Seasonal Changes in the Chemical Composition of Some Important Arizona Range Forage Plants

by

Charles W. Hodgson

Submitted in partial fulfillment of the requirements for the degree of

Master of Science

in the Graduate College,

University of Arizona

1 9 3 6

Approved E. B. Stanley, 5/11/36
Major Professor Date

TABLE OF CONTENTS

INTRODUCTION

Actual range experiments to determine the nutritive value of range forages are difficult and expensive to conduct. They require considerable land, livestock, equipment, and labor, and, in many instances, the cooperation of range livestock men. Studies of this nature have been made only during the more recent years; and, as a consequence, very little information is available regarding the nutritive value of Arizona range forages. Since range forage plants constitute the principal source of feed for Arizona livestock, any information concerning the nutritive value of these plants should be of economic interest to the livestock industry.

According to Stanley (28), there are five vegetation types in Arizona. The desert type is below 3,000 feet in elevation with an annual precipitation of 4-10 inches. Palo verde, mesquite, creosote bush, cacti, weeds, and winter annuals are the characteristic plants of this type, with a few perennial grasses at the upper limits.

The grassy plains type, sometimes known as yearlong range, varies from about 3,000 to 5,000 feet in altitude and extends from the desert up to the mountain brush type. This type is characterized by perennial grasses, which include Rothrock's grama, blue grama, black (wire) grama, hairy grama, and curly mesquite. Galleta and tobosa grasses may occur on the heavier soils. The predominating shrubs and small trees are mesquite, calclaw, and yuccas at the lower elevations, with oak coming in at the upper limits. The annual precipitation is 10-20 inches.

The mountain brush type, also called chaparral and oak woodland, varies in elevation from 4,000 to 5,500 feet with an annual precipitation of 15-25 inches. The gramas, curly mesquite, and other grasses occur here.

Bordering the yellow pine forests and varying in elevation from 5,000 to 7,000 feet is found the pinon-juniper woodland with an annual precipitation of 15-20 inches. The grama, bluestem, and galleta grasses and weeds are the principal forage species.

Ponderosa pine, firs, and spruces characterize the forest trees type, which occurs above an altitude of 6,500 feet. Open mountain parks are used for summer grazing. Blue grama, bluestem, Arizona fescues, mountain muhlenbergia, and beardless bunchgrass are found. The annual precipitation varies from 18 to 40 inches.

Smith (27) states that Arizona has two rainy seasons, the most important one occurring in July, August, and September. Approximately 43 percent of the annual precipitation falls during these months. The winter rainy season (December to March) furnishes approximately 35 percent of the annual precipitation.

From the last of July to about November 1 and for about six weeks in March and April forage conditions on Arizona ranges are usually good, and livestock thrive. During the remainder of the year, the range grasses are dead and dry, causing a marked loss in the weight and condition of range livestock.

For the past three years the Animal Husbandry Department of the University of Arizona has been conducting range experiments relating to the nutritive value of Arizona range forages. One phase of this project is a study of the seasonal changes in the chemical composition of the forage plants. The present paper is devoted primarily to this problem.

Although a chemical analysis of a feed is not a complete measure of its nutritive value, it does indicate the approximate nutritive value when considered in the light of the results of digestion trials which have been made with similar feeds. For instance, feeds high in crude protein and low in crude fiber have been shown to have a high nutritive value, being rich in total digestible nutrients and digestible crude protein. One high in crude fiber is, as a rule, low in total digestible nutrients. Livestock, dependent upon forage of low phosphorus content are more likely to suffer from phosphorus deficiency diseases than when eating forage that is high in phosphorus.

Considerable work has been done regarding seasonal changes in the chemical composition of forage plants in various parts of the world, but no previous study of this nature has been made in Arizona. It was thought advisable, therefore, to conduct the present study. The following paragraphs represent a brief review of previous work bearing upon this subject.

McCreary (19) found that the percentage of crude protein in grass plants was highest during May and that there was a gradual decrease in the percentage of crude protein until November, with the exception of a slight increase during a few weeks immediately following a rainy spell in August. From November until April the percentage of crude protein remained practically constant except in a few cases where it showed a slight increase, possibly due to the fact that the weight of crude protein remained constant while some of the other nutrients were leached out. The nitrogen-free extract showed no definite trend during the fall and winter months. The percentage of crude fiber in grasses increased from May to November but decreased between November and April, varying inversely with the amount of rainfall. The crude fiber content of evergreen browse plants remained practically constant during the fall and winter months. The percentage of ether extract in grass was variable until November but decreased between November and April. This investigator found the percentage of total ash to increase slowly as the season advanced, but he further states that this increase may not have been significant because of the dust accumulation on the plants. The percentage of phosphorus varied directly with that of crude protein, while the percentage of calcium slowly, but gradually, increased as the season progressed.

Cundy (6), studying the chemical composition of hays cut at different stages of growth, reports that in nearly every case the percentage of crude protein decreased as the haying season advanced. The percentage of nitrogen-free extract increased with the advance in stage of plant maturity. Wire grass, deschampsia, and redtop increased in ether extract toward the end of the season, while the reverse was true with timothy. Timothy decreased in ash toward the end of the season.

McCreary (20) reports that the percentage of protein in certain grasses was highest during the early growing stage, decreasing until the plants were entirely dead; but "after the death of the grasses in the fall, the dead plants may remain standing all winter without much change in chemical composition". The percentage of crude fiber increased with increase in age of the plant. The percentages of fat and total ash were highest during the green, growing stage and decreased until the plants were dead.

Cruickshank (5) found that the percentages of both calcium and phosphorus rose to a maximum at the beginning of

July and fell more or less steadily until October. The vari-ations in phosphorus were not quite so regular, and the range in variation was much less than in the case of calcium.

Aston, Grimmett, and Brogan (2) found that the nitrogen and phosphorus contents of pasture forages rose steadily with an increase in rain, being highest in the spring and falling through the summer to their lowest levels in the autumn. The percentage of calcium decreased steadily as the rainfall in-creased, being lowest in the winter and rising to a maximum in the autumn.

Ferguson (9) found that the percentages of nitrogen, phosphorus, and, to a lesser extent, of calcium fell during the dry period. This change was followed by an increase in the first two and by a further fall in calcium when rains came at the end of the season.

Greenhill and Page (10) report that the calcium content of pasture plants showed no definite seasonal trend.

Guilbert, Meade, and Jackson (11) found that leaching of forage plants caused a greater loss of phosphorus than of calcium. Depending upon the nature of the forage, leaching resulted in a loss of from 1 to 18 percent of the crude pro-tein and from 6 to 35 percent of the nitrogen-free extract. In every case the leached herbage was richer in fiber and ether extract and lower in nitrogen-free extract than was the original material.

According to Lush (16), "Season of year and rate of growth appear to be more important than type of vegetation in influencing the protein and fibre contents of monthly clipped pasture grass".

Roy and Sen (26) state that "Drought affected the P_2O_5 content more than the CaO content. During the growing season with increase in rainfall both constituents rose; but with the approach of winter and dry conditions, the P_2O_5 alone decreased".

Richardson, Trumble, and Shapter (25), using carefully controlled pot cultures of a perennial grass (Phalaris tuberosa), found that the percentages of nitrogen-free extract and crude fiber increased with advance in stage of growth. The percentages of crude protein and phosphorus decreased from the early stages of growth until maturity. The lime content showed a similar trend to that of phosphate, but was less marked.

Leukel, Camp, and Coleman (15) report that the percentage of phosphorus in those plants that were allowed to reach maturity gradually decreased as maturity was approached. The percentage of calcium was more uniform throughout the season.

Hart, Guilbert, and Goss (13), working with range grasses, found that during the early stages of growth the percentage of moisture varied from 80 to 87 percent. When the heads were forming, the moisture content was about 75 percent; when the plants were fully mature and were beginning to wilt, they contained about 65 percent moisture; and in the dry, leached stage the moisture content varied between 6 and 10 percent during hot, dry weather. The percentage of crude protein decreased from the early stages of growth until maturity. The percentage of silica-free ash in most of the plants studied decreased from the early stages of growth to the dry, leached stages. In some species, particularly the alfilarias, an increase in calcium, coincident with a reduction in the phosphorus content, occurred as the season advanced. The percentage of fat and nitrogen-free extract in the available portions of sweet birch increased as maturity was approached, while the percentage of crude protein decreased.

Daniel and Hoarce (7), studying the relation between effective rainfall and total calcium and phosphorus in alfalfa and prairie hays, found that when the effective rainfall was high, the calcium content decreased and the phosphorus content increased. When the effective rainfall was low, the calcium content increased and the phosphorus content decreased.

Christensen and Hopper (4) report that the prairie grasses have a high protein content during the early growing stages but that the protein content decreases as the grasses reach maturity. The April cutting was only slightly higher in crude fiber than was the October cutting. The July cutting was lower in crude fiber than was either of the other two cuttings. The percentage of ash was highest during the early growing stages and at maturity with a dip in the percentage during the intervening period.

Knight, Hepner, and Nelson (14) compared samples of grass collected during the summer with samples collected during the winter. The percentage of protein was highest during the summer, but the crude fiber content was greatest in the winter samples. There was slight change in the percentage of nitrogen-free extract, while the percentage of ether extract dropped materially in the winter samples.

Norman (22) found that both the ash and the protein contents in the barley plant showed slight initial rises which were followed by steady declines until the plant was mature. The percentage of lignin increased steadily until about one month before the plant was mature, after which it decreased slightly.

Malhotra (17) experimented with hard red winter wheat grown under natural conditions from September, 1930, to June, 1931, inclusive. There was less moisture during the winter and at maturity with the highest percentage in between. Oils were highest at maturity. Ash decreased from the first stages to maturity. Sugar was at a minimum in the beginning, increasing for a time and then decreasing again.

Phillips and Goss (24) report that the percentage of lignin in barley leaves and straw increased from 1.71 percent in the first sample taken to 8.36 percent when the plants were mature. The percentages of total ash and nitrogen decreased as the stage of plant maturity advanced.

Capen and LeClerc (3), working with native sedge, redtop, and cottongrass, found that the percentage of protein decreased as the season advanced. The percentage of crude fiber increased as the plant approached maturity, while the ether extract was fairly constant and appeared to show no definite seasonal trend. The percentage of total ash in redtop was higher during the later stages of plant growth, while the reverse was true with cotton grass and sedge.

Dustman and Shriver (8) found that up to the blooming stage the crude protein, nitrogen-free extract, and ash contents of Ambrosia trifida ran high, while the percentage of crude fiber ran correspondingly low. After the blooming stage the first three constituents decreased, and crude fiber increased.

This review of literature indicates that, in practically every case, the crude protein, phosphorus, and moisture contents of forage plants were highest during the early growth stages, decreasing to a minimum as the plants became mature and dry; but the review fails to show any consistent trend in calcium, total ash, and ether extract. The percentage of crude fiber, nitrogen-free extract, and lignin tended to increase as the plants approached maturity.

