Leaf and Crude Protein Percentages Among Strains of Some Forage Grasses

by

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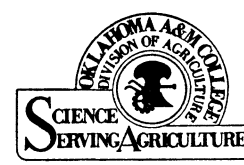

EXPERIMENT STATION

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What This Study Is About

There are millions of acres in Oklahoma, and in the Southern Great Plains, which should be reseeded to grasses. The native grasses are the best adapted for such a use over this area. Except during periods of lush growth, levels of protein and other important chemical constituents in these grasses are often low, and protein and mineral supplements must be fed for maximum efficient beef production.

If grass nutrient levels could be increased, particularly during stress periods, greater beef production and considerable savings in expensive supplemental feeds would be evident. Strains of grass with higher nutrient levels than in common varieties would be of great value to the farmers and ranchmen of the area. Fundamental information on variations in chemical content among genotypes is essential to planning efficient breeding programs aimed at developing grasses with higher chemical analyses. Such information for several grasses can be found in this publication.

Leaf and Crude Protein Percentages Among Strains of Some Forage Grasses

William R. Kneebone and V. G. Heller*

Introduction

Animal production is determined by the amount and nutritive value of available feed. The cheapest animal feeds are forages. Improved grasses presently in use owe their advantage primarily to an increase in total or seasonal forage production rather than in food value per unit yield. Relatively little is known about the possibilities of increasing digestible nutrients per unit yields by breeding, particularly with range grasses. These studies were designed to investigate those possibilities.

Review of Literature

Chemical composition of pasture plants and its relationship to feeding value has been reviewed by Sullivan and Garber (26). In their conclusion they state, "Forage plants differ with respect to their inherent capacities to absorb and to synthesize substances of importance to the nutrition of the animal. The plant breeder can take advantage of this fact and produce by breeding a strain relatively rich or poor in a given substance. Before engaging in an extensive breeding program, however, one should be certain that there is a real need for the particular element in the total diet of the animal and that it can be most economically supplied by the proposed procedure."

The general statement may be made that, although far from perfect, crude protein percentage is one of the best single characters to use as a measure of the digestibility and nutritive value of grass, whether hay or pasture. Studies with rabbits, beef cattle, and sheep (6, 7, 11, 12, 13, 28) have shown that forage protein percentages are highly correlated with digestibility and with animal gains. McCullough (20) has shown that protein content is a useful indicator of forage characteristics necessary for high milk production.

As implied in the introduction, studies of breeding for quality have been relatively rare. Smith (24), in a comprehensive review of the literature on the subject up to

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Note: Studies on bromegrass were part of research presented to the University of Minnesota by the senior author in partial fulfillment of the requirements for the Ph.D. degree. The remainder of the studies reported on here were cooperative between the Oklahoma Agricultural Experiment Station and the Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture.

1952, cited published and unpublished data from thirteen investigators, showing differences in protein percentage among strains of various grass species. Strain differences in other chemical constituents have also been found. Constituents of proven nutritive importance such as carotene and phosphorus have been shown by many studies to be correlated with protein percentage. In a recent study with orchard grass, Clarke (4) found that most of the clones tested produced progenies with higher protein percentages from crosses with high protein clones than from crosses with low protein clones.

Grazing animals tend to graze leafy growth and by choice, eat mainly leaves. Since leaves of grass have from 1.5 to 3 times the protein percentage of stems and are high in other nutrients as well (8, 9, 10, 16, 17, 26, 27), clippings do not always give a true picture of grass value. Hardison, et al. (15) made estimates of the proximate composition of herbage eaten by grazing steers. They found that the material eaten by the grazing animals was higher in protein and lower in fiber than material cut and fed from adjoining pastures. Digestibility was also higher. The reason given was that the grazing animals were able to select and eat mainly leaves while those fed clippings ate most of what was offered to them. This preference for leaves and the value of leaves as feed stress their importance in any program of breeding for quality. Economic production of a strain can probably be increased by increasing the leaf percentage even without changing yield. Starr pearl millet is a good example of such an increase. Burton and DeVane (3) found that Starr produced the same amount of forage as common but gave 275 pounds of beef per acre in 124 animal days while common produced 223 pounds in 128 animal days. Starr is considerably leafier than common and was selected for that reason.

Differences in leaf percentage among strains have been demonstrated and exploited by various foreign workers in orchardgrass, ryegrasses, timothy, and tall oatgrass (5, 8, 23, 25). Relative palatability of grass strains to sheep has been found to vary with leafiness. More leaf was eaten from the more palatable strains than from the less palatable ones (25).

