (8) fertility of the soil, (9) nitrate development, and (10) utilization of bluestem pastures.

The two experimental areas were divided into plots which were burned over once a year or once each two years, successive burnings of each being at approximately the same time of year as the first burning, as follows: (1) Early spring, March 20; (2) medium spring, April 10; (3) late spring, May 5; and (4) late fall, December 1. The Casement experimental area contains five plots; an unburned, or check plot, and four which were burned annually at approximately the dates specified.

The experiments on the college pasture were outlined to obtain information on the effect of burning both under grazing and under protection. Ten plots were established, comprising two series of five plots each. One series of four plots was burned annually. The other series was burned on alternate years at the approximate time specified above. Each series included one check or unburned plot.

The size and arrangement of the plots are shown for each pasture in figure 3.

The experimental plan and size of the plots are the same in the college pasture for the protected and grazed units.

The plots were burned at approximately the time specified in the diagram (fig. 3) varying a week either way, depending on weather conditions. It was planned to burn all the plots shortly after a rain when the ground was moist, in, order to prevent soil burning and to protect the crowns of the dominant grasses. It was possible to accomplish this in all but one burning. The burning was also done when there was little wind, in order to control the fire more easily and to keep the heat of the fire to a minimum. To accomplish this it was found advisable to burn either in the early morning or in the evening. To help in controlling the burning, alleys 3 feet wide separated the plots in the two experimental areas in the college pasture. These were mowed in the fall before the fall burning was done. The mowed grass was allowed to lie in the alleys until the adjacent plot was burned, when it was raked off.

Before these experiments were started the part of the pasture containing the experimental areas had been burned about two years in three, and the burning was all done at the same time. The grazing on both pastures was moderate; neither area had ever been overgrazed. The Casement area was grazed a little closer, owing to the fact that it is on the ridge top where the cattle graze a little closer than on the slopes.

One of the principal concerns of a pasture owner regarding burning is the effect that it will have on the yield of the pasture vegetation. In order to obtain yields of vegetation it was necessary to protect the experimental burning plots from grazing. The effects of the tramping by the stock in grazing the vegetation are therefore not recorded on these plots. It was attempted partially to remedy this discrepancy in extending the experiment to the college pasture in 1928 by using wire cages that could be changed each year on the grazed plots. It was found, however, that these cages, which were 7 meters square, attracted the cattle and caused excessive tramping around them, making the practice inadvisable.

The yields of vegetation under complete protection are higher than those where the grass is clipped or grazed during the growing season, the yield being proportionate to the frequency of clipping or the intensity of grazing. The treatment of all the plots was similar except for the burning.

The yields of the vegetation were taken after maturity, or early in October of each year. At the Casement pasture the yield of vegetation was obtained by clipping an area ½ by 1 rod or ½ square rod with a hand sickle. This area was carefully selected so that it represented an average of the vegetation of the plot. At the college pasture a 5-foot strip the length of each plot, 66 feet, was cut with a mower. The vegetation on the clipped areas was separated into weeds and grasses and the green weights of each obtained. Representative samples of the grass and weeds were then taken for moisture determinations when air dried. The remainder of the clipped vegetation was spread on the

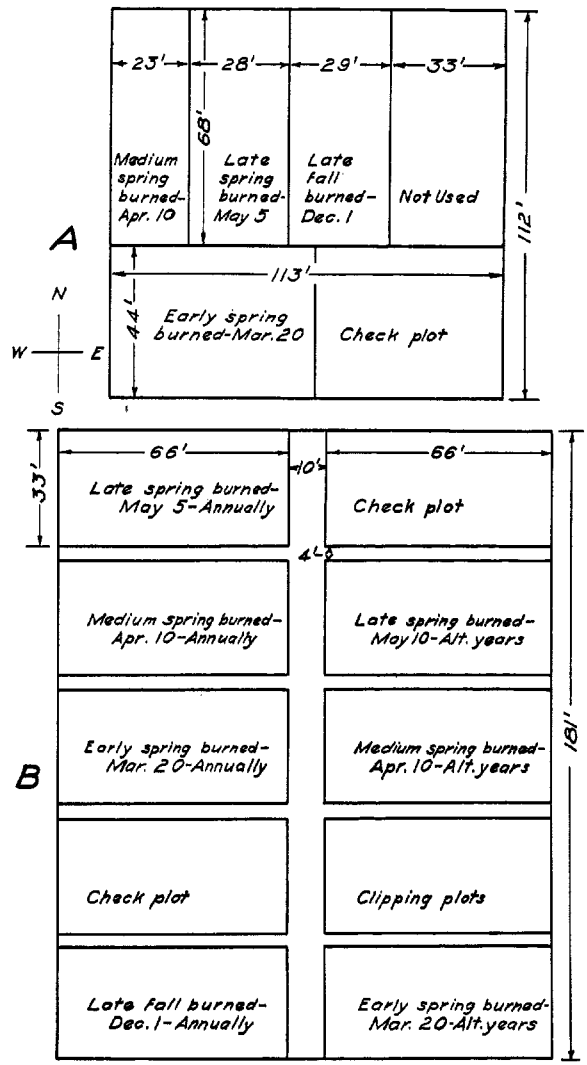

FIG. 3.—Diagram of experimental burning areas, showing size and arrangement of plots. (A) Casement pasture. (B) College pasture.

plot to protect the ground during the winter and it was burned at the time the plot was burned.

The unburned plots were raked in the early season to remove most of the dry vegetation. If this was not done it was found that the accumulation of this material attracted rodents and tended to cause abnormal fungus growth. It also had a tendency to check the emergence of the seedlings. Complete protection without removing any of the dead vegetation greatly reduced the density of the vegetation, especially where the major vegetative covering was big bluestem or Indian grass.

EXPERIMENTAL RESULTS

EFFECT OF BURNING ON YIELD OF VEGETATION

Casement Pasture.—The yields of native air-dry vegetation for the seven years at Casement pasture show considerable variation due mainly to great differences in growing conditions. These data are given in Table II, and are presented in graphic form in figure 4, A. These yields, as previously stated, were obtained from cuttings made of a representative area early in October of each year. The yield of the unburned plot was highest, followed closely by the late spring burned plot. The yield of the medium spring burned plot was third, and was only slightly higher than the plot burned in the early spring. The yield of the plot burned in the fall was the lowest.

The plot burned in the late spring contained the highest yield of grass and the lowest yield of weeds. The unburned plot contained slightly less grass with a much higher weed content. The yield of grass for the other three burning treatment plots, listed in their order from the highest to the lowest, was medium spring, early spring, and late fall. The kind of vegetation on these plots will be further discussed under burning for controlling weeds and brush.

College Pasture.—The yields of the mature air-dry vegetation cut from the plots in the college pasture are presented in Table II and shown graphically in figure 4, B. These results are similar to those obtained at the Casement pasture.

The yield of the unburned plot, however, averaged approximately 48 per cent more than that of the plot burned in the late spring, The unburned plot also yielded about 54 per cent more than the plot burned in the medium spring, 72 per cent more than the plot burned in early spring, and 88 per cent more than the plot burned in the late fall. The yield of grasses on these plots was approximately in the same proportion as the total yield of vegetation, the check plot being greatest, followed by the late spring, medium spring, early spring, and late fall-burned plots.

The yield on the plots burned in alternate years was greater than on the plots burned annually. The mean yield of the vegetation on the plot burned alternate years in the early spring was 24 per cent more than the plot burned at this time annually, 16 per cent more than the plot burned annually in medium spring, and 48 per cent more than the plot burned annually in late spring. The general trend of the yields was similar to that of the plots burned annually. During two years, however, 1928 and 1931, the yield of the late spring-burned plots was higher than the yield of the unburned plot, and in 1930 the yield of the late spring-burned plot was lower than the early and medium spring-burned plots. The late spring-burned plots showed a much greater variation than any of the other treatments.

The data given in Table II were tested biometrically, using Student's method *(15)* to compare the yields from each of the burning treatments with the unburned or check plot. In the Casement pasture differences in the yields

TABLE II.—EFFECT OF BURNING ON YIELD OF NATURE VEGETATION (AIR DRY)

TIME OF BURNING AND KIND OF VEGETATION.	Yield per acre, pounds.								Decrease due to burning.	
	1927.	1928.	1929.	1930.	1931.	1932.	1933.	Mean.	Pounds.	Odds.
Casement Pasture										
Early spring:										
Grass	2,309	2,308	1,101	1,856	2,275	2,254	1,530	1,948	.....	.....
Weeds	411	480	273	408	180	139	175	295	.....	.....
Total	2,720	2,788	1,374	2,264	2,455	2,393	1,705	2,243	1,119	1,250:1
Medium spring:										
Grass	2,116	1,613	1,530	2,073	2,590	2,240	1,984	2,021	.....	.....
Weeds	870	428	428	248	180	85	192	347	.....	.....
Total	2,986	2,041	1,958	2,321	2,770	2,325	2,176	2,368	994	216:1
Late spring:										
Grass	2,620	3,578	2,142	3,280	2,850	2,752	3,020	2,892	.....	.....
Weeds	64	41	183	48	25	16	40	59	.....	.....
Total	2,684	3,619	2,325	3,328	2,875	2,767	3,060	2,951	411	120:1
Fall:										
Grass	1,973	1,786	1,322	1,507	1,785	1,792	1,293	1,637	.....	.....
Weeds	571	459	489	525	325	212	210	399	.....	.....
Total	2,544	2,245	1,811	2,032	2,110	2,004	1,503	2,036	1,326	4,445:1
Check (unburned):										
Grass	2,932	4,116	2,019	3,280	2,970	3,328	3,008	3,093	.....	.....
Weeds	548	292	612	243	75	86	30	269	.....	.....
Total	3,480	4,408	2,631	3,523	3,045	3,414	3,038	3,362	.....	.....

TABLE II.—*Concluded*

TIME OF BURNING AND KIND OF VEGETATION.		Yield per acre, pounds.							Decrease due to burning.	
		1927.	1928.	1929.	1930.	1931.	1932.	1933.	Mean.	Pounds.	Odds.
College Pasture											
Early spring:											
Grass	Burned annually.		2,040	1,316	1,415	1,980	1,690	1,419	1,643	.....	.....
Weeds			174	47	105	165	74	126	115	.....	.....
Total			2,214	1,363	1,520	2,145	1,764	1,545	1,758	1,281	519:1
Medium spring:											
Grass			2,464	1,189	1,555	2,145	2,297	1,683	1,888	.....	.....
Weeds			160	34	65	85	54	58	76	.....	.....
Total			2,624	1,223	1,620	2,230	2,351	1,741	1,964	1,075	4,999:1
Late spring:											
Grass			2,683	1,716	1,478	2,110	2,270	1,848	2,017	.....	.....
Weeds			120	9	18	10	44	2	34	.....	.....
Total			2,803	1,725	1,496	2,120	2,314	1,850	2,051	988	1,250:1
Fall:											
Grass			2,046	789	1,428	1,915	1,584	1,353	1,519	.....	.....
Weeds			144	83	87	155	47	54	95	.....	.....
Total			2,190	872	1,515	2,070	1,631	1,407	1,614	1,425	4,449:1
Check (unburned):											
Grass			3,096	2,444	2,532	3,465	3,643	2,376	2,926	.....	.....
Weeds			240	30	78	70	59	204	113	.....	.....
Total			3,336	2,474	2,610	3,535	3,702	2,580	3,039	.....	.....
Early spring, total	Burned alternate years.		2,420	1,955	1,858	2,805	2,429	1,683	2,192	956	45:1
Medium spring, total			2,565	1,964	1,884	3,069	1,848	2,409	2,290	858	67:1
Late spring, total			3,505	2,714	1,710	3,895	2,482	3,894	3,038	110	3.1
Check (unburned), total			2,620	3,077	2,381	3,333	3,221	4,257	3,148	.....	.....

of the fall- and early spring-burned plots from the check plots are highly significant. The yields for the medium spring and late spring-burned plots are more variable, but the odds 215:1 and 120:1 are high enough to make the results statistically significant.

In the college pasture the differences in the yields of all the plots burned annually from the unburned check plots are highly significant, the odds ranging from 519:1 for the early spring-burned to 4:999:1 for the medium spring-burned plots. The results from the plots burned in alternate years show more variability. The differences between the yields of the checks and the plots

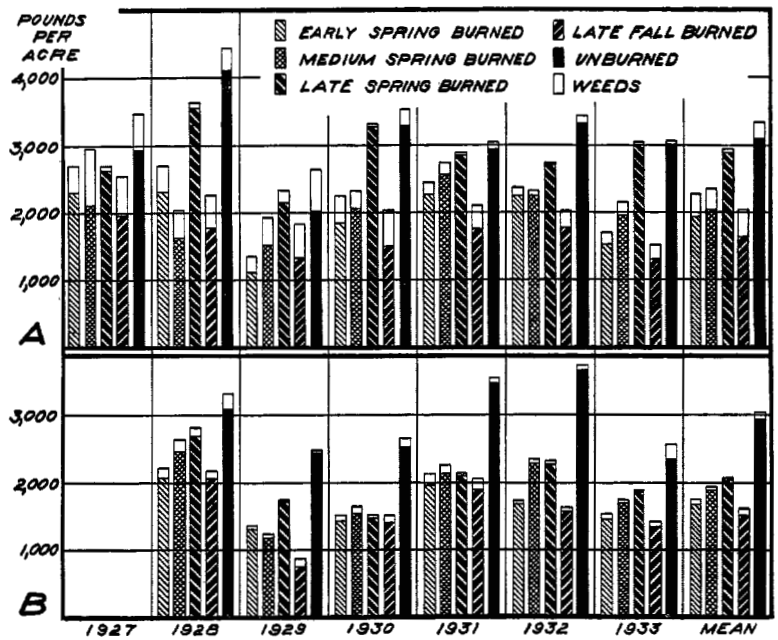

FIG. 4.—Graphs showing effect of burning on the total yield of mature vegetation (air dry). (A) Casement pasture. (B) College pasture.

burned in alternate years in the late spring have odds of only 3:1, which are not significant, while the early spring and medium spring-burned plots have odds of 45:1 and 67:1, which are questionably significant.

As a check on the effect of the time of burning on the early season growth of the vegetation, cuttings were made at the college pasture on July 26, 1933. A strip 5 feet wide was mowed the length of the plots and the total yield of the vegetation determined, both green and air dry. The vegetation was growing vigorously at this time, having been revived from the extremely dry and hot June by good rains on July 7, 12, and 17. The vegetation again showed the effects of drought shortly after these yields were taken.

The yields of vegetation cut on July 26 and October 10, 1933, from the plots burned annually at four different periods, are recorded in Table III.

The yields of vegetation even this early in the season are approximately in the same order as at maturity, for the early spring, medium spring, and fall-burned plots, being approximately 65 per cent of the yield in October. The yield of the late spring-burned plots was lower than on the other burned

TABLE III.—YIELD OF VEGETATION ON PLOTS BURNED ANNUALLY

College pasture, Manhattan, Kan., 1933

TIME OF BURNING.	Pounds per acre, July 26.		Percentage air dry.	Pounds per acre air dry, October 10.	July yield in percentage of October yield.
	Green.	Air dry.			
Early spring	1,949	995	51.0	1,545	65
Medium spring	2,275	1,137	50.0	1,741	65
Late spring	2,178	1,082	49.7	1,850	53
Fall	1,782	962	54.0	1,407	65
Check (unburned)	3,201	1,856	58.0	2,580	72

plots. This can be attributed mainly to the fact that the burning on these plots is done after growth is well started, and as a result it is set back about three weeks, or until the latter part of May. The extremely dry, hot June further checked the growth of the late spring-burned plot, as was also true of the other burned plots; this is shown by the percentage of its seasonal growth made at the time the cutting was made. Under normal conditions bluestem grasses should have made about 65 per cent of their growth by July 1. The unburned plot closely approached this proportion, while the burned plots were in all probability 12 to 15 per cent short of it.

The question naturally arises, why do the plots burned in the late spring have a higher yield of vegetation than the plots burned at other periods? Three explantions are suggested: (1) The late spring burning reduces the density of the stand of vegetation. This results in more vigorous plants which more than compensate in height of the plants and yield for the reduced number of plants per unit area. (2) There is a succession in the late spring-burned plots to the coarser, ranker species, such as big bluestem and Indian grass, with a reduction in the density of the little bluestem. This change produces an increase in the yield of vegetation. (3) Moisture determinations of the soil show that the late spring-burned plots have slightly higher moisture content than those under any other burning treatment.

More detailed discussion of (1) and (2) will be given later under "effect of burning on plant succession and density of the vegetative stand."

EFFECT OF BURNING ON WEED AND BRUSH CONTROL

Methods.—To determine the effect of burning in controlling the growth of weeds and brush, weights were taken of the weedy plots at the close of the growing season at the same time the total yield of vegetation was obtained. These data are presented in Table II. In order to determine the effect of burning on the growth of weeds earlier in the season, counts were made of the total plant population and the number of weeds on two permanent square-meter plots located in each plot on the two experimental areas. These counts were made at four different times at the college pasture. The first count was made approximately April 10, or about the time growth starts; the second, about May 15; the third, July 1; and the last, August 1. At the Casement pasture three counts were made as follows: April 10, May 15, and July 1. Counts were not made on the medium spring and late spring-burned plots at the time of the first charting, owing to the fact that the late spring-burned plot

had not been burned at this time and the medium spring-burned plot would have been burned so recently that it would not have contained any vegetative growth.

In making these population counts a frame having an inside measurement of one meter square was used. The frame was divided into 400 equal subdivisions by cross wires. These were grouped into 16 major divisions, which were very helpful in recording the data in the field. The frame is shown in figure 5.