EXPERIMENTAL PROCEDURE

The Animal Husbandry experiment range, from which the samples used in this study were taken, is located in the rolling grassland range type, near Sonoita, in Southern Arizona. This area is almost devoid of browse plants, being characterized primarily by perennial grasses. The predominating species are curly mesquite, blue grama, and hairy grama with some black grama, Texas timothy, and several species of Aristida occurring in varying amounts. Small amounts of shrubby buckwheat (*Eriogonum wrightii*), isolated bunches of loco, occasional colonies of *Yucca elata*, and appreciable amounts of *Senecio longilobus* are found. Some weeds and annual grasses are present during and for a short time following the rainy seasons.

Blue grama (*Bouteloua gracilis*), hairy grama (*Bouteloua hirsuta*), and curly mesquite (*Hilaria belangeri*) are the species that were studied. These are three of the most important range grasses in Arizona. The gramas occur at all elevations from the upper limits of the desert type up to and including the mountain ranges, being particularly prevalent on the grassland ranges. Curly mesquite is very important on the prairies and foothills and at the higher elevations of the desert ranges.

The summer rains initiate the annual growth of these perennial grasses in late July. The plants grow rapidly, mature quickly, and by the middle of October begin to dry up. Except for a few green shoots in the early spring, these grasses show no further growth until the following summer rains.

Beginning August 9, 1934, about two weeks after new growth had started, pure samples of each of the three species studied were collected from the experiment range at 10 to 14-day intervals until November 1. From November until April, 1935, monthly samples were taken. After April, sampling ceased until new growth had started. Beginning with August 3, 1935, sampling proceeded in a manner similar to that of the previous year, being terminated in January, 1936.

The grass samples were obtained by clipping the plants about 1-1/2 inches above the ground with scissors. Only those plants which had not been previously clipped or grazed were collected, in order that the samples would represent successive stages of growth. The grass was then placed in weighed muslin bags and the weights of the fresh samples determined. After remaining in the laboratory until they had ceased to lose moisture, the samples were again weighed; and calculations were made for the amount of moisture lost by air drying. Representative portions of the samples were then finely ground in a mill; and determinations were made for moisture, crude protein, total ash, ether extract, crude fiber, nitrogen-free extract, lignin, calcium, and phosphorus.

The total moisture present in the freshly-clipped grass was arrived at by combining the moisture lost by oven drying with that lost by air drying. The other constituents were all calculated on the moisture-free basis.

Analyses for total ash, crude protein, ether extract, crude fiber, and nitrogen-free extract were made according to the A.O.A.C. methods (1). Calcium was determined volumetrically by the standard oxalate method and phosphorus volumetrically by means of the standard molybdate method.

The following procedure was used in determining lignin: a small sample (2-3 grams) of the plant material was allowed to stand overnight in 25 cc. of 80 percent sulfuric acid. 375 cc. of water were then added, and the resulting mixture was autoclaved at 15 pounds pressure for one hour. This was followed by filtration through a previously dried and weighed filter paper. The filter paper plus residue was dried at 105° C. and the weight of the residue determined. Determinations were made for the crude protein and ash present in the residue. The weight of the residue minus the combined weights of the ash and crude protein that it contained was taken as the weight of lignin present in the original sample.

DATA SECURED

The seasonal changes in the chemical compositions of blue grama, curly mesquite, and hairy grama are given in Tables I, II, and III, respectively. The trends in the various chemical constituents are presented graphically in Plates 1-9. The three species are represented in each plate.

The moisture content (Plate I) was very high in the young plants and fell steadily until the plants were mature and dry in November. From November until March there was little change in the percentage of moisture, with an increase occurring during March and April after new growth had started.

The percentage of total ash (Plate 2) and that of ether extract (Plate 4) were extremely variable, and no definite trend was found in either case. It is interesting to note, however, that curly mesquite was considerably higher in total ash throughout both seasons than were the gramas.

Plate 3 shows a steady decline in the percentage of crude protein from the early growth stages in August until the last of November. Very little change occurred in the protein content from November until the latter part of February, but a small rise accompanies the spring growth of the grasses during March.

The crude fiber content (Plate 5) rose rapidly during August but was somewhat variable from September to December.

TABLE I. SEASONAL CHANGES IN THE CHEMICAL COMPOSITION OF BLUE GRAMA (<u>Bouteloua gracilis</u>). August 9, 1934 - January 20, 1936.

Date Collected	H_2O in Fresh Sample %	Moisture-Free Basis: Total Ash %	Crude Protein %	Ether Extract %	Crude Fiber %	N-free Extract %	Lignin %	CaO %	P_2O_5 %
Aug. 9, 1934	67.09	11.02	20.98	2.06	23.10	42.84	34.61	.532	.965
Aug. 20, 1934	70.62	11.08	15.29	2.10	28.61	42.92	33.63	.543	.966
Sept. 1, 1934	67.18	9.13	12.13	1.24	32.96	44.53	39.33	.345	.627
Sept. 13, 1934	54.08	8.58	6.43	1.59	32.93	50.47	40.22	.250	.472
Sept. 22, 1934	52.51	9.88	7.21	1.10	32.83	48.97	31.85	.314	.534
Oct. 5, 1934	41.95	11.19	6.96	1.44	32.35	48.06	35.23	.353	.589
Oct. 16, 1934	36.58	10.21	4.25	.96	35.49	49.08	45.56	.326	.456
Nov. 1, 1934	18.98	10.53	4.30	.93	33.57	50.67	45.19	.313	.416
Nov. 26, 1934	8.62	6.50	2.75	.87	37.52	52.36	50.53	.208	.159
Dec. 26, 1934	11.77	7.44	2.89	.95	35.59	53.14	50.52	.208	.138
Jan. 30, 1935	10.79	8.46	3.34	.77	30.16	57.26	40.69	.274	.159
Feb. 18, 1935	8.08	8.00	2.58	.93	32.79	55.70	41.54	.270	.129
Mar. 23, 1935	15.92	11.38	3.67	.76	31.08	53.10	39.04	.296	.218
Apr. 15, 1935	24.76	11.14	3.90	.79	28.88	55.29	37.33	.249	.255
Aug. 3, 1935	63.97	9.70	15.13	1.82	24.91	48.45	28.60	.454	.942
Aug. 14, 1935	65.35	11.98	13.77	2.14	27.96	44.15	26.71	.451	.935
Aug. 23, 1935	64.07	9.44	9.85	1.43	36.08	43.19	29.49	.369	.864
Sept. 3, 1935	62.58	7.60	8.23	.75	37.15	46.26	30.99	.247	.628
Sept. 14, 1935	52.18	9.43	7.69	.86	33.81	48.21	30.50	.297	.672
Sept. 25, 1935	49.44	7.56	8.19	1.11	33.44	49.69	30.73	.266	.554
Oct. 3, 1935	46.39	9.93	5.92	1.20	35.63	47.31	33.09	.309	.619
Oct. 13, 1935	42.23	12.74	4.98	1.01	32.22	49.05	32.98	.498	.668
Oct. 26, 1935	31.06	11.79	3.75	1.06	33.84	49.52	28.73	.460	.611
Dec. 1, 1935	-----	10.57	2.17	1.09	34.06	52.10	30.11	.306	.200
Jan. 20, 1936	8.95	8.94	2.75	1.31	30.18	56.81	34.03	.244	.119

TABLE II. SEASONAL CHANGES IN THE CHEMICAL COMPOSITION OF CURLY MESQUITE (*Hilaria belangeri*). August 9, 1934 - January 20, 1936.

Date Collected	H_2O in Fresh Sample %	Moisture-Free Basis: Total Ash %	Crude Protein %	Ether Extract %	Crude Fiber %	N-free Extract %	Lignin %	CaO %	P_2O_5 %
Aug. 9, 1934	71.55	13.46	12.94	2.28	26.01	45.30	36.11	.369	.323
Aug. 20, 1934	70.54	13.76	12.21	2.36	28.17	43.51	34.99	.514	.316
Sept. 1, 1934	63.86	13.00	8.63	1.72	30.08	46.57	37.51	.338	.619
Sept. 13, 1934	52.15	13.85	5.90	2.03	29.43	48.80	41.23	.380	.424
Sept. 22, 1934	42.14	10.64	5.17	1.47	30.82	51.90	37.62	.318	.438
Oct. 5, 1934	30.24	12.32	3.38	1.52	30.01	52.77	42.41	.327	.350
Oct. 16, 1934	20.36	11.48	3.18	2.04	30.23	53.08	46.96	.296	.249
Nov. 1, 1934	7.32	12.01	2.54	1.30	30.29	53.86	44.53	.299	.331
Nov. 27, 1934	-----	13.77	2.19	1.12	32.81	50.11	45.34	.193	.138
Dec. 26, 1934	8.36	12.83	2.63	.94	33.50	50.11	41.75	.223	.128
Jan. 30, 1935	6.83	17.56	2.32	1.36	28.80	49.96	37.01	.191	.104
Feb. 18, 1935	5.04	12.42	2.61	.97	30.77	53.23	37.15	.216	.094
Mar. 23, 1935	24.47	11.94	4.87	1.12	32.48	49.59	38.77	.201	.190
Apr. 15, 1935	30.40	13.14	4.85	1.52	27.80	52.70	36.80	.205	.255
Aug. 3, 1935	67.74	12.39	12.01	2.42	28.90	44.28	28.58	.359	.741
Aug. 14, 1935	67.53	14.17	10.06	1.82	30.81	43.15	26.81	.328	.806
Aug. 23, 1935	65.65	12.94	9.05	1.87	33.33	42.81	29.51	.351	.775
Sept. 3, 1935	60.87	13.69	6.76	1.27	33.22	45.06	29.96	.266	.669
Sept. 14, 1935	53.31	13.91	6.00	2.15	32.69	45.25	30.06	.352	.538
Sept. 25, 1935	50.82	12.72	4.95	1.22	34.04	47.07	30.90	.335	.427
Oct. 3, 1935	46.15	17.48	4.68	1.47	30.65	45.72	30.03	.386	.456
Oct. 13, 1935	39.61	18.62	3.58	1.25	30.70	45.84	32.31	.386	.382
Oct. 26, 1935	33.88	17.03	3.59	1.14	30.15	48.09	32.59	.362	.411
Dec. 1, 1935	-----	13.99	2.28	2.22	29.90	51.61	30.01	.332	.155
Jan. 20, 1936	7.17	16.12	2.60	1.37	25.95	53.95	31.68	.310	.100

TABLE III. SEASONAL CHANGES IN THE CHEMICAL COMPOSITION OF HAIRY GRAMA (<u>Bouteloua</u> <u>hirsuta</u>). August 11, 1934 - January 20, 1936.

