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THE CHEMICAL COMPOSITION OF FORAGE GRASSES FROM THE GULF COAST PRAIRIE AS RELATED TO SOILS AND TO REQUIREMENTS FOR RANGE CATTLE

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Sufficient phosphoric acid (phosphorus) for best results is frequently not supplied to grazing animals by forage grasses grown on the soils of the Gulf Coast Prairie. Protein in the forage may be insufficient for best results at times, especially when the grass is old or dried up. Sufficient lime (calcium) is supplied by nearly all forages.

Fertilization of pastures can increase the protein and phosphoric acid content of the grasses, as well as increase the yields. The grass which grew after mowing contained more phosphoric acid and protein than unmown grass available at the same time.

Chemical analyses were made of 1,140 samples of different species of forage at various stages of growth from nearly 100 locations in the Gulf Coast Prairie of Texas. The chemical composition of the samples varied widely with differences in species, stage of maturity, and location. Protein and phosphoric acid decreased markedly with advancing maturity, crude fiber and nitrogen free extract in general increased slightly, and changes in lime were irregular. Protein and phosphoric acid in nearly all of the samples ranged from fair to very deficient. As the plants became older, the proportion of samples which were deficient or very deficient in protein and phosphoric acid increased markedly. At the mature stage of growth, 92% of the samples were deficient in protein and 96% were deficient in phosphoric acid. Very few of the samples were deficient in lime. Johnson, Dallis, and Bermuda grasses were in general higher in protein, phosphoric acid, and lime than were the principal native species sampled.

Soils which contained relatively high percentages of nitrogen, active phosphoric acid and active lime produced young grass which contained higher percentages of protein, phosphoric acid, and lime than were found in grass produced on soils which contained lower amounts of these constituents. The relation of the composition of the soils to the composition of forage at intermediate and mature stages of growth was not so clear as for young forage.

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THE CHEMICAL COMPOSITION OF FORAGE GRASSES FROM THE GULF COAST PRAIRIE AS RELATED TO SOILS AND TO REQUIREMENTS FOR RANGE CATTLE

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An adequate supply of minerals in the rations consumed by animals has long been recognized as of importance in their growth and maintenance. Recent intensive and extensive studies have shown that a number of diseases and other evidences of malnutrition in range animals are definitely associated with a deficiency of minerals in the available forage (1, 4, 5, 6, 9, 10, 18, 19, 27, 28, 31, 32, 33, 34). The percentage of each constituent in the forage is the chief determining factor in the development of nutritional disturbances. Animals grazing on ranges on which there is an abundance of forage may show marked evidences of mineral deficiencies. The quantity of forage eaten by an animal is limited; if the percentage of a constituent in the forage is sufficiently low, the quantity of the constituent eaten will be insufficient for satisfactory growth, maintenance, or reproduction.

Phosphoric acid is the constituent usually deficient in Texas. The symptoms of its deficiency include the chewing of wood, bones, or other substances (pica), stiffness of the legs, swollen joints, emaciation, and usually poor, unthrifty appearance and, in some cases, a lower production of calves. Various names have been used for these abnormal conditions; these include "creeps" in Texas, "stiffs" and "sweeny" in Florida (4), "styfsiekte" in South Africa (9), and "cripples" or "pegleg" in Australia (34). Bone chewing may lead to other serious diseases, such as "loin disease" in the Gulf Coast region of Texas (26), "lamsiekte" in South Africa (33), and others (31). A deficiency of calcium may also cause disturbances in the health of animals, but these are of much less frequency and importance in Texas than those due to a deficiency of phosphoric acid. Deficiency of either phosphoric acid or lime may result in decreased growth and unthrifty condition, even when no symptoms of disease are visible. A low protein content is often associated with a low phosphoric acid content of forage plants (14, 15, 17), so that forage which is deficient in phosphoric acid is often deficient in protein. Disturbances in nutrition due to a deficiency of protein in the forage may accompany and accentuate those due to a deficiency of phosphoric acid. Deficiencies in cobalt, copper, and other elements, have been found elsewhere but not in Texas (7).

DESCRIPTION OF THE GULF COAST PRAIRIE

The area called the Gulf Coast Prairie of Texas covers about 8,000,000 acres of land in a nearly flat strip of country along the Gulf Coast, varying from 20 to 80 miles in width and extending from the Louisiana line to about the San Antonio River. The surface is nearly flat except for local areas near the interior border, where it may be gently undulating. Surface drainage is slow because of the level topography; subsurface drainage is very slow because of the heavy, dense clay subsoil and substrata which underlie most of the soils. A narrow fringe of marshy or semi-marshy soils extends along the coast line. Rainfall is heavy over most of the region.

The principal soil series is called the Lake Charles and is composed principally of dark-colored soils with heavy texture, but soils of light texture occur in small areas throughout the region. A narrow belt of light-colored, sandy soils of the Hockley and Katy series occurs along the interior border of the region. Small areas of similar soils of the Edna series occur in the region, usually in association with Lake Charles soils. The soils which occur in marshy or semi-marshy areas along the coast are called Harris soils. Considerable areas of alluvial soils occur along the lower stretches of a number of rivers. Upland soils of the region are usually fairly well supplied with total nitrogen, fair to good in potash and lime, low to very low in total phosphoric acid and active phosphoric acid, and are usually slightly acid (13). Alluvial soils usually contain higher quantities of these constituents than the upland soils.

SAMPLES USED

Forage samples, numbering 1140, were collected during 1936, 1937, 1938, and 1940 from nearly 100 locations in counties well distributed through the area, including Brazoria, Calhoun, Chambers, Fort Bend, Galveston, Harris, Jackson, Jefferson, Liberty, Matagorda, Orange, Victoria, and Wharton. Locations from which samples were taken were accurately described so that subsequent samples of forage and soil could be taken from the same place. The stage of maturity (whether young, medium young, in bloom, or mature) of each species of forage was noted and the soil type identified. All of the important species of forage on each location were sampled. Individual samples consisted entirely of the current year's growth of a single species. The samples, after cutting, were packed loosely in a cloth bag, dried at 45°C, ground in a Wiley mill, and analyzed by methods of the Association of Official Agricultural Chemists (3).

The number of samples of a given species which were collected varied widely. Some species, such as little bluestem, are of widespread occurrence throughout the entire area so that many samples were taken, while other species are of importance only at certain times of the year or on certain locations so that only a few samples were taken. For example, annual bluegrass (*Poa annua*) is an early spring grass and disappears during summer and fall; salt grass or sacahuiste (*Spartina spartinae*) occurs only along the coast where the soils contain considerable salt. Bermuda (*Cynodon dactylon*), Dallis (*Papsalum dilatatum*), and carpet (*Axonopus affinis*) grasses occur usually on more fertile soils which have at some time been under cultivation. The native grasses on virgin soil are largely various beard grasses or bluestems, Indian grass, and Eastern gama grass. Big bluestem (*Andropogon provincialis*) is of great importance on the better drained areas of virgin soils, while bushy beardgrass (*Andropogon glomeratus*) is of importance only on poorly drained soils. The species of forage which may be growing on a given location are determined by a number of factors, and these factors may also affect, to some extent, the chemical composition of the forage.

The grouping of samples of the same species on the basis of stage of growth, that is, whether young, in bloom, or mature, is sometimes difficult. In some species, particularly the *Papsalums,* all three stages of growth can be found on the same plant at the same time. Some species, such as Bermuda and carpet grasses, may come into bloom and mature seed at any time during the growing season when weather conditions become unfavorable for vigorous growth. Other species, such as the *Andropogons,* come into bloom only once during the latter part of the growing season. Even with these species, considerable variation is possible, since the plant will be designated as young at any time between the first vigorous growth of the spring and the very slow growth in the latter part of the summer, when moisture and heat conditions over much of the region are so unfavorable that growth has practically stopped. An attempt has been made to overcome this difficulty to some extent by separating the young growth into two groups, one, designated as young, collected in the spring, and the other, designated as medium, in the summer. A decision as to whether a given sample should be considered in the bloom stage or the mature stage is sometimes difficult, because there is a gradual gradation, and mature seeds may occur on one part of the plant while other parts of the plant are just coming into bloom. Grazing, burning, or mowing on the area selected may be such that very young plant material is secured throughout the growing season, regardless of the natural growth habit of the species.

Soil samples were collected from all areas from which forage samples were secured several times. The samples were taken to a depth of about six inches, dried, passed through a 20-mesh sieve, and analyzed for total nitrogen and total phosphoric acid by the methods of the Association of Official Agricultural Chemists (3), and for active phosphoric acid and active lime (soluble in 0.2 N nitric acid).

COMMON AND BOTANICAL NAMES OF THE PLANTS

The common names of many of the species collected, arranged in alphabetical order, together with the botanical names as given by Cory and Parks (8), are given in Table 1. These are, in nearly all cases, the same as those used by Hitchcock (20). In many cases, the same species is known in different localities by different common names; for example, the common names of *Spartina spartinae* are salt grass, sacahuiste, or simply bunch grass. A single common name may also be applied to a number of species differing in botanical name. On the Gulf Coast, sacahuiste is *Spartina spartinae,* while in West Texas, it is *Nolina texana,* which is not a grass. No attempt was made to separate a single species into different varieties of that species. When no common name is in general use for the species, only the botanical name is used in later tables.

MOST IMPORTANT GRASSES ON THE PASTURES

Most of the range land in the area is native pasture. The forage is chiefly various bluestem or beard grasses, as was the case in the East Texas Timber Country to the north (15). Little bluestem (*Andropogon scoparius*) is by far the most important, although big bluestem (*Andropogon provincialis*) is also of considerable importance. Indian grass (*Sor-*

Table 1. Common and botanical names of species sampled

Common name	Botanical name
Alkali sacaton grass	*Sporobolus airoides*
Angleton grass	*Andropogon annulatus*
Bahia grass	*Paspalum notatum*
Beardgrass, annual	*Polypogon monspeliensis*
Beardgrass, bushy	*Andropogon glomeratus*
Beardgrass, East Texas	*Andropogon tener*
Beardgrass, silver	*Andropogon saccharoides*
Bermuda grass	*Cynodon dactylon*
Bluegrass, annual	*Poa annua*
Bluestem grass, big	*Andropogon provincialis*
Bluestem grass, little	*Andropogon scoparius*
Bristlegrass, green	*Setaria viridis*
Bristlegrass, knotroot	*Setaria lutescens*
Broomsedge grass	*Andropogon virginicus*
Black medick	*Medicago lupulina*
Buffalo grass	*Buchloe dactyloides*
Canary grass, Southern	*Phalaris caroliniana*
Canary grass, little	*Phalaris minor*
Carpet grass	*Axonopus affinis*
Clover, bur	*Medicago spp.*
Clover, white	*Trifolium repens*
Cord grass	*Spartina patens*
Dallis grass	*Paspalum dilatatum*
Eastern gama grass	*Tripsacum dactyloides*
Feather sage grass	*Andropogon saccharoides*
Fescue grass, slender	*Festuca octoflora*
Finger grass	*Chloris spp.*
Foxtail grass	*Setaria spp.*
Georgia grass	*Paspalum plicatulum*
Grama grass, hairy	*Bouteloua hirsuta*
Grama grass, sideoats	*Bouteloua curtipendula*
Grama grass, Texas	*Bouteloua rigidiseta*
Honeydew grass	*Paspalum plicatulum*
Indian grass	*Sorghastrum nutans*
Johnson grass	*Sorghum halepense*
Joint grass	*Elyonurus tripsacoides*
Knot grass	*Paspalum distichum*
Lespedeza	*Lespedeza striata*
Long-awned hair grass	*Muhlenbergia capillaris*
Longtom grass	*Paspalum lividum*
Love grass	*Eragrostis spp.*
Maidencane	*Panicum hemitomon*
Molasses grass	*Melinis minutiflora*
Needle grass	*Aristida spp.*
Needle grass, Texas	*Stipa leucotricha*
Pull-and-be-damned grass	*Paspalum lividum*
Rabbitfoot grass	*Polypogon monspeliensis*
Rescue grass	*Bromus catharticus*
Sacahuiste	*Spartina spartinae*
Sage grass	*Andropogon spp.*
Salt cedar grass	*Monanthocloe littoralis*
Salt grass	*Spartina spartinae*
Salt water Bermuda grass	*Distichlis spicata*
Sand dropseed grass	*Sporobolus cryptandrus*
Spanish moss	*Tillandsia usneoides*
Spear grass	*Stipa leucotricha*
Smut grass	*Sporobolus Poiretii*
Switch grass	*Panicum virgatum*
Tanglehead grass	*Heteropogon contortus*
Tickle grass	*Agrostis hiemalis*
Vasey grass	*Paspalum urvillei*

ghastrum nutans), Eastern gama grass (*Tripsacum dactyloides*), and alkali sacaton (*Sporobolus airoides*) often occur in the same areas, but supply a very small part of the total forage. Various members of the *Paspalum* and *Panicum* genera may provide considerable forage on limited areas. Of these, Georgia or honeydew grass (*Paspalum plicatulum*), longtom or pull-and-be-damned (*Paspalum lividum*), and switch grass (*Pani-*

cum virgatum) are the most important. On other areas where local conditions affect the botanical population, other species are of importance. Smut grass (*Sporobolus Poiretii*) occurs in wooded areas along the northern edge of the region. Bushy beardgrass (*Andropogon glomeratus*) and Florida paspalum grass (*Paspalum floridanum*) occur in low areas where water tends to collect or drain off slowly. Salt grass or sacahuiste (*Spartina spartinae*), cord grass (*Spartina patens*), salt water Bermuda (*Distichlis spicata*), and salt cedar grass (*Monanthochloe littoralis*) occur in limited areas along the coast, where considerable salt is present in the soil. Short grasses, such as buffalo (*Buchloe dactyloides*), grama grasses (*Bouteloua spp.*), and crowfoot or finger grasses (*Chloris spp.*), typical of the subhumid section of the state, occur in the western border of the region. Bermuda grass (*Cynodon dactylon*), Dallis grass (*Paspalum dilatatum*), and carpet grass (*Axonopus affinis*) frequently occur on land which has been under cultivation at one time, and along streams. The latter are the principal grasses being used in the region for pasture improvement (29).