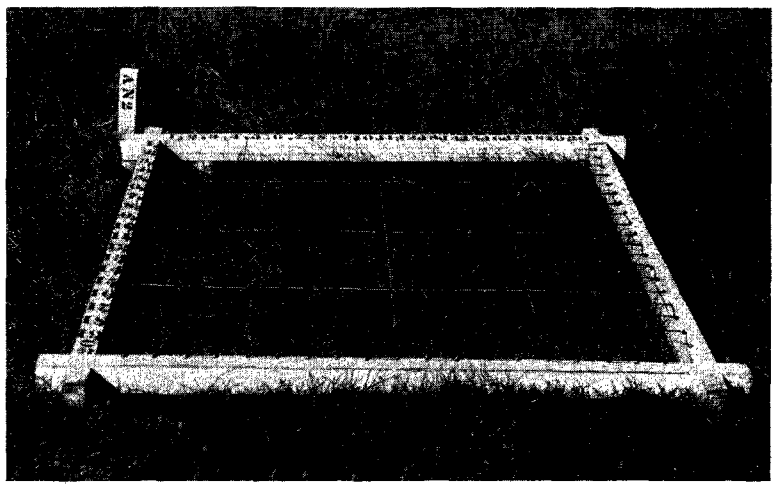

FIG. 5.—Charting frame for making counts of vegetation.

In recording the plant population one person counted the vegetation while the second recorded the data on a sheer having the same number of subdivisions as the counting frame. In the April and May counts, the plant population was recorded as grasses, weeds, and sedges. In the later counts the species of the entire plant population were determined and recorded. The species of the plants were recorded by symbols which had been devised for each plant growing in the experimental areas.

In making the plant population determinations the stems of the grasses, sedges, and weeds were counted and used as the unit of measurement in making comparisons on the effect of the burning treatments. In this publication number of plants is used synonymously with number of plant stems.

The study of the effect of burning on controlling brush was conducted on two separate areas, one for buckbrush *(Symphoricarpos)* and another for sumac *(Rhus glabra)*. These are the most common shrubs in the Kansas bluestem pastures.

Weeds.—The investigations of the effect of burning in weed control show in general that burning is not effective in controlling weeds unless it is done in the late spring. At the Casement pasture the yields of weeds at the close of the season were greatest on the plots burned in the fall, followed by the plots burned in the medium spring. The early spring-burned plots had about 14 per cent less weeds than those burned in the medium spring, and the unburned plot about 8 per cent less than the plot burned in the early spring. The late sring-burned plot had a very small percentage of weeds. The weeds growing

on the plots at the close of the season included nearly all of the noxious ones found on Kansas bluestem pastures. The mean percentages of weeds in the total yield of vegetation at the Casement pasture for seven years, 1927 to 1933, were as follows:

Time of burning	*Mean percentage of weeds*
Early spring	13
Medium spring	14
Late spring	2
Fall	19
Check (unburned)	8

At the college pasture the mean for six years, 1928 to 1933, shows that the fall- and early spring-burned plots have about the same amount of weeds. The unburned plot was third, the medium spring, fourth, and the late spring, last, having a very small amount. The mean percentages of weeds in the total yield of vegetation in the plots at the college pasture were as follows:

Time of burning	*Mean percentage of weeds*
Early spring	6.0
Medium spring	4.0
Late spring	1.6
Fall	6.0
Check (unburned)	4.0

There is a close correlation between the quantity of weeds and the burning treatment, when the amount of weeds is considered in terms of the percentage of total yield of vegetation. The data on quantity of weeds obtained at the close of the season do not include some of the early-maturing weeds. One of the principal ones not included is wild alfalfa *(Psoralea tenuiflora),* which matures in July. The stems break off at the ground shortly after maturity and blow away.

The counts on the quadrats for each of the plots made earlier in the season are summarized in Table IV. For the six-year period the weeds made up a small percentage of the total plant population, which is as it should be in a normal stand of prairie grasses. At the Casement pasture the early spring-burned plots contained the greatest number of weeds in comparison to the total plant population. This was followed very closely by the fall-burned. The medium spring-burned was third, the check, fourth, and the late spring-burned, last. There was very little difference among the plots burned in the early spring, medium spring, and in the fall. The number of weeds in the late spring-burned plot was significantly less than in any of the others.

At the college pasture the fall-burned and unburned plots contained the greatest weed population in comparison to the total plant population, followed rather closely by the plots burned in the early spring and the medium spring. The number of weeds on the late-burned plot is significantly lower than any of the others. The unburned plots contain the greatest number of weeds at the April counting. This is due to the protection afforded by the dry grass during the winter and early spring, allowing some of the very early weeds to grow. These are eliminated in the early spring-burned plot and in the fall-burned plot by lack of winter protection. These early weeds are mainly early annuals that disappear by the time the May counts are made.

Buckbrush.—Buckbrush is one of the most common shrubs in Kansas bluestem pastures. It usually grows on the best soil along the streams. After becoming established it spreads rapidly, mainly by stems that grow along the ground, assuming a stoloniferous character of growth and taking root at fre-

TABLE IV.—MEAN TOTAL PLANT AND WEED POPULATIONS AND PERCENTAGE OF WEEDS IN TOTAL PLANT POPULATION FOR SIX YEARS, 1928 TO 1933, ON TWO METER-SQUARE QUADRATS IN THE CASEMENT PASTURE AND TWO IN THE COLLEGE PASTURE

TIME OF BURNING.	Approximate date of count.												Mean.		
	April 10.			May 15.			July 1.			August 1.					
	T. P.	T. W.	P.	T. P.	T. W.	P.	T. P.	T. W.	P.	T. P.	T. W.	P.	T. P.	T. W.	P.
Casement Pasture															
Early spring	2,792	193	6.9	4,781	284	5.9	4,315	283	6.6	.....	.....	.....	3,963	253	6.4
Medium spring	.....	.....	.....	3,600	198	5.5	3,295	219	6.6	.....	.....	.....	3,448	209	6.0
Late spring	.....	.....	.....	2,514	115	4.6	2,429	110	4.5	.....	.....	.....	2,472	113	4.6
Fall	2,783	248	8.9	5,143	328	6.4	4,654	320	6.9	.....	.....	.....	4,193	299	7.1
Check	1,221	144	11.8	3,283	222	6.8	3,011	172	5.7	.....	.....	.....	2,505	179	7.1
College Pasture															
Early spring	4,561	300	6.6	7,679	380	4.9	6,941	343	4.9	6,442	220	3.4	6,406	311	4.9
Medium spring	.....	.....	.....	6,554	258	3.9	6,203	287	4.6	5,670	157	2.8	6,142	234	3.8
Late spring	.....	.....	.....	5,277	71	1.3	5,673	109	1.9	5,190	24	.5	5,380	68	1.3
Fall	5,663	222	3.9	8,176	256	3.1	6,808	225	3.3	6,617	146	2.2	6,816	212	3.1
Check	3,350	230	6.9	7,035	256	3.6	6,057	214	3.5	5,839	95	1.6	5,570	199	3.6

T. P., total plant population; T. W., total weed population; P., percentage of total plants that are weeds.

quent intervals, thus establishing new plants at these places. Buckbrush is able to compete with the bluestem grasses and to increase on protected areas. Since this shrub is unpalatable to cattle, it is not affected by grazing except for slight injury from tramping. Investigations indicate that where buckbrush is well established in bluestem pastures some eradication measures will be necessary to kill it or prevent it from spreading. Because buckbrush is rather widely distributed in pastures, its eradication can be practical only by some method involving little expense. Burning affords a very cheap method, if it can be used effectively.

Experiments were started in 1926 at Casement pasture to determine the effect of burning on the eradication of buckbrush. An area containing a vigorous growth of buckbrush was selected. (Fig. 6.) The area, which was approximately 2 rods square, was fenced, and five plots were established. Treatments were as follows: (1) Burned in the late fall; (2) burned medium spring; (3) burned late spring; (4) unburned; and (5) protected until 1929 and then burned in the late spring. The data obtained in these experiments are recorded in Table V.

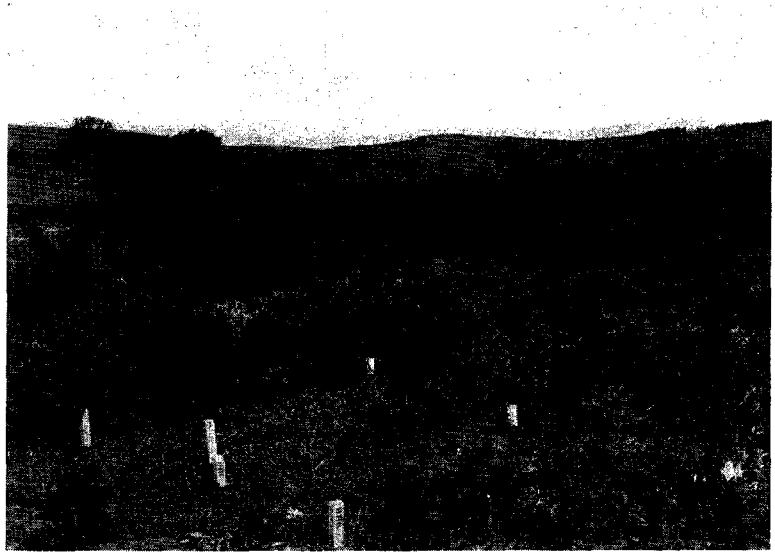

FIG. 6.—Buckbrush growing in a bluestem pasture.

These experiments show that the number of stems is not decreased by burning unless it is done in the late spring. The burning done in the fall and medium spring increased the number of stems, yet these stems were not so high nor so thick as those on the unburned plot. After the second burning they did not make enough top growth to shade the ground, allowing the bluestem grasses to increase in density where the buckbrush clumps had formerly been. It is doubtful whether burning annually in the fall, early spring, or medium spring would eliminate buckbrush. There are years when the amount of dead grass does not justify burning, consequently the buckbrush plant would build up its food reserves so that it could withstand burning in the other years.

TABLE V.—EFFECT OF BURNING IN ERADICATING BUCKBRUSH FROM BLUESTEM PASTURES

ITEMS IN DATA.	Time of burning.				
	Fall '27-'33.	Medium spring '27-'33.	Late spring '27-'33.	Check '27-'33.	Late spring '29-'33.
Number of stems, October, 1926	370	480	104	330	.....
Growth, 1927:					
Numbers of stems	2,147	1,607	84	334	.....
Average height of stems (inches)	24	20	8	33	.....
Growth, 1928:					
Numbers of stems	1,071	1,075	42	342	.....
Average height of stems (inches)	17	13	6	36	.....
Growth, 1929:					
Numbers of stems	905	1,303	22	443	398
Average height of stems (inches)	12	18	6	36	6
Growth, 1930:					
Numbers of stems	1,266	1,112	14	622	87
Average height of stems (inches)	13	15	7	36	6
Growth, 1932:					
Numbers of stems	802	669	38	863	100
Average height of stems (inches)	15	18	8	36	8
Growth, 1933:					
Numbers of stems	140	133	0	628	37
Average height of stems (inches)	12	12	0	34	6

Data were obtained in October of each year. Plots were not burned in 1931.

TABLE VI.—TOTAL STARCH AND SUGAR IN BUCKBRUSH ROOTS DURING THE GROWING SEASON

Mean for three years, 1928 to 1930, on percentage dry basis

DATE.	Percentage total starch and sugar on dry basis.
March 15	13.45
April 10	9.02
April 24	8.77
May 12	7.36
May 28	11.75
June 7	12.27
June 21	11.29
July 2	13.56
July 16	12.35
August 1	13.26
August 14	12.84
September 28	14.44
September 10	14.25
October 24	15.13
October 3	15 73

Burning in the late spring is effective in removing buckbrush (fig. 7) because it is done when the food reserves, total starch and sugars, in the plant are at a low point. This is shown in Table VI, which gives the analyses of buckbrush roots collected at two-week intervals throughout the season.

When the top growth is removed in late April or early May the food reserves are so low that the plant cannot put out new growth so quickly as it could have done two weeks earlier. The data on food reserves show that in the fall the plant would be little affected by burning. The medium spring burning, which is done about April 10, is at a time when there are enough reserves to permit the buckbrush readily to continue growth.

In the season after the first burning there was a noticeable increase in the

FIG. 7.—Eradication of buckbrush by burning. Opposite corner, unburned; right corner, late spring burned; left side, medium spring and fall burned.

number of stems on the plots burned in the fall and medium spring. The number of stems was reduced the second season, as the larger stems survived at the expense of the weaker ones. There was a gradual increase in the number of stems under protection up to 1933, when there was a decrease. This is possibly due to the second very dry season and to the high temperatures of June and late July and early August. These severe conditions undoubtedly would reduce the number of stems. The significant reduction in the number of stems in fall- and medium spring-burned plots may be attributed to the same cause.

Sumac.—Sumac is very common in many bluestem pastures, growing most frequently on the rocky ridges. (Fig. 8.) It spreads mainly by running roots that occur from 6 inches to a foot under the surface. Under favorable conditions one vigorous plant may spread a rod in a single season. In order to study the effect of burning on the control of sumac, six plots, 41 by 100 feet, were established in the early spring of 1929 in a heavy growth of sumac and burned approximately April 15, April 29, May 8, May 20, and May 28, with an unburned plot to serve as a check. The results of these burning experiments are recorded in Table VII.

TABLE VII.—EFFECT OF BURNING IN ERADICATING SUMAC FROM BLUESTEM PASTURES

ITEMS IN DATA.	Plot number and date burned.					
	No. 1 Apr. 15.	No. 2 May 8.	No. 3 May 20.	No. 4 May 28.	No. 5 check.	No. 6 Apr. 29.
Number of Stems:						
Before burning	512	486	158	80	439	651
1930	502	581	147	86	449	742
1931	267	246	62	32	330	735
1932	200	211	86	48	614	1,031
1933	735	330	50	44	546	867
Average Height of Stems (inches):						
1930	13	14	12	16	19	19
1931	15	15	15	15	22	21
1932	15	15	11	11	18	22
1933	21	22	16	16	15	16

Data were obtained about June 15 each year except 1933, when they were obtained August 15. All plots were burned in 1929 and plots 3 and 4 in 1930.

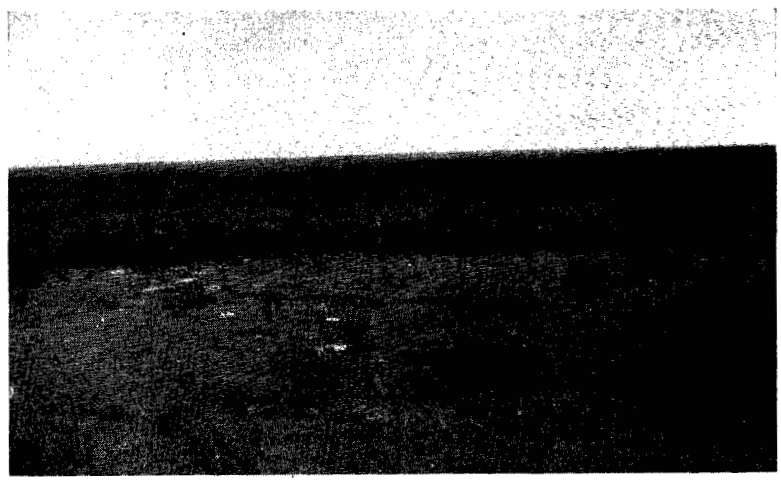

FIG. 8.—Sumac (beyond the fence) in an overgrazed bluestem pasture.

The data indicate that to decrease the vigor of sumac it is necessary to burn after the middle of May. Sumac is slow in starting growth in the spring. It is usually after the first of May before leaves are noticeable. The late date of starting delays the movement of the food reserves, as is shown by the data presented in Table VIII.

These data point out that the low point in the starch and sugar accumulated as food reserves is not reached until June 7. Therefore, to be effective burning must be done after the middle of May. This precludes the feasibility of using burning as a practical method of eradicating sumac because the bluestem grasses make too much early growth in an average year, even on protected plots, to make burning possible after the middle of May. The experimental burning done May 20 and May 28 necessitated the use of a kerosene burner to burn the plots properly.

TABLE VIII.—TOTAL STARCH AND SUGAR IN SUMAC ROOTS DURING THE GROWING SEASON

Mean for three years, 1928 to 1930, on percentage dry basis

DATE.	Percentage total starch and sugar on dry basis.
March 15	23.28
April 10	16.86
May 12	17.87
May 23	13.69
June 7	9.45
June 21	12.92
July 2	17.25
July 16	17.13
August 1	24.23
August 14	20.22
August 28	19.84
September 10	24.71
September 24	20.47

EFFECT OF BURNING ON THE QUALITY OF VEGETATION

In grazing a pasture that contains burned and unburned areas the livestock prefer to graze the areas that have been burned. This may be because the grass is more readily available on the burned area; or it may be more palatable, since it is more vigorous in the first part of the season. To obtain information on the differences in the quality of forage on the two areas, counts and measurements were made on June 14, 1927, of the number and size of the leaf blades in 25 average-sized big bluestem culms, and 25 average-sized little bluestem culms on the unburned and the early spring-burned plots in the Casement pasture. Table IX records the results.

These counts and measurements were made on carefully selected plants of big and of little bluestem from the early spring-burned and unburned plots. While the number of plants measured is not large the differences are very significant, as shown by the statistical analysis of these data. The probable error of the mean and the probable error of the difference show the differences in width and length of the leaves on the burned and unburned plots to be highly significant. The leaf blades on the burned plot are more numerous and wider than on the unburned plot. This is true for both species. The little bluestem on the burned plots averaged 64 per cent greater leaf area per plant than on the unburned plot, and the big bluestem plants on the burned area had an average of 23 per cent greater leaf area than on the unburned area. These comparisons show the grass on the burned areas to be more leafy and, therefore, probably more palatable. This would be particularly true in a wet year, such as 1927, when conditions were favorable to pasture grasses.

Representative samples were collected on June 4, 1932 from the college-pasture plots burned annually, for chemical analyses of their nutritive materials. Each of the samples was a composite of a small amount of grass collected in six different parts of the plot. The samples are believed to be representative of the total vegetative covering. The data on chemical composition of these plants are presented in Table X.