Date Collected	H_2O in Fresh Sample %	Moisture-Free Basis							
		Total Ash %	Crude Protein %	Ether Extract %	Crude Fiber %	N-free Extract %	Lignin %	CaO %	P_2O_5 %
Aug. 11, 1934	61.96	8.55	12.82	1.94	29.04	47.65	33.41	.380	.361
Aug. 20, 1934	65.96	11.26	12.00	1.88	32.46	42.40	32.94	.376	.428
Sept. 1, 1934	68.54	11.40	10.63	1.78	33.11	43.09	37.69	.441	.670
Sept. 13, 1934	47.69	8.41	7.57	1.08	35.32	47.62	41.41	.249	.339
Sept. 22, 1934	33.29	7.11	5.93	1.49	33.09	52.38	37.72	.189	.211
Oct. 5, 1934	22.94	8.13	5.13	1.97	32.51	52.26	44.06	.253	.335
Oct. 16, 1934	18.44	8.15	4.08	1.84	34.50	51.42	44.41	.193	.249
Nov. 1, 1934	9.93	7.65	4.06	1.76	36.67	49.86	46.26	.148	.158
Nov. 27, 1934	10.45	6.94	2.68	1.18	37.22	51.98	47.35	.148	.159
Dec. 26, 1934	12.90	7.22	2.29	.81	37.24	52.44	46.31	.119	.080
Jan. 30, 1935	10.11	6.55	2.35	.98	31.31	58.81	40.07	.157	.062
Feb. 18, 1935	11.19	7.74	2.54	.89	34.24	54.59	40.39	.167	.060
Mar. 23, 1935	13.32	8.74	5.73	1.07	35.36	49.10	40.68	.151	.087
Aug. 10, 1935	-----	9.66	14.54	1.66	31.30	42.83	24.18	.451	.606
Aug. 19, 1935	65.99	10.60	13.18	1.01	32.00	43.21	24.53	.498	.652
Aug. 30, 1935	66.41	9.82	10.30	1.20	34.64	44.04	27.58	.438	.610
Sept. 10, 1935	58.70	9.27	8.53	1.54	32.30	48.36	29.47	.350	.591
Sept. 19, 1935	50.74	8.75	5.86	.83	37.09	47.47	30.42	.342	.476
Oct. 3, 1935	46.64	10.18	6.69	1.12	32.83	49.19	30.26	.367	.439
Oct. 13, 1935	35.39	9.92	5.54	1.63	32.92	49.99	32.56	.466	.387
Oct. 26, 1935	30.61	11.47	3.72	1.31	34.03	49.47	28.78	.279	.387
Dec. 1, 1935	-----	9.36	2.23	1.17	33.60	53.63	29.80	.215	.132
Jan. 20, 1936	13.51	8.26	2.61	1.27	32.34	55.51	33.62	.176	.112

PLATE I

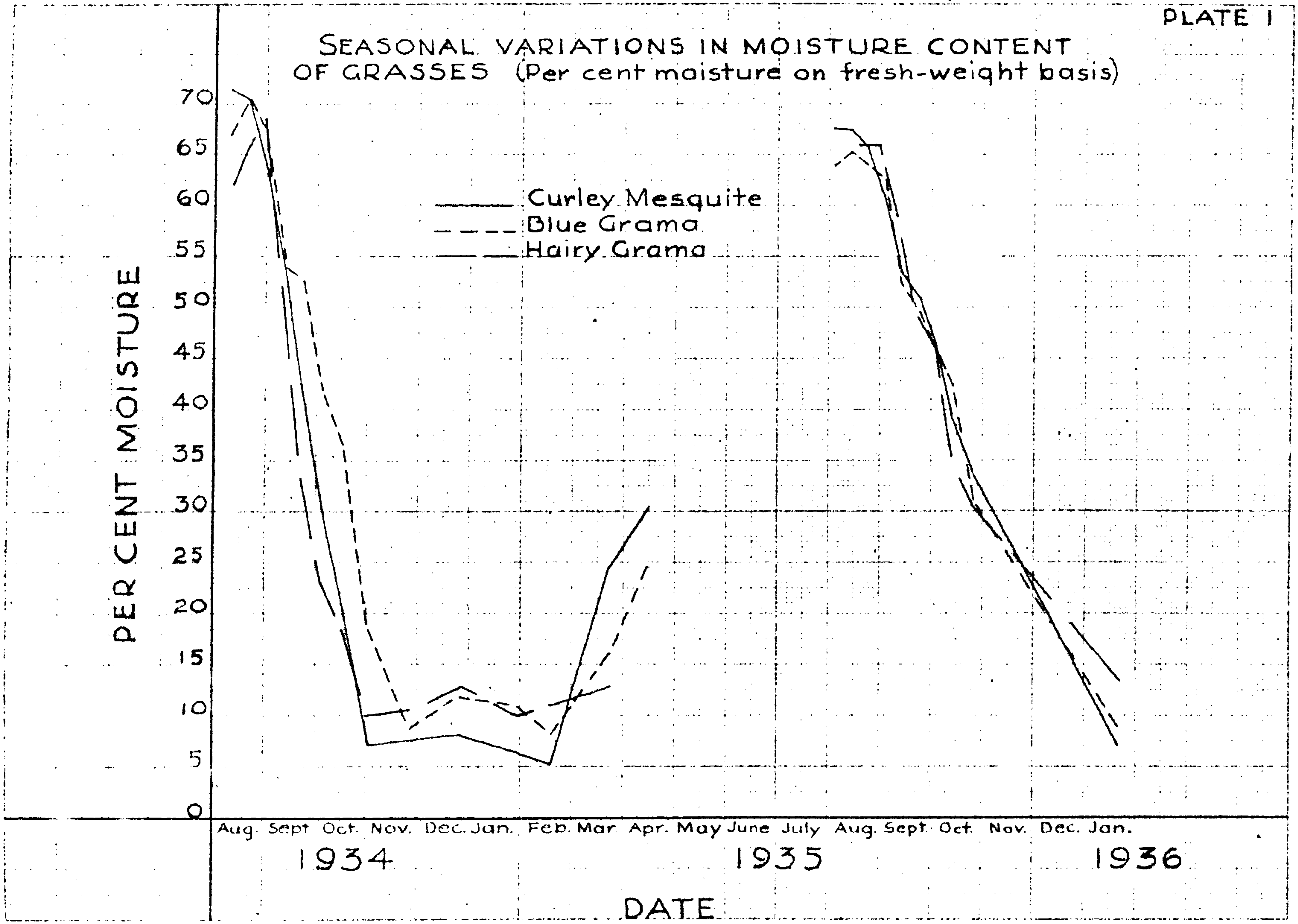

SEASONAL VARIATIONS IN MOISTURE CONTENT OF GRASSES (Per cent moisture on fresh-weight basis)
Curley Mesquite
Blue Grama
Hairy Grama
PER CENT MOISTURE
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Aug. Sept Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept Oct. Nov. Dec. Jan.
1934
1935
1936
DATE

PLATE 2

SEASONAL VARIATIONS IN TOTAL ASH CONTENT OF GRASSES
(Per cent ash on moisture-free basis)

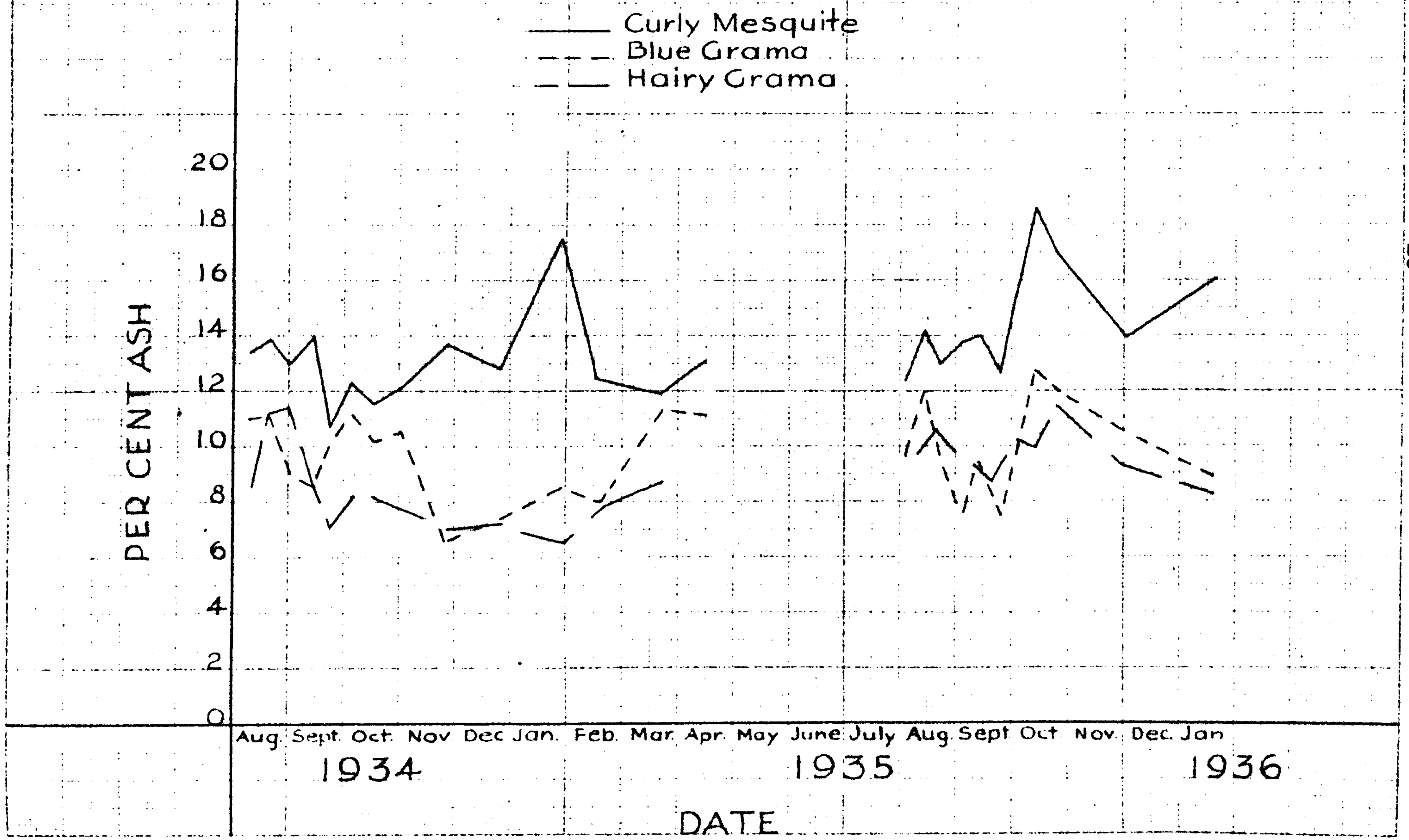
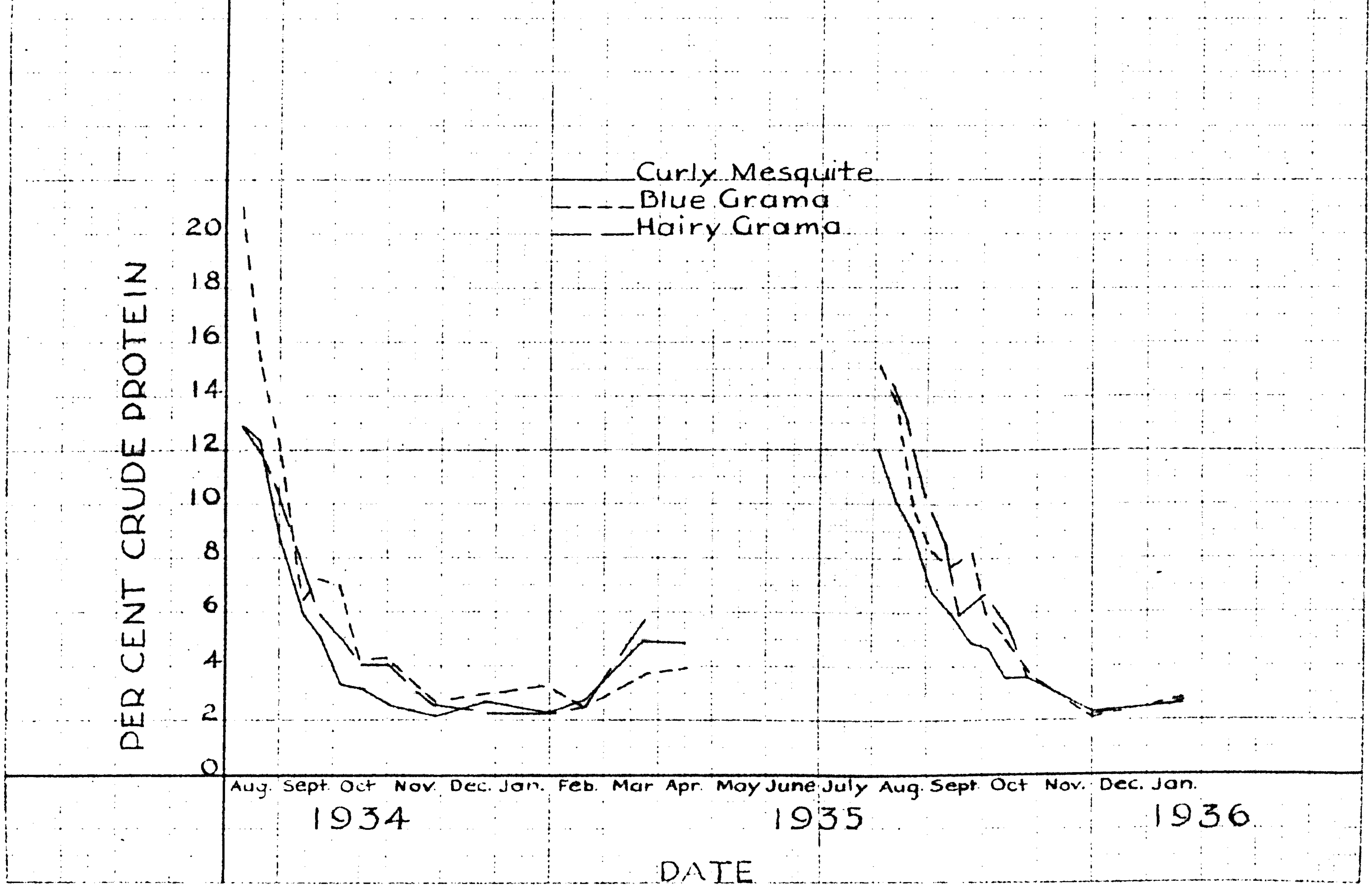