Some of the most important species of grasses in the region are the same as those which are most important in the East Texas Timber Country (15). Carpet grass and some of the *Paspalums* (such as *P. plicatulum, P. lividum, P. floridanum*) are of considerably greater importance on the Gulf Coast Prairie than in the East Texas Timber Country. On the other hand, various *Eragrostis* species (particularly *E. lugens*) and some of the *Paspalums* (*P. setaceum, P. pubiflorum, P. urvillei*) and *Panicums* (*P. anceps, P. capillare, P. capillioides,* etc.), which were of importance on the sandy soils of the wooded areas of the East Texas Timber Country are not generally found on the Gulf Coast Prairie. Legumes do not grow well on most of the pastures of the Gulf Coast Prairie; hence, such legumes as lespedeza (*Lespedeza striata*) and bur clovers (*Medicago spp.*) are not as common on the Gulf Coast Prairie as in the East Texas Timber Country. Fertilization with superphosphate encourages the growth of legumes in this region as it does in East Texas.

AVERAGE ANALYSES OF THE VARIOUS SPECIES OF FORAGE

The highest, lowest and average analyses for protein, phosphoric acid and lime in different species and at different stages of maturity are shown in Table 2. The plants have been divided into four groups according to the stage of growth. The young stage of growth is that at which the grass is either just well started in the spring or in which the grass has been kept in a similar state through rather intensive grazing or mowing. The medium stage extends from the period when the rapid growth of the young grass has slackened, to the period when seed stalks begin to appear in significant quantity. The bloom stage extends through the period of active blooming and seed formation. The mature stage covers that period after the seeds have matured and before new growth appears the following spring and, in general, includes those samples collected during the four or five winter months when the plant is relatively dormant. In some cases, where drought had induced dormancy in the fall, the samples have been included in the mature group. In many of the groups shown in Table 2, the number of samples of a given species at a certain stage of growth is so small that the averages are not satisfactory.

Table 2. Protein, phosphoric acid, and lime content of different species of grasses at various stages of growth (percentages of dried grass)

Name	Stage of growth	Number of samples	Protein Mean	Protein Low	Protein High	Phosphoric acid Mean	Phosphoric acid Low	Phosphoric acid High	Lime Mean	Lime Low	Lime High
Agrostis hiemalis (Tickle grass)	Young	3	9.47	8.57	10.30	.54	.37	.71	.36	.32	.41
Agrostis verticillata (Water bent grass)*	Young	2	8.63	8.21	9.04	.38	.32	.44	.69	.62	.76
Andopogon annulatus (Angleton grass)	Young	3	9.97	8.20	11.60	.53	.30	.85	.72	.38	.9
	Bloom	2	5.69	4.94	6.43	.34	.24	.43	.54	.43	.65
	Mature	1	4.39	. . .	. . .	.25	..	..	.55	..	..
Andropogon glomeratus (Bushy beard grass)	Young	15	10.24	8.10	13.67	.42	.24	.72	.59	.33	.8
	Medium	11	5.27	4.60	6.06	.19	.13	.34	.61	.43	.9
	Bloom	5	4.45	3.74	5.45	.19	.13	.28	.49	.27	.8
	Mature	6	3.88	3.31	4.59	.23	.11	.55	.39	.20	.75
*Andropogon provincialis** (Big bluestem grass)	Young	32	9.32	4.83	13.00	.33	.16	.56	.56	.31	.97
	Medium	12	5.03	4.54	6.34	.19	.14	.28	.64	.39	1.02
	Bloom	6	4.24	3.66	4.92	.16	.10	.22	.65	.50	.87
	Mature	20	3.64	2.60	6.70	.13	.08	.24	.61	.31	.90
*Andropogon saccharoides** (Silver beard grass)	Young	9	8.92	6.05	12.47	.36	.26	.58	.53	.35	.73
	Medium	1	5.42	. . .	. . .	.38	..	..	.55	..	..
	Bloom	8	5.42	4.24	6.63	.23	.19	.28	.49	.35	.85
	Mature	5	3.66	3.20	4.24	.16	.15	.19	.54	.39	.74
*Andropogon scoparius** (Little bluestem grass)	Young	109	7.85	4.20	12.55	.27	.13	.52	.57	.24	1.1
	Medium	38	5.49	3.64	9.34	.20	.11	.38	.64	.38	1.09
	Bloom	23	4.45	2.93	6.25	.16	.07	.28	.55	.34	1.04
	Mature	33	3.37	2.50	4.86	.12	.07	.23	.60	.28	1.73
*Andropogon tener**	Young	4	9.09	8.68	9.28	.31	.26	.37	.74	.50	1.10
	Medium	1	5.19	. . .	. . .	.24	..	..	.56	..	..
	Bloom	1	5.19	. . .	. . .	.17	..	..	.51	..	..
	Mature	7	3.62	1.81	5.34	.13	.05	.18	.46	.33	.89
*Andropogon virginicus** (Broomsedge)	Young	4	10.82	8.71	13.99	.44	.32	.63	.65	.46	.79
	Medium	2	5.44	5.37	5.51	.33	.30	.35	.71	.57	.85
	Bloom	1	3.74	. . .	. . .	.13	..	..	.49	..	..
	Mature	4	3.24	3.00	3.74	.11	.10	.13	.51	.36	.68
*Aristida longespica** (Needle grass)	Young	3	6.78	5.15	8.27	.18	.17	.19	.78	.68	.90
	Mature	3	5.58	5.29	5.95	.18	.16	.20	.44	.32	.55
*Aristida oligantha** (Needle grass)	Medium	1	4.85	. . .	. . .	.15	..	..	.44	..	..
	Bloom	1	5.27	. . .	. . .	.17	..	..	.39	..	..
*Axonopus affinis** (Carpet grass)	Young	51	7.19	4.40	10.15	.25	.16	.38	.64	.28	2.05
	Medium	20	5.80	4.17	7.43	.20	.16	.25	.52	.31	.86
	Bloom	10	5.37	4.08	6.90	.19	.13	.30	.52	.37	.81
	Mature	2	4.03	3.98	4.08	.15	.13	.17	.52	.41	.63
Bouteloua curtipendula (Sideoats grama grass)	Young	2	8.83	7.42	10.23	.30	.22	.38	.77	.74	.80
	Bloom	2	6.99	6.26	7.71	.26	.23	.28	.81	.57	1.04
	Mature	1	3.14	. . .	. . .	.08	..	..	.85	..	..
Bouteloua hirsuta (Hairy grama grass)	Mature	2	3.63	3.59	3.66	.11	.10	.12	.68	.46	.90
Bouteloua rigidiseta (Texas grama grass)	Young	2	7.68	7.10	8.25	.23	.21	.24	.55	.51	.60
	Bloom	5	6.81	5.92	7.31	.21	.15	.23	.61	.40	.75
*Bromus catharticus** (Rescue ghass)	Young	1	12.35	. . .	. . .	.37	..	..	.76	..	..
Buchloe dactyloides (Buffalo grass)	Young	6	8.65	7.42	9.93	.36	.22	.47	.60	.44	.76
	Medium	3	6.74	5.75	7.43	.31	.19	.51	.73	.42	.91
	Bloom	5	7.34	4.99	9.41	.27	.22	.36	.64	.43	1.12
	Mature	5	6.16	4.80	7.70	.25	.13	.37	.62	.52	.76
Chloris cucullata (Black finger grass)	Young	1	13.26	. . .	. . .	.57	..	..	.88	..	..
	Bloom	1	7.52	. . .	. . .	.34	..	..	.98	..	..
	Mature	1	5.16	. . .	. . .	.15	..	..	.69	..	..
*Cynodon dactylon** (Bermuda grass)	Young	22	11.37	6.36	16.63	.41	.24	.62	.67	.40	.89
	Medium	5	7.09	5.90	8.34	.34	.25	.55	.63	.44	.83
	Bloom	8	7.41	4.85	10.34	.33	.23	.51	.69	.43	1.02
	Mature	3	5.71	5.01	6.09	.24	.22	.25	.61	.57	.64
Distichlis spicata (Salt water Bermuda grass)	Young	4	7.37	6.39	8.58	.28	.24	.32	.28	.24	.35
	Medium	2	5.62	4.75	6.48	.20	.17	.22	.47	.30	.63
	Bloom	1	5.75	. . .	. . .	.36	..	..	.81	..	..
Elyonurus tripsacoides (Joint grass)	Bloom	2	4.91	4.86	4.95	.22	.14	.30	.32	.20	.43
Eragrostis spectabilis (Purple lovegrass)*	Medium	3	4.56	4.20	4.83	.18	.12	.23	.63	.54	.75
	Mature	2	4.17	3.79	4.55	.16	.16	.16	.64	.63	.64
Festuca octoflora (Slender fescue grass)	Young	2	8.47	8.09	8.84	.32	.27	.36	.54	.47	.61
Heteropogon contortus (Tanglehead grass)	Young	2	8.85	8.25	9.45	.34	.31	.36	.61	.53	.68
	Medium	2	6.95	6.38	7.52	.27	.19	.34	.76	.53	.98
	Bloom	2	4.31	4.00	4.62	.15	.14	.16	.28	.26	.29
	Mature	1	3.12	. . .	. . .	.10	..	..	.48	..	..
Hordeum murinum (Sea barley)	Young	3	9.25	7.98	10.91	.48	.46	.50	.46	.28	.69
Lespedeza striata (Lespedeza)*	Young	4	19.95	13.20	23.00	.58	.38	.68	1.75	1.56	2.08

*Averages for the East Texas Timber Country are given in Bulletin 582.

(continued)

Table 2. Protein, phosphoric acid, and lime content of different species of grasses at various stages of growth (percentages of dried grass) (Continued)

Name	Stage of growth	Number of samples	Protein Mean	Protein Low	Protein High	Phosphoric acid Mean	Phosphoric acid Low	Phosphoric acid High	Lime Mean	Lime Low	Lime High
go hispida (Bur clover)	Young	1	21.25	. . .	. . .	.66	..	..	1.34	..	..
go lupulina (Black medick)	Bloom	1	15.50	. . .	. . .	.43	..	..	.78	..	..
minutiflora (Mol'ses grass)	Young	1	13.64	. . .	. . .	.71	..	..	.64	..	..
ochloe litoralis	Young	1	7.19	. . .	. . .	.24	..	..	.27	..	..
t cedar grass)	Medium	2	5.49	5.45	5.53	.16	.15	.17	.30	.15	.45
	Bloom	2	5.69	5.68	5.70	.22	.21	.23	.30	.30	.30
*bergia capillaris**	Young	11	7.88	3.70	10.95	.26	.13	.56	.40	.29	.59
ng-awned hair grass)	Medium	4	4.71	4.00	5.58	.17	.13	.18	.47	.44	.49
	Bloom	3	4.15	3.86	4.69	.15	.13	.16	.37	.35	.41
	Mature	2	3.84	3.62	4.02	.16	.13	.18	.52	.45	.59
*capillarioides**	Young	7	8.81	7.01	12.16	.33	.20	.60	.44	.34	.62
fasciculatum	Young	1	8.61	. . .	. . .	.33	..	..	.48	..	..
	Bloom	1	5.89	. . .	. . .	.17	..	..	.44	..	..
*helleri**	Young	1	9.30	. . .	. . .	.21	..	..	.41	..	..
hemitomon (Maiden cane)	Young	2	13 26	11.80	14.71	.43	.26	.59	.70	.37	1.02
*Lindheimeri**	Young	10	8.97	7.21	11.48	.27	.17	.37	.74	.39	1.09
	Mature	1	5.03	. . .	. . .	.12	..	..	.84	..	..
virgatum	Young	14	9.04	5.55	11.98	.38	.22	.58	.55	.35	1.08
itch grass)	Medium	3	4.59	3.92	5.50	.19	.15	.26	.45	.42	.51
	Bloom	7	4.87	3.59	6.43	.21	.13	.33	.47	.23	.66
	Mature	9	3.74	2.47	5.12	.19	.11	.45	.61	.34	.94
alumum	Bloom	1	6.31	. . .	. . .	.25	..	..	1.04	..	..
*dilatatum**	Young	23	11.52	7.65	22.15	.42	.22	.78	.68	.46	.96
llis grass)	Medium	3	7.45	6.86	7.93	.46	.44	.48	.71	.54	.89
	Bloom	10	6.67	4.87	8.36	.26	.19	.49	.58	.30	.78
	Mature	4	5.72	2.55	8.46	.38	.19	.54	.78	.47	1.28
distichum (Knot grass)*	Young	6	10.21	7.85	11.39	.48	.26	.76	.77	.42	1.05
*floridanum**	Young	3	10.25	8.37	13.04	.25	.17	.36	.64	.61	.67
	Medium	8	5.66	4.48	8.90	.18	.12	.27	.55	.43	.73
	Bloom	4	5.07	4.40	5.75	.22	.14	.33	.67	.42	.88
	Mature	2	4.60	3.68	5.35	.14	.12	.16	.60	.58	.61
Hartwegianum	Young	7	9.93	7.30	14.51	.36	.23	.54	.61	.36	.84
	Mature	2	3.38	3.25	3.51	.13	.12	.14	.58	.53	.63
langei	Young	1	14.34	. . .	. . .	.44	..	..	.60	..	..
lividum	Young	7	9.49	7.10	12.64	.45	.24	.72	.71	.34	1.59
gtom)	Medium	13	6.26	4.45	7.13	.31	.17	.49	.59	.32	1.30
	Bloom	5	4.64	3.77	6.00	.26	.15	.49	.54	.40	.85
	Mature	7	4.07	3.48	5.63	.18	.11	.40	.47	.32	.88
*monostachyum**	Bloom	2	6.70	6.27	7.13	.32	.29	.35	.94	.68	1.19
*notatum**	Young	5	11.44	8.38	14.35	.41	.32	.51	.92	.61	1.38
hia grass)	Mature	1	7.75	. . .	. . .	.29	..	..	.56	..	..
*plicatulum**	Young	40	8.22	5.04	11.90	.28	.14	.41	.66	.42	1.08
rgia grass)	Medium	27	5.55	4.37	7.75	.21	.14	.41	.69	.39	1.10
	Bloom	19	5.08	3.61	7.19	.18	.11	.36	.70	.43	1.26
	Mature	21	4.13	2.55	5.71	.14	.08	.22	.68	.41	1.13
*pubescens**	Mature	1	4.50	. . .	. . .	.16	..	..	.41	..	..
publiflorum	Mature	1	8.29	. . .	. . .	.22	..	..	.63	..	..
*setaceum**	Young	3	10.85	9.18	12.38	.33	.30	.38	.81	.78	.86
	Medium	2	8.34	7.05	9.62	.28	.22	.33	.90	.85	.94
	Mature	1	4.99	. . .	. . .	.13	..	..	.71	..	..
*stramineum**	Young	6	10.53	8.85	11.71	.39	.31	.45	.69	.57	.80
	Bloom	1	7.47	. . .	. . .	.37	..	..	.90	..	..
*urvillei**	Young	5	8.58	7.90	9.56	.29	.18	.40	.76	.37	1.38
ey grass)	Medium	1	6.21	. . .	. . .	.26	..	..	.67	..	..
	Bloom	7	5.85	4.11	7.86	.27	.15	.46	.65	.43	1.10
	Mature	2	4.19	3.65	4.73	.17	.16	.18	.59	.41	.76
vaginatum (…d knot grass)	Young	1	21.16	. . .	. . .	.51	..	..	.42	..	..
carolinicus (…thern canary grass)	Young	3	9.08	8.30	10.35	.53	.42	.64	.63	.43	.83
minor (…le canary grass)	Young	3	9.36	9.04	9.72	.44	.33	.65	.54	.45	.68
…al bluegrass)*	Young	1	18.63	. . .	. . .	.81	..	..	.78	..	..
monspeliensis (…al beard grass)	Young	2	12.23	12.10	12.35	.69	.66	.71	.44	43	.45
niculata	Young	1	8.65	. . .	. . .	.36	..	..	.68	..	..
	Bloom	2	5.15	4.30	5.99	.42	.14	.69	.59	.51	.67
tescens (…w foxtail)*	Mature	1	5.44	. . .	. . .	.18	..	..	.34	..	..
ridis (…n foxtail)*	Young	4	11.35	10.41	12.45	.47	.36	.62	.57	.52	.69