TABLE IX.—AVERAGE NUMBER AND SIZE OF LEAF BLADES IN 25 AVERAGE CULMS OF LITTLE BLUESTEM AND 25 AVERAGE CULMS OF BIG BLUESTEM ON BOTH EARLY SPRING-BURNED AND UNBURNED PLOTS IN THE CASEMENT PASTURE, JUNE 14, 1927

BLUESTEMS.	Unburned plots.			Early spring-burned plots.		
	Average number of blades.	Average width of blade.	Average length of blade.	Average number of blades.	Average width of blade.	Average length of blade.
Little bluestem	4.6	*Mm.* 2.644 ± .0823	*Mm.* 144.36 ± .336	5.2	*Mm.* 3.5 ± .082 P. E. diff. .03667	*Mm.* 123.5 ± .2694 P. E. diff. .431
Area of average plant			*Sc. mm.* 1,660.14			*Sc. mm.* 2,247.70
Diff. in area of average plant						587.56
Big bluestem	5.8	6.5 ± .028	229.22 ± .7949	6.5	7.252 ± .081 P. E. diff. .038	229.34 ± .619 P. E. diff. .3201
Area of average plant			8,792.39			11,129.49
Diff. in area of average plant						2,337.10

The grass collected on the burned plots had a higher moisture content than that from the unburned plot. The grass on the plots burned in the late spring was younger than on the other plots, which accounts for its high moisture content. The crude protein content of the grass from the various plots is negatively correlated with the amount of growth. The samples from the plots burned in early spring and fall had the lowest protein content where the grass had made the greatest growth. The vegetation on these plots being a little more mature would naturally have a lower protein content. The grass on the plot burned in medium spring was next in growth and ranks third in protein content. The grass from the unburned plot had made a little less growth than the grass in the medium spring-burned plot and the protein content was accordingly a little higher. The grass in the later spring-burned plot had highest protein content. This can be attributed to its being much younger, having made its growth since May 5, when the plot was burned.

TABLE X.—ANALYSES OF GRASSES FROM BURNED AND FROM UNBURNED PLOTS

Collected from college pasture June 4, 1932

TIME OF BURNING.	Percentage on dry basis.					
	Moisture.	Crude protein.	Ether extract.	Crude fiber.	Ash.	N-free extract.
Early spring	66.59	8.50	2.30	30.78	6.98	51.44
Medium spring	68.13	9.31	2.05	30.88	6.57	51.19
Late Spring	71.66	12.37	2.14	31.68	7.84	45.97
Fall	66.15	8.96	2.67	30 00	6.37	52.00
Unburned (check)	65.48	10.53	2.41	31.31	7.81	47.88

These chemical analyses show that the grass on the burned plot is more lush, in all probability making it more palatable. This, combined with the fact that the stock can more readily graze it than the unburned area: accounts for burned land being more readily grazed during the first part of the grazing season.

EFFECT OF BURNING ON SOIL MOISTURE

Soil moisture determinations were made at irregular intervals, but sufficient samples were taken to indicate the differences in soil moisture that may result from the burning treatments.

During 1928, at the college pasture, soil samples were taken for moisture determinations at monthly intervals at 1 to 12, 12 to 24, and 24 to 36 inches. Three sets of soil samples were also taken at the same depths during 1933, which was the driest and probably the hottest season since the experiments were started. The 1933 drought was unusually serious because 1932 also was abnormally dry and hot, hence there was a deficiency in soil moisture from the previous year. The data on soil moisture obtained in 1928 at the college pasture are recorded in Table XI. The samples were taken with the standard soil tube; six samples were taken at the three depths on each plot at each sampling. The samples were weighed and placed in an oven heated to 102° C. for **24** hours, when the dry weights were obtained and the moisture content determined by the usual method.

In 1933, moisture determinations were made June 14, August 19, and November 8, on the unburned plots and on the four plots burned annually. The moisture percentages of these samples are shown in Table XII. The moisture equivalent determinations were made by the Briggs and Shanta methods from the soil samples obtained November 8. The wilting coefficient was obtained by using the Briggs and Shantz formula,

$$\frac{\text{moisture equivalent}}{1.84\pm\ ,013} = \text{wilting coefficient.}$$

TABLE XI.—SOIL MOISTURE DETERMINATIONS—DATA SHOWING THE EFFECT OF BURNING ON SOIL MOISTURE

College pasture, 1928

TIME OF BURNING. Depth of sample (inches).	Dates of taking samples and percentages of moisture.					
	Mar. 23.	Apr. 24.	May 17.	June 2.	Sept. 6.	Average.
Fall, December 5:						
0-12	24.65	26.60	24.60	13.10	21.65	21.10
12-24	20.85	25.10	22.00	18.20	20.92	21.41
24-36	14.65	21.00	18.60	18.70	16.28	17.84
Average	20.05	24.20	21.70	16.66	19.62	20.40
Unburned:						
0-12	29.50	28.10	26.40	16.10	19.48	23.91
12-24	23.15	27.00	23.10	21.30	20.48	23.00
24-36	20.00	24.80	21.30	20.00	19.33	21.08
Average	24.20	26.60	23.60	19.10	19.78	22.65
Early spring, March 19:						
0-12	27.70	28.20	23.20	13.70	20.33	22.62
12-24	24.20	27.20	23.20	19.90	18.91	22.68
24-36	18.85	24.00	22.20	19.80	16.96	20.35
Average	23.60	26.50	22.90	17.80	18.73	21.90
Medium spring, April 14:						
0-12	.....	25.80	25.00	14.40	17.78	20.74
12-24	.....	23.30	23.90	19.90	17.92	21.25
24-36	.....	21.10	21.30	19.00	16.55	16.99
Average	.....	23.40	23.40	17.77	17.42	20.49
Late spring, May 5:						
0-12	.....	.....	27.80	16.80	19.615	21.40
12-24	.....	.....	23.90	21.60	19.90	21.80
24-36	.....	.....	23.30	18.60	19.615	20.50
Average	.....	.....	25.03	19.00	19.71	21.05

Discussion.—The moisture samples taken in 1928 do not show any deficiency in moisture with the exception of the surface foot from the fall-burned plot, June 2. This season was a favorable one, the annual precipitation was above normal and was fairly well distributed to promote vigorous vegetative growth. The unburned plot had the highest soil moisture content. As an average of the five sets of samples taken in 1928 the check was 3 per cent above the early spring burned, 7 per cent above the late spring, 10 per cent above the medium spring, and 11 per cent above the plot burned in the fall.

The soil samples taken June 14, 1933, show that the moisture content was getting close to the critical amount required for the growth of the grass, particularly in the fall-burned plot, which had the least amount. There was a little burning on the ends of the leaves in this plot. At this date the unburned plot had the highest moisture content, 11 per cent above the late spring, 23 per cent above the medium spring, 31 per cent higher than the fall burned, and 32 per cent above the plot burned in the early spring.

The moisture content of soil samples taken on August 19 was very low. The lack of adequate soil moisture was accompanied by abnormally high temperatures. As a result there was considerable firing and drooping of the leaves. This appeared to be greatest in the fall-burned plots and least in the late spring-burned plots. The unburned plot, however, showed scarcely any firing. The mean of the moisture in the three depths to which the soil samples were taken shows the unburned to have 14 per cent more moisture than the plots burned in the late spring and in the fall, 17 per cent more than the plot burned in the medium spring, and 20 per cent more than the plot burned in the early spring.

TABLE XII.—SOIL MOISTURE DETERMINATIONS—DATA SHOWING THE EFFECT OF BURNING ON SOIL MOISTURE

College pasture, 1933

TIME OF BURNING. Depth of sample (inches).	Dates of taking samples and percentage of moisture. June 14.	Aug. 19.	Nov. 8.	Mean.	Moisture equivalent.	Wilting coefficient.
Late fall, January 2:						
0-12	14.03	11.51	17.07	14.20	26.5	14.4
12-24	13.17	12.88	16.00	14.02	25.0	13.5
24-36	13.05	12.05	13.05	12.72	25.0	13.5
Average	13.42	12.15	15.37	13.65	25.5	.....
Unburned:						
0-12	14.60	13.26	21.44	16.43	25.8	14.0
12-24	18.55	14.51	18.52	17.29	25.0	13.5
24-36	19.72	13.84	16.86	16.81	25.0	13.5
Average	17.62	13.87	19.04	16.84	25.3	.....
Early spring, March 11:						
0-12	11.51	10.65	16.24	12.80	23.2	12.6
12-24	14.02	12.35	14.61	13.66	22.4	12.1
24-36	14.35	12.24	12.68	13.09	22.0	12.1
Average	13.29	11.75	14.51	13.18	22.5	.....
Medium spring, April 19:						
0-12	12.57	10.71	16.68	13.32	23.1	12.5
12-24	14.85	12.46	14.22	12.84	26.1	14.1
24-36	15.72	12.28	12.91	13.63	26.5	14.4
Average	14.38	11.82	14.60	13.50	25.2	.....
Late spring, May 9:						
0-12	13.11	12.10	17.28	14.16	23.4	12.7
12-24	16.89	12.46	15.23	14.86	25.0	13.5
24-36	17.34	11.78	13.19	14.10	25.4	13.8
Average	15.78	12.11	15.23	14.37	24.6	.....

The moisture content of soil samples obtained November 8 had increased 3 to 8 per cent, the increase being mainly in the first 2 feet. The third foot in the plots burned in the early spring, fall, and medium spring had very little more moisture than in August. The unburned plot and the late spring-burned plot had significant increases in soil moisture. The higher moisture content of the unburned plot throughout the very dry season of 1933 explains to a large measure its higher yield during this dry season.

EFFECT OF BURNING ON THE COMPOSITION AND SUCCESSION OF THE VEGETATION

In order to study the effect of the different burning treatments on the growing vegetation, two permanent square meter quadrats were established on each of the experimental plots. These were charted three times annually at the Casement pasture and four times annually at the college pasture. In these

chartings a count was made of the entire vegetative population. In the first and second chartings, the vegetation was recorded in three classes—grasses, weeds, and sedges. In the third and fourth a determination was made of all the species of vegetation growing in the quadrats. This detailed classification was made to study the effect of burning on each of the more important species. The methods used in charting these quadrats have been described previously.

Data from three chartings at the Casement pasture and from charting in the college pasture, showing the effects of burning at different dates on the grasses, weeds, and sedges, are recorded in Table XIII.

Perhaps the most significant feature of these results is the fact that the plots burned in the fall contained the greatest plant population in a majority of the chartings. The number was much greater in the Casement pasture than in the college pasture. Based on the mean for the three periods when the chartings were made, the fall- and early spring-burned plots had about the same number of plants for the April charting, while the fall-burned plots had the greatest number for the other two chartings. In the college pasture there were only six of the 22 chartings in which the plant poulation of the early spring-burned plots exceeeded that of the plots burned in the fall.

The effect of burning on the number of plants at different times during the season is shown graphically in figure 9, which is an average of counts made during six years in the two experimental areas.

TABLE XIII.—EFFECT OF BURNING ON THE GRASSES, WEEDS, AND SEDGES, 1928 TO 1933, SHOWING PLANTS PER TWO SQUARE METERS

TIME OF BURNING. Plants.	Number of plants per two square meters—on dates of charting as indicated. 1928.	1929.	1930.	1931.	1932.	1933.	Mean.
Casement Pasture							
	April 16.	April 13.	April 14-15.	April 12.	April 22.	April 13.	
Fall Burned:							
Grasses	290	2,424	2,049	978	4,456	2,823	2,080
Weeds	197	461	354	136	193	145	248
Sedges	311	507	471	450	505	489	455
Totals	798	3,392	2,874	1,564	5,154	2,917	2,783
Check:							
Grasses	313	773	802	232	943	306	562
Weeds	162	235	213	78	133	47	144
Sedges	347	518	643	502	639	440	515
Totals	822	1,526	1,658	812	1,715	793	1,221
Early spring burned:							
Grasses	466	2,503	3,126	863	4,099	3,061	2,353
Weeds	197	240	226	118	193	182	193
Sedges	196	193	224	253	309	303	246
Totals	859	2,936	3,576	1,234	4,601	3,546	2,792
	May 16.	May 28-30.	May 28-29.	May 25-26.	June 6.	May 23.	
Fall burned:							
Grasses	2,128	4,987	3,522	4,518	5,053	5,979	4,364
Weeds	393	460	405	257	213	240	328
Sedges	355	408	458	520	485	479	451
Totals	2,876	5,855	4,385	5,295	5,751	6,698	5,143
Check:							
Grasses	1,656	2,811	2,098	1,941	2,969	3,557	2,505
Weeds	422	342	180	112	158	116	222
Sedges	428	446	600	685	498	679	556
Totals	2,506	3,599	2,878	2,738	3,625	4,352	3,283
Early spring burned:							
Grasses	2,887	4,618	4,103	4,022	4,239	5,726	4,266
Weeds	340	380	257	238	217	276	284
Sedges	164	157	219	246	288	311	231
Totals	3,391	5,155	4,579	4,506	4,744	6,313	4,781
Medium spring burned:							
Grasses	2,270	3,388	2,542	2,969	3,098	3,494	2,960
Weeds	393	400	217	132	128	123	232
Sedges	293	397	359	411	489	498	408
Totals	2,956	4,185	3,118	3,512	3,715	4,115	3,600
Late spring burned:							
Grasses	1,735	3,003	1,812	2,473	2,268	2,429	2,287
Weeds	246	278	78	38	35	16	115
Sedges	122	154	131	115	90	62	112
Totals	2,103	3,435	2,021	2,626	2,393	2,507	2,514

TABLE XIII—*Continued*

TIME OF BURNING. Plants.	Number of plants per two square meters—on dates of charting as indicated. 1928.	1929.	1930.	1931.	1932.	1933.	Mean.
Casement Pasture							
	July 4.	June 28-July 3.	June 30-July 1.	June 25-July 7.	July 1-6.	June 21-22	
Fall burned:							
Grasses	2,733	3,408	3,505	4,803	4,503	4,144	3,849
Weeds	307	454	414	289	225	228	320
Sedges	348	500	518	613	506	424	485
Totals	3,388	4,362	4,437	5,705	5,234	4,796	4,654
Check:							
Grasses	1,929	2,245	1,937	2,348	2,558	2,673	2,282
Weeds	327	223	183	114	97	88	172
Sedges	347	545	593	655	605	596	557
Totals	2,603	3,013	2,713	3,117	3,260	3,357	3,011
Early spring burned:							
Grasses	3,083	3,438	3,802	3,941	4,272	4,128	3,778
Weeds	340	362	266	245	248	244	283
Sedges	147	249	238	278	321	291	254
Totals	3,570	4,049	4,306	4,464	4,841	4,663	4,315
Medium spring burned:							
Grasses	2,711	2,340	2,668	2,772	2,776	2,866	2,688
Weeds	481	279	207	131	110	104	219
Sedges	237	315	376	409	502	488	388
Totals	3,429	2,934	3,251	3,312	3,388	3,458	3,295
Late spring burned:							
Grasses	2,061	2,461	1,950	2,514	2,148	2,047	2,197
Weeds	213	223	103	55	39	28	110
Sedges	120	190	135	126	84	78	122
Totals	2,394	2,874	2,188	2,695	2,271	2,153	2,429
College Pasture							
	April 9.	April 6-8.	April 11-12.	April 11.	April 16-18.	April 11.	
Fall Burned:							
Grasses	3,865	4,546	4,708	4,860	7,053	6,104	5,189
Weeds	468	216	163	168	173	142	222
Sedges	147	171	205	292	360	336	252
Totals	4,480	4,933	5,076	5,320	7,586	6,582	5,663
Check:							
Grasses	3,886	2,211	3,759	2,419	3,306	2,676	3,058
Weeds	734	100	114	109	221	103	230
Sedges	52	34	62	107	82	34	62
Totals	4,672	2,345	3,935	2,635	3,699	2,813	3,350
Early spring burned:							
Grasses	2,470	2,826	5,020	2,359	6,904	4,546	4,041
Weeds	855	186	164	107	247	244	300
Sedges	128	146	196	238	301	374	230
Totals	3,453	3,158	5,380	2,704	7,512	5,164	4,561

TABLE XIII—*Continued*

TIME OF BURNING. / Plants.	Number of plants per two square meters—on dates of charting as indicated. 1928.	1929.	1930.	1931.	1932.	1933.	Mean.
College Pasture							
	May 12-18.	May 16-23.	May 14-20.	May 16-19.	May 27-June 1.	May 18-20.	
Fall burned:							
Grasses	4,637	7,756	7,995	9,253	7,600	8,903	7,691
Weeds	616	230	224	171	145	153	256
Sedges	179	172	221	214	273	315	229
Totals	5,432	8,158	8,440	9,638	8,018	9,371	8,176
Check:							
Grasses	4,571	8,115	6,565	6,702	7,492	6,781	6,704
Weeds	755	190	110	130	171	180	256
Sedges	53	93	73	99	52	77	75
Totals	5,379	8,398	6,748	6,934	7,715	7,038	7,035
Early spring burned:							
Grasses	4,640	7,029	7,546	6,958	7,771	8,551	7,083
Weeds	766	350	305	266	322	292	380
Sedges	105	134	193	213	279	375	216
Totals	5,511	7,493	8,044	7,437	8,372	9,218	7,679
Medium spring burned:							
Grasses	3,997	6,137	5,525	7,764	6,451	6,453	6,055
Weeds	640	184	202	167	217	140	258
Sedges	107	163	251	280	315	337	242
Totals	4,744	6,484	5,978	8,211	6,983	6,930	6,555
Late spring burned:							
Grasses	3,572	4,419	4,923	6,994	5,986	5,102	5,166
Weeds	213	74	38	20	16	5	71
Sedges	58	25	52	66	56	43	50
Totals	3,843	4,518	5,013	7,080	6,058	5,150	5,277
	June 27-July 1.	July 1-13.	June 25-July 3.	June 26-July 1.	June 27-30.	June 16-20.	
Fall burned:							
Grasses	4,367	5,762	6,316	7,840	7,310	6,333	6,321
Weeds	463	248	176	176	157	129	225
Sedges	202	195	248	268	315	340	261
Totals	5,032	6,205	6,740	8,284	7,782	6,802	6,807
Check:							
Grasses	3,907	5,853	6,162	6,839	6,619	5,112	5,749
Weeds	555	173	139	152	132	132	214
Sedges	62	111	126	95	92	76	94
Totals	4,524	6,137	6,427	7,086	6,843	5,320	6,057
Early spring burned:							
Grasses	4,892	5,645	6,246	6,671	7,480	7,228	6,360
Weeds	628	282	358	298	313	177	343
Sedges	122	215	224	232	295	339	288
Totals	5,642	6,142	6,828	7,201	8,088	7,744	6,941
Medium spring burned:							
Grasses	3,902	5,323	5,802	6,524	6,108	6,122	5,630
Weeds	728	221	210	210	207	151	288
Sedges	163	265	292	309	352	329	285
Totals	4,793	5,809	6,304	7,043	6,667	6,602	6,203
Late spring burned:							
Grasses	4,291	5,229	5,463	6,609	5,966	5,310	5,478
Weeds	380	146	54	35	31	6	109
Sedges	110	119	80	77	74	58	86
Totals	4,781	5,494	5,597	6,721	6,071	5,374	5,673