PLATE 3

SEASONAL VARIATIONS IN CRUDE PROTEIN CONTENT OF GRASSES.
(Per cent crude protein on moisture-free basis)



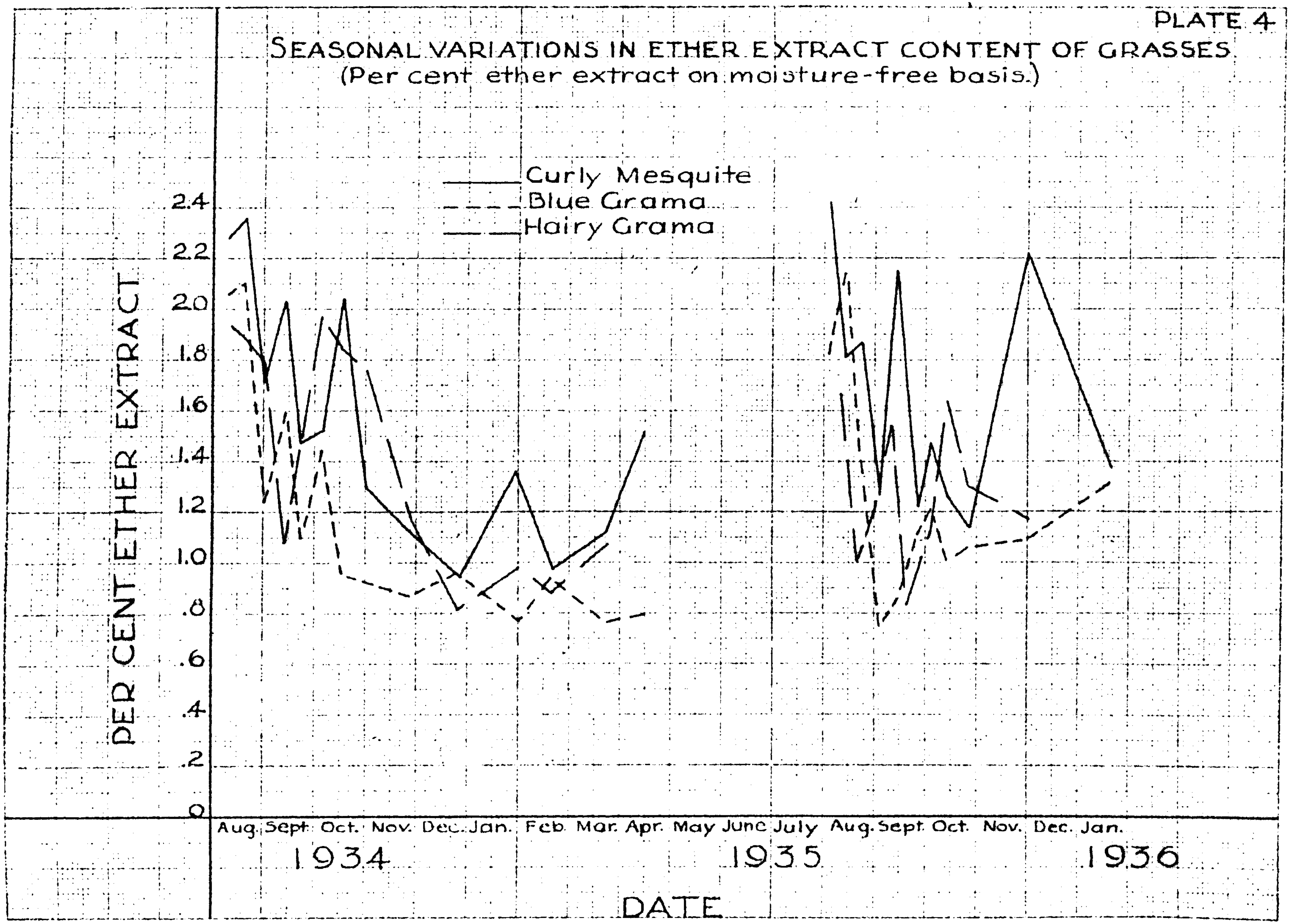


PLATE 4
SEASONAL VARIATIONS IN ETHER EXTRACT CONTENT OF GRASSES
(Per cent ether extract on moisture-free basis.)
Curly Mesquite
Blue Grama
Hairy Grama
PER CENT ETHER EXTRACT
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan.
1934
1935
1936
DATE