…ages for the East Texas Timber Country are given in Bulletin 582.

(continued)

Table 2. Protein, phosphoric acid, and lime content of different species of grasses at various stages of growth (percentages of dried grass) (Continued)

Name	Stage of growth	Number of samples	Protein Mean	Protein Low	Protein High	Phosphoric acid Mean	Phosphoric acid Low	Phosphoric acid High	Lime Mean	Lime Low	Lime High
*Sorghastrum nutans**	Young	16	10.02	6.35	12.92	.38	.18	.70	.68	.46	[illegible]
(Indian grass)	Medium	10	4.91	4.35	5.60	.16	.12	.22	.77	.56	[illegible]
	Bloom	3	5.02	3.73	6.07	.21	.19	.25	.45	.33	
	Mature	9	3.58	2.61	4.91	.15	.11	.23	.67	.53	[illegible]
*Sorghum halepense**	Young	5	13.01	9.78	15.67	.65	.49	.96	1.16	.86	[illegible]
(Johnson grass)	Medium	4	7.11	6.69	7.82	.38	.30	.44	1.03	.86	[illegible]
	Bloom	4	6.55	5.31	8.06	.34	.26	.44	1.03	.89	[illegible]
	Mature	1	4.47	...	...	.19	..	..	.78	..	
Spartina patens	Young	5	8.47	4.53	10.36	.31	.12	.46	.39	.27	
(Cord grass)	Medium	10	4.89	3.71	6.34	.20	.13	.29	.62	.22	[illegible]
	Bloom	1	4.32	...	...	.16	..	..	.59	..	
	Mature	4	4.35	3.22	5.91	.15	.09	.26	.43	.28	
Spartina spartinae	Young	10	9.34	6.38	12.60	.33	.17	.52	.51	.23	[illegible]
(Salt grass)	Medium	5	5.05	4.08	7.61	.19	.14	.28	.66	.33	[illegible]
	Bloom	6	5.66	5.12	6.20	.22	.20	.23	.49	.35	
	Mature	7	4.36	2.94	5.06	.16	.11	.26	.50	.25	
Sporobolus airoides	Young	19	9.02	5.93	12.11	.32	.21	.53	.57	.35	[illegible]
(Alkali sacaton)	Medium	11	5.75	4.70	7.38	.21	.12	.34	.60	.41	
	Bloom	8	6.55	4.45	9.41	.24	.20	.27	.49	.30	
	Mature	5	5.00	3.55	7.09	.17	.12	.23	.27	.33	
*Sporobolus cryptandrus**	Young	1	10.00	...	...	.25	..	..	.41	..	
Sporobolus Poiretii	Young	20	9.04	6.38	11.38	.31	.22	.47	.50	.32	
(Smut grass)	Medium	6	6.65	5.65	7.78	.27	.19	.39	.47	.35	
	Bloom	11	6.83	5.24	8.90	.26	.18	.35	.50	.32	
	Mature	8	5.48	4.63	7.46	.19	.14	.28	.59	.32	[illegible]
Stipa leucotricha	Young	9	9.80	8.20	13.30	.34	.27	.45	.56	.43	
(Spear grass)	Medium	2	6.17	5.33	7.00	.19	.17	.22	.54	.38	
Tillandsia usneoides (Spanish moss)	—	4	4.62	4.03	5.00	.08	.07	.09	.51	.37	
Trifolium repens (White clover)*	Young	1	19.86	...	...	.61	..	..	1.56	..	
Triodia albescens (White triodia)	Young	1	9.35	...	...	.42	..	..	.80	..	
*Tripsacum dactyloides**	Young	6	10.96	9.09	12.65	.46	.23	.63	.60	.39	[illegible]
(Eastern gama grass)	Medium	7	5.37	4.31	6.39	.21	.16	.28	.64	.49	[illegible]
	Bloom	1	7.09	...	...	.30	..	..	.79	..	
	Mature	6	4.16	2.92	5.74	.16	.11	.24	.64	.51	
Vicia Leavenworthii	Young	1	18.54	...	...	.47	..	..	1.05	..	

*Averages for the East Texas Timber Country are given in Bulletin 582.

The analyses given in Table 2 and succeeding tables are stated in terms of protein (sometimes called crude protein, or the percentage of nitrogen multiplied by 6.25), phosphoric acid (phosphorus pentoxide, P_2O_5), and lime (calcium oxide, CaO). The analyses given may be converted into terms of the element concerned by multiplying protein by 0.16 for nitrogen (N), phosphoric acid by 0.4368 for phosphorus (P), and lime by 0.7147 for calcium (Ca).

The average, minimum, and maxium analyses given in Table 2 show marked variations among different kinds of plants and among samples at different stages of maturity of the same kind of plant. Little bluestem averaged 7.85% protein while Dallis grass averaged 11.48% protein at the young stage of growth. Corresponding averages for phosphoric acid were .27% and .42%, and for lime, .57% and .68%. Differences among species were usually wider for protein and phosphoric acid than for lime. Lower percentages of protein and phosphoric acid were found in older plants, as compared with young plants, while percentages of lime in most species did not change greatly. The relative differences with older plants varied widely with different grasses. For example, protein in little bluestem averaged 7.85% in the young grass and 3.37% in the mature grass, a relative difference of 57%, while the corresponding figures for buffalo grass were 8.65% and 6.16%, a relative difference of only 29%. Similar differences were observed with phosphoric acid; the averages for young and mature little bluestem were .27% and .12%, a relative difference of 56%, and for buffalo grass, .36% and .25%, a relative difference of only 30%. In general, the tall, bunchy, native grasses, such as the bluestems or beardgrasses, contained lower percentages of protein and phosphoric acid than the short, fine-stemmed grasses, such as Bermuda and buffalo grasses, and the relative decreases in percentages as the plants advanced in maturity were greater in the tall grasses than in the short grasses.

In order to show more clearly the differences among different species and stages of growth, the averages for the principal species given in Table 2 have been rearranged in Table 3 to compare the relative order with respect to protein, phosphoric acid and lime in samples of young and mature grasses. In the young grasses, protein ranged from 11.53% in Johnson grass to 7.19% in carpet grass, a relative difference of 38%; phosphoric acid ranged from .59% in Johnson grass to .25% in carpet grass, a relative difference of 58%; lime ranged from 1.14% in Johnson grass to

Table 3. Principal species of grasses arranged in order of their average protein, phosphoric acid and lime contents at young and mature stages of growth

		Young stage of growth			
Protein, %		**Phosphoric acid, %**		**Lime, %**	
	Good		Fair		High
Johnson	11.53	Johnson	.59	Johnson	1.14
Dallis	11.52	Eastern gama	.46		Good
Bermuda	11.37	Dallis	.42	Longtom	.71
Eastern gama	10.96	Bushy beard	.42	Dallis	.68
	Fair	Bermuda	.41	Indian	.68
Bushy beard	10.24	Longtom	.40	Bermuda	.67
Indian	10.02	Buffalo	.36	Georgia	.66
Texas needle	9.80	Indian	.38	Carpet	.64
Salt	9.34	Switch	.38	Buffalo	.60
Big bluestem	9.32	Silver beard	.36	Eastern gama	.60
Longtom	9.16	Texas needle	.34	Bushy beard	.59
Smut	9.04	Salt	.33	Alkali sacaton	.57
Switch	9.04	Big bluestem	.33	Little bluestem	.57
Alkali sacaton	9.02		Deficient	Big bluestem	.56
Silver beard	8.92	Alkali sacaton	.32	Texas needle	.56
Buffalo	8.65	Smut	.31	Switch	.55
Georgia	8.22	Georgia	.28	Silver beard	.53
Little bluestem	7.85	Little bluestem	.27	Salt	.51
Carpet	7.19	Carpet	.25	Smut	.50
		Mature stage of growth			
Protein, %		**Phosphoric acid, %**		**Lime, %**	
	Fair		Fair		Good
Buffalo	6.16	Dallis	.38	Dallis	.78
	Deficient		Deficient	Georgia	.68
Dallis	5.72	Buffalo	.25	Indian	.67
Bermuda	5.71	Bermuda	.24	Eastern gama	.64
Smut	5.48	Bushy beard	.23	Buffalo	.62
Alkali sacaton	5.00	Smut	.19	Bermuda	.61
Salt	4.36	Switch	.19	Big bluestem	.61
Eastern gama	4.16	Longtom	.18	Switch	.61
Georgia	4.13	Alkali sacaton	.17	Little bluestem	.60
Longtom	4.07		Very deficient	Smut	.59
Carpet	4.03	Eastern gama	.16	Silver beard	.54
Bushy beard	3.88	Salt	.16	Carpet	.52
Switch	3.74	Silver beard	.16	Alkali sacaton	.51
Silver beard	3.66	Indian	.15	Salt	.50
Big bluestem	3.64	Carpet	.15	Longtom	.47
Indian	3.58	Georgia	.14		Fair
Little bluestem	3.37	Big bluestem	.13	Bushy beard	.39
		Little bluestem	.12		

.50% in smut grass, a relative difference of 56%. At the mature stage of growth, the relative order of the grasses is considerably changed. Protein ranged from 6.16% in buffalo grass to 3.37% in little bluestem, a relative difference of 45%; phosphoric acid from .38% in Dallis grass to .12% in little bluestem, a relative difference of 50%. Only one mature sample of Johnson grass was collected. The data in Table 3 show the comparatively wide differences in chemical composition among different species, the marked decrease in percentages of protein and phosphoric acid with maturity, and the different effects of maturity upon the relative composition of the different grasses.

Of the 18 species of grasses whose average composition is shown in Table 3, Johnson grass, Dallis grass, and Bermuda grass were the highest and little bluestem and carpet grass were the lowest in protein and phosphoric acid. At the young stage of growth, Johnson, Dallis, Bermuda, and Eastern gama grasses contained more than 10.5% protein and hence may be considered good grasses in this respect (see Table 5). All other species listed in Table 3 contained more than 6% protein, and hence contain fair percentages of protein, but both little bluestem and carpet grass contained less than 8% protein and are the lowest in the list. Johnson, Eastern gama, Dallis, bushy beard, and Bermuda grasses contained sufficient phosphoric acid at the young stage of growth, while alkali sacaton, smut, Georgia, little bluestem, and carpet grasses contained less than .33% phosphoric acid, and hence are considered deficient in this constituent, even at the young stage of growth. At the mature stage of growth, buffalo, Dallis, and Bermuda grasses contained more protein than the other species, but buffalo grass was the only species which was not deficient in protein. Dallis grass was the only species which was not deficient in phosphoric acid. Little bluestem is at the bottom of the list in both protein and phosphoric acid. Carpet grass is intermediate in protein and near the bottom in phosphoric acid.