TABLE XIII—*Concluded*

TIME OF BURNING. Plants.	Number of plants per two square meters—on dates of charting as indicated. 1928.	1929.	1930.	1931.	1932.	1933.	Mean.
College Pasture							
			July 30-Aug. 5.	Aug. 5-7.	Aug. 1-4.	Aug. 5-9.	
Fall burned:							
Grasses			6,384	6,844	5,871	5,724	6,206
Weeds			182	176	125	100	146
Sedges			197	252	275	335	265
Totals			6,763	7,272	6,271	6,159	6,617
Check:							
Grasses			5,588	5,834	5,610	5,595	5,657
Weeds			100	93	81	106	95
Sedges			117	103	61	69	87
Totals			5,805	6,030	5,752	5,770	5,839
Early spring burned:							
Grasses			5,298	5,799	6,258	6,650	6,001
Weeds			294	253	224	110	220
Sedges			240	182	222	239	221
Totals			5,832	6,234	6,704	6,999	6,442
Medium spring burned:							
Grasses			5,049	5,404	5,174	5,417	5,261
Weeds			171	160	180	116	157
Sedges			261	232	272	245	252
Totals			5,481	5,796	5,626	5,778	5,670
Late spring burned:							
Grasses			4,918	5,306	4,999	5,172	5,099
Weeds			47	28	18	3	24
Sedges			86	47	80	55	67
Totals			5,051	5,381	5,097	5,230	5,190

The plots burned in the early spring contained the second largest number of plants, using the mean of all chartings in each experimental area. In the Casement area the plots burned in the medium spring ranked third in number of plants for the second and third chartings, having an average of 10 to 15 per cent more plants than the unburned plots. The unburned plot was fourth in number at the Casement pasture and the late spring-burned plot last. At the college pasture the unburned plot ranked third in plant population, except for chartings made in late June, when the average for the four chartings gave the plots burned in the medium spring a few more plants. The plots burned in the medium spring were fourth, with the exception stated above. The plots burned in the late spring contained the least number of plants.

The comparative total plant populations stated in percentages above or below the check plots are shown in Table XIV. In these tables the number of plants on the check plot is stated as 100 per cent.

The number of grassses on the quadrats ranks approximately the same as the total plant population. At the Casement pasture the number is greatest in the early spring-burned plots at the April charting, and in the fall-burned plot for the second and third chartings. The unburned plot ranks third, the plots burned in medium spring rank fourth, and the late spring-burned plots rank fifth.

At the college pasture the plots burned in the late fall had the greatest grass population, based on an average for all chartings at the four periods.

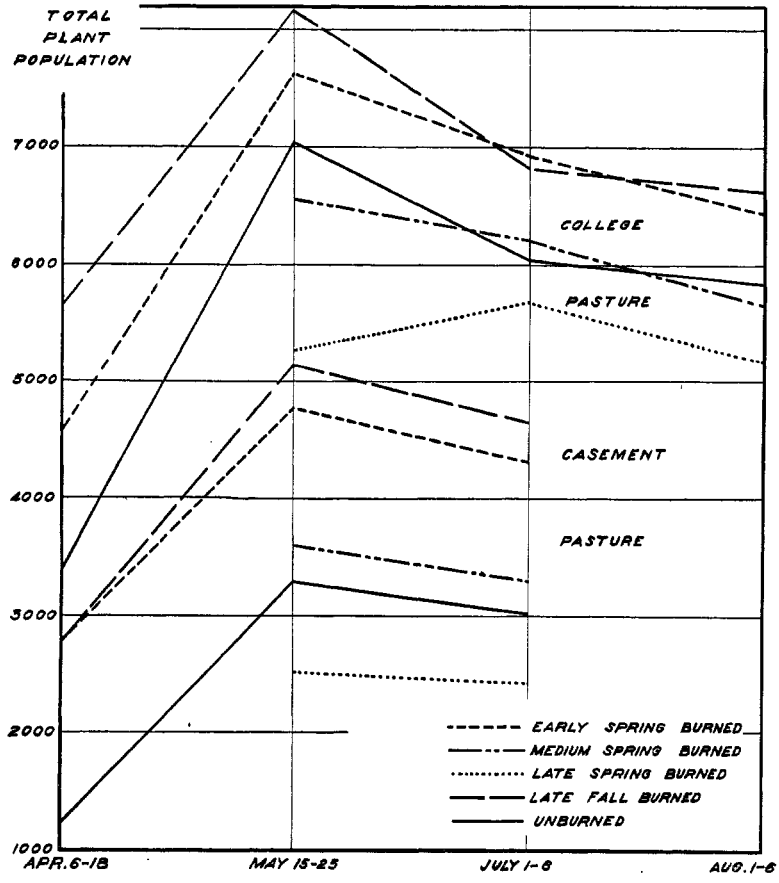

FIG. 9.—Graphs showing the effect of time of burning on total number of plants per two square meters in both the Casement and the college pastures. Averages for six years.

TABLE XIV.—EFFECT OF BURNING ON TOTAL PLANT POPULATION, 1928 TO 1933

Figures give percentages of number of plants on unburned plot

TIME OF BURNING.	Percentage of unburned plot on various dates of charting.						
	1928.	1929.	1930.	1931.	1932.	1933.	Mean.
Casement Pasture							
	Apr. 16.	Apr. 13.	Apr. 14.	Apr. 12.	Apr. 22.	Apr. 13	
Early spring	104	193	215	152	268	447	228
Fall	98	222	173	192	300	367	228
	May 16.	May 29.	May 28.	May 25.	June 6.	May 23.	
Early spring	135	143	158	169	130	145	148
Medium spring	117	116	108	127	102	94	115
Late spring	83	95	73	95	65	58	72
Fall	114	162	152	193	158	156	157
	July 4.	July 1.	July 1.	July 1.	July 4.	June 21.	
Early spring	145	135	158	144	148	138	144
Medium spring	135	97	118	106	104	102	110
Late spring	97	95	81	86	69	64	82
Fall	157	145	163	180	160	142	152
College Pasture							
	April 9.	April 6-8.	April 11-12.	April 11.	April 16-18.	April 11.	
Early spring	74	134	136	102	205	183	136
Fall	95	210	129	202	205	234	168
	May 12-18.	May 16-23.	May 14-20.	May 16-19.	May 27-31.	May 18-20.	
Early spring	102	88	119	107	108	130	109
Medium spring	88	77	89	118	90	98	93
Late spring	71	54	74	100	78	73	75
Fall	101	97	126	140	104	133	116
	June 27-July 1.	July 1-13.	June 25-July 3.	June 26-July 1.	June 27-30.	June 16-20.	
Early spring	125	100	106	101	117	145	114
Medium spring	106	91	99	100	97	124	102
Late spring	106	86	88	94	88	94	92
Fall	125	100	105	117	113	129	112
			Aug. 1-5.	Aug. 5-7.	Aug. 1-4.	Aug. 5-9.	
Early spring			100	103	117	121	110
Medium spring			94	96	97	100	97
Late spring			87	89	88	92	89
Fall			116	120	109	107	113

The early spring-burned plots were second, the unburned, third, the medium spring-burned, fourth, and the late spring-burned, fifth.

The total number of weeds and sedges comprised less than 10 per cent of the plant population on all the experimental plots. The proportion of weeds has been discussed previously, under the effect of burning on the quality of the vegetation. Summarizing this discussion it may be stated that in general the late fall-burned plots contained the greatest number of weeds and the plots burned in late spring the least.

The sedges, which were limited mainly to two species *(Carex meadii* and *Carex pennsylvanica),* were most abundant on the unburned plot at Casement pasture, the fall-burned ranking second, medium spring-burned, third, early spring-burned, fourth, and the plots burned in late spring, last. There was little difference in the number of plants growing in the unburned, late fall-burned, and medium and early spring-burned plots.

The unburned plots at the college pasture contained very few sedges, having only slightly more than the plots burned in the late spring. The number of sedges found on the plots burned in the late fall, early spring, and medium spring was approximately the same. Only late spring burning appeared to reduce the sedges below the check plot in the college pasture, whereas in the Casement pasture the sedges were lower in all burned plots than in the check plot, and ran considerably higher than in the unburned plot. No explanation can be offered for the differences in sedge population of the unburned plots in the Casement pasture and in the college pasture.

The burned plots in the college pasture contained only about one-half the number of sedges found on the plots receiving the same burning treatment at the Casement pasture. However, to begin with, there were approximately six times as many sedges in the Casement check plots as in the college check plots. This difference may be attributed to different habitats presented in the two areas. The college pasture area is typically upland and perhaps a little drier and therefore less favorable to these two sedges.

EFFECT OF BURNING ON PLANT SUCCESSION

The determination of the effect of burning on the succession or changes made in species of vegetation was made at the third charting in the two pastures. This charting was made the latter part of June or the first of July of each year. An additional charting was made in the college pasture the latter part of July and early August, when similar data were obtained. In these chartings the number and species of plants were determined on the two meter square quadrats located on each of the five experimental burning plots. These data are presented in Tables XV and XVI.

Perhaps the most significant feature of the effect of burning on plant succession is the fact that the greatest increase in the plant population was found on the plots burned in the late fall. On the other hand the plots burned in the late spring contained the smallest number of plants. The greater plant population of the late fall-burned plots came mainly from an increase in the number of *Andropogon scoparius* plants.

The effect of burning on the more important species of vegetation will be analyzed for each of the five experimental plots on each of the pastures.

TABLE XV.—EFFECT OF BURNING ON SUCCESSION OF VEGETATION, LATE JUNE AND EARLY JULY, 1928 TO 1933

Total number of plants

SPECIES.	1928.	1929.	1930.	1931.	1932.	1933.	Mean.
Casement Pasture							
FALL BURNED:							
A*	642	692	496	581	539	528	579
B	1,136	1,721	2,034	2,847	2,622	2,463	2,137
C	59	102	112	162	169	139	148
D	102	101	262	340	348	312	244
E	767	734	561	817	780	648	718
F	27	50	40	53	39	37	41
G	0	0	0	0	0	0	0
H	0	7	0	3	0	3	3
I and J	0	1	0	0	0	14	3
K	0	0	0	0	7	0	1
L	36	74	5	0	3	11	22
M	199	155	146	125	89	85	133
N	0	35	25	13	9	8	15
O	0	0	0	0	0	0	0
P	0	111	154	82	73	86	84
Q	3	2	0	0	2	2	2
R	14	15	22	0	17	7	13
S	42	54	54	42	23	24	40
Other weeds	13	8	8	27	9	5	12
T	348	500	518	613	506	424	485
Grasses	2,733	3,408	3,505	4,803	4,503	4,144	3,849
Weeds	307	454	414	289	225	228	320
Sedges	348	500	518	613	506	424	485
Totals	3,388	4,362	4,437	5,705	5,234	4,796	4,654
CHECK:							
A	1,267	1,347	1,077	870	(a)	1,273	1,167
B	366	437	403	851	.....	718	555
C	120	119	104	149	.....	198	138
D	152	230	210	226	.....	369	237
E	0	1	10	19	.....	19	10
F	4	21	13	17	.....	17	14
G	20	78	120	216	.....	78	102
H	0	12	0	0	.....	0	2
I and J	0	0	0	0	.....	3	1
K	0	0	0	0	.....	0	0
L	135	91	13	3	.....	0	48
M	23	30	35	35	.....	32	31
N	1	7	8	3	.....	4	5
O	4	0	3	2	.....	0	2
P	0	4	2	0	.....	14	4
Q	68	0	38	17	.....	19	28
R	0	0	0	0	.....	0	0
S	0	0	1	0	.....	0	0
Other weeds	96	91	83	54	.....	19	69
T	347	545	593	655	.....	596	547
Grasses	1,929	2,245	1,937	2,348	.....	2,673	2,226
Weeds	327	223	183	114	.....	88	187
Sedges	347	545	593	655	.....	596	547
Totals	2,603	3,013	2,713	3,117	.....	3,357	2,960

TABLE XV—*Continued*

SPECIES.	1928.	1929.	1930.	1931.	1932.	1933.	Mean.
Casement Pasture							
EARLY SPRING BURNED:							
A	492	474	417	486	460	336	444
B	1,812	2,062	2,570	2,512	2,662	2,736	2,392
C	33	79	96	84	113	120	88
D	411	404	451	558	652	596	513
E	303	266	227	274	359	315	291
F	32	35	29	26	22	13	26
G	0	3	0	0	0	0	0
H	0	108	9	1	3	9	22
I and J	0	7	3	0	0	3	2
K	0	0	0	0	1	0	0
L	142	101	12	9	2	3	45
M	22	56	48	36	41	41	41
N	2	32	24	20	15	21	19
O	27	0	45	51	61	60	41
P	0	48	21	23	38	48	30
Q	70	52	44	41	43	35	47
R	34	46	41	43	26	16	34
S	1	2	2	2	0	0	1
Other weeds	33	25	29	20	22	20	25
T	147	249	238	278	321	291	254
Grasses	3,083	3,438	3,802	3,941	4,272	4,128	3,778
Weeds	340	362	266	245	248	244	283
Sedges	147	249	238	278	321	291	254
Totals	3,570	4,049	4,306	4,464	4,841	4,663	4,315
MEDIUM SPRING BURNED:							
A	1,531	1,136	1,271	1,217	1,320	1,160	1,273
B	981	872	973	1,119	1,002	1,244	1,032
C	19	44	58	55	54	64	49
D	102	169	296	300	344	376	265
E	76	65	0	5	45	16	35
F	2	6	8	4	4	4	5
G	0	4	0	0	7	0	2
H	0	31	62	72	0	0	27
I and J	0	13	0	0	0	0	2
K	0	0	0	0	0	2	0
L	86	38	7	4	3	1	23
M	311	158	151	82	54	60	136
N	2	15	15	13	6	5	9
O	0	0	0	1	0	0	0
P	0	2	1	2	1	0	1
Q	13	9	11	15	19	0	11
R	0	0	0	0	1	0	0
S	11	0	2	0	0	0	2
Other weeds	55	59	20	15	26	38	36
T	237	315	376	409	502	488	388
Grasses	2,711	2,340	2,668	2,772	2,776	2,866	2,688
Weeds	481	279	207	131	110	104	219
Sedges	237	315	376	409	502	488	388
Totals	3,429	2,934	3,251	3,312	3,388	3,458	3,295

TABLE XV—*Continued*

SPECIES.	1928.	1929.	1930.	1931.	1932.	1933.	Mean.
Casement Pasture							
LATE SPRING BURNED:							
A	741	848	609	785	756	746	747
B	533	524	485	726	440	420	525
C	108	189	120	175	190	145	155
D	331	401	381	534	485	538	445
E	281	305	206	184	176	126	213
F	47	93	24	22	19	10	36
G	0	0	0	0	0	0	0
H	0	96	125	88	82	62	75
I and J	0	4	0	0	0	0	1
K	0	1	0	0	0	0	0
L	29	40	1	0	0	0	12
M	149	108	52	9	4	2	54
N	0	4	5	6	5	5	4
O	5	0	5	2	2	0	2
P	0	9	0	0	0	0	1
Q	15	19	16	14	11	8	15
R	0	0	0	0	0	0	0
S	0	0	0	0	0	0	0
Other weeds	15	43	22	24	17	13	22
T	120	190	135	126	84	78	122
Grasses	2,061	2,461	1,950	2,514	2,148	2,047	2,197
Weeds	213	223	103	55	39	28	110
Sedges	120	190	135	126	84	78	122
Totals	2,394	2,874	2,188	2,695	2,271	2,153	2,429
College Pasture							
FALL BURNED:							
A	852	1,017	1,010	1,135	1,288	1,190	1,082
B	1,263	1,666	1,990	2,992	2,966	3,270	2,358
C	209	249	210	280	254	251	242
U	156	151	133	152	147	180	153
D	482	682	764	910	808	317	660
K	1,210	1,864	2,114	2,283	1,783	1,080	1,722
F	70	67	68	80	59	40	64
G	116	41	25	3	2	0	31
I and J	9	10	2	4	3	2	5
V	0	0	0	1	0	0	0
E	0	15	0	0	0	3	3
M	43	30	25	41	33	39	35
P	60	75	72	68	63	59	66
R	82	78	52	50	44	18	54
W	0	14	1	1	0	0	3
L	228	5	0	0	4	1	40
Q	0	0	0	0	0	0	0
N	9	33	19	12	7	6	14
Other weeds	42	13	5	3	6	6	13
T	202	195	248	268	315	340	261
Grasses	4,367	5,762	6,316	7,840	7,310	6,333	6,321
Weeds	463	248	176	176	157	129	225
Sedges	202	195	248	268	315	340	261
Totals	5,032	6,205	6,740	8,284	7,782	6,802	2,808