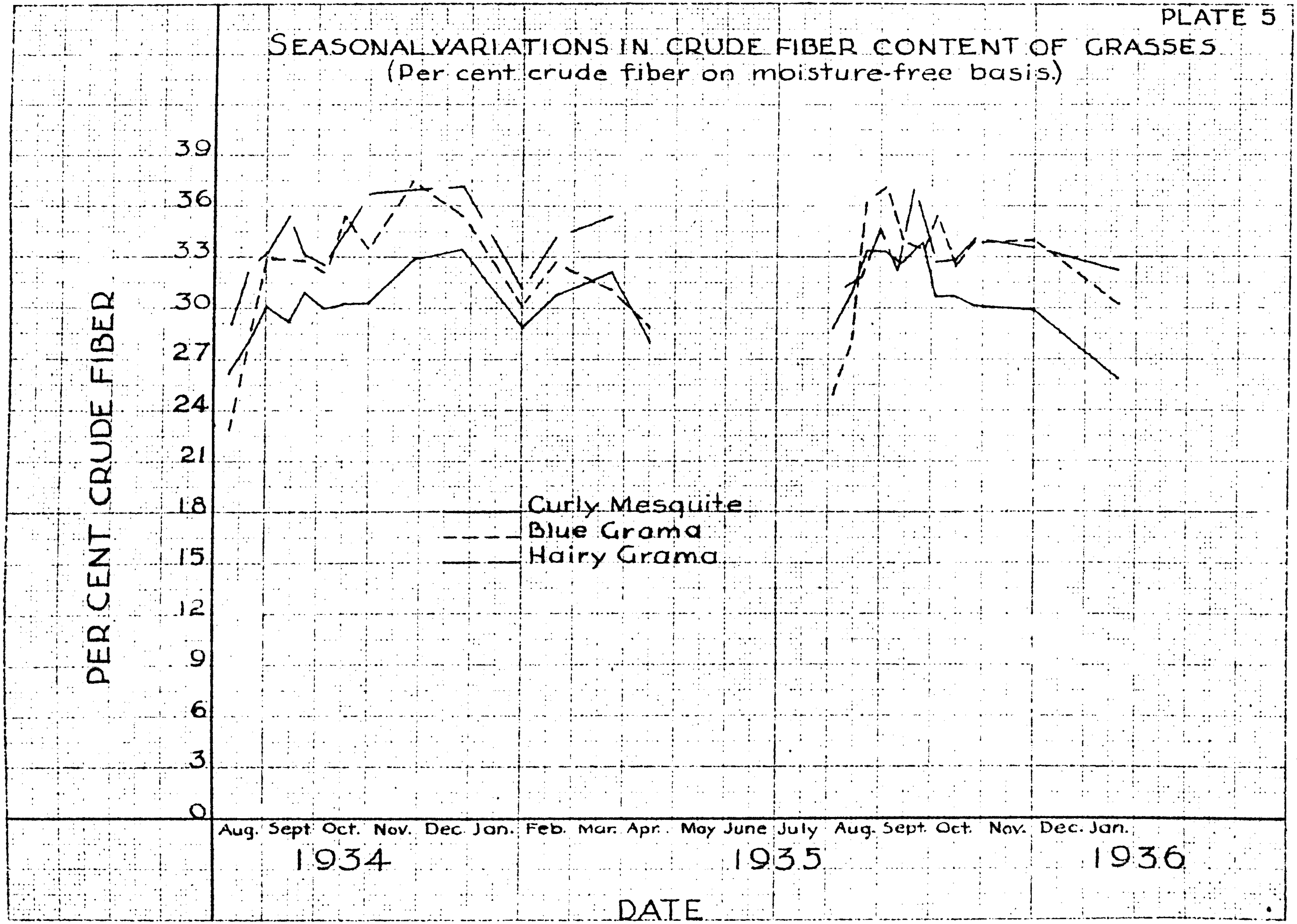
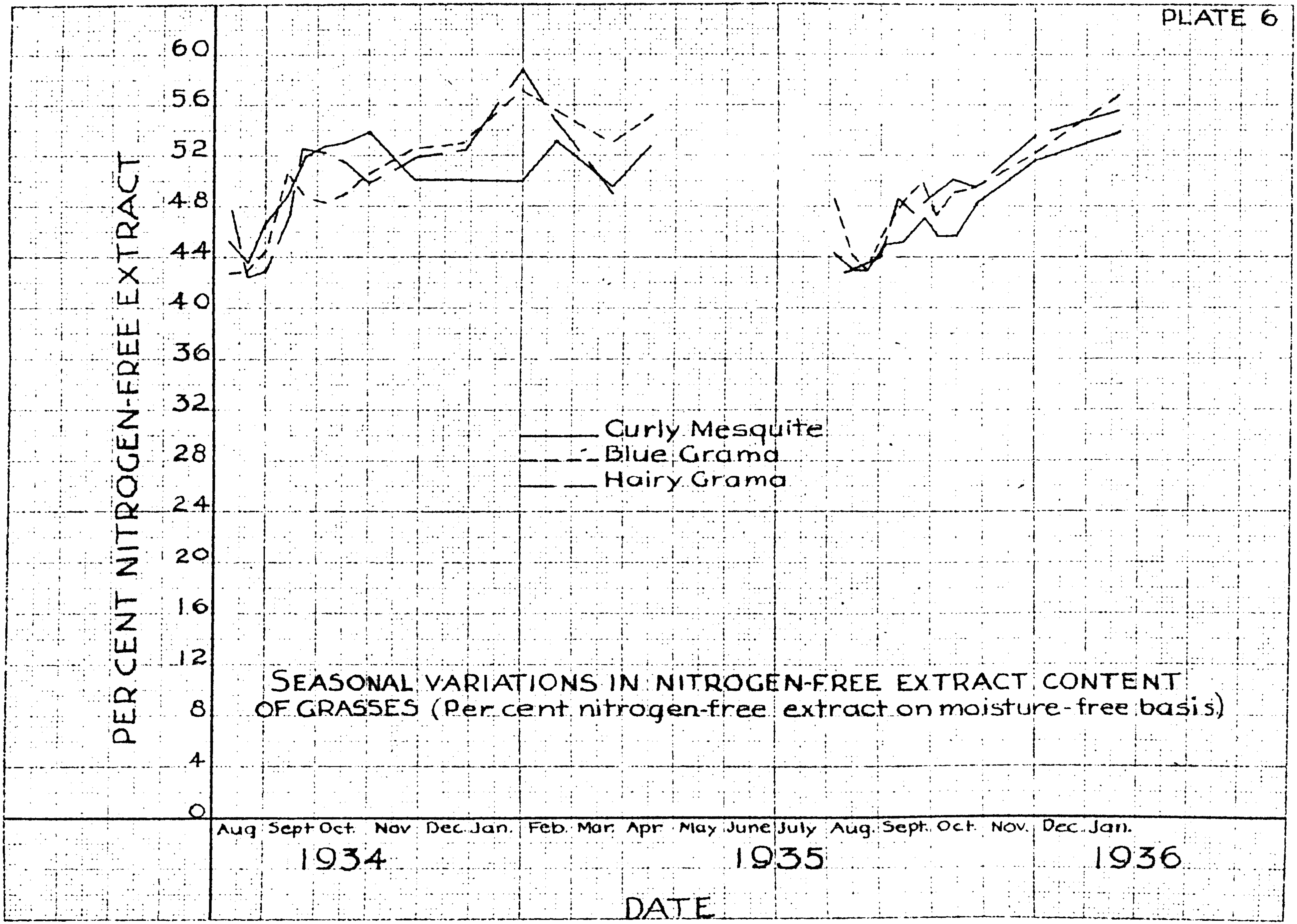


PLATE 5

SEASONAL VARIATIONS IN CRUDE FIBER CONTENT OF GRASSES
(Per cent crude fiber on moisture-free basis)

PLATE 6


PER CENT NITROGEN-FREE EXTRACT
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
Curly Mesquite
Blue Grama
Hairy Grama
SEASONAL VARIATIONS IN NITROGEN-FREE EXTRACT CONTENT OF GRASSES (Per cent nitrogen-free extract on moisture-free basis)
Aug Sept Oct. Nov Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan.
1934
1935
1936
DATE

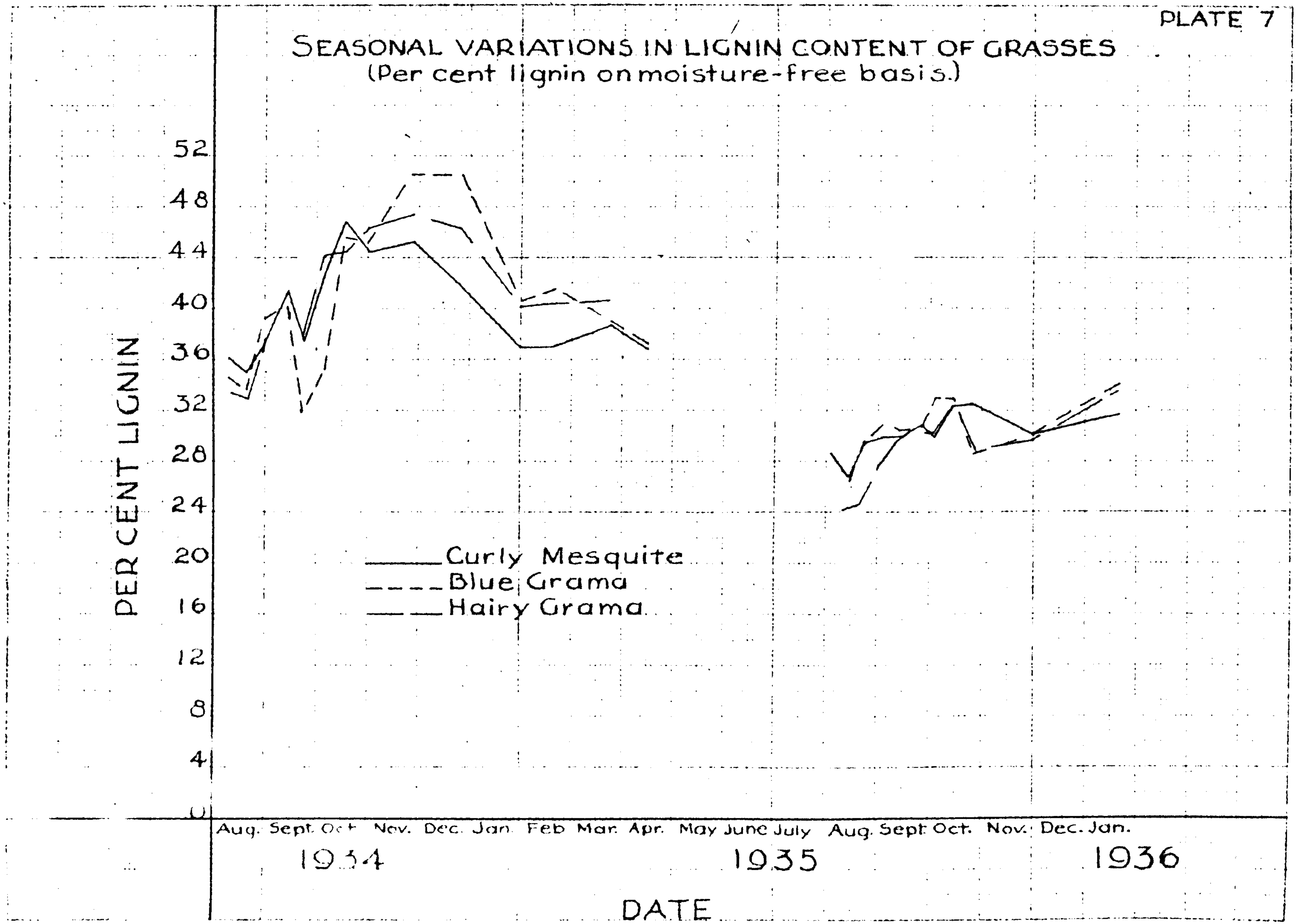


PLATE 7
SEASONAL VARIATIONS IN LIGNIN CONTENT OF GRASSES
(Per cent lignin on moisture-free basis.)
PER CENT LIGNIN
52
48
44
40
36
32
28
24
20
16
12
8
4
0
Curly Mesquite
Blue Grama
Hairy Grama
Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan.
1934
1935
1936
DATE