AVERAGE FEED CONSTITUENTS IN THE VARIOUS SPECIES OF FORAGE

The usual feed analyses were made on samples of most of the species of grasses collected; averages of these analyses are shown in Table 4. Averages for protein given in Table 4 are slightly different from those given in Table 2 because the averages given in Table 4 do not include all of the samples whose averages are given in Table 2. However, the averages in Table 4 show differences among different species and stages of growth similar to those discussed in the preceding section. Ether extract was low in all samples and it is doubtful if the differences between different species at the same stage of growth is significant; the decrease with advancing maturity is in most cases small, but occurs regularly and is therefore probably significant. Crude fiber was lower in short grasses, such as Bermuda and buffalo, usually running about 25%, than in the tall bunch grasses, which often contained more than 30% crude fiber. Crude fiber was usually lowest in young samples. In the later stages of growth, the differences among different grasses were usually quite small. Nitrogen-free extract usually ranged from 40% to 45% in young grasses, and from 45% to 50% in mature grasses; differences among species were

Table 4. Average chemical composition of different grasses at various stages of growth (percentages of dried grass)

Name	Stage of growth	Number of samples	Protein	Ether Extract	Crude Fiber	Nitrogen-free Extract	Water	Ash
Agrostis hiemalis (Tickle grass)	Young	1	10.30	2.06	30.99	40.93	7.81	7.91
Agrostis verticillata	Young	2	8.63	2.21	27.46	40.97	7.29	13.44
Andropogon glomerateus	Young	6	9.78	1.93	28.93	41.77	7.79	9.80
(Bushy beard grass)	Mature	3	4.16	1.38	31.22	48.07	8.35	6.82
Andropogon provincialis	Young	6	8.76	2.59	29.41	41.96	7.74	9.54
(Big bluestem)	Mature	2	4.95	1.49	25.06	50.36	7.15	10.99
Andropogon saccharoides	Young	2	7.63	1.42	28.42	41.27	8.78	12.48
(Silver beard grass)	Medium	1	5.42	1.52	31.32	44.44	7.64	9.66
	Bloom	3	5.29	1.60	32.09	44.32	7.24	9.46
	Mature	2	3.43	1.32	32.08	45.71	8.01	9.45
Andropogon scoparius	Young	35	7.28	1.93	29.39	44.21	8.38	8.81
(Little bluestem)	Medium	3	6.60	1.82	29.18	45.58	7.72	9.10
	Bloom	2	4.76	1.70	33.27	44.21	7.54	8.52
	Mature	7	3.41	1.74	30.66	47.93	8.00	8.26
Andropogon tener	Young	2	8.97	2.50	26.98	44.54	7.73	9.28
	Bloom	1	5.46	2.37	29.04	47.72	6.81	8.60
	Mature	2	4.64	1.89	31.45	46.04	8.18	7.80
Andropogon virginicus	Young	2	12.49	1.70	28.55	39.79	7.33	10.14
Aristida longespica	Young	3	6.78	1.63	27.71	44.65	8.37	10.86
	Mature	2	5.62	2.27	32.02	45.22	6.91	7.96
Aristida oligantha	Young	1	4.85	2.00	28.89	47.35	7.96	8.95
Axonopus affinis	Young	8	7.20	1.47	27.04	46.62	8.39	9.28
(Carpet grass)	Bloom	1	6.90	1.33	30.69	45.06	7.65	8.37
Bouteloua curtipendula	Young	1	10.23	2.01	26.17	44.02	7.57	10.00
(Sideoats grama)	Mature	1	3.14	2.03	26.92	48.16	7.85	11.90
Bouteloua rigidiseta	Young	2	7.78	1.73	28.69	41.45	8.06	12.29
(Texas grama)	Bloom	3	6.64	1.61	27.02	41.20	7.34	16.19
Bromus catharticus (Rescue grass)	Young	1	12.35	1.99	26.77	31.47	7.24	20.18
Buchloe dactyloides	Young	3	8.54	2.14	26.22	46.30	9.13	7.67
(Buffalo grass)	Bloom	4	6.86	1.53	25.68	47.70	7.63	10.60
	Mature	3	7.00	1.50	26.11	47.32	7.86	10.21
Cynodon dactylon	Young	11	9.85	1.77	24.80	45.50	8.66	9.42
(Bermuda grass)	Bloom	2	10.27	2.04	25.46	44.63	8.93	8.67
	Mature	1	6.75	1.82	26.34	48.85	8.80	7.44
Distichlis spicata	Young	4	7.37	1.58	28.43	48.86	7.72	8.04
(Salt water Bermuda)	Bloom	1	5.75	1.61	22.21	54.16	8.02	8.25
Elyonurus tripsacoides	Bloom	1	4.86	1.59	36.24	44.80	7.50	5.01
Festuca octoflora	Young	2	8.47	2.00	27.28	42.13	7.34	12.78
Heteropogon contortus	Young	2	8.85	1.85	28.47	43.49	8.18	9.16
(Tanglehead)	Bloom	2	4.31	3.22	32.87	46.96	7.33	5.31
	Mature	1	3.12	1.81	31.81	49.55	7.60	6.11
Hordeum murinum	Young	1	10.01	2.05	27.57	41.00	7.69	11.68
Medicago hispida	Young	1	21.25	2.71	21.23	38.31	7.78	8.72
Medicago lupulina	Bloom	1	15.50	2.67	22.92	41.90	7.33	9.68
Melinis minutiflora	Young	1	13.64	2.03	30.62	33.49	6.72	13.50
Monanthochloe littoralis	Young	2	6.36	1.60	26.07	45.55	7.49	12.93
(Salt cedar grass)	Bloom	2	5.69	1.16	27.67	47.28	7.51	10.69
Muhlenbergia capillaris	Young	4	9.21	1.80	32.44	40.03	7.47	9.05
(Long-awned hair grass)	Mature	1	3.62	1.57	34.34	46.00	7.62	6.85
Panicum helleri	Young	1	9.30	2.24	26.97	42.42	8.17	10.90
Panicum hemitomon	Young	1	11.80	1.93	25.86	41.81	6.94	11.66
Panicum Lindheimeri	Young	4	9.60	2.30	25.76	40.85	7.24	14.25
Panicum virgatum	Young	3	9.69	2.41	27.19	42.18	7.99	10.54
(Switch grass)	Medium	1	3.92	1.43	33.29	47.99	7.32	6.05
	Bloom	3	5.04	1.59	30.91	49.64	6.98	5.84
	Mature	4	3.49	1.70	29.37	50.03	8.25	7.16
Paspalum almum	Bloom	1	6.31	2.01	28.43	47.54	7.44	8.27
Paspalum dilatatum	Young	9	9.24	2.23	28.88	40.78	9.44	9.43
(Dallis grass)	Bloom	1	6.45	2.18	29.14	44.13	9.31	8.79
	Mature	1	7.34	2.02	31.19	41.65	7.63	10.16
Paspalum distichum	Young	2	9.57	2.04	27.19	41.74	7.29	12.17
Paspalum floridanum	Medium	3	5.52	1.47	31.66	43.81	8.56	8.98
	Bloom	1	4.92	1.83	31.85	44.91	8.81	7.68
	Mature	2	4.60	1.44	29.71	46.88	8.48	8.89
Paspalum Hartwegianum	Young	2	11.52	2.35	24.59	42.55	7.70	11.29
	Mature	2	3.38	1.27	32.29	46.59	8.61	7.86
Paspalum Langei	Young	1	14.34	2.59	24.87	34.96	10.85	12.39
Paspalum lividum	Young	3	6.82	1.69	26.49	47.70	7.66	9.64
(Longtom)	Medium	1	5.41	1.21	30.76	46.72	7.31	8.59
	Bloom	4	4.73	1.62	27.65	47.83	8.00	10.17
	Mature	4	3.67	1.28	28.42	50.24	8.23	8.16
Paspalum notatum	Mature	1	7.75	1.88	28.20	43.49	7.98	10.70

(continued)

Table 4. Average chemical composition of different grasses at various stages of growth (percentages of dried grass) (Continued)

Name	Stage of growth	Number of samples	Protein	Ether Extract	Crude Fiber	Nitrogen-free Extract	Water	Ash
Paspalum plicatulum (Georgia grass)	Young	5	8.97	1.95	26.33	44.12	8.03	10.60
	Medium	1	5.55	1.74	29.17	47.70	7.51	8.33
	Bloom	6	5.76	1.56	29.25	45.91	8.12	9.40
	Mature	9	4.32	1.75	29.91	47.27	8.31	8.44
Paspalum pubescens	Mature	1	4.50	1.32	32.72	44.86	8.18	8.42
Paspalum pubiflorum	Mature	1	8.29	1.42	28.86	40.00	8.15	13.28
Paspalum setaceum	Young	1	11.00	1.92	23.55	38.97	8.22	16.34
	Medium	1	7.05	1.78	30.44	43.93	7.31	9.49
Paspalum stramineum	Young	5	10.30	1.99	28.58	38.77	7.88	12.48
Paspalum urvillei (Vasey grass)	Young	3	8.52	1.90	29.37	40.80	8.41	11.00
	Bloom	4	6.29	1.83	36.18	39.29	7.39	9.02
Phalaris carolinicus	Young	3	9.08	2.11	25.99	38.42	8.71	15.69
Phalaris minor	Young	2	9.19	2.22	23.62	38.11	7.69	19.17
Polypogon monspeliensis	Young	1	12.35	2.52	25.94	36.91	8.85	13.43
Setaria lutescens	Mature	1	5.44	1.65	31.96	44.64	7.54	8.77
Sorghum halepense (Johnson grass)	Young	1	9.78	2.75	31.26	39.11	6.36	10.74
	Medium	3	7.24	2.09	29.09	43.76	8.21	9.61
	Bloom	2	6.69	1.92	30.48	44.38	7.99	8.55
Sorghastrum nutans (Indian grass)	Young	6	10.49	2.02	28.11	40.45	7.86	11.07
	Bloom	1	5.26	3.08	32.33	45.26	6.42	7.65
	Mature	4	3.44	1.71	31.07	46.37	8.04	9.37
Spartina patens (Cord grass)	Young	2	10.21	2.15	29.35	39.91	7.91	10.47
	Medium	3	4.81	2.14	30.90	46.13	7.46	8.56
	Mature	4	4.35	2.17	30.38	47.53	8.32	7.25
Spartina spartinate (Salt grass)	Young	4	10.17	2.34	29.35	40.49	8.40	9.25
	Bloom	4	5.85	2.31	30.93	44.15	8.60	8.16
	Mature	4	4.05	1.84	32.74	44.53	10.15	6.69
Sporobolus airoides (Alkali sacaton)	Young	2	11.47	2.43	27.87	41.11	7.75	9.37
	Bloom	3	7.20	1.77	31.92	43.05	6.68	9.38
Sporobolus Poiretii (Smut grass)	Mature	4	5.16	1.70	32.30	46.20	7.95	6.69
	Medium	1	7.27	1.49	30.35	47.79	6.49	6.61
	Bloom	7	6.97	1.71	29.38	46.29	7.83	7.82
	Mature	5	5.71	1.55	28.93	46.74	9.10	7.97
Stipa leucotricha	Young	5	8.73	2.12	28.80	41.28	8.05	11.02
Triodia albescens	Young	1	9.35	1.71	28.14	44.83	7.32	8.65
Tripsacum dactyloides (Gama grass)	Young	5	11.06	1.98	26.77	41.24	8.12	10.83
	Medium	3	5.77	1.89	28.90	47.99	6.90	8.55
	Bloom	1	7.09	1.89	27.44	46.55	7.20	9.83
	Mature	2	4.73	1.80	27.92	47.58	8.33	9.64
Tillandsia usneoides (Spanish moss)	—	2	4.49	2.04	30.80	49.10	8.34	8.23

small and of doubtful significance. Water analyses averaged about 8% after the samples had been dried in the usual procedure, that is, at about 45°C. in a ventilated oven. This average of 8% is sufficiently accurate in most cases for use in converting analyses given in the various tables to a moisture-free basis where this is desired. Ash analyses ran approximately from 8% to 10%, although in some samples it was higher; ash contains not only the minerals taken up by the plants, but also the residue from soil or dust which has collected on them.

GRADES OF CONSTITUENTS OF FORAGE

In order to facilitate comparison of the composition of the samples, they are grouped into 5 grades or classes (Table 5), as was done in a previous publication (15). The groups have been arranged to carry as much meaning as possible and the limits of the grades were decided upon after careful consideration of a large amount of experimental work reported in the literature. The limits of grades used in Table 5 are based upon the requirements of beef animals on the range.

The quantity of a given constituent utilized by an animal depends upon the percentage of that constituent in the feed, the quantity of feed

Table 5. Grades for percentages of protein, phosphorus and calcium in forage for range animals

Grade	Crude Protein	Protein	
1	High	15.00 or more	
2	Good	10.50 to 14.99	
3	Fair	6.00 to 10.49	
4	Deficient	3.00 to 5.99	
5	Very deficient	0 to 2.99	
	Phosphorus	**P**	**P_2O_5**
1	High	.45 or more	1.01 or more
2	Good	.30 to .44	.67 to 1.00
3	Fair	.15 to .29	.33 to .66
4	Deficient	.08 to .14	.17 to .32
5	Very deficient	0 to .07	0 to .16
	Calcium	**Ca**	**CaO**
1	High	.61 or more	.83 or more
2	Good	.31 to .60	.43 to .82
3	Fair	.16 to .30	.22 to .42
4	Deficient	.08 to .15	.11 to .21
5	Very deficient	0 to .07	0 to .10

consumed, and the utilization of the constituent by the animal (2, 12, 22, 25). These factors are interrelated, and the percentage of one constituent may affect the utilization of another constituent.

The relative utilization of a constituent is related to some extent to the percentage of that or other constituents in the ration. For example, according to data given by Morrison (25) and Fraps (12), when forage contains much less than 12% protein, only about 56% is digested; when the forage contains more than 12% protein, about 75% is digested. On the other hand, Archibald and Bennett (1) found that dairy heifers on a low-phosphorus ration utilized a higher percentage of the phosphorus than did heifers on a high-phosphorus ration, although the low-phosphorus ration was deficient in phosphorus and the animals were not as good as those on the high phosphorus ration. Beeson and others (5) found that feed was not utilized as well on a low-phosphorus ration as on a normal ration; steer calves required 30% more feed deficient in phosphorus to make a pound of growth, and gained 37% slower than calves on a ration containing sufficient phosphorus. Feeds high in crude fiber are usually less digestible than those low in crude fiber.

The requirements of animals as estimated by different investigators are not the same. Mitchell and McClure (24) estimate that the quantity of calcium required by fattening steers ranges from 24.7 grams per day for a 300 pound steer to 14.0 grams for a 1,000 pound steer; the percentages required in the ration range from .48% to .17% calcium (equivalent to from .67% to .24% lime). Weber and others (36) estimated that fattening calves required more than 11 grams of calcium per day. Theiler, Green, and DeToit (32) found that 4.99 grams of calcium per day was not enough for cattle. Lindsey, Archibald, and Nelson (23) found that an average daily intake of 5.97 grams of calcium per 100 pounds of live weight resulted in normal growth and development, and that equally satisfactory growth was secured with 3.17 grams, although there was a considerably lower storage of calcium.