TABLE XV—*Continued*

SPECIES.	1928.	1929.	1930.	1931.	1932.	1933.	Mean.
College Pasture							
CHECK:							
A	515	888	600	568	566	167	551
B	1,438	2,313	2,779	3,178	3,089	2,862	2,610
C	619	647	570	621	542	456	576
U	3	1	0	1	12	0	3
D	325	418	521	616	560	478	486
K	619	1,084	1,052	992	627	181	759
F	41	50	44	64	39	25	44
G	309	379	534	767	1,152	855	666
I and J	22	4	3	0	1	56	14
V	16	0	44	1	0	0	10
E	0	69	15	31	31	32	30
M	131	107	86	84	56	73	89
P	4	4	7	13	22	7	9
R	5	6	4	7	4	1	5
W	0	2	1	5	5	0	2
L	366	7	0	3	0	36	69
O	0	0	0	3	7	2	2
N	9	23	15	20	2	1	12
Other weeds	43	24	26	17	36	12	26
T	62	111	126	95	92	76	94
Grasses	3,907	5,853	6,162	6,839	6,619	5,112	5,749
Weeds	558	173	139	152	132	132	214
Sedges	62	111	126	95	92	76	94
Totals	4,527	6,137	6,427	7,086	6,843	5,320	6,057
EARLY SPRING BURNED:							
A	880	982	1,161	1,229	1,323	1,448	1,170
B	1,499	1,781	2,325	2,788	3,565	3,841	2,633
C	201	281	321	346	428	404	330
U	19	15	0	0	0	0	6
D	674	860	618	582	774	679	698
K	1,296	1,402	1,469	1,340	1,002	482	1,165
F	167	179	219	228	214	160	195
G	109	72	38	20	18	23	46
I and J	36	0	0	0	0	0	6
V	2	0	3	0	0	0	1
E	2	73	92	138	156	191	109
M	28	30	75	80	92	88	66
P	96	83	75	68	41	27	65
R	39	50	73	72	86	49	61
W	0	4	7	10	10	1	5
L	305	11	1	1	4	0	54
O	0	0	0	3	8	1	2
N	69	85	106	58	47	2	61
Other weeds	91	19	21	6	25	9	29
T	122	215	224	232	295	339	238
Grasses	4,892	5,645	6,245	6,671	7,480	7,228	6,360
Weeds	628	282	358	298	313	177	343
Sedges	122	215	224	232	295	339	238
Totals	5,642	6,142	6,828	7,201	8,088	7,744	6,941

TABLE XV—*Concluded*

SPECIES.	1928.	1929.	1930.	1931.	1932.	1933.	Mean.
College Pasture							
MEDIUM SPRING BURNED:							
A	1,025	1,331	1,447	1,472	1,557	1,570	1,400
B	1,283	2,203	2,352	2,812	2,700	2,924	2,379
C	180	240	232	303	161	184	217
U	33	8	0	0	0	0	7
D	505	638	561	505	609	689	584
K	574	555	756	1,031	767	523	701
F	126	111	148	83	116	56	107
G	102	139	216	179	80	17	122
I and J	49	0	0	0	0	1	8
V	25	8	20	0	0	0	9
E	0	90	70	139	118	158	96
M	238	77	78	67	82	87	105
P	29	23	18	10	10	9	17
R	39	40	42	34	37	6	33
W	0	0	1	12	7	0	3
L	223	8	1	1	8	4	41
O	0	0	0	19	3	0	4
N	28	48	45	45	35	29	38
Other weeds	171	25	25	22	25	16	47
T	163	265	292	309	352	329	285
Grasses	3,902	5,323	5,802	6,524	6,108	6,122	5,630
Weeds	728	221	210	210	207	151	288
Sedges	163	265	292	309	352	329	285
Totals	4,793	5,809	6,304	7,043	6,667	6,602	6,303
LATE SPRING BURNED:							
A	905	1,101	1,005	1,334	1,513	1,743	1,266
B	1,342	1,936	1,863	2,308	2,035	1,920	1,901
C	136	191	169	195	445	325	243
U	0	0	0	0	0	0	0
D	542	639	674	801	758	820	706
K	1,058	1,052	1,571	1,818	1,068	447	1,169
F	89	84	46	40	43	25	55
G	186	185	115	102	104	11	117
I and J	8	0	0	0	0	20	4
V	25	0	20	0	0	0	8
E	0	41	0	11	0	0	9
M	138	80	21	6	5	0	42
P	22	15	6	7	0	0	8
R	10	4	1	1	1	0	3
W	0	0	0	1	1	0	0
L	129	9	1	1	0	0	24
O	0	0	0	1	5	1	1
N	11	32	20	13	7	3	14
Other weeds	70	6	5	3	12	2	17
T	110	119	80	77	74	58	86
Grasses	4,291	5,229	5,463	6,609	5,966	5,311	5,478
Weeds	380	146	54	33	31	6	109
Sedges	110	119	80	77	74	58	86
Totals	4,781	5,494	5,597	6,719	6,071	5,375	5,673

(*a*) Not charted in 1932.

KEY:

A—*Andropogon furcatus*
B—*Andropogon scoparius*
C—*Bouteloua curtipendula*
D—*Sorghastrum nutans*
E—*Sporobolus heterolepis*
F—*Panicum scribnerianum*
G—*Poa pratensis*
H—*Panicum virgatum*
I—*Sporobolus cryptandrus*
J—*Eragrostis pectinacea*
K—*Koeleria cristata*
L—*Ambrosia psilostachya*
M—*Aster multiflorus*
N—*Sisyrinchium campestre*
O—*Solidago rigida*
P—*Solidago glaberrima*
Q—*Asclepias verticillata*
R—*Antennaria campestris*
S—*Petalostemum purpureus*
T—*Carex*
U—*Bouteloua hirsuta*
V—*Panicum virgatum*
W—*Linum rigidum*

TABLE XVI.—EFFECT OF BURNING ON SUCCESSION OF VEGETATION, COLLEGE PASTURE, AUGUST 1, 1930, TO 1933

Total number of plants

SPECIES.	1930.	1931.	1932.	1933.	Mean.
FALL BURNED:					
A*	977	1,077	1,072	1,062	1,047
B	1,985	2,434	2,169	2,723	2,328
C	236	246	240	289	253
U	148	173	116	153	148
D	756	812	801	675	761
K	2,197	2,026	1,406	766	1,599
F	65	76	63	42	61
G	9	0	0	1	2
I and J	6	0	4	13	6
V	5	0	0	0	1
E	0	0	0	0	0
M	30	19	24	26	25
P	71	103	55	47	69
R	57	45	33	17	38
W	1	0	0	0	0
L	0	0	3	1	1
O	0	1	1	0	0
N	20	1	3	2	7
Other Weeds	3	8	6	7	6
T	197	252	275	335	265
Grasses	6,384	6,844	5,871	5,724	6,206
Weeds	182	176	125	100	146
Sedges	197	252	275	335	265
Totals	6,763	7,272	6,271	6,159	6,617
CHECK:					
A	469	550	420	211	412
B	2,561	2,573	2,532	3,266	2,733
C	589	577	539	596	563
U	0	1	0	0	0
D	485	579	680	523	567
K	954	825	445	122	587
F	18	51	35	33	34
G	501	658	930	734	706
I and J	0	0	1	82	21
V	52	0	0	0	13
E	9	20	28	28	21
M	64	54	39	58	54
P	5	9	11	6	8
R	2	4	4	1	3
W	0	1	0	0	0
L	0	1	0	27	7
O	1	0	6	0	2
N	9	6	4	1	5
Other weeds	19	18	17	13	16
T	117	103	61	69	87
Grasses	5,588	5,834	5,610	5,595	5,657
Weeds	100	93	81	106	95
Sedges	117	103	61	69	87
Totals	5,805	6,030	5,752	5,770	5,839

TABLE XVI—*Continued*

SPECIES.	1930.	1931.	1932.	1933.	Mean.
EARLY SPRING BURNED:					
A	983	1,213	1,107	1,190	1,123
B	1,848	2,218	2,788	3,734	2,647
C	254	351	393	490	372
U	0	1	0	0	0
D	638	542	718	542	610
K	1,303	1,104	907	363	919
F	191	2,246	202	143	195
G	17	7	12	7	11
I and J	0	0	1	6	2
V	4	0	0	0	1
E	60	117	130	175	121
M	61	48	68	57	58
P	67	45	24	5	35
R	69	89	70	36	66
W	3	6	8	0	5
L	1	6	5	0	3
O	0	0	9	0	2
N	84	33	28	1	36
Other weeds	9	26	12	11	15
T	240	182	222	239	221
Grasses	5,298	5,799	6,258	6,650	6,001
Weeds	294	253	224	110	220
Sedges	240	182	222	239	221
Totals	5,832	6,234	6,704	6,999	6,442
MEDIUM SPRING BURNED:					
A	1,221	1,250	1,245	1,322	1,260
B	2,037	2,080	2,240	2,666	2,256
C	233	283	201	210	232
U	0	6	0	0	0
D	513	414	603	572	526
K	644	910	633	490	669
F	103	189	91	47	108
G	221	148	62	4	109
I and J	0	0	0	6	1
V	24	0	0	0	6
E	53	124	95	100	93
M	62	56	78	74	68
P	15	5	7	6	8
R	28	40	26	5	25
W	1	1	3	0	1
L	1	2	7	3	3
O	0	6	2	0	2
N	43	18	28	12	25
Other weeds	21	32	29	16	25
T	261	232	272	245	252
Grasses	5,049	5,404	5,174	5,417	5,261
Weeds	171	160	180	116	157
Sedges	261	232	272	245	252
Totals	5,481	5,796	5,626	5,778	5,670

TABLE XVI—*Concluded*

SPECIES.	1930.	1931.	1932.	1933.	Mean.
LATE SPRING BURNED:					
A	954	1,096	1,238	1,604	1,223
B	1,595	1,793	1,664	1,924	1,744
C	179	175	199	224	195
U	0	0	0	0	0
D	690	656	767	899	753
K	1,324	1,426	1,011	466	1,057
F	40	43	34	16	33
G	111	110	77	6	76
I and J	0	0	0	28	7
V	25	0	0	0	6
E	0	7	9	5	5
M	12	7	1	0	5
P	6	1	4	0	3
R	1	2	1	0	1
W	0	0	0	0	0
L	0	1	1	0	0
O	1	2	0	0	1
N	26	6	5	2	10
Other weeds	1	9	6	1	4
T	86	47	80	55	67
Grasses	4,918	5,306	4,999	5,172	5,099
Weeds	47	28	18	3	24
Sedges	86	47	80	55	67
Totals	5,051	5,381	5,097	5,230	5,190

* KEY: For key see Table XV.

Casement Pasture

Fall-burned Plot.—On the fall-burned plot at Casement pasture the number of *Andropogon furcatus* has decreased about 17 per cent. *Andropogon scoparius,* the dominant species, has more than doubled in population. The number of plants of *Bouteloua curtipendula* has more than doubled, but the quantity was not large enough to have much significance. There was a slight increase in the *Sorghastrum nutans* and a slight decrease in *Sporobolus heterolepis.*

There were a few *Panicum scribnerianum* plants in the plot, which increased slightly. *Poa pratensis* has been eliminated from the plot. The weeds were few and have decreased in number. *Aster multiflorus, Solidago glaberrima,* and *Petalostemum purpureus* were the most abundant, except in 1933. The number of sedges increased a little. The decrease in 1933 was undoubtedly due to the dry, hot June of that year.

Unburned Plot.—The unburned plot at the Casement pasture has approximately 35 per cent less total vegetative population than the plot burned in the fall. Big bluestem *(Andropogon furcatus),* the dominant species, has about maintained its density in the six years. There are only about one-half as many *Andropogon scoparius* plants as big bluestem, but the number has almost doubled since 1928. There has been an increase in the population of *Bouteloua curtipendula* and *Sorghastrum nutans* and a decrease in *Sporobolus heterolepis.* The plants of *Panicum scribnerianum* are very scattered. Plants of Kentucky bluegrass have increased. Since this is the only plot in the Casement experimental area that contains any of this grass, and since this species is increasing on the unburned plot, we may conclude that burning is detrimental to its growth.

The weeds have decreased in number, the dominant ones being about the same species as on the fall-burned plot. They make up about 6 per cent of the total plant population in the unburned plot. The number of sedges has nearly doubled in the past five years. They averaged about 18 per cent of the total plant population for this period.

Early Spring-burned Plot.—The plant population of the early spring-burned plot increased about 33 per cent in six years. *Andropogon scoparius* is the dominant plant, comprising approximately 56 per cent of the total population. This species has increased about 50 per cent since 1928. *Andropogon furcatus* is only about one-fifth as abundant as the *A. scoparius*. *A. furcatus* has decreased about 30 per cent since the plots were first charted. *Sorghastrum nutans* is third in abundance, comprising about 12 per cent of the total population of the two quadrats. It has made little change in six years. About 8 per cent of the vegetative covering of the plot is *Sporobolus heterolepis,* which has shown little change from the burning in the early spring during the six years. There is a scattering of plants of *Bouteloua curtipendula,* but the number of plants has more than doubled since the plant counts were first made. There are also a few plants of *Panicum scribnerianum* and *Panicum virgatum,* both of which have decreased in number. There were three *Poa pratensis* plants recorded in the plot in 1929, but none has been recorded since.

The weeds comprise a little less than 6 per cent of the total plant popuiation and the number has gradually decreased. The species are about the same as found on the unburned plot. The sedges comprised about the same proportion of the total plant population as the weeds, showing little change from the six years of burning in the early spring.

Medium Spring-burned Plot.—The plant population on the plot burned in the medium spring has remained about the same. The number of grasses has increased to a slight extent. The number of sedges has more than doubled, while the weeds have decreased 79 per cent. *Andropogon furcatus* is the dominant plant, averaging 23 per cent more than *Andropogon scoparius*. There has been some variation in numbers during the five years for which data are available, but the trend is toward a decrease. *Andropogon scoparius* has shown a proportionate increase. These two grasses comprise about 70 per cent of the total plant population of the plot. *Bouteloua curtipedula* has also increased, but the total number of plants comprises only 1.5 per cent of the vegetative cover. The number of *Sorghastrum nutans* plants has more than doubled. The other grasses have been intermittently present throughout the five years. *Amborsia psilostachya* and *Aster multiflorus* comprised 80 per cent of the weeds. Each of these species has decreased more than one-half.

Late Spring-burned Plot.—The total plant population on the late spring-burned plot is the least for any of the treatments. The total number of grasses has remained about stationary, but there has been a large decrease in the weeds and a decrease of about a third in the number of sedges. *Andropogon furcatus* is the dominant grass, exceeding *Andropogon scoparius* about 40 per cent. In number of plants these two species comprise about 60 per cent of the total grass population, being less than in any of the other plots. There has been a slight decrease in the number of plants of *Andropogon scoparius*. This is the only burning treatment where this species did not increase. *Bouteloua curtipendula, Sorghastrum nutans,* and *Sporobolus heterolepis* are present in greater numbers in this plot than in any of the others, comprising about 33 per cent of the total grass population. The two former have increased more than one-third while the latter has decreased 55 per cent. A few plants of *Panicum scribnerianum* were present in the plot each year. *Panicum virgatum* was also recorded every year except 1928. Its absence during this year may have been due to incorrect identification.

The number of weeds has decreased more than in any of the other burning treatments. The number remaining after six years burning is negligible. The sedges have tended to decrease, and their number is less than has been found in any of the other plots.

College Pasture

In the burning experimental area in the college pasture, little bluestem *(Andropogon scoparius)* is the dominant plant in the natural sod. Big bluestem *(Andropogon furcatus)* and Indian grass *(Sorghastrum nutans)* are of secondary importance. Prairie June grass *(Kœleria cristata)* is second in abundance on some of the plots, but being rather low growing and of fine texture it is not conspicuous in the prairie. Owing to the fact that little bluestem is the dominant plant, the plant population is higher on the plots in the college area than at the Casement pasture. The following analysis, taken from Table XV (college pasture section), has been made of the vegetative succession on the two meter-square quadrats on each experimental plot. The counts of the vegetation made in late July and early August for the years 1930 to 1933, inclusive, appear in Table XVI.

Fall-burned Plot.—Little bluestem comprises about 34 per cent of the plant population in the plot burned in the fall and the number of plants of this grass has increased nearly two and one-half times in the six-year period. General observation of the plot shows it to contain more little bluestem than on any other burning treatment. The big bluestem has changed very little in numbers. This is also true of side oat grama, black grama, and Indian grass. Prairie June grass increased about 80 per cent in the first four years or until 1931. The last two years it has decreased to slightly less than the original number of plants. The extreme, dry conditions of the past two years may be responsible for this change. The plot contains a small number of plants of *Panicum scribnerianum,* which have about maintained their numbers. In 1928 Kentucky bluegrass comprised about 2 per cent of the plant population. It decreased rapidly, however, disappearing in four years.

The total number of weeds has decreased more than one-half. The principal ones were *Aster multiflorus, Solidago glaberrima, Antennaria campestris,* and *Ambrosia psilostachya.* The number of sedges, which comprise only about 4 per cent of the total plant population, has increased about 60 per cent.

Unburned Plot.—The total plant population of the unburned plot is not so high as that of the plots burned in the late fall or early spring. Little bluestem is the principal grass and it has about doubled in numbers in the six years. Big bluestem comprises about 9 per cent of the plant population. It about maintained its numbers until 1933, when it decreased very materially. Side oat grama comprises about 9.5 per cent of the vegetation, having made no material change in the six years. Indian grass is common on the plot, comprising a little less than 10 per cent of the plant population, and making about 47 per cent increase. Prairie June grass is the second grass in number of stems on the plot. It increased during the first three years and decreased rapidly during the past two dry years.

Perhaps the most significant feature of the plant succession in this plot is the increase in the stand of Kentucky bluegrass, which has more than doubled in number of stems in the six years. Since a similar succession occurred on the unburned plot at the Casement pasture it should justify the conclusion that burning is very detrimental to this grass. The unburned plot contains a very few scattering plants of *Sporobolus heterolepis,* a prairie bunch grass that is decreasing in the bluestem pastures. It appears to be unable to withstand close grazing,

The unburned plot contained a large number of *Ambrosia psilostachya* in 1928. The other weeds have increased slightly on the plot. The species of weeds were about the same as listed for the fall-burned plot. The number of sedges is lowest in this plot and has not changed during the six years.