In the United States, Anderson and Aldous (1) with little bluestem and Law and Anderson (19) with big bluestem showed that average leaf area per plant could be increased by mass selection. They found distinct differences among progeny lines within each species.

Materials and Methods

Smooth bromegrass, **Bromus inermis** Leyss., was grown and studied at St. Paul, Minn. in 1950. Four other species were grown and studied at Woodward, Okla. during the period 1951-55. These were: sand lovegrass, **Eragrostis trichodes** (Nutt) Nash.; blue grama, **Bouteloua gracilis** (H.B.K.) Lag.; sideoats grama, **B. curtipendula** (Michx.) Torr.; and sand bluestem, **Andropogon hallii** Hack.

Protein and other chemical analyses were made by standard A.O.-A.C. (2) methods. Analyses of bromegrass were made by the senior author at St. Paul, Minn. All other analyses were done by the junior author at Stillwater, Okla.

Eight clones of smooth bromegrass and their polycross progenies (resulting from a polycross of many other clones in addition to the eight) were studied as spaced plants (spacing three feet in each direction). The clones were included in a clonal nursery having three replicates. Progenies were included in a spaced planting having two replicates which was adjacent to the clonal nursery. Each progeny replicate consisted of ten plants.

Each parental and each progeny plant was sampled in the afternoon of the day following first anthesis and sampling was reported ten days later. Duplicate samples, a handful in size, were cut and enclosed in kraft paper bags.

Green weights were taken and the samples oven dried to two percent moisture. Dry weights were determined and samples then separated into leaf and stem. "Leaves" consisted of blades broken off at the sheath, sometimes with portions of sheath breaking with them. "Stems" were the remainder, including inflorescences. The portions were weighed immediately after separation and leaf percentages calculated from weights thus obtained. All samples were analyzed for crude protein. Because of missing plants, severe lodging in one line which prevented a second sampling, etc., numbers of progeny plants studied per parent clone varied from six to eleven instead of the expected twenty.

Crude protein analyses for strains of sand lovegrass, blue grama, and sideoats grama were obtained from clippings made during 1951-52-53 from replicated small plot trials. Plots were ten by ten feet, and three replicates (only two of some blue grama strains) were planted in 1950. An additional two replicates of sideoats grama were planted in 1951, first clippings being in 1952. Plots were clipped when height reached six inches. Because of extreme drouth, only six clippings of sand lovegrass and five of the gramas were obtained during the entire testing period.

Additional data for sideoats grama were obtained from clones selected in 1953. A double handful of material was cut from each clone in 1953 and 1954 in late July and again in the fall. Plants were in full bloom at each of the four samplings. Only one plant of each clone was sampled.

Data for sand bluestem were obtained from selected parental clones and from their open-pollination progenies. Thirty-six plants were selected from a breeding nursery in 1952. Open-pollination seed was taken from each and a handful of the remaining plant material taken for protein analysis. In the spring of 1952 these selected plants were transplanted to a holding block (one replicate only). Samples for protein analysis were cut from them in October 1952, October 1953, January 1954, July 1954, October 1954, January 1955, July 1955, and January 1956. October and January samplings followed seed harvest. The July samples were taken at time of first anthesis. Division into leaf and stem was done the same way as with bromegrass. Leaf percentages were

calculated from air-dry weights of leaf and stem.

Open-pollination seed from the 36 selected sand bluestem clones was used to establish a nursery of individual spaced plants (44" spacing each way) in 1953. Numbers of plants per progeny varied from 20 to 40. Progenies were not replicated. Every 20 to 30 rows, a row of common material was planted as a check. Samples for protein analysis were taken in October 1953, July 1954, October 1954, January 1955, July 1955, and January 1956. In each sampling a handful was taken from each of ten or more plants per progeny. The July samplings were separated into leaf and stem before analysis and consisted of samples from the first ten plants in each progeny which were at the stage of first anthesis at time of sampling. Overall stage of maturity of progeny plants averaged early to midbloom. Other samplings took plants in sequence from the beginning plant and included from 10 to 15 plants.

Results

Smooth Bromegrass

Using figures obtained for leaf and stem percentage and the percentage protein in each portion, the percentage of protein in whole bromegrass plants was calculated. Data obtained are presented in Table 1. They show that some clones were significantly higher than others in protein percentage at first anthesis. The range was reduced after ten days, some clones falling rapidly in protein percentage, others not. Differences were not then statistically significant. The variance among progeny plants within lines was used as an error variance to compare lines. The variance among progeny lines was not significantly greater than that within them. Considerable segregation within lines was apparent, making the numbers of plants too small for adequate evaluation of average progeny values.