The estimated requirements for phosphorus also vary, but not as widely as in the case of calcium. Beeson and others (5) claim that the phosphorus requirement for fattening beef steers was met by a phosphorus percentage in the ration of .18% (.41% phosphoric acid), while a deficiency of phosphoric acid was apparent in calves which received a ration containing .15 phosphorus (.34% phosphoric acid). Henderson and Weakley (19) estimate that the ration for dairy animals should exceed .20% phosphorus (.46% phosphoric acid). Mitchell and McClure estimate that the phosphorus in rations necessary for fattening beef steers ranges from .34% for a 300 pound steer to .18% for a 1,000 pound steer (.78% to .41% phosphoric acid). Black and others (7) have found a phosphorus content of .13% (.30% phosphoric acid) and a calcium content of .23% (.32% lime) as the minimum amounts of these elements required for Texas range cattle.

A study of the available literature concerning the phosphorus content of forage from areas which were known to produce forage deficient in phosphorus, as compared with areas on which the cattle showed no evidence of phosphorus deficiency, showed that grass samples from deficient areas contained an average of .082% phosphorus (.19% phosphoric acid), while those from normal areas contained an average of .170% phosphorus (.39% phosphoric acid). Of 53 samples of forage reported from South Africa by Theiler (33) from a deficient area, 31 samples contained less than .17% phsophoric acid, and 48 contained less than .33%. Of 81 samples reported from Florida by Becker, Neal, and Shealy (4), 14 samples from ranges producing healthy animals averaged .167% phosphorus (.38% phosphoric acid), while 67 samples from deficient areas averaged .103% phosphorus (.24% phosphoric acid). Of 51 samples of prairie hay from a deficient area in Minnesota reported by Eckles, Gullickson, and Palmer (11), 44 contained less than .33% phosphoric acid. Of 54 samples from Montana reported by Scott (27), samples from normal areas averaged considerably more than .33% phosphoric acid while those from deficient areas averaged considerably less. Spring samples of grass in Utah, reported by Stoddart and Greaves (30), averaged .283% phosphorus and fall samples averaged .185% (.65% and .43% phosphoric acid); none of these samples was considered to be deficient in phosphorus. The limits of the grades shown in Table 5 thus have considerable meaning.

DISTRIBUTION OF SAMPLES ACCORDING TO GRADES OF CONSTITUENTS

The distribution of the samples with respect to different grades of protein, phosphoric acid and lime is shown in Table 6. Protein was very deficient (Grade 5) in only 31 of the total of 1140 samples (3% of the total), but was deficient (Grade 4) in 479 samples (42% of the total). Phosphoric acid was very deficient (Grade 5) in 245 samples (21% of the total), and deficient (Grade 4) in 605 samples (53%). Lime was very deficient (Grade 5) in no samples, deficient (Grade 4) in only 5 samples, and fair in 199 samples (17% of total). None of the samples was high in phosphoric acid and only 16 were high in protein, of which 7 were legumes.

The distribution of the samples of a given species in the different grades varied widely with the different species. Protein was deficient in 13% of the samples of Bermuda grass and in 55% of the samples of little bluestem. Phosphoric acid was very deficient in none of the Bermuda

Table 6. Numbers of samples of different species of grasses at various stages of maturity in each grade of constituents (Continued)

	Stage of growth	Number of samples	Protein grade					Phosphoric acid grade				Lime grade			
			Very deficient	Deficient	Fair	Good	High	Very deficient	Deficient	Fair	Good	Deficient	Fair	Good	High
			5	4	3	2	1	5	4	3	2	4	3	2	1
			0—2.99%	3.00—5.99%	6.00—10.49%	10.50—14.99%	15.00% or more	0—.16%	.17—.32%	.33—.66%	.67—1.00%	.11—.22%	.23—.42%	.43—.82%	.83% or more
Agrostis hiemalis (Tickle grass)	Young	3			3					2	1		3		
Agrostis verticillata	Young	2			2				1	1				2	
Andropogon annulatus (Angleton grass)	Young	3			2	1		1	1	1	1		1	1	1
	Bloom	2		1	1				1	1				2	
	Mature	1		1					1					1	
Andropogon glomeratus (Bushy beard grass)	Young	15			10	5			3	11	1		3	12	
	Medium	11		10	1			2	8	1				10	1
	Bloom	5		5				2	3				3	1	1
	Mature	7		7				4	2	1		1	4	1	1
Andropogon provincialis (Big bluestem)	Young	31			23	8		1	14	16			3	27	1
	Medium	13		12	1			3	10				2	8	3
	Bloom	6		6				4	2					5	1
	Mature	20	7	11	2			17	3				3	14	3
Andropogon saccharoides (Silver beard grass)	Young	9		7	2				5	4			3	6	
	Medium	1		1						1				1	
	Bloom	8		6	2				8				3	4	1
	Mature	5		5				3	2				2	3	
Andropogon scoparius (Little bluestem)	Young	109		25	73	11		8	77	24		1	16	86	6
	Medium	38		30	8			7	29	2			1	31	6
	Bloom	23	3	19	1			15	8				6	14	3
	Mature	33	10	23				32	1				7	22	4
Andropogon tener	Young	4			4				2	2				3	1
	Medium	1		1					1					1	
	Bloom	1		1					1					1	
	Mature	7	2	5				5	2				4	3	
Andropogon virginicus (Broom sedge)	Young	4			2	2			1	3				4	
	Medium	3		3				1	1	1			1	1	1
	Bloom	1		1				1						1	
	Mature	3		3				3					1	2	
Aristida longesita (Needle grass)	Young	3		1	2				3					2	1
	Mature	3		3				1	2				1	2	
Aristida oligantha (Prairie grass)	Young	1		1				1						1	
	Bloom	1		1					1				1		
Axonopus affinis (Carpet grass)	Young	51		9	41		1	1	46	4			9	36	6
	Medium	20		10	10			3	17				7	12	1
	Bloom	10		8	2			5	5				3	7	
	Mature	2		2				1	1				1	1	

(continued)

Table 6. Numbers of samples of different species of grasses at various stages of maturity in each grade of constituents (Continued)

	Stage of growth	Number of samples	Protein grade: Very deficient 5 0—2.99%	Protein grade: Deficient 4 3.00—5.99%	Protein grade: Fair 3 6.00—10.49%	Protein grade: Good 2 10.50—14.99%	Protein grade: High 1 15.00% or more	Phosphoric acid grade: Very deficient 5 0—.16%	Phosphoric acid grade: Deficient 4 .17—.32%	Phosphoric acid grade: Fair 3 .33—.66%	Phosphoric acid grade: Good 2 .67—1.00%	Lime grade: Deficient 4 .11—.22%	Lime grade: Fair 3 .23—.42%	Lime grade: Good 2 .43—.82%	Lime grade: High 1 .83% or more
Bouteloua curtipendula	Young	2			2				1	1				2	
(Sideoats grama grass)	Bloom	2			2				2					1	1
	Mature	1		1				1							1
Bouteloua hirsuta (Hairy grama grass)	Mature	2		2				2						1	1
Bouteloua rigidiseta	Young	3		1	2			1	2					2	1
(Texas grama grass)	Bloom	4	1		3			1	3				1	3	
Bromus catharticus (Rescue grass)	Young	1				1				1				1	
Buchloe dactyloides	Young	6			6				2	4				6	
(Buffalo grass)	Medium	3		1	2				2	1			1		2
	Bloom	5		2	3				4	1				4	1
	Mature	5		2	3			1	3	1				5	
Chloris cucullata	Young	1				1				1					1
(Black finger grass)	Bloom	1			1					1					1
	Mature	1		1				1						1	
Cynodon dactylon	Young	22			12	8	2		5	17			2	16	4
(Bermuda grass)	Medium	5		1	4				3	2				4	1
	Bloom	8		3	5				4	4				8	
	Mature	3		1	2				3					3	
Distichlis spicata (Salt	Young	4			4				4				4		
water Bermuda grass)	Medium	2		1	1				2				1	1	
	Bloom	1		1						1				1	
Elyonurus tripsacoides (Joint grass)	Bloom	2		2				1	1			1		1	
Eragrostis spectabilis	Medium	3		3				1	2					3	
(Purple love grass)	Mature	2		2				2						2	
Festuca octoflora	Young	2			2				1	1				2	
Heteropogon contortus	Young	2			2				1	1				2	
(Tanglehead grass)	Medium	2			2				1	1				1	1
	Bloom	2		2				2					2		
	Mature	1		1				1						1	
Hordeum murinum (Sea barley)	Young	3			3					3			2	1	
Lespedeza striata	Young	4					4			3	1				4
Medicago hispida	Young	1					1			1	1				1
Medicago lupulina	Bloom	1					1			1				1	
Melinis minutiflora	Young	1				1					1			1	

(continued)

Table 6. Numbers of samples of different species of grasses at various stages of maturity in each grade of constituents

	Stage of growth	Number of samples	Protein grade: Very deficient 5 0—2.99%	Protein grade: Deficient 4 3.00—5.99%	Protein grade: Fair 3 6.00—10.49%	Protein grade: Good 2 10.50—14.99%	Protein grade: High 1 15.00% or more	Phosphoric acid grade: Very deficient 5 0—.16%	Phosphoric acid grade: Deficient 4 .17—.32%	Phosphoric acid grade: Fair 3 .33—.66%	Phosphoric acid grade: Good 2 .67—1.00%	Lime grade: Deficient 4 .11—.22%	Lime grade: Fair 3 .23—.42%	Lime grade: Good 2 .43—.82%	Lime grade: High 1 .83% or more
Monanthochloe littoralis	Young	1			1				1				1		
(Salt cedar grass)	Medium	2		2				1	1			1		1	
	Bloom	2		2					2				2		
Muhlenbergia capillaris	Young	11		1	9	1		3	6	2			8	3	
(Long-awned hair grass)	Medium	4		4				1	3					4	
	Bloom	3		3				3					3		
	Mature	2		2				1	1					2	
Panicum capillarioides	Young	7			6	1			4	3			4	3	
Panicum fasciculatum	Young	1			1					1				1	
	Bloom	1		1					1					1	
Panicum hemitomon	Young	2				2			1	1			1		1
Panicum helleri	Bloom	1			1				1				1		
Panicum Lindheimeri	Young	10			8	2			8	2			1	5	4
	Mature	1		1				1							1
Panicum virgatum	Young	14		2	8	4			4	10			4	9	1
(Switch grass)	Medium	3		3				1	2				1	2	
	Bloom	7		5	2			3	3	1			3	4	
	Mature	9	2	7				6	2	1			2	6	1
Paspalum almum	Bloom	1			1				1						1
Paspalum dilatatum	Young	23			10	11	2		6	16	1			20	3
(Dallis grass)	Medium	3			3					3				2	1
	Bloom	10		1	9				10				1	9	
	Mature	4	1	1	2				1	3				3	1
Paspalum distichum	Young	6			4	2			3	2	1		1	2	3
Paspalum floridanum	Young	3			2	1			2	1				3	
	Medium	8		6	2			3	5					8	
	Bloom	4		4				1	2	1			1	2	1
	Mature	2		2				2						2	
Paspalum Hartwegianum	Young	7			5	2			3	4			1	5	1
	Mature	2		2				2						2	
Paspalum Langei	Young	1				1				1				1	
Paspalum lividum	Young	7			5	2			2	3	2		1	5	1
(Longtom)	Medium	13		6	7				7	6			2	8	3
	Bloom	5		4	1			1	3	1			1	3	1
	Mature	7		7				5	1	1			4	2	1
Paspalum monostachyum	Bloom	2			2				1	1				1	1
Paspalum notatum	Young	5			2	3			2	3				2	3
(Bahia grass)	Mature	1			1				1					1	

(continued)

Table 6. Numbers of samples of different species of grasses at various stages of maturity in each grade of constituents (Continued)

	Stage of growth	Number of samples	Protein grade: Very deficient 5 0—2.99%	Deficient 4 3.00—5.99%	Fair 3 6.00—10.49%	Good 2 10.50—14.99%	High 1 15.00 or more	Phosphoric acid grade: Very deficient 5 0—.16%	Deficient 4 .17—.32%	Fair 3 .33—.66%	Good 2 .67—1.00%	Lime grade: Deficient 4 .11—.22%	Fair 3 .23—.42%	Good 2 .43—.82%	High 1 .83% or more
Paspalum plicatulum	Young	40		4	31	5		1	31	8			3	30	7
(Georgia grass)	Medium	27		21	6			7	19	1			1	20	6
	Bloom	19		17	2			7	11	1				15	4
	Mature	21	1	20				15	6				1	18	2
Paspalum pubescens	Mature	2		1	1			1	1				1	1	
Paspalum setaceum	Young	3			1	2			2	1				2	1
	Medium	2			2				1	1					2
	Mature	1		1				1						1	
Paspalum stramineum	Young	6			3	3			1	5				6	
	Bloom	1			1					1					1
Paspalum urvillei	Young	5			5				3	2			1	3	1
(Vasey grass)	Medium	1			1				1					1	
	Bloom	7		4	3			1	4	2				5	2
	Mature	2		2				1	1				1	1	
Paspalum vaginatum	Young	1					1			1			1		
Phaloris caroliniana	Young	3			3					3				2	1
Phaloris minor	Young	3			3					3				3	
Poa annua	Young	1					1				1			1	
Polypogon monspeliensis	Young	2				2				1	1			2	
Setaria geniculata	Young	1			1					1				1	
(Knotroot bristlegrass)	Bloom	2		2				1			1			2	
Setaria lutescens	Mature	1		1					1				1		
Setaria viridis (Green foxtail)	Young	4				4				4				4	
Sorghastrum nutans	Young	16		9	1				8	7	1			13	3
(Indian grass)	Medium	10		10				7	3					7	3
	Bloom	3		2	1				3				1	2	
	Mature	9	2	7				7	2					7	2
Sorghum halepense	Young	5			1	3	1			3	2				5
(Johnson grass)	Medium	4			4				1	3					4
	Bloom	4		1	3				2	2					4
	Mature	1		1					1					1	
Spartina patens	Young	5		1	4			1	2	2			3	2	
(Cord grass)	Medium	10		9	1			3	7			1	2	5	2
	Bloom	1		1				1						1	
	Mature	4		4				3	1				3	1	
Spartina spartinae	Young	10			7	3			4	6			5	3	2
(Salt grass)	Medium	5		4	1			2	3				2	2	1