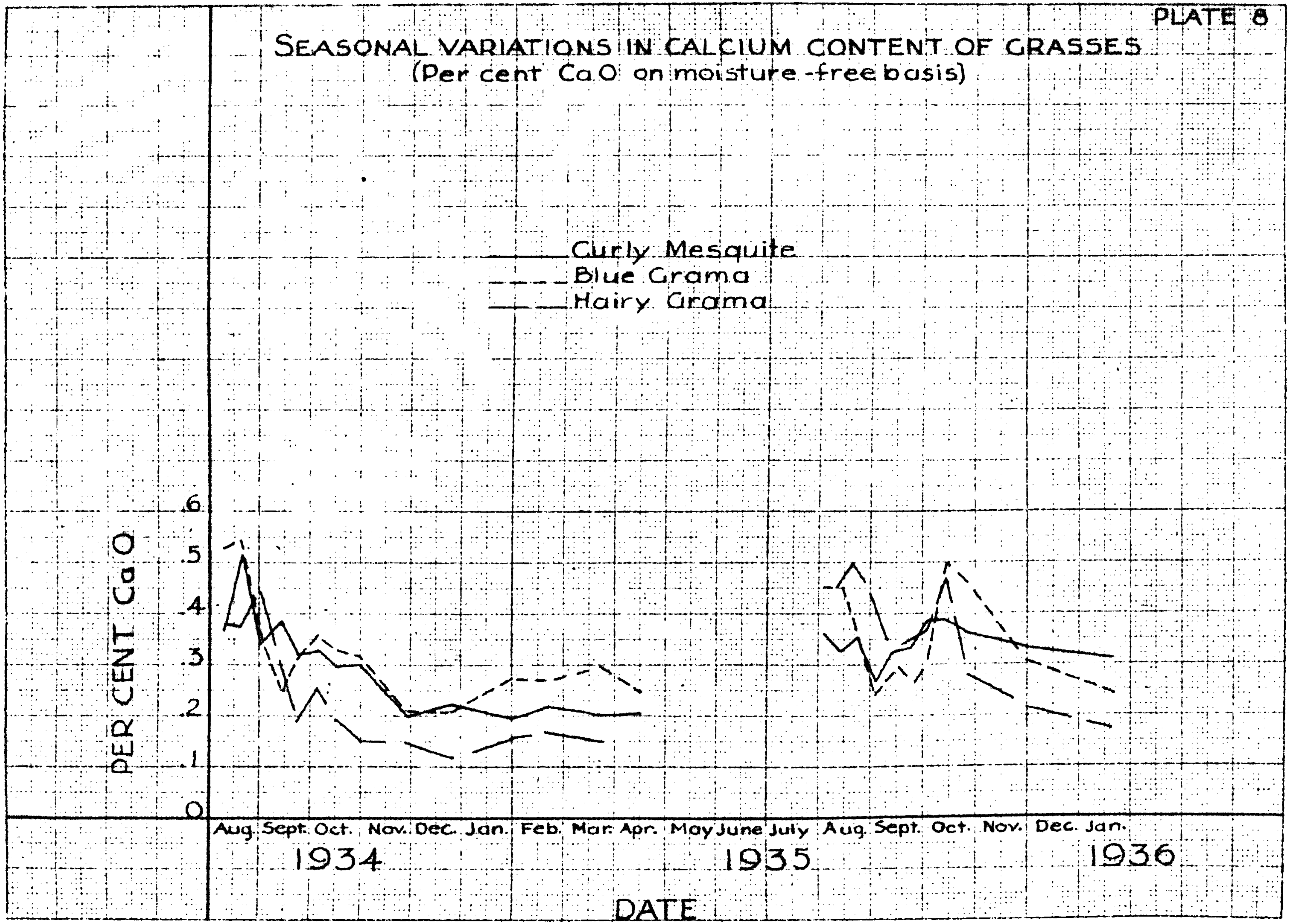


PLATE 8
SEASONAL VARIATIONS IN CALCIUM CONTENT OF GRASSES
(Per cent CaO on moisture-free basis)
Curly Mesquite
Blue Grama
Hairy Grama
PER CENT CaO
.6
.5
.4
.3
.2
.1
0
Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan.
1934
1935
1936
DATE

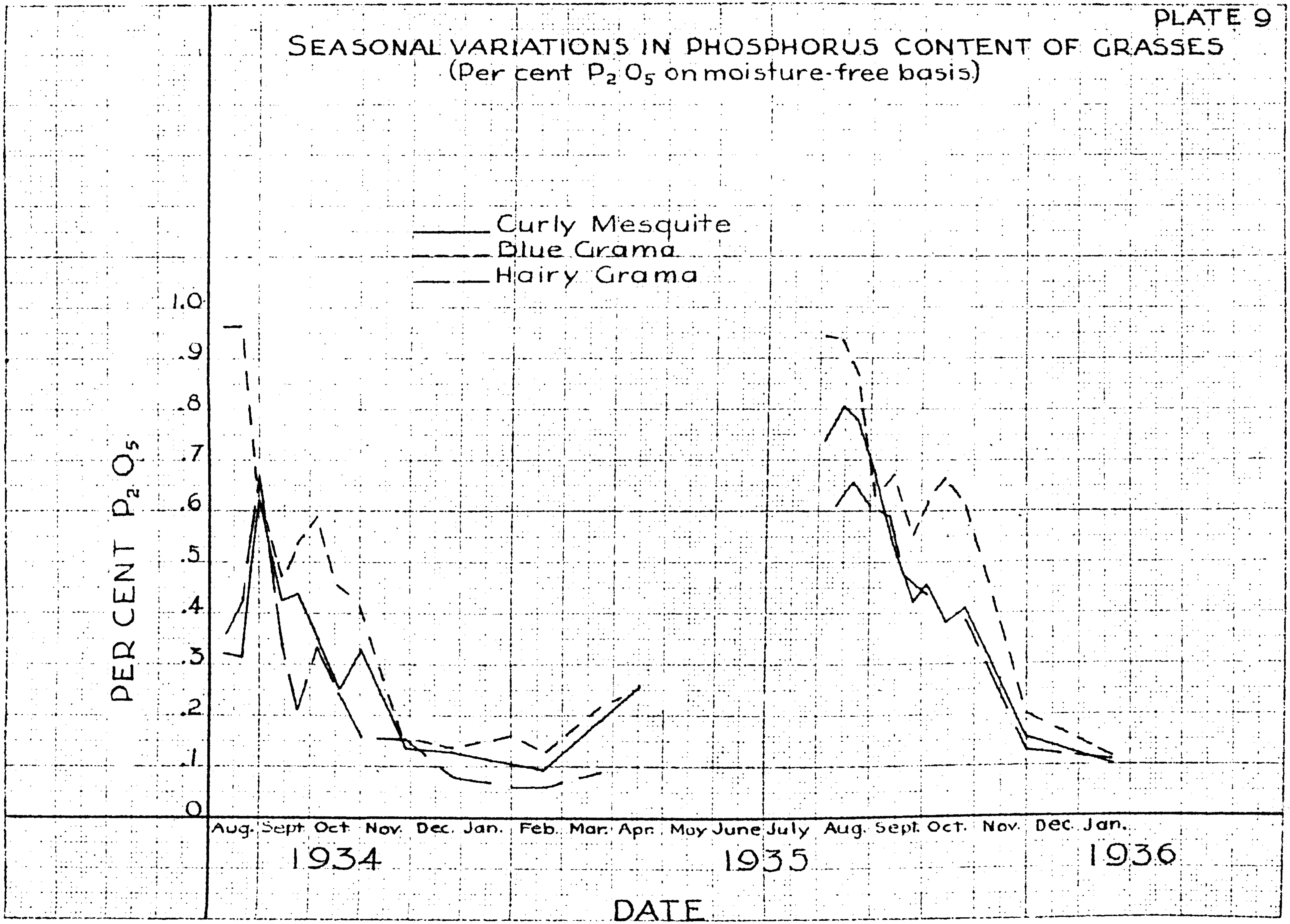


PLATE 9
SEASONAL VARIATIONS IN PHOSPHORUS CONTENT OF GRASSES
(Per cent P_2O_5 on moisture-free basis)
Curly Mesquite
Blue Grama
Hairy Grama
PER CENT P_2O_5
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan.
1934
1935
1936
DATE

A decrease occurred during January, followed by another rise in February and March.

Plate 6 shows the trends in nitrogen-free extract. Following slight decreases during August in the cases of curly mesquite and hairy grama in 1934 and of curly mesquite and blue grama in 1935, the percentage of nitrogen-free extract gradually rose to its peak in the latter part of January. Curly mesquite in 1934 may be regarded as a possible exception to the general trend. During 1934, the nitrogen-free extract content of curly mesquite fell slightly during November and, after remaining constant until February, rose again to its former level. All three species showed a decline in March, with another rise occurring during April in the curly mesquite and blue grama.

A higher lignin content was obtained throughout the season in 1934 than in 1935 (Plate 7). The results are somewhat variable but do show a general upward trend in lignin from August to the latter part of November in 1934, and from August to the middle of October in 1935. In 1934 there was a sharp decline during January, followed by a period in which the percentage of lignin remained more or less constant. The gramas, during the latter part of October, and curly mesquite, during November, dropped slightly in lignin content in 1935. These declines were followed by increases in December and January.

In each of the species studied the calcium content (Plate 8) was high during the early stages of growth and low in December and January. During the intervening period the percentage of calcium was somewhat variable but tended to decrease from the middle of August until the latter part of September, to rise in October, and then to fall again during November. A slight increase occurred in February and March with the advent of new plant growth.

Except for initial rises in the cases of curly mesquite and hairy grama, together with a few irregularities during October, the phosphorus content (Plate 9) showed a steady, and very marked, decline during the period of August to November. From November until February there was a further gradual decrease, which was followed by a small rise during March and April.

DISCUSSION

Tables I-III and Plates 1-9 show that blue grama, hairy grama, and curly mesquite were quite similar with respect to seasonal trends in chemical composition. The same generalization holds true regarding quantitative amounts of the various chemical constituents except in the case of total ash. Curly mesquite was noticeably higher than the other two species in total ash throughout both seasons.

The seasonal trends observed during the present study agree, for the most part, with those reported by other investigators, which include McCreary (19), Cundy (6), Cruickshank (5), Richardson, Trumble and Shapter (25), Hart, Guilbert, and Goss (13), and several others. This agreement is particularly striking in the cases of moisture, crude protein, and phosphorus.

Table IV shows the seasonal distribution of rainfall on the experimental range, from August 1, 1934, to January 31, 1936, by half-month periods. The summer rainy season occurred from the latter part of July through September. The winter rains came in December, January, February, and March. There was very little rainfall during the remaining months.