Early Spring-burned Plot.—The plot burned in the early spring has increased 37 per cent in total plant population in six years. There has been an increase in the number of all the grasses, with the exception of Kentucky bluegrass, which has been greatly decreased by burning. Little bluestem comprises nearly 40 per cent of the total plant population. It has made the greatest increase in this plot, having increased 156 per cent in six years. Big bluestem has increased about 60 per cent, having made a steady gain. Side oat grama, while of minor importance on the plot, has about doubled in numbers, Black grama has been eliminated, as was the case on the unburned plot. This is perhaps due to shading of the tall grasses rather than to the effects of burning. Indian grass, which is the fourth grass in abundance, has made little change. Prairie June grass, which was the second grass in abundance in 1928, increased slightly the first two years and decreased very materially the last two. This can undoubtedly be attributed to the very dry, hot weather of the 1932 and 1933 seasons. *Panicum scribnerianum*, a minor grass, has been able to maintain its numbers. Kentucky bluegrass has been reduced, but not eliminated. *Sporobolus heterolepis* has increased.

With the exception of 1928, when ragweed was abundant in the plot, the weeds have comprised less than 5 per cent of the plant population of the plot. The dominant ones are limited to four species, the same as were listed on the unburned plot. The sedges make up a little less than 5 per cent of the plant population, but have made a steady gain, approximately doubling in numbers.

Medium Spring-burned Plot.—There has been an increase in plant population of 37 per cent in this plot. Little bluestem, the dominant grass, has increased nearly 127 per cent. Big bluestem has made a steady gain, having increased 53 per cent. Indian grass has about the same number of plants as in 1928, as was true in the fall- and early spring-burned plots. Prairie June grass is not so abundant in this plot. This species increased about 200 per cent in the first four years and then decreased to the original number in the last two years. Scribner's panic grass, which is of minor importance, has decreased 56 per cent. Sporobolus heterolepis has increased 75 per cent.

The weeds comprise about 4 per cent of the total plant population and are limited largely to four species. In 1928 ragweed was the dominant weed, but leaving out this season there has been a decrease in the number of weeds. The sedges have about doubled in numbers, indicating that spring burning is not detrimental to their growth even though they do start early in the season.

Late Spring-burned Plot.—The plots burned in the late spring contain the smallest plant population of any of the five experimental plots. The weeds have been practically eradicated, and the sedges have decreased about a third, although they comprise less than 2 per cent of the plant population.

Little bluestem, the dominant species, occurs in smaller numbers than in any of the other treatments on the college pasture. The big bluestem is more abundant, making up 24 per cent of the vegetation. This species has also nearly doubled in number, the gain being greater than on any of the other plots. There has also been an increase in side oat grama and Indian grass. The prairie June grass increased for four years, nearly doubling, then decreasing to about one-fourth its number in the past two years.

The Kentucky bluegrass has decreased, but not to the extent that it has in the other burning treatments.

The data contained in Tables XV and XVI are summarized in Tables XVII and XVIII. The percentage that each species constitutes in the total plant population is given in Table XVII. The percentage change that each species has made from 1928 to 1933 is shown in Table XVIII.

The effect of burning on the number of grasses, as shown in the late June and early July counts for the sir-year period, 1928 to 1933, is shown graphically in figure 10. The effect of burning on the number of grasses is similar in both areas. The increase was greatest on the fall-burned plot and least in the plots burned in the late spring. There was a general increase in number of grasses on all plots for the first four years and a decrease the past two years. The decrease can undoubtedly be attributed to the lack of moisture which would naturally cause a thinning out of the top growth.

The college pasture has a greater number of plants on all the plots than has the Casement pasture. This, as previously explained, is due to the dominance of the little bluestem, which has more stems per unit area than any of the other bluestem grasses.

EFFECT OF BURNING ON STARTING GROWTH IN THE SPRING

The opinion is generally held that burning causes earlier growth of the vegetation in the spring. This conclusion has been arrived at largely from the fact that the burned areas appear greener in the spring than the unburned ones. Whether or not this difference is due to the dead vegetation partially covering the growing shoots on the unburned plots has been in doubt.

To obtain definite information on the effect of burning in starting growth in the spring, counts were made on the two square-meter quadrats on each of the burning experimental plots at the college and Casement pastures. The first counts were made about the time that growth of bluestems starts in the spring, or approximately April 10, the second approximately a month later, and the third the last of June. The results of these counts appear in Table XIII.

An analysis of these data shows that even by the middle of April there is a greater vegetative population on the plots burned in the fall and early spring than on the unburned plot. In the Casement pasture the plot burned in the medium spring had a slightly greater number of plants from the middle of May throughout the season than the unburned one, but the late spring-burned plot had the least number of any of the experimental plots. At the college pasture the plots burned in the medium spring and late spring each had a lower plant population than the unburned plot.

The greatest increase in plant population of the burned plots over the unburned plots was at the time growth starts in the spring. At the college pasture an average of counts for six years shows the fall-burned plots to have 69 per cent greater plant population at the April charting than the unburned plot. The plots burned in the early spring had 36 per cent more plants.

At the Casement pasture both the fall and early spring-burned plots had a little more than twice the number of plants in the unburned plot. Part of this may be due to the accumulated increase in plant population that results from burning, particularly on the Casement plots, which have been burned for a longer period.

The effect of burning in stimulating growth is progressively less as the season advances. At the college pasture the fall-burned plot had 14 per cent and the early spring-burned 9 per cent greater vegetative covering than the unburned plot at the May charting. At Casement pasture there was a 58 per cent increase in covering for the fall-burned and 43 per cent increase for the early spring-burned plot. At the late June charting the late fall- and early spring-burned plots at the college pasture had approximately 14 per cent more covering than the unburned plot. At Casement pasture the covering was 55 per cent greater on the fall-burned and 45 per cent greater on the plots burned

TABLE XVII.—AVERAGE PERCENTAGE OF TOTAL PLANT POPULATION IN EACH OF THE IMPORTANT SPECIES OF VEGETATION FOUND ON THE EFFECT OF BURNING PLOTS, 1928 TO 1933

Casement and college pastures

TIME OF BURNING.	Early spring.		Medium spring.		Late spring.		Fall burned.		Check.	
PASTURE.	Casement.	College.	Casement.	College.	Casement.	College.	Casement.	College.	Casement.	College.
GRASSES.										
Andropogon furcatus	10.3	17.0	39.0	22.5	31.0	24.0	12.6	16.0	39.4	9.0
Andropogon scoparius	56.0	38.0	31.0	38.0	21.0	33.0	47.0	34.0	19.0	43.0
Bouteloua curtipendula	2.0	5.0	1.5	3.5	6.0	4.0	3.2	3.5	4.6	9.5
Bouteloua hirsuta	.0	.0	.0	.0	.0	.0	.0	2.3	.0	.0
Sorghastrum nutans	12.0	10.0	8.0	9.4	18.0	12.4	5.0	10.0	8.0	8.0
Sporobolus heterolepis	6.7	1.5	1.0	1.5	9.0	.0	15.4	.0	.0	.5
Panicum scribnerianum	.5	3.0	1.0	1.7	1.0	1.0	1.0	1.0	.0	1.0
Panicum virgatum	.5	.0	.0	.0	3.0	.0	.0	.0	.0	.0
Poa pratensis	.0	.7	.0	1.9	.0	2.0	.0	.5	3.4	11.0
Sporobolus cryptandrus	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Koeleria cristata	.0	16.0	.0	11.0	.0	20.0	.0	25.0	.0	12.5
WEEDS.										
Antennaria campestris	.0	.8	.0	.5	.0	.0	.0	1.0	.0	.0
Ambrosia psilostachya	1.0	.8	.7	.6	.5	.3	.5	1.6	.0	1.0
Solidago glaberrima	1.0	.9	.0	.0	.0	.0	1.4	1.0	1.0	.0
Aster multiflorus	1.0	.9	4.0	1.7	2.0	1.0	2.8	.5	1.0	1.4
Asclepias verticillata	.6	.0	.0	.0	.0	.0	.0	.0	1.0	.0
Sisyrinchium campestre	.5	.7	.0	.6	.0	.0	.0	.0	.0	.0
Solidago rigida	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Other weeds	.0	.2	1.0	.7	.8	.0	2.0	.0	2.0	.5
Sedges	6.0	3.4	11.8	4.6	4.9	1.5	10.0	3.8	18.4	1.5
Total grasses	88.0	91.6	82.0	90.8	90.5	96.6	83.0	92.4	75.0	95.0
Total weeds	6.0	5.0	6.2	4.6	4.6	1.9	7.0	3.8	6.6	3.5
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE XVIII.—CHANGES IN PERCENTAGES OF THE TOTAL PLANT POPULATION MADE BY THE IMPORTANT SPECIES OF VEGETATION FOUND ON THE EFFECT OF BURNING PLOTS DURING THE SIX-YEAR PERIOD, 1928 TO 1933

Casement and college pastures

TIME OF BURNING.	Early spring.		Medium spring.		Late spring.		Fall burned.		Check.	
PASTURE.	Casement.	College.	Casement.	College.	Casement.	College.	Casement.	College.	Casement.	College.
GRASSES.										
Andropogon furcatus	—32	+65	—25	+53	.....	+93	+17	+39	.....	—7
Andropogon scoparius	+51	+156	+27	+127	—22	+43	+117	+159	+96	+100
Bouteloua curtipendula	+263	+100	+236	.....	+34	+139	+135	+20	+63	—27
Bouteloua hirsuta	.....	—100	.....	—100	.....	.....	.....	+16	.....	—100
Sorghastrum nutans	+45	.....	+270	+33	+62.5	+51	+150	—34	+142	+47
Sporobolus heterolepis	+4	+161	—79	+75	—55	.....	—18	.....	.....	—50
Panicum scribnerianum	.....	.....	+100	—56	—80	—72	+37	—43	.....	—39
Panicum virgatum	.....	.....	.....	—100	—40	—100	.....	.....	—100	—100
Poa pratensis	.....	—80	.....	—84	.....	—94	.....	.....	+290	+176
Sporobolus cryptandrus	.....	.....	.....	—100	.....	.....	.....	.....	.....	.....
Koeleria cristata	.....	—63	.....	—9	.....	—58	.....	—11	.....	—70
WEEDS.										
Antennaria campestris	—59	+25	.....	—85	.....	—100	.....	—78	.....	.....
Ambrosia psilostachya	—98	—100	—98	—98	—100	—100	—70	—100	—100	—90
Solidago glaberrima	.....	—72	.....	—70	.....	—100	.....	.....	.....	.....
Aster multiflorus	+86	+214	—81	—62	—99	—100	—57	—1	+40	—44
Asclepias verticillata	—50	.....	.....	.....	.....	.....	.....	.....	—72	.....
Sisyrinchium campestre	—34	—97	.....	.....	.....	—97	.....	.....	.....	—90
Solidago rigida	+122	.....	.....	.....	.....	.....	.....	.....	.....	.....
Other weeds	—39	—90	—31	—90	—15	—98	—80	—86	.....	—70
Sedges	+98	+179	+221	+100	—35	—47	+22	+68	+72	+22
Total grasses	+34	+48	+6	+57	.....	+24	+51.6	+45	+38	+31
Total weeds	—29	—72	—79	—79	—87	—98	—26	—72	—73	—76
Totals	+31	+37	+.8	+37	—9	+12	+41	+35	+29	+18

in the early spring. The number of grass plants for late June and early July charting at both experimental areas for the six-year period, 1928 to 1933, is shown graphically in figure 10.

The counts made at the college pasture the last of July and early August gave an average increase in plant population of 13 per cent for the fall-burned plots, and 10 per cent for the plots burned in the early spring. It is possible this represents an accumulated increase in plant population.

The fact that the plots burned in the late fall and early spring have a greater plant population in all the chartings does not mean that this represents the difference in the amount of forage on the three plots. The yields taken at the college pasture July 26, 1933 (Table III), gave the unburned plot the highest yield, followed by the plots burned in the medium spring, late spring,

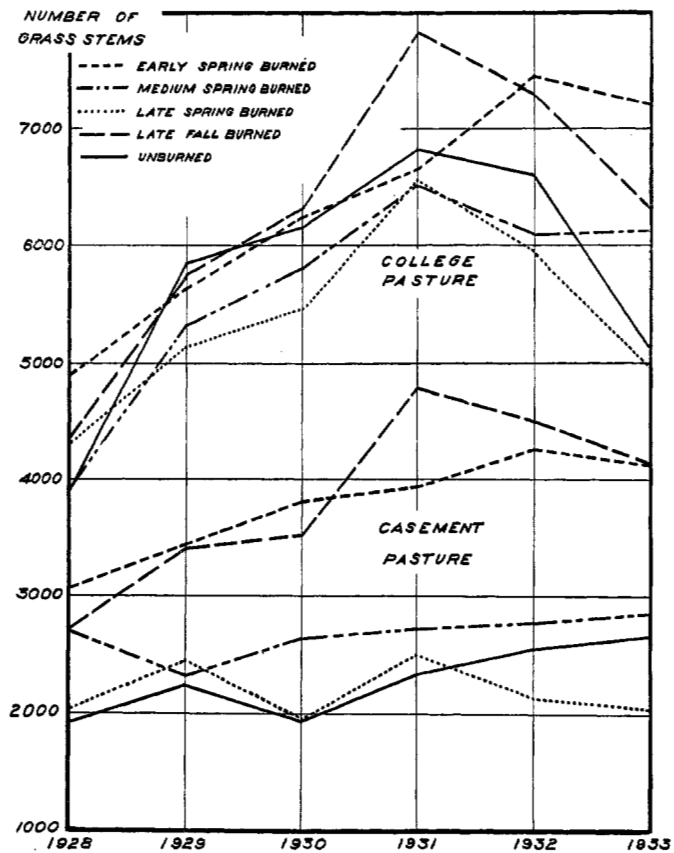

FIG. 10.—Graphs showing the effect of burning on number of grass stems on two square meters in the Casement pasture and two square meters in the college pasture, July 1, 1928, to 1933.

early spring, and in the fall. This is in almost reverse order to the number of plants on these plots as shown by the counts made August 5 of that year.

To determine more definitely the effect of burning on the actual yield of vegetation early in the season, strips were cut through the plots at the college pasture with a high-cut lawn mower. The yields obtained were so variable that they have not been used. They indicated, however, that the burning did increase the yield, the amount being greatest at the beginning of the growing season and decreasing as the season advances, being the same as the unburned plots by about the middle of June. From this time on the unburned plots have more vegetation. The yield of the unburned plots was relatively greater in very dry seasons such as those of 1932 and 1933.

EFFECT OF BURNING ON SOIL TEMPERATURES

Soil temperatures were recorded primarily to determine whether they were affected by burning and whether this difference is correlated with vegetative growth. Other experimental work has shown that burning raises the temperature of the soil. Steiger *(14)* recorded the temperatures of the soil at 1-, 2-, and 6-inch depths near Lincoln, Neb. His data were obtained March 28 on areas of low prairie that had been burned, unburned, mowed, and denuded. The soil temperatures on the burned area at 1 and 2 inches were about 10° F. above the unburned and about 6° higher at the 6-inch depth. The temperatures of the mowed area were about 2° higher for each of the three depths than for the unburned, undisturbed area.

Soil temperatures were obtained at the Casement pasture at 1- and 3-inch depths on the early spring-burned and unburned plots for the years 1918 to 1922, inclusive, and for the season of 1927. In 1928 temperatures for the top 7 inches of soil were recorded at the college pasture for the unburned plot and the plot burned in the early spring.

The temperatures were obtained with a Columbia self-recording thermograph. The thermograph consists of a hollow flexible wire and an elongated cylindrical metallic bulb filled with mercury. This is connected to a circular dial, operated by an eight-day clock, which records the temperatures in degrees Fahrenheit. The thermometer bulbs were placed horizontal with the surface of the soil and at the 1- and 3-inch depths. For obtaining the temperatures for the surface 7 inches, the bulbs were placed at an angle so that they would be covered at the surface and extend to a depth of 7 inches. A standardized thermometer was inserted beside the center of the cylinder to check the readings. The thermographs were all calibrated before being placed in position at the beginning of each season.

For comparative purposes the data were tabulated as daily mean maximum and mean minimum temperatures for the different depths at which the temperatures were recorded. These data have been condensed to weekly mean maximum and minimum temperatures for 1- and 3-inch depths in the burned and unburned plots. They are presented in this form in Tables XIX and XX. These daily mean maximum and mean minimum temperatures for both 1 and 3 inches are shown graphically in figure 11 for the year 1918. The differences are fairly typical for burned and unburned areas.

The mean maximum and mean minimum weekly temperatures for the burned and unburned plots of the surface 7 inches are given in Table XX. The daily differences are clearly shown in figure 12.

TABLE XIX.—DATA ON SOIL TEMPERATURES AT A DEPTH OF ONE INCH SHOWING EFFECT OF BURNING ON THE TEMPERATURE OF THE SOIL

Mean maximum and minimum weekly temperatures, degrees F.