(continued)

Table 6. Numbers of samples of different species of grasses at various stages of maturity in each grade of constituents (Continued)

	Stage of growth	Number of samples	Protein grade: Very deficient 5 0—2.99%	Deficient 4 3.00—5.99%	Fair 3 6.00—10.49%	Good 2 10.50—14.99%	High 1 15.00% or more	Phosphoric acid grade: Very deficient 5 0—.16%	Deficient 4 .17—.32%	Fair 3 .33—.66%	Good 2 .67—1.00%	Lime grade: Deficient 4 .11—.22%	Fair 3 .23—.42%	Good 2 .43—.82%	High 1 .88% or more
	Bloom	6		4	2				6				2	4	
	Mature	7	1	6				5	2				4	3	
Sporobolus airoides	Young	19		1	14	4			12	7			3	15	1
(Alkali sacaton)	Medium	11		8	3			3	7	1			2	8	1
	Bloom	8		3	5				8				2	6	
	Mature	5		4	1			3	2				3	2	
Sporobolus Poiretii	Young	20			16	4			13	7			3	17	
(Smut grass)	Medium	6		1	5				5	1			2	4	
	Bloom	11		1	10				8	3			4	7	
	Mature	8		6	2			2	6				2	5	1
Stipa leucotricha	Young	9			7	2			6	3				9	
(Texas needlegrass)	Medium	2		1	1				2				1	1	
Tillandsia usneoides	—	4		4				4					1	3	
(Spanish moss)															
Trifolium repens	Young	1					1			1					1
Triodia albescens	Young	1			1				1					1	
Tripsacum dactyloides	Young	6			1	5			1	5			1	4	1
(Eastern gama grass)	Medium	7		6	1			1	6					6	1
	Bloom	1			1				1					1	
	Mature	6	1	5				4	2					5	1
Vicia Leavenworthii	Young	1					1			1					1
All samples	Young	535	0	66	359	97	13	19	295	209	12	1	89	381	64
	Medium	222	1	153	65	3	0	46	150	25	1	2	27	153	40
	Bloom	198	4	115	70	6	3	51	111	34	2	1	41	128	28
	Mature	185	26	145	14	0	0	129	49	7	0	1	42	123	19
	TOTAL	1140	31	479	508	106	16	245	605	275	15	5	199	785	151

grass samples and 31% of the little bluestem samples. In general, much larger proportions of the samples of the tall grasses than of short grasses were deficient or very deficient in protein and phosphoric acid.

The distribution of the samples of each species at different stages of growth is also shown in Table 6. The portion of the samples of the species containing percentages of protein and phosphoric acid in the lower grades is greater with older plants. At the young stage of growth, protein was very deficient (Grade 5) in none of the samples, and deficient (Grade 4) in only 12%, while at the mature stage of growth, protein was very deficient in 14% and deficient in 78% of the samples. For samples at young, medium, bloom, and mature stages of growth, the percentages of samples which were deficient in protein were 8, 69, 60, and 93, respectively; for phosphoric acid, the percentages were 59, 89, 82, and 96. The effect of the stage of growth varied with the different species. Of 340 samples of 12 species of tall grasses at medium, bloom, and mature stages of growth, 94% were deficient (Grades 5 and 4) in protein and 96% deficient in phosphoric acid. Of 86 samples of 5 species of short grasses, 40% were deficient in protein and 76% deficient in phosphoric acid. Of these samples, protein was very deficient (Grade 5 only) in 8% of the tall grasses and in none of the short grasses, and phosphoric acid was very deficient in 48% of the tall grasses and in only 13% of the short grasses.

The figures in Table 6 show that many of the samples were deficient in protein, most of them were deficient in phosphoric acid and very few were deficient in lime; advancing maturity increased the proportion of samples deficient in protein and phosphoric acid, and different species varied widely in the proportion of samples in the different grades.

THE CHEMICAL COMPOSITION OF THE SOILS

Chemical analyses of 68 soils from which forage was collected were made in order to study the relation between the chemical composition of the soils and that of the grasses grown on those soils. A knowledge of this relation might enable one to predict the probable relative composition of forage from soil types whose general average chemical composition is already known and to apply knowledge already available concerning the chemical composition of a large number of Texas soils (13).

Averages for the principal constituents concerned in this study in the samples of the six principal groups of soils of the region are given in Table 7. The distribution of the samples in different grades or levels of the different constituents is also shown in that table. The grades shown are the same as those previously proposed and discussed by the authors (15). However, since most of the soils were low in phosphoric acid, the grades for phosphoric acid have been divided into two sections in order to show a greater differentiation among the samples. Nitrogen was probably deficient in only one of the 68 soils. Total phosphoric acid was deficient (below .051%) in 58 of the soils, of which 13 were very deficient (below .026%). Active phosphoric acid was deficient (below 100 parts per million) in 62 of the 68 soils; of these, 47 were very deficient (below 31 p.p.m.). Active lime was relatively low in 15 samples, although only 3 of them

Table 7. Number of samples of soils in different grades of constituents.

	Harris soils	Hockley Katy soils	Edna soils	Lake Charles light soils	Lake Charles heavy soils	Alluvial soils	Total
Total number of soils	4	10	19	10	22	3	68
Nitrogen, average, %	.160	.106	.127	.127	.157	.176	
Grade 4, .031—.060%	0	0	0	0	0	1	1
Grade 3 , .061—.120%	2	8	9	4	5	0	28
Grade 2, .121—.180%	1	2	7	6	9	0	25
Grade 1, .181% or more	1	0	3	0	8	2	14
Total phosphoric acid, average, %	.056	.029	.029	.032	.046	.103	
Grade 5, 0—.025%	0	3	7	1	2	0	13
Grade 4, .026—.035%	1	6	8	6	5	0	26
Grade 4, .036—.050%	1	1	4	3	10	0	19
Grade 3, 2, 1, .051% or more	2	0	0	0	5	3	10
Active phosphoric acid, average, p.p.m.	111	22	22	30	57	275	
Grade 5, 0—18 p.p.m	0	2	8	2	10	0	22
Grade 5, 19—30 p.p.m.	0	7	9	4	5	0	25
Grade 4, 31—64 p.p.m	1	1	2	3	4	0	11
Grade 4, 65—100 p.p.m.	1	0	0	1	1	1	4
Grade 3, 2, 1, 101 p.p.m or more	2	0	0	0	2	2	6
Active lime, average, p.p.m	3675	1753	3069	3227	7245	17119	
Grade 5, 0—800 p.p.m.	0	1	0	2	0	0	3
Grade 4, 801—1600 p.p.m.	1	6	4	1	0	0	12
Grade 3, 1601—3200 p.p.m.	1	2	10	3	3	0	19
Grade 2, 3201—6400 p.p.m.	1	1	4	3	10	1	20
Grade 2, 16401 p.p.m. or more	1	0	1	1	9	2	14
pH, average	6.98	6.26	6.18	6.41	6.33	7.44	
Grade 5, below 5.0	0	0	0	2	1	0	3
Grade 4, 5.1—5.5	0	2	3	0	5	0	10
Grade 3, 5.6—6.0	0	3	5	1	3	0	12
Grade 2, 6.1—7.5	3	4	11	6	13	2	39
Grade 1, 7.6 or more	1	1	0	1	0	1	4

were more acid than pH 5.0. The pH was below 6.0 in 25 of the 68 samples; while soil acidity may not be a limiting factor for the growth of grasses on most of these soils, it is possible that some of the soils are sufficiently acid to respond to the application of lime, particularly for the growth of legumes.

Significant differences in average composition and in distribution in the different grades occurred among the soil groups. Hockley and Katy soils were considerably lower than any other group in several constituents. Edna soils were higher than those of the Hockley-Katy group in nitrogen and active lime but the same in total phosphoric acid. Light-textured soils of the Lake Charles series were practically the same as the Edna soils in all constituents, while the heavy-textured soils were the highest of any of the upland groups. Considerable variation in the composition of the Harris soils is evident. Alluvial soils were much higher in all constituents than any of the upland groups.

RELATION OF CHEMICAL COMPOSITION OF SAMPLES OF FORAGE TO DIFFERENT GROUPS OF SOILS

It is important to know whether there were important variations in the average chemical composition of forage as related to different groups of soils. In order to study this question, two groupings of the soils were made. The first grouping was based on the nature of the soils, as indicated by the name of their series, or in the case of the Lake Charles series, whether light-textured or havy-textured. The second grouping was based on the chemical composition of the soils. The average protein, phosphoric acid, and lime in all samples of forage at different stages of growth were calculated for each soil group. For this purpose, the samples at the medium and bloom stages of growth (Table 2) were combined and designated as intermediate growth. The percentages of the total number of samples from each group of soils which contained protein, phosphoric acid, or lime percentages within different ranges were also ascertained. Because of the marked decrease in the percentage of protein and phosphoric acid in the grasses at different stages of growth, the limits chosen were different for the different stages. Limits for lime were the same for all periods of growth, since the lime percentages were fairly constant.

Effect of the General Nature of the Soil

The data with respect to the general nature of the soils are given in Table 8. In the young samples of grass, protein was lowest in those from the Hockley-Katy group (8.60%) and highest in those from the light-textured soils of the Lake Charles series (9.54%). The difference between the Edna soils (9.02%) and the heavy-textured Lake Charles soils (8.94%) is probably not significant, but the other differences are significant. Protein in the samples of forage at the intermediate stage of growth was definitely higher in those grown on the Edna soils (5.99%) than in those from any of the other soils (about 5.5%), which did not vary significantly among themselves. Differences at the mature stage of growth were relatively small, with a slight advantage in favor of the light-textured Lake Charles soils. For all of the samples, protein was slightly but significantly lower in the samples from the Hockley-Katy soils than in those from any of the other groups, among which the differences were quite small.

Phosphoric acid was definitely lower in the samples from the Hockley-Katy and Edna groups than in those from either of the Lake Charles groups. At the young stage of growth, samples from the Hockley-Katy group averaged only .27% phosphoric acid, with 75% of the samples being deficient (below .33%); those from the Edna soils averaged .31% phosphoric acid, with 61% of the samples deficient; those from the Lake Charles soils averaged about .35% phosphoric acid with only about half of the samples deficient in phosphoric acid. At the intermediate stage of growth, the Hockley-Katy soils were again lowest (.19% phosphoric acid, 37% of the samples below .17%), but the differences among the other groups were very small. At the mature stage of growth, the differences among the soil groups were very small, but the proportion of samples which were very deficient in phosphoric acid (below .17%) was much higher in the Hockley-Katy (88%) and the Edna (78%) soils than in the Lake Charles soils (55% and 66%). Overall averages also show that the samples from the Hockley-Katy soils (.22% phosphoric acid) were definitely below those from the Edna soils (.25%), which were in turn below samples from the two groups of Lake Charles soils (.28% and .28%).

Lime was definitely lower in the samples from the Hockley-Katy soils (overall average of .57%) and the Edna soils (.56%) than in those from the groups of Lake Charles soils (.64% and .64%). Lime averaged slightly higher in the young samples than in intermediate or mature samples, but the differences were probably not significant. As previously noted, very few of the samples were deficient in lime.

Table 8. Average chemical composition and percentages of forage samples containing different levels of constituents and from different groups of soils based on general characteristics.

Soil group	Number of samples	Average protein in plants	Distribution of samples with respect to protein				Average phosphoric acid in plants	Distribution of samples with respect to phosphoric acid				Average lime in plants	Distribution of samples with respect to lime			
Forage at the young stage of growth																
			Protein in plants: 0 to 5.9%	6.0 to 8.2%	8.3 to 10.4%	Over 10.4%		Phosphoric acid in plants: 0 to .16%	.17 to .32%	.33 to .49%	Over .49%		Lime in plants: 0 to .42%	.43 to .62%	.63 to .82%	Over .82%
			Percentage of samples from each soil group					Percentage of samples from each soil group					Percentage of samples from each soil group			
Hockley-Katy	98	8.60	5	31	41	23	.27	3	72	24	1	.60	17	48	23	12
Edna	116	9.02	4	34	40	22	.31	3	58	35	4	.55	21	51	24	4
Lake Charles—Light	93	9.54	12	17	53	18	.35	3	40	41	16	.63	16	29	42	13
Lake Charles—Heavy	197	8.94	12	33	34	21	.34	4	55	28	13	.66	10	45	29	16
Forage at the intermediate stage of growth																
			Protein in plants: 0 to 3.9%	4.0 to 4.9%	5.0 to 5.9%	Over 5.9%		Phosphoric acid in plants: 0 to .16%	.17 to .24%	.25 to .32%	Over .32%		Lime in plants: 0 to .42%	.43 to .62%	.63 to .82%	Over .82%
			Percentage of samples from each soil group					Percentage of samples from each soil group					Percentage of samples from each soil group			
Hockley-Katy	64	5.37	5	42	27	26	.19	36	50	8	6	.53	17	61	17	5
Edna	107	5.99	0	18	37	45	.22	16	52	20	12	.58	20	43	24	13
Lake Charles—Light	74	5.52	8	27	33	32	.25	19	42	23	16	.68	9	44	24	23
Lake Charles—Heavy	132	5.58	9	34	32	25	.23	28	45	17	10	.64	16	40	26	18
Forage at the mature stage of growth																
			Protein in plants: 0 to 2.9%	3.0 to 4.4%	4.5 to 5.9%	Over 5.9%		Phosphoric acid in plants: 0 to .10%	.11 to .16%	.17 to .24%	Over .24%		Lime in plants: 0 to .42%	.43 to .62%	.63 to .82%	Over .82%
			Percentage of samples from each soil group					Percentage of samples from each soil group					Percentage of samples from each soil group			
Hockley-Katy	41	3.93	12	59	29	0	.13	17	71	12	0	.53	24	39	22	15
Edna	40	3.96	12	63	17	8	.15	5	73	20	2	.54	33	33	33	1
Lake Charles—Light	38	4.41	9	53	30	8	.16	18	37	29	16	.59	10	45	38	7
Lake Charles—Heavy	68	3.98	22	48	24	6	.17	22	46	22	10	.62	24	34	28	14

In addition to the four main groups of soils just discussed, some forage samples were collected from a few locations on alluvial soils and Harris soils. Samples of grasses from three alluvial soils at the young stage of growth averaged 11.45% protein, .57% phosphoric acid, and .63% lime. The inclusion of *Lespedeza striata* in the averages changed them to 14.02% protein, .55% phosphoric acid, and .92% lime. The young forage from these soils was thus comparatively high in protein, phosphoric acid and lime. At the intermediate stage of growth, forage from one of the Miller soils averaged 6.24% protein, .38% phosphoric acid, and .80% lime; protein was no higher than in corresponding samples from upland soils but phosphoric acid was considerably higher. Forage samples from four Harris soils, which lie very near the Gulf and on which growth was comparatively sparse, averaged 10.07% protein, .39% phosphoric acid, and .46% lime at the young stage of growth; at the intermediate stage of growth, the averages were 5.85%, .22%, and .47%, respectively. These averages are very similar to those for similar forage samples from the usual upland soils.