Plate 10 shows the relationship between the rainfall and the crude protein and phosphorus contents of blue grama, hairy grama, and curly mesquite. The crude protein and phosphorus

TABLE IV. SEASONAL DISTRIBUTION OF RAINFALL ON THE EXPERIMENTAL RANGE. AUGUST 1, 1934 - JANUARY 31, 1936. (TOTAL INCHES OF RAINFALL BY HALF-MONTH PERIODS)

Date	Inches of Rainfall
1934	
August 1 - 15	2.89
16 - 31	2.86
September 1 - 15	0.00
16 - 30	0.39
October 1 - 15	0.12
16 - 31	0.00
November 1 - 15	0.00
16 - 30	0.74
December 1 - 15	0.65
16 - 31	1.57
1935	
January 1 - 15	1.02
16 - 31	0.16
February 1 - 14	1.54
15 - 28	0.04
March 1 - 15	1.11
16 - 31	0.06
April 1 - 15	0.09
16 - 30	0.00
May 1 - 15	0.33
16 - 31	0.00
June 1 - 15	0.06
16 - 30	0.00
July 1 - 15	0.30
16 - 31	1.93
August 1 - 15	2.08
16 - 31	2.42
September 1 - 15	0.76
16 - 30	1.80
October 1 - 15	0.00
16 - 31	0.00
November 1 - 15	0.48
16 - 30	1.30
December 1 - 15	0.00
16 - 31	1.37
1936	
January 1 - 15	0.00
16 - 31	0.48

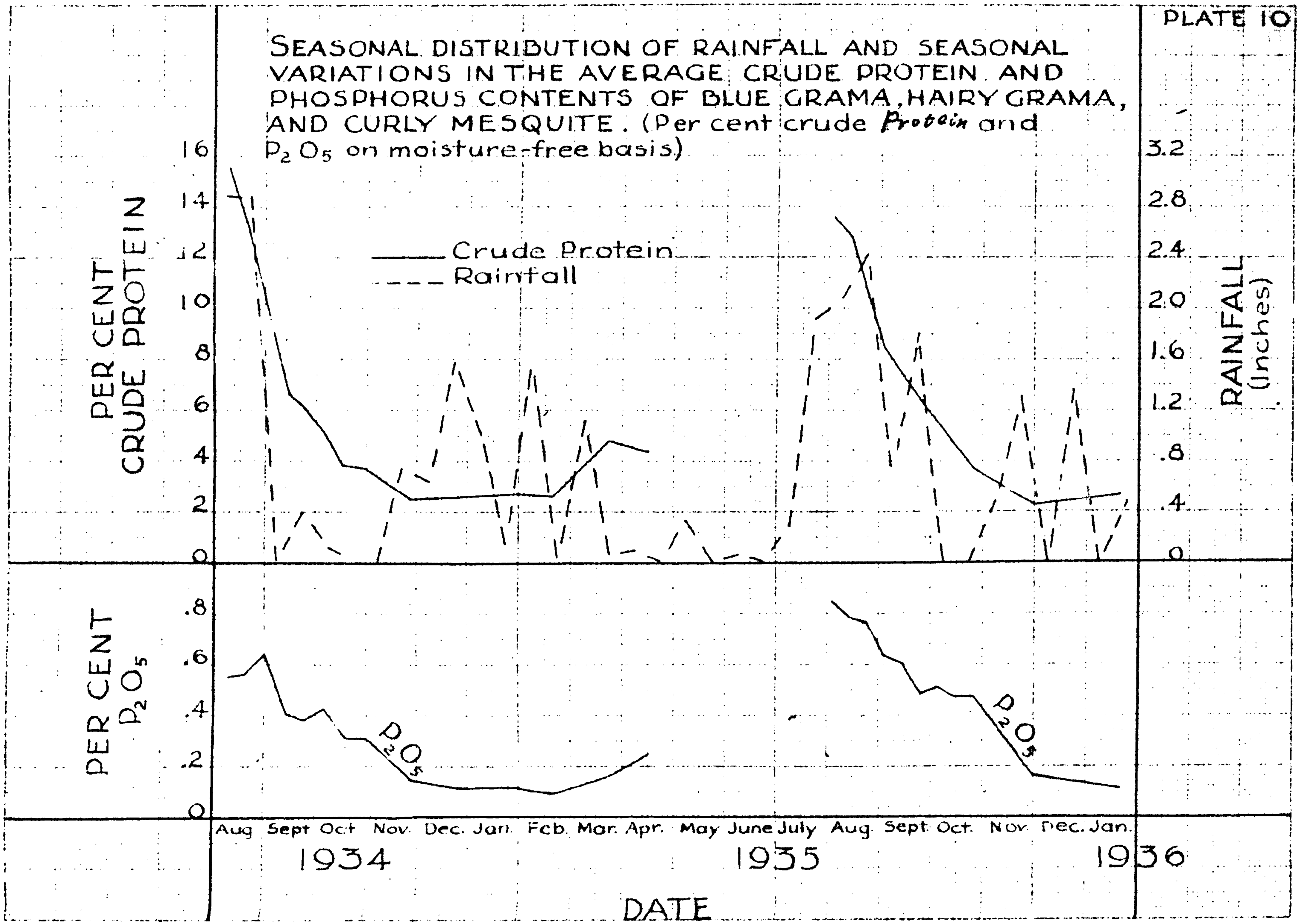


PLATE 10
SEASONAL DISTRIBUTION OF RAINFALL AND SEASONAL VARIATIONS IN THE AVERAGE CRUDE PROTEIN AND PHOSPHORUS CONTENTS OF BLUE GRAMA, HAIRY GRAMA, AND CURLY MESQUITE. (Per cent crude Protein and P_2O_5 on moisture-free basis)
Crude Protein
Rainfall
PER CENT CRUDE PROTEIN
16
14
12
10
8
6
4
2
0
RAINFALL (Inches)
3.2
2.8
2.4
2.0
1.6
1.2
.8
.4
0
PER CENT P_2O_5
.8
.6
.4
.2
0
P_2O_5
P_2O_5
Aug Sept Oct Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec. Jan.
1934
1935
1936
DATE

curves represent averages of all three species. Both crude protein and phosphorus were high during the summer rainy season, fell in the autumn, and tended to rise again following the winter rains. Samples collected during March and April contained some new growth mixed with the old grass.

Although the percentages of crude protein and phosphorus tend to vary directly with the amount of rainfall, they are influenced by the rainfall in an indirect, rather than a direct, way. The phosphorus and protein contents of range grasses depend upon the stage of plant growth, which is influenced, to a marked degree, by the amount of rainfall.

No definite trend was observed in the percentage of total ash. The amount of total ash, however, is not nearly so significant in determining the nutritive value of a feed as are the amounts of the more important minerals, such as calcium and phosphorus, that are present. The grass may have become contaminated with dust while it was still standing, which would account for some increases in total ash. No effort was made to determine the presence or degree of this contamination. Woodman and co-workers (31) report that some soil was included in their grass samples during the cutting process.

The crude fiber content reached its peak sooner than was expected. Perennial grasses, on Arizona ranges tend to grow rapidly and to mature quickly because of the late growing season and the warm weather which accompany the summer rains. These factors may account for the rapid increase in crude fiber. The drop in crude fiber during the winter months was probably due to a partial decomposition of cellulose by weathering. A rise in fiber resulted from new plant growth in the spring.

The nitrogen-free extract fraction is of doubtful nutritive value. By definition, it is the easily soluble carbohydrates; but, actually, it may contain varying amounts of several constituents. During the determination of crude fiber, much of the lignin is removed by boiling with dilute alkali. This lignin is reported as nitrogen-free extract. The onset of lignification during the later stages of plant growth may explain in part the increase in percentage of nitrogen-free extract.

Regarding the digestibility of nitrogen-free extracts, Woodman, Blunt, and Stewart (30) observed that the digestibilities of the crude fiber and nitrogen-free extract of frequently clipped pasture grass were about equal. Christensen and Hopper (4) obtained higher coefficients of digestion for crude fiber than for nitrogen-free extract in the October and April cuttings of prairie hay, while the nitrogen-free extract was slightly more digestible in the July cutting.

The calcium content was high during the early growth stages, low during the winter months, and somewhat variable during the intervening period. The work of other investigators fails to show consistent seasonal trends in calcium. Cruickshank (5), Ferguson (9), and Richardson, Trumble, and Shapter (25) report that calcium tended to decrease as the plants approached maturity. McCreary (19) and Hart, Guilbert, and Goss (13) found that calcium increased as the stage of plant growth advanced. Several investigators, including Aston and co-workers (2) and Daniel, Hurley, and Horace (7), found that the percentage of calcium in plants tended to vary inversely with the amount of rainfall.

Although similar trends were obtained in lignin for both seasons, the percentage of lignin was considerably higher throughout 1934 than it was in 1935 (Plate 7). Seasonal differences may have caused part of this difference.

The lignin figures for 1935 also appear abnormally high. Norman (22), using 72 percent sulfuric acid instead of 80 percent, found that the lignin content of the barley plant increased from 14.4 percent to 19.7 percent and then dropped back to 17.4 percent as the stage of maturity advanced. Phillips and Goss (24), using fuming hydrochloric acid, report that the percentage of lignin in the barley plant increased from 1.71 to 8.36 percent.

The lowest lignin results obtained during the present investigation were in 1935, with hairy grama, which had a lignin content of 24.18 percent during the early growth stages, increasing to 33.62 percent during the winter (Table III). Variety differences may have accounted for the discrepancies between these results and those reported by Norman; but the extremely low figures obtained by Phillips and Goss were undoubtedly due, in a large measure, to differences in analytical procedure.

The chemical nature of lignin is not very well understood, and no entirely satisfactory method for its analysis has thus far been developed. Norman (22) has suggested that the 72 percent sulfuric acid method is far from satisfactory. "It is certain that the lignin is changed by this treatment and by no means certain that errors do not occur when, along with carbohydrate material, there is also protein present, since humin bodies may be formed." (loc. cit.) The use of 80 percent instead of 72 percent sulfuric acid would probably result in similar errors.

Although the foregoing results apply primarily to curly mesquite, hairy grama, and blue grama grown on a specific range area, the general trends in chemical composition would, no doubt, be applicable to the forage grown on any range. These trends should be considered, however, from the standpoint of the stage in plant maturity rather than corresponding months of the year because different species may have different growing seasons and the same species may not have the same growing season under different conditions of moisture and temperature. It has also been shown that the exact amounts of phosphorus, calcium, and other mineral elements present in a plant may be influenced by the type of soil upon which the plant has been grown.

An analysis of the perennial grasses does not give a complete picture of the seasonal forage conditions on Arizona ranges. Except for a little growth during March and April, the only time that the perennial grasses are green is from late July until the latter part of October. During March and April, however, the winter rains produce a large number of annual weeds and grasses, many of which have a fairly high feeding value for a period of six to eight weeks. Composite samples of all the forage plants present on the range during the various months of the year would show two seasons at which the forage is relatively high in crude protein and phosphorus, indicating two periods of good forage conditions instead of one as is indicated by the present investigation.

It has been shown that young range grasses have a high water content, are rich in crude protein and phosphorus, and are relatively low in crude fiber and lignin. Digestion trials have shown the dry matter of young grass to be highly digestible. Range livestock gain rapidly in weight when the forage is young, which furnishes further evidence of the high nutritive value of young forage.

Woodman, Blunt, and Stewart (30) found that the digestion coefficients of organic matter and crude protein in young pasture grass resembled more closely those of a concentrate than those of a roughage. The digestibilities of the crude fiber and the nitrogen-free extract were about equal, and both were high. Their experimental results indicated that young pasture grass was in effect a "watered protein concentrate" and, that on account of its low content of indigestible fiber, should not be classed as a coarse fodder. It was much superior in digestibility to the best grade of meadow hay.

As the stage of maturity advances, the percentages of protein and phosphorus decrease; and crude fiber increases. The digestibility of the forage also gradually decreases. Woodman and Norman (29) found that lengthening the period between cuttings to five weeks caused a definite, though not very marked, decrease in the digestibility of pasture grass. Crude protein was the constituent most affected, while the digestion coefficient of crude fiber remained high.