TIME OF RECORD	Temperatures on burned plots.							Temperatures on unburned plots.							Differences.						
	1918.	1919.	1920.	1921.	1922.	1927.	Mean.	1918.	1919.	1920.	1921.	1922.	1927.	Mean.	1918.	1919.	1920.	1921.	1922.	1927.	Mean.
MAXIMUM.																					
4-3*	73.4	69.0	.....	.....	.....	.....	71.2	60.8	62.0	.....	.....	.....	.....	61.4	12.6	7.0	.....	.....	.....	.....	9.8
1-4	75.4	81.0	.....	.....	.....	.....	78.2	58.8	71.0	.....	.....	.....	.....	64.9	16.6	10.0	.....	.....	.....	.....	13.3
2-4	77.1	78.0	.....	62.1	.....	.....	72.4	59.5	66.0	.....	47.6	.....	.....	57.7	17.6	12.0	.....	14.5	.....	.....	14.7
3-4	66.4	88.0	.....	66.6	64.5	.....	71.4	55.1	74.0	.....	49.6	60.8	.....	59.9	11.3	14.0	.....	17.0	3.7	.....	11.5
4-4	55.7	96.0	.....	70.7	65.4	.....	71.9	51.5	80.0	.....	48.0	58.8	.....	59.8	4.2	16.0	.....	22.7	6.6	.....	12.4
1-5	77.4	82.0	.....	74.4	84.0	79.4	79.4	61.7	77.0	.....	63.0	70.0	70.1	68.4	15.7	5.0	.....	11.4	14.0	9.3	11.1
2-5	94.0	81.0	.....	71.5	80.0	63.4	78.0	74.7	75.0	.....	66.3	68.3	58.2	68.5	19.3	6.0	.....	5.2	11.7	5.2	9.5
3-5	100.8	87.0	.....	77.0	79.4	84.2	89.7	79.4	83.0	.....	72.6	66.0	78.2	75.8	21.4	4.0	.....	4.4	13.4	6.0	9.8
4-5	88.6	92.0	76.3	92.8	82.3	71.8	83.9	76.3	84.0	72.7	85.8	72.0	62.4	75.5	12.4	8.0	3.6	7.0	10.3	9.4	8.4
5-5	90.7	90.3	90.4	91.4	92.0	96.8	92.4	77.4	85.0	75.7	87.6	74.0	89.4	81.5	13.3	8.0	14.7	3.8	18.0	7.4	10.8
1-6	99.7	86.0	98.9	87.0	.....	86.8	91.7	83.3	91.0	83.3	77.4	.....	76.0	82.2	16.4	—5.0	15.6	9.6	.....	10.8	10.4
2-6	.....	.....	97.8	.....	.....	88.4	93.1	.....	.....	88.1	.....	.....	82.2	85.1	.....	.....	9.7	.....	.....	6.2	7.9
3-6	.....	.....	93.7	.....	.....	88.0	90.8	.....	.....	82.7	.....	.....	84.8	83.8	.....	.....	11.0	.....	.....	3.2	7.1
4-6	.....	.....	104.3	.....	.....	99.4	101.8	.....	.....	85.3	.....	.....	96.1	90.7	.....	.....	19.0	.....	.....	3.3	11.1
1-7	.....	.....	.....	.....	.....	99.8	99.8	.....	.....	88.7	.....	.....	94.7	91.7	.....	.....	.....	.....	.....	5.1	.....
2-7	.....	.....	102.6	.....	.....	101.8	102.2	.....	.....	85.4	.....	.....	98.1	91.7	.....	.....	17.2	.....	.....	3.7	10.4
Mean	81.7	84.8	94.8	77.0	78.2	87.3	83.9	67.1	77.1	82.7	66.4	67.1	80.9	73.1	14.6	7.7	12.9	10.6	11.1	6.3	10.5
MINIMUM.																					
4-3	42.3	35.0	.....	.....	.....	.....	38.6	46.0	39.0	.....	.....	.....	.....	42.5	—3.7	—4.0	.....	.....	.....	.....	—3.8
1-4	43.3	40.0	.....	.....	.....	.....	41.6	46.5	42.0	.....	.....	.....	.....	44.2	—3.2	—2.0	.....	.....	.....	.....	—2.6
2-4	39.0	36.0	.....	38.0	.....	.....	34.3	42.8	34.0	.....	25.1	.....	.....	33.9	—3.8	2.0	.....	12.9	.....	.....	5.5
3-4	43.9	40.0	.....	39.3	42.5	.....	41.4	47.2	37.0	.....	27.7	43.1	.....	38.8	—3.3	3.0	.....	11.6	—0.6	.....	2.7
4-4	38.7	46.0	.....	48.0	38.5	.....	42.8	42.7	44.0	.....	18.0	40.3	.....	36.2	—4.0	2.0	.....	30.0	—1.8	.....	6.5
1-5	43.0	51.0	.....	38.7	44.0	49.8	45.4	45.4	50.0	.....	32.6	44.0	43.2	43.0	—2.4	1.0	.....	6.1	.0	6.6	2.8
2-5	54.7	57.0	.....	49.3	50.0	55.1	53.2	58.6	52.0	.....	47.0	49.1	40.8	49.5	—3.9	5.0	.....	2.3	.9	14.3	3.7
3-5	58.1	55.0	.....	47.6	51.1	54.7	53.3	56.3	53.0	.....	45.1	52.2	49.4	51.2	1.8	2.0	.....	1.7	—1.1	5.3	1.9
4-5	60.0	54.0	56.1	63.8	50.8	61.7	57.7	52.7	53.0	50.0	55.6	53.7	57.8	53.8	7.3	1.0	6.1	8.2	—2.9	3.9	4.1
5-5	65.5	68.0	59.0	60.4	48.0	69.7	61.8	60.9	64.0	54.9	56.6	54.0	57.1	57.9	4.6	4.0	4.1	3.8	—6.0	12.6	4.7
1-6	63.8	58.0	66.9	60.1	.....	58.5	61.5	60.7	54.0	54.3	53.3	.....	52.8	55.0	3.1	4.0	12.6	6.8	.....	5.7	6.4
2-6	.....	.....	70.3	.....	.....	69.8	70.0	.....	.....	62.3	.....	.....	53.8	58.0	.....	.....	8.0	.....	.....	16.0	12.0
3-6	.....	.....	62.3	.....	.....	69.1	65.7	.....	.....	61.0	.....	.....	60.1	60.5	.....	.....	1.3	.....	.....	9.0	5.1
4-6	.....	.....	71.6	.....	.....	74.5	73.0	.....	.....	57.1	.....	.....	65.8	61.4	.....	.....	4.5	.....	.....	8.7	6.6
1-7	.....	.....	.....	.....	.....	76.5	.....	.....	.....	63.4	.....	.....	66.8	65.1	.....	.....	.....	.....	.....	9.7	.....
2-7	.....	.....	73.1	.....	.....	77.2	75.1	.....	.....	56.7	.....	.....	69.7	63.2	.....	.....	16.4	.....	.....	7.5	11.9
Mean	50.2	49.1	65.6	49.6	46.4	65.1	54.3	50.9	47.4	57.5	40.1	48.1	56.9	50.1	—0.7	2.0	7.6	9.3	—1.7	9.0	4.3

* KEY: 4-3, fourth week of March.

TABLE XX.—DATA ON SOIL TEMPERATURES AT A DEPTH OF THREE INCHES SHOWING EFFECT OF BURNING ON THE TEMPERATURE OF THE SOIL

Mean maximum and minimum weekly temperatures, degrees F.

TIME OF RECORD.	Temperatures on burned plots.							Temperatures on unburned plots.							Differences.						
	1918.	1919.	1920.	1921.	1922.	1927.	Mean.	1918.	1919.	1920.	1921.	1922.	1927	Mean.	1918	1919.	1920.	1921.	1922	1927	Mean.
MAXIMUM.																					
4-3*	60.8	64.0	.....	.....	.....	.....	62.4	56.0	57.0	.....	.....	.....	.....	56.5	4.8	7.0	.....	.....	.....	.....	5.9
1-4	62.4	74.0	.....	.....	.....	51.4	62.6	57.3	60.0	.....	.....	.....	57.4	58.2	5.1	14.0	.....	.....	.....	—6.0	4.3
2-4	63.1	66.0	.....	53.1	.....	58.8	60.2	58.7	56.0	.....	33.7	.....	57.4	52.2	4.4	10.0	.....	16.4	.....	1.4	8.0
3-4	60.7	.....	.....	53.0	59.1	59.6	58.1	55.0	64.0	.....	44.0	58.0	59.4	56.1	5.7	.....	.....	9.0	1.1	0.2	4.0
4-4	50.4	90.0	.....	62.7	52.0	55.1	62.0	46.4	68.0	.....	62.4	54.0	55.8	57.3	4.0	22.0	.....	0.3	—2.0	—0.7	5.6
1-5	65.1	74.0	.....	63.6	66.0	70.5	67.8	59.7	67.0	.....	58.8	74.0	63.5	64.6	5.4	7.0	.....	4.8	—8.0	7.0	4.7
2-5	79.0	69.0	.....	62.4	72.1	67.8	70.1	66.5	66.0	.....	63.4	66.0	60.0	64.4	12.5	3.0	.....	—1.0	6.1	7.8	5.7
3-5	77.7	.....	.....	67.0	71.7	66.8	70.8	66.7	70.0	.....	69.5	64.5	60.1	66.2	11.0	.....	.....	—2.5	7.2	6.7	5.6
4-5	83.5	78.0	68.0	79.1	72.5	71.8	73.5	65.7	70.0	64.1	83.0	66.5	63.0	68.7	17.8	8.0	3.9	—3.9	6.0	8.8	6.8
5-5	80.7	80.0	.....	81.2	80.0	74.4	79.3	69.4	76.0	67.9	85.2	78.0	63.8	73.4	11.3	4.0	.....	—4.0	2.0	10.6	4.8
1-6	86.0	80.0	77.0	77.7	.....	66.7	77.5	70.6	77.0	77.0	80.2	.....	62.8	73.5	15.4	3.0	.....	—2.5	.....	3.9	4.0
2-6	.....	.....	82.6	.....	.....	65.4	74.0	.....	.....	85.1	.....	.....	62.8	73.9	.....	.....	—2.5	.....	.....	3.6	0.5
3-6	.....	.....	80.3	.....	.....	64.7	72.5	.....	.....	78.9	.....	.....	61.0	69.9	.....	.....	1.4	.....	.....	3.7	2.5
4-6	.....	.....	81.1	.....	.....	73.2	77.1	.....	.....	83.0	.....	.....	65.8	74.4	.....	.....	—1.9	.....	.....	7.4	2.7
1-7	.....	.....	90.3	.....	.....	74.5	82.4	.....	.....	83.0	.....	.....	66.5	74.7	.....	.....	7.0	.....	.....	8.0	7.5
2-7	.....	.....	85.0	.....	.....	73.5	79.2	.....	.....	.....	.....	.....	66.8	.....	.....	.....	.....	.....	.....	6.7	.....
Mean	69.9	75.0	80.6	66.6	67.6	66.2	70.9	61.1	66.3	77.0	64.8	66.0	61.7	66.1	8.8	8.7	1.3	2.1	1.6	4.5	4.5
MINIMUM.																					
4-3	45.4	41.0	.....	.....	.....	.....	43.2	44.7	40.0	.....	.....	.....	.....	42.3	0.8	1.0	.....	.....	.....	.....	0.9
1-4	46.5	43.0	.....	.....	.....	45.0	44.8	44.7	41.0	.....	.....	.....	56.5	47.4	1.8	2.0	.....	.....	.....	—11.5	—2.5
2-4	41.6	42.0	.....	39.8	.....	51.7	43.8	40.9	34.0	.....	22.8	.....	53.8	37.9	0.7	8.0	.....	17.0	.....	—2.1	5.9
3-4	46.5	.....	.....	41.7	43.4	51.8	45.8	46.1	39.0	.....	27.0	44.0	54.2	42.0	0.4	.....	.....	14.7	0.6	—2.4	3.3
4-4	38.7	59.0	.....	48.7	40.0	45.2	46.3	39.3	42.0	.....	48.1	41.4	51.0	44.3	—0.6	17.0	.....	0.1	—1.4	—5.8	1.9
1-5	46.0	37.0	.....	46.2	51.0	56.2	47.3	43.7	46.0	.....	42.8	48.0	56.4	47.4	2.3	—9.0	.....	3.4	3.0	—0.2	0.1
2-5	59.6	45.0	.....	50.5	52.4	49.0	51.3	55.3	50.0	.....	47.5	50.0	56.1	51.8	4.3	—5.0	.....	3.0	2.4	—7.1	—0.5
3-5	62.4	56.0	.....	52.1	54.5	53.1	55.6	56.7	50.0	.....	49.8	52.5	53.1	52.4	5.7	6.0	.....	2.3	2.0	.....	3.2
4-5	66.2	63.0	55.6	60.7	57.0	62.0	60.7	56.6	53.0	48.9	62.8	56.3	57.1	55.8	9.6	10.0	6.7	—2.1	0.7	4.9	5.0
5-5	66.8	60.0	.....	65.4	54.0	59.7	61.2	63.9	60.0	50.3	63.5	52.0	57.4	57.8	2.9	.....	.....	1.9	2.0	2.3	1.8
1-6	69.6	57.0	60.4	64.5	.....	54.7	61.2	63.1	53.0	59.3	62.0	.....	55.7	58.6	3.5	4.0	1.1	2.5	.....	—1.0	2.0
2-6	.....	.....	68.0	.....	.....	54.4	61.2	.....	.....	65.0	.....	.....	55.2	60.1	.....	.....	3.0	.....	.....	—0.8	1.1
3-6	.....	.....	68.4	.....	.....	55.4	61.9	.....	.....	64.4	.....	.....	55.5	59.9	.....	.....	4.0	.....	.....	—0.1	1.9
4-6	.....	.....	64.9	.....	.....	60.2	62.5	.....	.....	60.0	.....	.....	59.0	59.5	.....	.....	4.9	.....	.....	1.2	3.0
1-7	.....	.....	73.3	.....	.....	60.7	67.0	.....	.....	79.5	.....	.....	58.0	68.7	.....	.....	—6.2	.....	.....	2.7	—1.7
2-7	.....	.....	65.1	.....	.....	60.0	62.5	.....	.....	.....	.....	.....	59.5	.....	.....	.....	.....	.....	.....	0.5	.....
Mean	53.6	50.3	65.1	52.1	50.3	54.6	54.3	50.5	46.2	61.1	47.3	49.1	55.9	51.7	3.1	3.4	2.2	4.8	1.2	—1.3	2.2

* KEY: 4-3, fourth week in March.

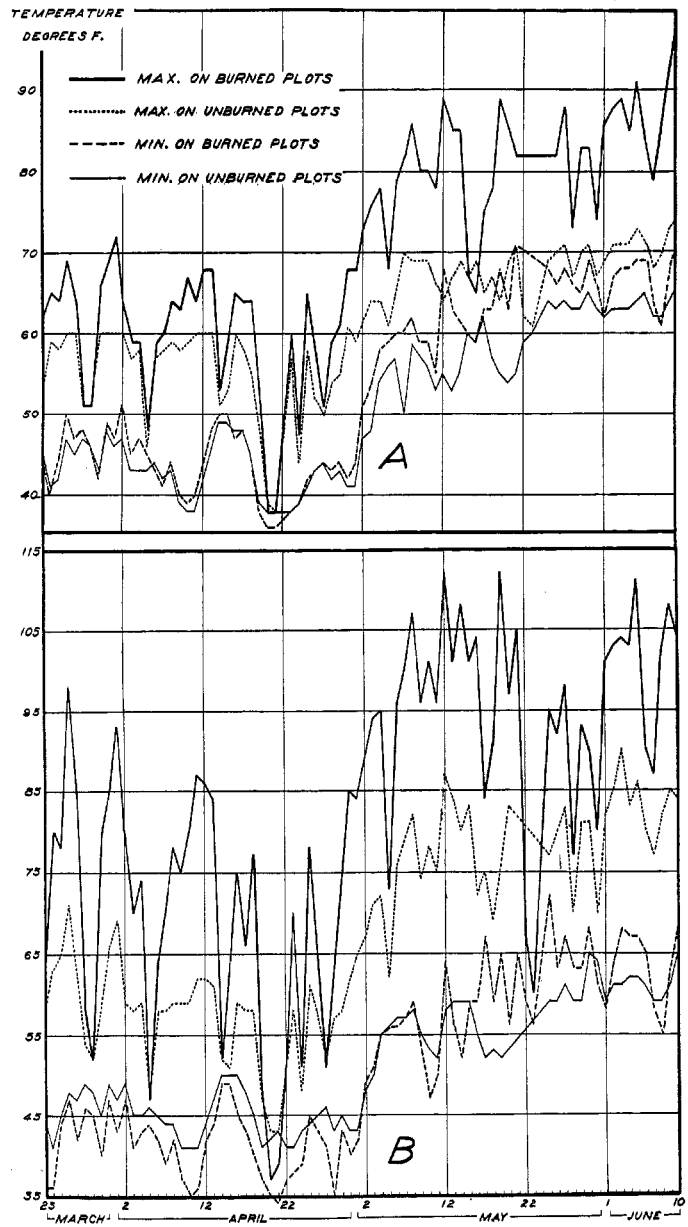

FIG. 11.—Graphs showing the effect of burning on the daily temperature of the surface soil. Casement pasture, 1918. (A) Temperatures at a depth of 9 inches. (B) Temperatures at a depth of 1 inch.

The temperatures were recorded at 1-inch depth because germinating seed is found in this zone, and at 3 inches because this zone contains about one-fourth of the root content of most of the high-prairie grasses. Early growth of the above-ground parts is mainly stimulated from this portion of the root system. It was realized later that temperatures should be obtained for a major part of the root zone, hence the thermograph bulbs were placed to record the average temperatures of the surface seven-inch layer, which contains more than half the roots of the native grasses on the high prairie.

The soil thermometers were usually started soon after the first plot was burned in the spring and were continued until June, when differences in soil temperatures become a minor factor in the growth of the grasses in the burned and unburned plots.

The soil temperatures on the burned plots are higher than on the ones that are not burned. The differences are greater at 1-inch than at 3- and 7-inch levels. The temperatures of the surface soil naturally showed more variation, changing more readily according to fluctuations in the weather. The temperatures at the 1-inch level went lower at night and higher in the day, following more closely the air temperatures, as is graphically shown in figure 11, B.

The mean maximum weekly temperatures ranged from 7 to 14.7 degrees, with a mean 10.5 degrees, higher on the burned plots than on the unburned. The mean minimum temperatures showed less variation. At the beginning of the season they ranged lower on the burned than on the unburned plots. For the major part of the season, however, these temperatures were higher on the burned than on the unburned plots. The mean temperature for the season up to the second week in July was 4.3 degrees higher on the burned plot.

The soil temperatures taken at a depth of 3 inches show a narrower range between the burned and the unburned plots, also between the mean miximum and mean minimum temperatures of the two treatments. The mean maximum temperatures are, with few exceptions, higher on the burned plots. Where the temperatures on the unburned plot were higher the differences were slight. The mean weekly range between maximum and minimum temperatures was always higher on the burned plot, ranging from 0.5 to 8 degrees more.