Very few of the soils produce forage which is deficient in protein at the young stage of growth, or which is not deficient in protein at the mature stage of growth. Most of the soils on which native grasses predominate probably produce forage which is deficient in protein at intermediate stages of growth, while many of those on which certain of the better grasses, such as Bermuda, Dallis, and Johnson grasses predominate, may produce forage in which protein is not deficient. Many of the soils, particularly of the Hockley, Katy, and Edna series, produce forage which is deficient in phosphoric acid at all stages of growth. Most of the common upland soils produce forage which is deficient in phosphoric acid at intermediate and mature stages of growth. Some of the alluvial soils produce forage which is not deficient in phosphoric acid at intermediate and mature stages of growth.

Effect of the Chemical Composition of the Soils

Protein in samples of young forage from soils containing different levels of total nitrogen (Table 9) increased significantly as the total nitrogen in the soils increased. At the intermediate and mature stages of growth, however, differences in average protein content of the forage were very small and showed no relation to the quantity of total nitrogen in the soil. The distribution of the samples containing the same levels of protein but grown on soils containing different levels of total nitrogen did not vary significantly with the different soil groups. These results are in substantial agreement with those of work previously published (17) which showed that, for nitrogen, the relation between the plant and the soil is much closer in young samples than in older ones.

Phosphoric acid in the young forage increased significantly as the quantity of active phosphoric acid in the soil increased beyond 30 parts per million. However, three-fourths of the young samples collected were from soils in which active phosphoric acid was below 30 parts per million, and of these samples, two-thirds were deficient (below .33%) in phosphoric acid. At the intermediate and mature stages of growth, the average phosphoric acid in the samples was low until the quantity of active phosphoric

Table 9. Average chemical composition and percentages of forage samples containing different levels of constituents and from different groups of soils based on chemical composition.

Nitrogen in soils, %	Number of samples	Average protein	Protein in plants: Distribution of samples with respect to protein in plants				Active phosphoric acid in soils, p.p.m.	Number of samples	Average phosphoric acid	Phosphoric acid in plants: Distribution of samples with respect to phosphoric acid in plants				Active lime in soils, p.p.m.	Number of samples	Average lime	Lime in plants: Distribution of samples with respect to lime in plants			
Forage at the young stage of growth																				
			Protein in plants: 0 to 5.9%	6.0 to 8.2%	8.3 to 10.4%	Over 10.4%				Phosphoric acid in plants: 0 to .16%	.17 to .32%	.33 to .49%	Over .49%				Lime in plants: 0 to .42%	.43 to .62%	.63 to .82%	Over .82%
			Percentage of samples from each soil group							Percentage of samples from each soil group							Percentage of samples from each soil group			
0 to .120	201	9.02	6	34	37	23	0 to 18	146	.29	5	60	25	10	0 to 1600	98	.52	30	44	23	3
.121 to .180	150	9.33	9	25	47	19	19 to 30	152	.30	2	63	32	3	1601 to 3200	110	.62	16	42	28	14
Over .180%	79	10.59	6	16	34	44	31 to 100	106	.41	1	24	53	22	3201 to 6400	138	.67	7	44	34	15
							Over 100	26	.55	0	8	30	62	Over 6400	84	.76	12	33	31	24
Forage at the intermediate stage of growth																				
			Protein in plants: 0 to 3.9%	4.0 to 4.9%	5.0 to 5.9%	Over 5.9%				Phosphoric acid in plants: 0 to .16%	.17 to .24%	.25 to .32%	Over .32%				Lime in plants: 0 to .42%	.43 to .62%	.63 to .82%	Over .82%
			Percentage of samples from each soil group							Percentage of samples from each soil group							Percentage of samples from each soil group			
0 to .120	164	5.70	6	29	31	34	0 to 18	112	.22	26	44	18	12	0 to 1600	67	.53	18	58	24	0
.121 to .180	123	5.63	6	32	31	31	19 to 30	132	.20	33	47	14	6	1601 to 3200	108	.60	18	43	23	16
Over .180%	76	5.62	4	30	40	26	31 to 100	91	.23	14	54	22	10	3201 to 6400	94	.66	7	41	24	28
							Over 100	28	.37	0	25	21	54	Over 6400	94	.67	9	41	23	27
Forage at the mature stage of growth																				
			Protein in plants: 0 to 3.9%	4.0 to 4.9%	5.0 to 5.9%	Over 5.9%				Phosphoric acid in plants: 0 to .10%	.11 to .16%	.17 to .24%	Over .24%				Lime in plants: 0 to .42%	.43 to .62%	.63 to .82%	Over .82%
			Percentage of samples from each soil group							Percentage of samples from each soil group							Percentage of samples from each soil group			
0 to .120	66	4.08	58	23	15	4	0 to 18	48	.15	19	56	19	6	0 to 1600	33	.54	21	58	21	0
.121 to .180	55	3.76	75	11	9	5	19 to 30	60	.14	19	61	20	0	1601 to 3200	47	.56	31	33	27	9
Over .180%	42	4.22	45	36	10	9	31 to 100	45	.19	13	38	31	18	3207 to 6400	58	.64	14	30	35	21
							Over 100	1	.40	0	0	0	100	Over 6400	25	.64	16	36	44	8

acid in the soils exceeded 100 p.p.m. Unfortunately, only 6 of the 68 soil samples contained more than 100 p.p.m. active phosphoric acid ,and from these soils, only 55 samples of the forage were collected. The low number of samples from these soils decreases the significance of the averages. In order to secure a differentiation in the bulk of the samples, which were from soils containing active phosphoric acid in Grade 5, or less than 30 p.p.m., the grade was divided into two sections of 0 to 18 and 19 to 30 p.p.m. However, as shown by both the average phosphoric acid in the samples and the distribution of the samples at different levels of phosphoric acid content, there was no significant difference between these two groups of soils.

Lime in the forage at all stages of growth increased significantly with increases in the level of active lime in the soils. This is shown both by the average percentage of lime in the samples and by the distribution of the samples as related to the lime content of the soils. As the quantity of active lime in the soils increased, a larger proportion of the samples contained higher percentages of lime. None of the soils was sufficiently low in active lime to produce forage which was deficient in lime (below .22%).

The effect of variations in both nitrogen and active phosphoric acid in the soil upon the protein and phosphoric acid in the forage is shown by the averages given in Table 10. Protein in the forage increased significantly with an increase in the level of either nitrogen or active phosphoric acid in the soil. Averages for protein ranged from 7.34% in forage from soils containing less than .120% nitrogen and 17 parts per million

Table 10. Effect of different levels of nitrogen and active phosphoric acid in the soil upon the percentages of protein and phosphoric acid in young forage

Active phosphoric acid in soils	Total nitrogen in soils 0 to .120%	.121 to .180%	.181% or more
	Protein in forage		
0 to 16 p.p.m.	7.34	8.93	9.73
17 to 30 p.p.m.	8.15	9.14	10.88
31 to 100 p.p.m.	9.87	9.59	11.37
101 p.p.m. or more	11.11	11.79	12.75
	Phosphoric acid in forage		
0 to 16 p.p.m.	.26	.31	.32
17 to 30 p.p.m.	.26	.32	.32
31 to 100 p.p.m.	.36	.43	.48
101 p.p.m. or more	.65	.56	.53

active phosphoric acid to 12.75% in forage from soils containing more than .180% nitrogen and 100 p.p.m. active phosphoric acid. At the same level of one constituent in the soil, protein in the forage increased significantly with an increase in the other constituent in the soil. At the lowest level of nitrogen in the soil, the range in protein associated with increased active phosphoric acid in the soil was from 7.34% to 11.11%; at the lowest level of active phosphoric acid, the range associated with increasing levels of nitrogen in the soil was from 7.34% to 9.73%. The increase in average protein was due to an increase in protein among the samples of the same species and also to the fact that species normally higher in protein were found more frequently on the more fertile soils.

Phosphoric acid content of forage from the different soil groups did not change as markedly nor as regularly as the protein. The range in phosphoric acid was from .26% in forage from the lowest soil group to .53% in forage from the highest soil group. The relation is apparently reversed in soils containing more than 100 p.p.m. active phosphoric acid, but the number of samples in these groups was small. Changes in the averages in forage from soils containing less than 30 p.p.m. active phosphoric acid were quite small. In these groups, it seems probable that an increase in the quantity of either active phosphoric acid or nitrogen in the soil was accompanied by an increase in the quantity of forage produced on the soil, so that while more phosphoric acid might have been removed from the soils by the plants, it was distributed through more plant material and had little effect or no effect upon the percentage of phosphoric acid found in the forage. However, considering all groups, there seems to be a definite increase in phosphoric acid in the forage with an increase in either nitrogen or active phosphoric acid in the soil.

EFFECT OF SOME PASTURE PRACTICES UPON THE CHEMICAL COMPOSITION OF FORAGE

The work just presented has shown that different species of grass vary markedly in average chemical composition, that percentages of protein and phosphoric acid in the forage decrease significantly as the plants pass from the young to the mature stages of growth, and that there is a definite relation between the chemical composition of the forage and that of the soil on which it is grown. These facts suggest the possibility that certain pasture practices may increase considerably the quality of forage available to grazing animals. Mowing tends to keep the forage at a younger stage of growth, with relatively high percentages of protein and phosphoric acid, and may promote the growth of more desirable species of forage plants. Rotational grazing, properly conducted, would have essentially the same effect as mowing. Fertilization of the soil, particularly with fertilizers carrying phosphoric acid, may increase the percentage of protein and phosphoric acid in the forage and often results in an increase in the proportion of forage supplied by more desirable species of plants. During the course of the work reported in this bulletin, information on these subjects was secured from a number of experiments. The results of these experiments will be discussed in the following sections.

Effect of Mowing the Pastures

An experiment to determine the effect of monthly mowing on the yield and chemical composition of pasture grasses was conducted by the Division of Agronomy on plats at Substation No. 3 at Angleton during 1934 and 1935. The plats supported stands of different species or combinations of species of grasses. The pure stands of grasses included Angleton, Bermuda, carpet, and Dallis grasses; mixed stands of native pasture grasses (principally little bluestem, big bluestem, and bushy beard grasses) and of improved pasture grasses (Bermuda, carpet, and Dallis grasses) were included in the experiment. Agronomic aspects of the results have been discussed and detailed chemical analyses of the samples have already been published (29), but the general results secured are pertinent to the work discussed in this bulletin.

Table 11. Effect of clipping monthly on average chemical composition of forage (percentages of air-dry matter)

Grass	Treatment	Protein	Ether extract	Crude fiber	Nitrogen-free extract	Water	Ash	Phosphoric acid	Lime
Angleton	Clipped	7.80	2.45	24.93	42.93	8.23	13.64	.29	.83
Angleton	Unclipped	3.58	1.97	34.72	42.79	8.29	8.66	.14	.51
Bermuda	Clipped	9.78	1.91	21.87	44.73	7.82	13.88	.31	.52
Bermuda	Unclipped	5.81	1.55	23.46	49.36	7.80	12.02	.19	.48
Carpet	Clipped	9.36	1.70	23.09	45.66	8.43	11.76	.27	.47
Carpet	Unclipped	5.63	1.25	26.24	46.85	8.37	11.66	.18	.43
Dallis	Clipped	10.23	2.40	24.53	40.18	7.74	14.91	.32	.61
Dallis	Unclipped	5.86	1.74	30.03	43.79	8.12	10.44	.19	.47
Improved	Clipped	9.08	2.03	25.06	43.73	7.88	12.21	.29	.62
Improved	Unclipped	5.49	1.78	29.88	45.97	7.90	8.98	.18	.62
Native	Clipped	9.33	1.99	26.15	42.11	7.94	12.51	.29	.68
Native	Unclipped	4.33	2.00	29.99	46.99	8.15	8.54	.17	.84
All grasses	Clipped	9.26	2.08	24.27	43.24	8.01	13.14	.29	.62
All grasses	Unclipped	5.13	1.71	29.05	49.95	8.10	10.06	.18	.54

The soil of most plats was a Lake Charles clay loam, with some small areas of Lake Charles fine sandy loam. Soil samples from all of the plats were analyzed for some of the more important constituents. The soils of the various plats did not differ significantly among themselves in chemical composition. Averages of the constituents in the surface soils (0 to 6") were as follows: Nitrogen, .143%; active phosphoric acid, 16 p.p.m.; active lime, 3695 p.p.m.; active potash, 139 p.p.m.; basicity, .84%; pH, 6.6. The soils were thus well supplied with nitrogen and active lime, comparatively low in active potash, slightly acid, and very low in active phosphoric acid.

Averages of the principal constituents of the clipped and unclipped forage samples are shown in Table 11. Protein and phosphoric acid in samples from plats which were clipped monthly averaged nearly twice as high as in the samples from plats which were not clipped. The overall average for protein was 9.26% in the forage from clipped plats and 5.13% in that from the unclipped plats. Protein was deficient (below 6%) in none of the 92 samples from the clipped plats and in 49 of the samples from the unclipped plats. Phosphoric acid was deficient (below .33%) in 54 of the samples from the clipped plats, of which none were very deficient (below .17%). Phosphoric acid was deficient in 77 of the samples from the unclipped plats, of which 46 were very deficient. Lime was slightly higher in the samples from the clipped plats except in the case of the mixed native grasses; the overall averages were .62% and .54%. Crude fiber was significantly lower in the samples from the clipped plats (24.27%) than in those from the unclipped plats (29.05%). Nitrogen-free extract was slightly lower in samples from the clipped plats (43.24%) than in those from the unclipped plats (49.95%), except in the case of Angleton grass. Monthly clipping thus greatly increased the protein and phosphoric acid, slightly decreased nitrogen-free extract, and markedly decreased crude fiber in the forage.