Results of protein analyses of the leaf and stem portions are given

Table 1.—Average crude protein percentages in smooth bromegrass clones and their polycross progenies.[1]

		Parents			Progenies		
Clone		First anthesis	Ten days later	Mean	First anthesis	Ten days later	Mean
6		8.9	8.4	8.2	15.6	13.1	14.3
7		11.0	8.3	9.7	14.6	11.4	13.0
12		10.8	8.8	9.8	14.8	13.0	13.9
17		10.1	7.9	9.0	14.2	12.4	13.3
20		13.2	10.4	11.8	16.0	13.8	14.9
39		12.0	9.4	10.7	14.2	12.8	13.5
41		10.2	8.4	9.3	14.8	12.4	13.6
46		9.5	7.9	8.2	15.0	13.6	14.3
L.S.D.	.05	1.6	N.S.	1.3	N.S.	N.S.	N.S.

[1] Calculated from data on leaf and stem portions.

Table 2.—Average crude protein percentages in leaves of smooth bromegrass clones and their polycross progenies.

Clone	Parents			Progenies		
	First anthesis	Ten days later	Mean	First anthesis	Ten days later	Mean
6	12.4	12.8	12.6	21.4	20.0	20.7
7	13.8	11.8	12.8	19.6	18.0	18.8
12	13.4	12.4	12.9	20.8	19.4	20.1
17	12.9	10.7	11.8	19.4	19.2	19.3
20	16.2	13.4	14.8	20.8	20.2	20.5
39	15.7	14.1	14.9	19.5	18.8	19.2
41	13.4	11.6	12.5	20.0	18.6	19.3
46	13.4	10.9	12.2	21.5	20.0	20.8
L.S.D. .05	2.1	N.S.	1.6	N.S.	N.S.	N.S.

Table 3.—Average crude protein percentages in stems of smooth bromegrass clones and their polycross progenies.

Clone	Parents			Progenies		
	First anthesis	Ten days later	Mean	First anthesis	Ten days later	Mean
6	7.2	6.6	6.9	12.4	10.0	11.2
7	9.6	6.8	8.2	12.2	8.4	10.3
12	9.4	7.0	8.2	11.5	9.9	10.7
17	7.8	5.8	6.8	11.3	9.1	10.2
20	11.4	8.8	10.1	13.1	10.1	11.6
39	9.8	7.4	8.6	11.1	9.4	10.3
41	8.7	6.8	7.8	11.5	8.2	9.9
46	7.6	6.4	7.0	12.2	10.6	11.4
L.S.D. .05	1.6	1.3	1.2	1.3	1.3	1.2

in tables 2 and 3. The leaf values (table 2) show a situation similar to that observed for the calculated whole plant figures. Differences at the late sampling were not significant, the range being reduced because some clones had lower values while others changed very little. The values for stems (table 3), however, decreased rather uniformly in the ten-day interval between samplings; and the clones differed significantly at both periods. Variances for the stem proteins were also significant among progeny lines.

Protein percentage in the leaves averaged 1.6 times that in the stems at first anthesis. Ten days after first anthesis the leaf protein percentage was 1.9 times that of the stems. As maturity advanced, the value of the leaf fraction of the plants became more apparent. The stems decreased in protein percentage proportionately more than did the leaves.

Table 4 gives the values for leaf percentage determined for the parental clones and their progenies. Significant differences were found in all cases. Percentage leaf decreased during the ten-day period between samplings. The extent of the decrease varied among the clones. The heritability for leaf

percentage as indicated by the regression of progeny values on their parents appears to be low. Clone 20 was high and had high progeny. The agreement was otherwise poor, indicating the need for progeny testing.

The data in table 5 on percentage dry matter indicate that clones and lines of bromegrass differ in this characteristic at similar stages of maturity. The usual relationship between dry matter percentage and maturity is shown by the increase between samplings, but there is apparently genic control of this character unrelated to maturity effects.

Sand Lovegrass, Blue Grama, and Sideoats Grama

Table 6 summarizes data obtained from the small clipping plot trials. One strain of sand lovegrass (W2) was consistently high in all samplings and another (W5) was consistently low in protein percentage. The somewhat wider range in protein percentage found in the blue grama was a consequence, probably, of the greater number of strains. The relatively low forage yield of the high protein strain, Dunlap, was in line with the expected negative relationship between yield and protein

Table 4.—Average leaf percentages in samples taken from smooth bromegrass clones and their polycross progenies.