The mean minimum temperatures were generally higher on the burned plots. However, there is less difference than in the mean maximum temperatures. Considering the weekly mean one may note there were three weeks when the mean temperature was lower for the burned plots. The mean weekly temperatures for the entire 16 weeks ranged from 2.5 degrees lower to 5.9 degrees higher on the burned than on the unburned plots. The mean for the entire period was 2.2 degrees higher for the burned plot.

Starting in 1928, soil temperatures were obtained for the top 7 inches. Since this depth of soil contains a large portion of the roots of the prairie grasses, the temperatures are probably a more effective indicator than surface soil temperatures of the possible effects of burning in stimulating the early growth of the bluestem grasses. New self-recording thermometers were ordered early in 1928, but they did not arrive until the latter part of May, so only five weeks temperatures were taken that season. During 1929, however, records were started the first of April and were obtained until the middle of July.

TABLE XXI.—DATA ON SOIL TEMPERATURES AT A DEPTH OF SEVEN INCHES SHOWING EFFECT OF BURNING ON THE TEMPERATURE OF THE SOIL

Temperature in degrees F., college pasture, 1928 and 1929

TIME OF RECORD.	Mean maximum weekly temperatures.							Mean minimum weekly temperatures.						
	Burned plots.			Unburned plots.			Mean diff.	Burned plots.			Unburned plots.			Mean diff.
	1928.	1929.	Mean.	1928.	1929.	Mean.		1928.	1929.	Mean.	1928.	1929.	Mean.	
1–4*	.....	57	57	.....	51	51	6	.....	49	49	.....	47	47	2
2–4	.....	49	49	.....	47	47	2	.....	45	45	.....	44	44	1
3–4	.....	52	52	.....	49	49	3	.....	48	48	.....	46	46	2
4–4	.....	54	54	.....	51	51	3	.....	48	48	.....	47	47	1
1–5	.....	55	55	.....	51	51	4	.....	48	48	.....	48	48	0
2–5	.....	54	54	.....	50	50	4	.....	49	49	.....	47	47	2
3–5	.....	58	58	.....	55	55	3	.....	53	53	.....	52	52	1
4–5	.....	64	64	.....	59	59	5	.....	57	57	.....	55	55	2
5–5	71	67	69	68	63	65.5	2.5	61	63	62	61	63	62	0
1–6	65	63	64	62	59	60.5	4.5	59	59	59	59	60	59.5	0.5
2–6	66	69	67.5	65	65	65	2.5	61	65	63	62	67	64.5	—1.5
3–6	72	70	71	69	65	67	4	65	65	65	65	68	66.5	—1.5
4–6	69	70	69.5	68	65	66.5	3	63	65	64	63	68	65.5	—1.5
1–7	.....	73	73	.....	70	70	3	.....	68	68	.....	66	66	2
2–7	.....	71	71	.....	68	68	3	.....	68	68	.....	65	65	3
Mean	69	71.5	70.2	66	67.8	66.9	3.3	62	67.8	64.9	62	54.8	58.4	4.5

* KEY: 1-4, first week of April.

The mean maximum and minimum temperatures for the early spring-burned and the unburned plots are given in Table XXI. The daily maximum and minimum temperatures for these two plots for 1929 have been plotted in figure 12. The temperatures for the burned plot are significantly higher than for the unburned plot.

The higher soil temperatures of the burned plots apparently are effective in stimulating greater vegetative growth during the early spring or until the latter part of May, if ample soil moisture is available. During the seasons when soil moisture was limited the effect in stimulating growth was not so marked. After May, when the temperatures are always sufficiently high to promote vegetative growth, the higher soil temperatures might become disadvantageous by increasing soil evaporation, especially if soil moisture was limited as was the case in June, 1933.

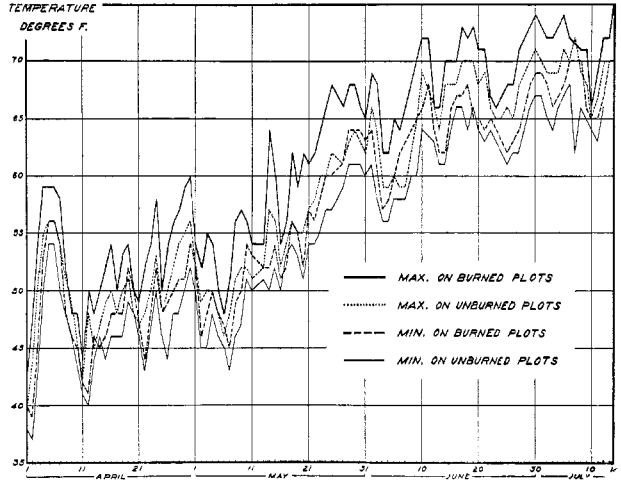

FIG. 12.—Graphs showing the effect of burning on the daily temperatures of the surface seven inches of soil. College pasture, 1929.

EFFECT OF BURNING ON THE FERTILITY OF THE SOIL

Perhaps the most vital question in burning pastures is its effect on the fertility of the soil. To obtain information on this important phase of the subject, soil samples were taken at the college pasture September 17 and 19, 1928, on the unburned, early spring-burned, and fall-burned plots that are protected from grazing and burned annually and on the fall-burned and unburned plots that are grazed. The samples were taken at four depths, as follows: 0-6, 6-12, 12-24, and 24-36 inches. The samples were analyzed for total nitrogen and organic matter (carbon percentage). Twelve sets of samples were taken in each of the plots. In order that future samples could be taken very near the originals, thus avoiding discrepancies that may arise from soil differences, they were taken at 12 places in each plot distributed according to a definite plan.

Each sample composited of 12 borings was thoroughly dried, ground, and mixed, thus making the samples that were analyzed representative of the entire soil samples taken from each depth. The same plots were resampled August 23, 1932, four years later. The analytical results for the two sets of samples are presented in Table XXII.

TABLE XXII.—RESULTS OF ANALYSES OF REPRESENTATIVE SOIL SAMPLES, COLLECTED FROM PLOTS ON THE COLLEGE PASTURE, 1928 AND 1932

Showing effect of burning on soil fertility

TIME OF BURNING.	Percentage nitrogen.		Percentage carbon.		Percentage increase.	
Depth of sample (ins.).	1928.	1932.	1928.	1932.	Nitrogen.	Carbon.
Fall burned:						
0- 6	0.200	0.208	2.40	2.51	0.008	0.11
6-12	.140	.140	1.49	1.63	.000	.14
12-24	.082	.087	.80	.90	.005	.10
24-36	.048	.055	.39	.45	.007	.06
Check:						
0- 6	.199	.204	2.44	2.47	.005	.03
6-12	.138	.142	1.63	1.69	.004	.06
12-24	.081	.084	.78	1.04	.003	.26
24-36	.046	.051	.34	.54	.005	.20
Early spring:						
0- 6	.200	.202	2.47	2.47	.002	.00
6-12	.136	.142	1.63	1.72	.006	.09
12-24	.085	.084	.81	.97	—.001	.16
24-36	.051	.051	.39	.56	.000	.17
Fall burned: *						
0- 6	.184	.200	2.28	2.40	.016	.12
6-12	.131	.142	1.51	1.72	.011	.21
12-24	.071	.080	.76	.95	.009	.19
24-36	.034	.046	.29	.54	.012	.25
Check: *						
0- 6	.182	.198	2.21	2.49	.016	.28
6-12	.124	.141	1.38	1.76	.017	.38
12-24	.072	.081	.73	.95	.009	.22
24-36	.037	.048	.34	.55	.011	.21

* Grazed.

These analyses show a slight accumulation of total nitrogen on all the plots, the increase being equally as high on the burned as on the unburned plots. While the increases were not large enough to be significant, yet it can be safely concluded that burning has not resulted in any decrease in total nitrogen. The increase in carbon was a little higher on the unburned plots. This increase undoubtedly came from stimulated root development rather than from the accumulation of surface material. This conclusion is reached from the fact that the increase in carbon percentage was higher in the second foot than it was in the surface 6 inches.

The increase in root development on the protected plots might be attributed to the higher top growth which would naturally stimulate greater root development. However, the increase also was greater on the grazed fall-burned and unburned plots, which suggests some other cause. In Mississippi, Greene *(6)* attributed a higher nitrogen content of burned plots to an increase in leguminous plants that came in as a result of burning. While it is true that the college pasture has a number of legumes, mainly *Psoralea,* yet they are not present on the plots in sufficient numbers to have an important influence on soil nitrogen.

The higher nitrogen and carbon content on the unburned grazed plots may be due in part to the greater accumulation of manure on this plot. There was a tendency for the stock to lie on this plot at night more than on any of the others.

The unburned, grazed plot was very lightly grazed. The amount of top growth removed was insufficient to reduce the vigor of the plants and to

decrease root development. The unprotected fall-burned plot was grazed about the same as the average of the pasture, which was moderate and not heavy enough to be harmful to the vegetation.

EFFECT OF BURNING ON NITRATE DEVELOPMENT

In 1928 soil samples were taken from all the protected plots burned annually to obtain information on the effect of burning on nitrate accumulation. Soil samples were taken at the college pasture from the fall-burned, early spring-burned, and the unburned plots on March 23, which was before growth of the bluestem grass had started and shortly after the early spring plot was burned. These three plots and the medium spring-burned plots were sampled on April 24. Samples were taken from the five plots in the series burned annually, on May 17, June 2, and September 6.

These soil samples were taken in duplicate at the first-, second-, and third-foot intervals. There was ample moisture in all these soil samples to permit favorable nitrate development. Nitrate determinations were made by the phenol-disolphonic acid method. The means of the duplicate samples are given in Table XXIII.

Investigations have shown that there is small accumulation of nitrates under a growing crop, since the plants use them about as rapidly as they are formed. It has also been determined that growing plants have a depressing effect on nitrate formation. The determinations of nitrates under grasses also show a very limited accumulation during the period of vigorous growth.

TABLE XXIII.—RESULTS OF ANALYSES OF SOIL SAMPLES SHOWING EFFECT OF BURNING ON NITRATE DEVELOPMENT

Samples taken from annually burned series of plots in college pasture, 1928

Time of Burning.	Nitrates, P. P. M. of NO_3 on dates indicated.					
Depth of sample (ins.).	Mar. 23.	April 24.	May 17.	June 2.	Sept. 6.	Average.
Fall:						
0-12	0	82.4	3.75	2.80	3.30	18.45
12-24	0	65.1	2.90	T	3.20	14.20
24-36	0	83.4	2.75	2.85	2.90	18.20
0-36 Mean	0	77.3	3.13	1.90	3.13	16.95
Check:						
0-12	T	86.4	3.60	5.50	3.80	19.90
12-24	2.25	51.0	2.90	T	3.95	12.02
24-36	2.05	61.5	2.85	T	3.95	14.07
0-36 Mean	1.45	66.3	3.11	1.80	3.90	15.31
Early spring:						
0-12	4.35	63.7	3.55	2.55	4.35	15.70
12-24	2.65	46.9	2.80	3.75	3.40	11.90
24-36	2.65	42.2	T	3.90	3.35	10.40
0-36 Mean	3.22	50.9	1.06	3.40	3.70	12.46
Medium spring:						
0-12	*	49.4	3.60	5.55	14.65	18.30
12-24	*	53.3	T	3.60	6.70	15.90
24-36	*	54.9	T	4.20	4.85	15.99
0-36 Mean		52.5	.60	4.45	8.73	16.57
Late spring:						
0-12	*	*	3.60	3.30	4.80	
12-24	*	*	T	3.15	4.90	
24-36	*	*	T	3.00	3.25	
0-36 Mean			.60	3.15	4.65	

* No sample.

The samples taken March 23 were a little in advance of growth activity of the bluestem grasses. The differences in nitrate content of the three plots are probably not enough to have any significance. The samples taken April 24 show the greatest nitrate accumulation. This is about the time that vigorous growth of bluestems starts in an average year.

The plots burned in the fall had the largest nitrate content, followed in order by the medium spring-burned and the unburned, with the early spring-burned last. No satisfactory explanation can be given for these differences. It might be expected that the highest quantity would be found on the unburned plot, owing to the fact the growth of vegetation is delayed in this plot because of lower soil temperatures. No explanation can be given for the early spring-burned plot having a lower amount of nitrates than the fall-burned plot. The difference between the two plots probably is not enough to be significant. The differences between the early spring- and medium spring-burned plots are also too small to have any significance.

The samples taken May 17 indicate that the plant activity was sufficient not only to use the nitrates accumulated the previous month, but also to utilize them as rapidly as available. The fall-burned and unburned check plots have a slight accumulation, while the amount on the other plots is negligible. It is doubtful if the difference existing in any of the plots is enough to have any significance. The samples taken June 2 are very much the same, as is true of those taken September 6, with the exception of the samples obtained from the medium spring-burned plots which are higher in nitrate content. No explanation can be offered for this difference.

Considering the general subject of the effect of burning on nitrate development it can be stated that there is little, if any, difference in the effects of burning on nitrate accumulations in the soil. This seems to hold true for the plots burned at different times as well as for a comparison of the unburned plots with the burned plots as a group.

EFFECT OF BURNING ON THE UTILIZATION OF BLUESTREAM PASTURES

The growth of the forage in the bluestem pastures, perhaps the most stabilized of all types of pastures, varies considerably with climatic conditions. A properly managed pasture should be stocked according to its grazing capacity in an average year. This means that there may be a shortage of forage in the dry years and an excess in the favorable ones. If it were possible to anticipate the good years and if extra stock were available to utilize the excess forage there would be no need of burning to permit uniform grazing of all parts of the pasture the next season. In some instances this excess production has been cut for hay on pastures where the land is smooth enough to permit the use of a mowing machine. In many bluestem pastures mowing is either impossible owing to the topography or the rocky nature of the soil, or it can be done only with such difficulty as to make the use of this method impractical.

In years following seasons of very high forage production it seems safe to conclude that unless the steeper slopes or parts of the pasture where stock graze less frequently are burned, these areas will be undergrazed, and the bottoms of the draws or the ridge tops and the part of the pasture near water will be overgrazed. Burning seems to be highly desirable if not essential on bluestem pastures about every other year if they are stocked about the same each year. Burning may be effectively used in making the utilization of the forage possible in these less accessible places.

Pastures should be burned only in the spring following years having a large carry over of dead grass. The places in the pasture where the stock prefer to graze, and which are accordingly more heavily grazed, should not be

burned. This difference in treatment would make the less frequently grazed places more attractive to the stock and thus bring about a more even utilization of the forage.

While the investigations reported in this bulletin do not show that burning is harmful to bluestem grasses, it should be taken into consideration that the burning was always done when the ground was moist, thus preventing excessive burning of the soil and the crowns of the plants. It is highly probable that very different results would have been obtained had the burning been done when the ground was very dry, as is sometimes the case in the bluestem pastures of eastern Kansas where burning is a common practice.

SUMMARY AND CONCLUSIONS

The experiments were conducted on two areas of bluestem pastures near Manhattan, Kan., where the mean annual precipitation is 31.49 inches. Big bluestem *(Andropogon furcatus)* and little bluestem *(Andropogon scoparius)* are the dominant grasses on both areas. These two grasses are about equally divided in the Casement pasture area, and little bluestem comprises about 50 per cent of the vegetative cover in the college pasture. Other important grasses in the two areas include Indian grass *(Sorghastrum nutans),* side oat grama (*Boutleoua curtipendula*), prairie June grass (*Koeleria cristata*), prairie dropseed *(Sporobolus heterolepis),* Kentucky bluegrass *(Poa pratensis),* and switch grass *(Panicum virgatum)*.

The major portion of the experiments were started in 1927 to obtain information on the effect of burning on (1) yield of vegetation, (2) control of weeds and brush, (3) quality of the vegetation, (4) soil moisture and soil temperature, (5) composition and succession of the vegetation, (6) starting growth in the spring, and (7) effect on the fertility of the soil.

The experimental plots were burned annually in the late fall, early spring, medium spring and late spring. The college area contained an additional burning series that was burned in alternate years. Each burning series contained an unburned or check plot.

Burning decreased the yield of the mature vegetation. The yield was least on the plots burned in the late fall. The plot burned in the early spring was next, followed by the plot burned in medium spring. The plots burned in the late spring yielded more mature vegetation than plots under any of the other burning treatments.

Burning had little effect in controlling weeds and brush unless it was done in the late spring or after April 20. The effectiveness of burning is largely dependent upon the time the plants start growth in the spring and the movement of their food reserves. If the low point in the organic food reserves is later than May, as is true of sumac, burning is not an effective means of eradication.

The bluestem grasses on the burned plots were more leafy during the early part of the growing season than on the unburned plots. The nutritive content of the forage depended upon the amount of growth. In early June the protein content was highest for the vegetation obtained on the plots burned in the late spring, followed by the forage on the unburned plot. The vegetation growing on medium spring-burned plots ranked third and the vegetation from the fall- and early spring-burned plots had the lowest protein content.

The moisture content of the soil on the unburned plot was higher than on any of the burned plots. The time of burning had some effect on the moisture content of the soil. During 1933, an extremely dry season, the moisture content of the soil was greatest in the plots burned in the late spring, followed by those burned in the medium spring and lowest in the plots burned in the fall and early spring.

The plant population was greatest on the plots burned in the late fall and least on those burned in the late spring. The plots burned in the late fall and early spring had a greater number of plants than the unburned plot. The plots burned in the late fall had a succesional change toward the little bluestem, while in the plots burned in the late spring the change was toward the coarser grasses, mainly big bluestem. Kentucky bluegrass increased on all the unburned plots and was either decreased or was eliminated on all the burned plots.

Burning stimulated early growth in the spring, owing mainly to the higher soil temperatures. The plots burned in the early spring and late fall contained a greater vegetative growth until early in June, when moisture rather than temperature was the controlling factor in the growth of the vegetation.

Burning did not cause any decrease in the organic matter or total nitrogen during a five-year period. The accumulation of organic matter and total nitrogen in prairie grassland is governed more by root development than by the accumulation of surface material. In these experiments the burning was always done when the soil was moist. If the burning had been done when the soil was very dry, the results might have been different.

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