The evidence concerning the beneficial effects of clipping secured in this plat experiment was corroborated by analyses of forage collected under normal range conditions. Samples of little bluestem grass from mowed and closely adjacent unmowed areas were secured in the fall from several locations in ordinary pastures. Protein in the samples collected on

Table 12. Average chemical composition of forage collected in April, July, and in October following summer mowing (percentages of air-dry matter)

Month when collected	Katy fine sandy loam	Lake Charles fine sandy loam	Miller sandy loam
		Protein	
April	8.46	9.07	11.23
July	4.50	6.27	6.58
October	6.13	7.27	8.10
		Phosphoric acid	
April	.30	.44	.61
July	.14	.23	.33
October	.20	.27	.41
		Lime	
April	.80	.45	.62
July	.57	.55	.99
October	.57	.68	.72

the same date from the mowed areas and from the unmowed areas averaged 9.52% and 5.56%, respectively; phosphoric acid averaged .40% and .20%; lime averaged .56% and .61%. Protein and phosphoric acid were thus nearly twice as high in the samples from the mowed areas as in the samples from the unmowed areas; lime was slightly higher in the samples from the unmowed areas.

Another comparison was made of the influence of mowing upon the marked reduction in protein and phosphoric acid usually occurring in late fall samples, as compared with samples collected earlier in the year. Typical of results secured are the data presented in Table 12 for the average chemical composition of all forage samples collected from three sandy loam soils. The principal difference in the chemical composition of these soils was in the active phosphoric acid, of which the Katy fine sandy loam contained 20 p.p.m., the Lake Charles fine sandy loam, 70 p.p.m., and the Miller sandy loam, 195 p.p.m. These differences in the active phosphoric acid content of the soil were reflected in the averages of phosphoric acid found in the April samples of forage, which were .30%, .44%, and .61%, respectively. Samples of forage were secured from these soils in April, July, and October of 1940; subsequent to the sampling in July, these areas were all mowed by the owners. The effect of the mowing upon the chemical composition of later forage is shown by a comparison of the July and October samples. Protein and phosphoric acid in the October samples were considerably higher than in the July samples. The effect with respect to lime is not regular nor important, since all of the samples contained sufficient lime. Early fall mowing thus resulted in late fall forage which was higher than summer forage in protein and phosphoric acid. All of this evidence indicates that mowing has a beneficial effect upon the protein and phosphoric acid content of the forage.

Effect of Fertilization of the Soils

An experiment to determine the effect of various fertilizers upon the yield of forage grown on plats at Substation No. 4 at Beaumont was started by the Division of Agronomy in 1935. During 1938 and 1939, the samples collected for yield data were analyzed by the Division of Chem-

Table 13. Effect of fertilization upon the yield, composition, and total constituents found in forage.

	Total yield of forage,	Protein			Phosphoric acid			Lime		
		Average percentages		Total in forage,	Average percentages		Total in forage,	Average percentages		Total in forage,
	lb./A	Actual	Weighted	lb./A	Actual	Weighted	lb./A	Actual	Weighted	lb./A
Found in forage										
No nitrogen	2979	8.54	8.04	236	.27	29	8.8	.96	.92	27.5
Sodium nitrate	3468	8.42	7.67	266	.27	.29	9.8	.84	.82	28.3
Ammonium sulfate	3174	8.33	8.13	258	.27	.29	9.2	.90	.89	28.5
No potash	6181	10.12	10.35	640	.43	.48	29.8	1.12	1.19	73.4
Potash	6339	10.19	10.21	647	.41	.46	29.0	1.19	1.25	74.0
No lime or superphosphate	2619	8.12	7.90	207	.26	.29	7.5	.83	.79	20.8
Lime alone	3795	8.73	7.90	300	.28	.29	11.0	.93	.93	35.3
Superphosphate alone	5404	10.10	10.27	555	.41	44	23.8	1.05	1.07	57.8
Lime and superphosphate	6633	10.98	10.69	709	.44	.48	31.9	1.26	1.32	87.3
Ratios — Untreated to Treated = 1 :										
No nitrogen : sodium nitrate	1.17	.99	.96	1.13	1.00	1.00	1.11	.88	.89	1.03
No nitrogen : ammonium sulfate	1.06	.98	1.01	1.09	1.00	1.00	1.04	.94	.97	1.04
No potash : potash	1.03	1.01	.98	1.01	.95	.96	.97	1.06	1.05	1.08
No lime or superphosphate:										
Lime alone	1.45	1.08	1.00	1.45	1.08	1.00	1.47	1.12	1.18	1.70
Superphosphate alone	2.07	1.25	1.30	2.68	1.58	1.52	3.18	1.27	1.35	2.78
Lime and superphosphate	2.53	1.35	1.35	3.43	1.69	1.65	4.27	1.52	1.67	4.20
Lime : superphosphate	1.42	1.16	1.30	1.85	1.46	1.52	2.16	1.13	1.15	1.63
Lime : lime and superphosphate	1.77	1.26	1.35	1.75	1.46	1.65	2.90	1.36	1.42	2.48
Superphosphate : lime and superphosphate	1.22	1.09	1.04	1.28	1.07	1.09	1.34	1.20	1.23	1.51

istry for protein, phosphoric acid, and lime. The results of this work have already been reported in detail (16). However, they are pertinent to the work reported here and a summary of the results secured in 1938 is shown in Table 13.

The soil used was a Crowley clay loam, a heavy-textured soil which closely resembles the Lake Charles soils. It was fair in nitrogen (.126%), weakly acid (pH of 5.8 on untreated plats), and very low in active phosphoric acid (23 p.p.m.).

The total yields shown in Table 13 are the sums of weights of the crops removed by mowing with a lawn mower in March, May, June, July, August, and September of 1938. The actual averages for the constituents are the averages of the analyses of the six crops; the weighted averages were calculated by multiplying the weight of each crop by the analysis of that crop and adding the products, thus securing the total weight of the constituents in the forage, and dividing this sum by the total yield. Where the weighted averages are significantly higher or lower than the actual averages, a larger proportion of the total yield contained percentages of the constituent which were relatively high or low.

Sodium nitrate increased the yield of forage by 17%, but did not significantly change the chemical composition of the forage. Ammonium sulfate and muriate of potash had no significant effect upon either yield or chemical composition.

Lime on the plats which did not receive phosphates increased the yield of forage by 45% and the percentage of lime in the forage by 18%, but had no significant effect upon percentages of protein or phosphoric acid. The difference between the actual and weighted averages for protein is due to small early spring samples which contained some lespedeza, which was quite high in protein. Lime on the plats which received phosphates increased the yield of forage and percentage of lime by 22%, but had no effect upon percentages of protein and phosphoric acid.

Superphosphate on the unlimed plats more than doubled the yield of forage, increased the percentages of protein and lime by about one-third, and increased the percentage of phosphoric acid in the forage by more than one-half. Superphosphate on both unlimed and limed sections greatly reduced the number of samples of forage which contained less than .33% phosphoric acid and were therefore probably deficient in phosphoric acid for range animals. Of the samples averaged in the data given in Table 13, 17 of the 18 samples from plats which had not received superphosphate or lime and 15 of the 18 samples from plats which had received lime but no superphosphate were deficient in phosphoric acid (weighted averages of .29%). None of the samples from plats which had received superphosphate were deficient in phosphoric acid (weighted averages of .44% on unlimed plats and .48% on limed plats).

Results for 1939 were essentially the same as those for 1938, except that low rainfall reduced the yields of forage. Samples of forage from both phosphated and unphosphated plats collected in January and December, 1938, when the forage was fully matured, were deficient (below .33%) in phosphoric acid.

Favorable results similar to those secured on the plat experiments were secured in one comparison in ordinary pastures. On the area concerned, one part of a pasture had received 200 pounds of 18% superphosphate in August, 1936, while a companion area had received none. In April of the next year, samples of carpet grass and of tickle grass were secured from both areas; the distance between the areas sampled was only a few feet across a fence. Carpet grass from the fertilized area and from the unfertilized plats contained, respectively, 8.48% and 8.26% protein, .38% and .31% phosphoric acid, and .63% and .54% lime. Tickle grass from the fertilized and unfertilized areas, respectively, contained 10.30% and 8.57% protein, .71% and .53% phosphoric acid, and .36% and .32% lime. The data in both cases indicate significant increases in lime in forage following the use of fertilizer, but the comparative increases in protein and phosphoric acid were different for the two species, being small for carpet grass and large for tickle grass.

Fertilization of pastures with superphosphate will, in many cases, increase the total production of forage, increase the percentages of phosphoric acid and protein, and promote the growth of legumes and more nutritious grasses.

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SUMMARY

Protein, phosphoric acid, and lime were determined in 1,140 samples of various species of forage at four stages of growth collected at various times during the years of 1936, 1937, 1938, and 1940, from nearly a hundred locations distributed throughout the Gulf Coast Prairie of Texas. Crude fiber, ether extract, and nitrogen-free extract were determined in a considerable number of these samples.

Protein, phosphoric acid, and lime varied widely with different species and with the same species at different stages of growth from different locations. Protein was highest in the few samples of legumes collected. The average protein content of the most important species of grasses at the young stage of growth ranged from 11.53% in Johnson grass to 7.19% in carpet grass; Johnson, Dallis, Bermuda, and Eastern gama grasses averaged more than 10.5% protein, while little bluestem and carpet grasses contained less than 8%. At the mature stage of growth, protein averages ranged from 6.16% in buffalo grass to 3.37% in little bluestem; buffalo grass was the only species in which the protein in mature samples averaged more than 6%, while protein in six important species averaged less than 4%.

Phosphoric acid in samples of young grasses ranged from .59% in Johnson grass to .25% in carpet grass. In Johnson, Eastern gama, Dallis, bushy beard, Bermuda, and long-tom grasses, phosphoric acid averaged .40% or more, while in Georgia, little bluestem, and carpet grasses, it averaged less than .30%. Phosphoric acid in mature samples ranged from .38% in Dallis grass to .12% in little bluestem. In the mature samples,

Dallis grass was the only species in which phosphoric acid averaged above .25%; phosphoric acid in Georgia, big bluestem, and little bluestem grasses averaged less than .15%.

Lime in the samples of young grass ranged from 1.14% in Johnson grass to .50% in smut grass; in the mature grass, the range was from .78% in Dallis grass to .39% in bushy beard grass.

Nitrogen-free extract usually ranged between 40% and 45% in young grasses and between 45% and 50% in mature grasses; differences among species at the same stage of growth were usually small. Crude fiber was usually lower in the young samples and increased with the age of the plants. Crude fiber was significantly lower in the short grasses, such as Bermuda and buffalo grasses (averaging about 25%), than in the tall bunch grasses (averaging about 30%).

In order to facilitate comparison between the samples and to provide an approximate estimate of their relative quality, the samples were grouped into grades according to their percentages of protein, phosphoric acid, and lime, as was done in previous work.

The distribution of the samples in the different grades varied widely with different species, stages of growth, and the constituent concerned. The proportion of samples which were deficient in protein and phosphoric acid was much larger in tall grasses than in short grasses, and in mature grasses than in young grasses. Protein was deficient in 55% of the samples of little bluestem and only 13% of the samples of Bermuda grass, in 12% of all young samples, and in 92% of all mature samples. Protein was good or high in 122 of the total of 1,140 samples; 110 of these were samples of young forage. Phosphoric acid was deficient in 65% of the samples of little bluestem and 39% of the samples of Bermuda grass, in 59% of all young samples and in 96% of all mature samples. Phosphoric acid was high in no sample and good in only 15 of the 1,140 samples; of these, 12 were young forage. Lime was deficient in only 5 samples, and good or high in 82% of 1,140 samples.

The average chemical composition of 6 groups of soils, comprising a total of 68 individual soils from which forage samples were collected, and the distribution of the soils with respect to grades of their constituents, are shown. Of the 68 soils, the numbers of soils which were deficient in total nitrogen was 1, in total phosphoric acid, 58, in active phosphoric acid, 64, and possibly in active lime, 15.

Protein in forage samples was slightly but significantly lower in samples from the Hockley-Katy group of soils than in those from any of the other soil groups. Phosphoric acid and lime were lower in samples from the soils of the Hockley, Katy, and Edna series than from any other soil groups.

The percentages of protein and phosphoric acid in young samples of forage, on an average, increased with an increase in either total nitrogen or active phosphoric acid in the soil. At intermediate and mature stages of growth, differences in protein and phosphoric acid in the forage from different groups of soils were very small. Lime in the forage at all stages of growth increased significantly with increases in the level of active lime in the soils.

Mowing of the pastures greatly increased the percentages of protein and phosphoric acid in the forage, slightly decreased the nitrogen-free extract, markedly decreased the crude fiber, and slightly increased the lime.

In an experiment on the value of different fertilizers for forage on plats of a Crowley clay loam, nitrogen and potash had little or no effect upon the yield or chemical composition of the forage. Lime increased the yield of forage by 45% and the percentage of lime by 18%. Superphosphate increased the yield by 107%, and caused relative increases of 30% in the percentage of protein in the forage, 52% in phosphoric acid, and 35% in lime. Lime and superphosphate together caused relative increases of 153% in yield, 35% in percentage of protein, 65% in phosphoric acid, and 67% in lime in the forage.

The forage grasses of this area do not contain enough phosphoric acid to give the best results with range cattle. The young grasses are better supplied with phosphoric acid than the older grasses. The mature grasses are also low in protein. Very few of the grasses were deficient in lime.

The deficiency of phosphoric acid can be supplied by feeding minerals containing phosphorus or by fertilizing the soils with phosphates. Fertilization has, in most cases, improved not only the quantity and phosphorus content of the forage, but has also encouraged the growth of legumes and of grasses which supplied a more favorable quality of both phosphorus and protein.

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