		Parents			Progenies		
Clone		First anthesis	Ten days later	Mean	First anthesis	Ten days later	Mean
6		32.8	29.2	31.0	34.8	30.7	32.8
7		35.4	30.7	33.0	34.0	30.9	32.4
12		34.3	32.6	33.5	32.5	32.0	32.2
17		44.4	43.6	44.0	34.6	32.7	33.7
20		38.0	34.8	36.4	38.4	36.5	37.5
39		36.7	30.9	33.8	36.2	36.1	36.2
41		32.4	32.9	32.6	38.4	38.5	38.5
46		33.5	32.4	33.0	31.0	34.4	32.7
L.S.D.	.05	3.6	4.9	3.5	3.5	5.0	2.4

Table 5.—Average dry matter percentages in samples taken from smooth bromegrass clones and their polycross progenies.

		Parents			Progenies		
Clone		First anthesis	Ten days later	Mean	First anthesis	Ten days later	Mean
6		33.3	41.3	37.3	32.4	39.0	35.7
7		35.4	45.4	40.4	34.2	40.8	37.5
12		34.6	44.1	39.3	32.9	39.9	36.4
17		40.3	50.7	45.5	36.1	41.8	38.9
20		34.8	43.5	39.1	32.3	38.9	35.6
39		35.2	46.1	40.7	36.3	44.1	40.2
41		37.3	36.9	42.1	35.7	44.7	40.2
46		36.1	46.3	41.2	34.3	42.5	38.4
L.S.D.	.05	1.5	1.9	1.2	2.2	2.8	2.1

Table 6.—Average crude protein percentages, total yields in pounds air-dry matter per acre and total protein yields in pounds per acre for strains of sand lovegrass, blue grama, and sideoats grama.[1]

Species	Strain	Average protein	Total harvested yield	Total protein yield
Sand lovegrass	W1	8.33	1594	133
	W2	8.56	1117	96
	W3	8.21	1507	124
	W4	8.38	1284	108
	W5	7.87	1329	105
L.S.D. .05 for sand lovegrass		.38	95	---
Blue grama	W1	7.90	2035	161
	W2	7.78	2066	161
	W3	7.93	2290	182
	W4	7.71	1843	142
	Roy	8.21	1990	163
	Pecos	8.48	2284	194
	Hueco	8.36	2654	222
	Marfa-Davis	8.14	1961	160
	Capitan	7.67	1719	132
	Dunlap	8.50	2080	177
	Van Horn	8.13	1817	148
	Caprock	8.03	2119	170
	Ruidoso	7.99	1666	133
L.S.D. .05 for Blue Grama		.46	157	---
Sideoats grama	W1	7.11	2689	191
	W2	6.82	2213	151
	W3	7.09	1945	137
	W4	6.87	2775	191
	El Reno	7.07	2107	149
	Logan	7.07	2144	152
	Vaughn	6.81	2279	155
	Tucson	7.66	2738	210
L.S.D. .05 for Sideoats grama		N.S.	153	---

[1] Figures are derived from plot averages for each clipping over the 1951, 1952, and 1953 seasons.

percentage shown by the sand lovegrass data, but the next high protein strain, Hueco, was high in forage yield as well.

Although the range in protein percentage among sideoats grama strains was as wide as for the other two species, results were not as consistent and differences were not statistically significant. The high strain, Tucson, however, has stood in the same relationship in protein content to El Reno in other tests. The same lack of consistency in protein percentage shown in clipping plot studies of sideoats grama was found in analyzing forage from seventy-two individual selections over a two-year period. Results are presented in appendix tables 1, 2, and 3.

Sand Bluestem

Since none of the material under observation was replicated, the data were analyzed using the year x clone or year x line interaction variances as error terms. In nearly every case, the year variance was significantly greater than the error variance. Significances of the variances among clones and among progeny lines are indicated by the L.S.D.'s shown in tables 7 and 8.

The first sampling of the parent clones was in the original nursery in 1952, the next and following ones being in the holding block to which the plants were moved. The variance among clones the first two years was significantly greater than the error term, with an inter-annual correlation of .760.

Table 7 shows average protein percentages of samples taken at various dates during a four-year period. Differences among parent clones were fairly consistent and clonal variances were all significantly greater than their error terms. Among the progenies, data were not so consistent and variation was not statistically significant. Since progeny samples were composites of ten or more plants, differences could not be expected to be as distinct as among the parents. Ranges were less and the year to year variation was also greater. The progeny values from October samplings were higher than normal because of the 1953 samples. The

Table 7.—Crude protein percentages among sand bluestem selections and among their open-pollination progenies averaged for the sampling dates indicated.