Later on in the season there is an increase in the amount of lignin. According to Miller (21), the cell walls of a young plant are almost pure cellulose; but, as the plant grows older, there is a gradual infiltration of lignin; and lignocellulose results. Lignocellulose is the chief constituent of mature cereal grasses and straws, wood, and jute. It is an inert substance and is supposed to give strength and rigidity to plant tissues. Phillips (23) found that too much lignin tended to make the plant tissues quite brittle. Former results indicated that lignin was not digested by animals, but more recent work indicates that it is broken down slightly with the splitting off of methoxyl.

Woodman and Oosthuizen (32) report that the forage produced from July to September was lower in digestibility and nutritive value than was spring forage. Aston and co-workers (2) suggest that "Waihi disease" is due more to droughty summers and autumns than to any inherent defect in the soil or class of pasture. It results from a seasonal rather than a continuous deficiency of phosphorus in the forage.

McCall (18) found that there was a large decrease in the nutritive value of blue bunchgrass (Festuca idahoensis) from the new growth stage to the time of maturity. After maturity the palatability of the grass was so low that the consumption by ewes and lambs, when fed grass only, was below that required for maintenance. He concluded that there was little change in the nutritive value of the grass during the winter months. Guilbert and Mead (12), however, observed that exposure to rain resulted in a decrease in the digestibility of every nutrient in bur clover except crude fiber. They obtained evidence which indicated that the greater part of this loss could be accounted for by the leaching out of soluble nutrients.

Christensen and Hopper (4) found that the April cutting of prairie hay was slightly higher in total digestible nutrients than was the October cutting, while both were considerably lower in this respect than was the July cutting. Palatability was also a big factor in determining the nutritive value of the hay. Only the July cutting was consumed in large enough amounts by experimental steers to produce appreciable gains in weight. The consumption of the other two cuttings was approximately that required for maintenance, or slightly less.

It is apparent that, after maturity, range grasses are quite low in both palatability and digestibility. Their extremely low protein content adds to their inefficiency for forage purposes, when they are the only source of feed. Unpublished data obtained by the Arizona Station have shown no benefits to be derived from the feeding of calcium and phosphorus supplements to cattle grazed on the experimental area.

This suggests that a low intake of total digestible nutrients and, possibly, of digestible crude protein may be one major reason why range cattle lose as much as 33 percent of their late summer weight during the dry seasons. The logical supplement during such periods is a protein-rich concentrate, Whether or not such supplementary feeding would be economical depends largely upon local conditions.

SUMMARY

Seasonal changes in the chemical composition of blue grama (*Bouteloua gracilis*), hairy grama (*Bouteloua hirsuta*), and curly mesquite (*Hilaria belangeri*) were determined for the growing seasons of 1934 and 1935. Moisture, crude protein, and phosphorus were high in young plants, decreasing to a minimum after the plants had become mature.

The percentage of total ash and of ether extract showed no definite trends. Nitrogen-free extract and lignin tended to increase from the early growth stages until the end of the season. The crude fiber content rose rapidly during the early part of the growing season but showed no definite trend from September to January, when a slight drop occurred. The percentage of calcium was high during August, when the plants were young, and low in the dry plants during the winter months but was somewhat variable during the intervening period.

The digestibility and palatability of young range grasses are high but decrease to relatively low values when the plants are mature and dry. Range cattle increase rapidly in weight while the forage is young and green, but decrease rapidly in weight during the dry seasons. It is suggested that a low intake of total digestible nutrients and, possibly, of digestible crude protein may account for these losses in weight.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Professor E. B. Stanley, Head of the Animal Husbandry Department, for his help in planning and conducting the experiment, to Dr. R. A. Greene, of the Agricultural Chemistry Department, for his help in running the chemical analyses, to Mr. Ernest Hussmann for collecting the samples, and to Mr. P. C. J. Oberholzer for his helpful advice throughout the experiment.

BIBLIOGRAPHY

1. A. O. A. C. Methods of Analysis, Third Edition. 1930.

2. Aston, B. C., R. E. R. Grimmett, F. J. A. Brogan, and P. H. Sykes. "Mineral Content of Pastures. The Wairarapa District." Nutrition Abstracts and Reviews, Vol. I, pp. 44-45. 1931.

3. Capen, R. G., and J. A. Le Clerc. "Chemical Composition of Native Alaskan Hays Harvested at Different Periods of Growth." Jour. of Agr. Res., Vol. 46, No. 7, p. 665. April, 1933.

4. Christensen, F. W., and T. H. Hopper. "Effect of Weathering and Stage of Maturity on the Palatability and Nutritive Value of Prairie Hay." Wis. Agr. Expt. Sta. Bul. No. 260. July, 1933.

5. Cruickshank, E. M. "Investigation on the Mineral Content of Pasture Grass and Its Effect on Herbivora. IV. Report on the Seasonal Variations in the Mineral Content of Pastures." Jour. of Agr. Sci., Vol. 16, pp. 89-97. 1926.

6. Cundy, A. T. "Wyoming Forage Plants and their Chemical Composition - Studies No. 6." Univ. of Wyo. Agr. Expt. Sta. Bul. No. 137. June, 1924.

7. Daniel, Harley A., and J. Hoarce. "The Relation Between Effective Rainfall and Total Calcium and Phosphorus in Alfalfa and Prairie Hay." Jour. of Am. Soc. of Agron., Vol. 27, No. 8, pp. 644-652. August, 1935.

8. Dustman, R. B., and L. D. Shriver. "The Chemical Composition of Ambrosia trifida at Successive Growth Stages." Jour. of Am. Soc. of Agron., Vol. 23, pp. 190-194. 1931.

9. Ferguson, W. S. "Investigations into the Intensive System of the Agricultural Research Staff of Imperial Chemical Industries, Ltd. 3. The Seasonal Variation in the Mineral Content of Pasture, with Particular Reference to Drought." Nutrition Abstracts and Reviews, Vol. I, p. 46. 1931.

10. Greenhill, A. W., and H. J. Page. "Investigations into the Intensive System of Grassland Management by Agricultural Research Staff of Imperial Chemical Industries, Ltd. 2. The Mineral Content of Intensively Treated Pastures and a Relationship between the Nitrogen and Phosphorus Contents." Nutrition Abstracts and Reviews, Vol. I, p. 46. 1931.

11. Guilbert, H. R., S. W. Mead, and H. C. Jackson. "The Effects of Leaching on the Nutritive Value of Forage Plants." Nutrition Abstracts and Reviews, Vol. I, p. 410. 1931.

12. Guilbert, H. R., and S. W. Mead. "The Digestibility of Bur Clover as Affected by Exposure to Sunlight and Rain." Hilgardia, Vol. 6, No. 1, May, 1931.

13. Hart, G. H., H. R. Guilbert, and H. Goss. "Seasonal Changes in the Chemical Composition of Range Forage and their Relation to Nutrition of Animals." Cal. Agri. Expt. Sta. Bul. No. 543. Nov., 1932.

14. Knight, H. G., F. F. Hepner, and A. Nelson. "Wyoming Forage Plants and their Chemical Composition Studies No. 3." Wyo. Agri. Expt. Sta. Bul. No. 76. March, 1908.

15. Leukel, W. A., J. P. Camp, and J. M. Coleman. "Effect of Frequent Cutting and Nitrate Fertilization on the Growth, Behavior, and Relative Composition of Pasture Grasses." Univ. of Fla. Agri. Expt. Sta. Bul. No. 269. July, 1934.

16. Lush, R. H. "Seasonal Composition of Pasture Grasses." Nutrition Abstracts and Reviews, Vol. III, p. 37. 1933.

17. Malhotra, R. C. "The Distribution of Some of the Reserve Substances in Hard Winter Wheat Plant at Successive Growth Stages and Their Possible Utilization." Jour. Agr. Sci., Vol. 22, pp. 485-496. 1932.

18. McCall, Ralph. "Nutritive Value of Winter Range Grasses." Forty-Fourth Annual Report of the Agri. Expt. Sta. of the State College of Washington. Bul. No. 305. Division of Animal Husbandry. December, 1934.

19. McCreary, O. C. "Wyoming Forage Plants and Their Chemical Composition." Univ. of Wyo. Agri. Expt. Sta. Bul. No. 184. August, 1931.

20. McCreary, O. C. "Wyoming Forage Plants and Their Chemical Composition - Studies No. 8." Univ. of Wyo. Agri. Expt. Sta. Bul. No. 157. 1927.

21. Miller, E. C. Plant Physiology, First Edition. McGraw-Hill Book Company, Inc. New York and London. 1931.

22. Norman, A. G. "Structural Constituents of the Barley Plant." Jour. Agri. Sci., Vol. 23, pp. 216-227. 1933.

23. Phillips, Max. "The Chemistry of Lignin." Chem. Reviews, Vol. 14, pp. 103-170. 1934.

24. Phillips, Max, and M. J. Goss. "Composition of the Leaves and Stalks of Barley at Successive Stages of Growth with Special Reference to the Formation of Lignin." Jour. Agr. Res., Vol. 51, No. 4, pp. 301-319. August 15, 1935.

25. Richardson, A. E. V., H. C. Trumble, and R. E. Shapter. "The Influence of Growth Stage and Frequency of Cutting on the Yield and Composition of a Perennial Grass - Phalaris tuberosa." Nutrition Abstracts and Reviews, Vol. II, pp. 472-73. 1932.

26. Roy, A. C., and K. C. Sen. "The Seasonal Variation of Lime and Phosphoric Acid in Some Hill Pastures." Nutrition Abstracts and Reviews, Vol. III, pp. 673-74. 1933.

27. Smith, H. V. "The Climate of Arizona." Univ. of Ariz. Expt. Sta. Bul. No. 130. April 1, 1930.

28. Stanley, E. B. "Regional Agricultural Planning Report on the Range Livestock Industry in Arizona." 1935.

29. Woodman, H. E., and D. B. Norman. Nutritive Value of Pasture.. IX. The Influence of the Intensity of Grazing on the Yield, Composition and Nutritive Value of Pasture (Part IV)." Jour. Agri. Sci., Vol. 22, p. 852. 1932.

30. Woodman, H. E., D. L. Blunt, and J. Stewart. "Nutritive Value of Pastures. I. Seasonal Variations in the Productivity, Botanical and Chemical Composition, and Nutritive Value of Medium Pasturage on a Light Sandy Soil." Jour. Agri. Sci., Vol. 16, p. 205. 1926.

31. Woodman, H. E., D. L. Blunt, and J. Stewart. "Nutritive Value of Pasture. II. Seasonal Variations in the

Productivity, Botanical and Chemical Composition, and Nutritive Value of Pasturage on Heavy Clay Soil." Jour. Agri. Sci., Vol. 17, p. 209. 1927.

32. Woodman, H. E., and P. M. Oosthuizen. "Nutritive Value of Pasture. XI. The Composition and Nutritive Value of Winter Pasturage." Jour. Agri. Sci., Vol. 24, No. 4, pp. 574-597. 1934.