Selection number	Parents			Progenies		
	July ('54-55)	October ('52-53-54)	January ('54-55-56)	July ('54-55)	October ('53-54)	January ('55-56)
1	5.94[1]	4.28	2.58[1]	5.91	7.03	3.78
2	5.26	4.89	2.11	5.72	6.79	3.50
3	6.20	5.26	2.41	6.38	6.70	3.99
4	6.14	6.39	3.80	6.55	7.51	3.90
5	7.04	4.79	2.39	6.05	6.83	3.86
6	4.92	5.45	3.17	6.14	7.39	3.89
9	5.30	5.91	4.42	6.55	7.37	3.38
10	4.44	5.06	2.79	6.02	7.10	3.87[1]
11	5.08	5.05	2.91	5.22	6.55	3.02[1]
12	4.72	5.84	2.67	5.84	6.76	3.72[1]
13	4.70	5.21	3.44	6.28	7.29	3.62
14	5.67	6.13	3.49	6.08	7.59	3.86
16	3.96	4.33	2.13	5.41[1]	7.16	4.08
17	4.40	4.79	1.82	6.28	7.19	3.29
18	4.49	5.19	2.17	6.02	7.19	3.98
19	4.56	4.61	2.46	6.08	6.36	4.14
20	4.30	4.74	2.33	6.18	7.26	4.12
21	3.86	4.48	1.83	5.84	7.09	3.98
22	5.02	4.77	2.13	6.10	6.76	4.24
23	5.14	4.60	3.23	6.02	7.31	4.10
24	4.96	3.81	2.35	5.96	6.64	4.12
25	4.60	3.94	1.98	5.45	6.20	4.51[1]
26	4.78	4.53	2.34	6.38	6.48	3.90
29	3.31[1]	4.58	3.14	5.80	6.94	2.95
30	4.33	4.36	2.19	5.84	8.09	3.94
31	4.56	3.91	2.22	5.76	7.67	3.02
32	6.34[1]	4.78	3.66[1]	6.74	7.79	3.26
33	4.61	5.75	3.28	7.02	7.71	4.31[1]
34	4.94	6.11	3.32	6.56	8.28	3.80
35	5.75[1]	4.72	3.24[1]	6.08	7.52	3.89
36	4.34	5.32	2.90	6.20	7.75	3.60
Average	4.96	4.95	2.74	6.08	7.17	3.79
L.S.D. .05	1.33	1.30	1.06	N.S.	N.S.	N.S.

[1] One year's data missing, L.S.D. does not apply.

planting was set out in spring 1953 and material collected that fall was almost entirely young leaves.

The data summarized in table 7 showed very low and non-significant correlations between parental and progeny values at any of the dates of sampling. Correlations were also low between sampling dates with the exception of the correlation between October and January sampling of the parents which was .653. There was an apparent difference among clones and progenies in the rate of drop in protein percentage between October and January, similar to the results with bromegrass over the ten-day sampling interval. Ranges based on averages of all sampling years show that the January range among parental values was slightly greater than that in October and July. This is of particular interest since the mid-winter period is one of protein deficiency and differences are of more importance then.

Data obtained from leaf-stem separation studies are shown in table 8. Average leaf percentage figures were higher than would normally be expected due to reductions in flowering because of drouth. Most of the stem in a sand bluestem plant at first anthesis is in the flowering culms. Any reduction in their number or extent of development means a higher leaf percentage. In 1955, early growth exhausted available moisture and the progeny plants in particular had few fully developed flowering culms. This is apparent in comparing average figures from the two years of sampling. In 1954, average leaf percentages were 42.8 for the parents and 39.8 for the progenies. The same figures in 1955 were 44.3 and 58.6 respectively. Although parental and progeny values were not closely correlated, indicating low heritabilities, selected material involved in these tests was considerably leafier than unselected check material of similar origin. The three check rows in the progeny test averaged 28.5 and 52.9 percent leaf in 1954 and 1955.

Protein percentage in the leaves of sand bluestem averaged 2.1 times that in the stems, a higher ratio than the 1.8 found with bromegrass. Variation among clones and among progenies in the ratio of leaf protein percentage to stem protein percentage was not significant, nor was that for the percentage of total plant protein which was leaf protein. The ranges in protein percentage were wider for the leaves than for the stems, and data were more consistent in the two years of sampling. Parent-progeny correlations were not significant.

A few samples were analyzed for ash constituents in both 1954 and 1955. In 1954 some analyses were made for crude fat, crude fiber and nitrogen free extract. The data obtained are presented in tables 9 and 10. Variation among clones and among progeny lines in these constituents was similar in extent to that found for protein. Analyses of variance made with progenies sampled in both years showed that only in one case, ash percentage in the leaves, was the line variance significantly greater than the error term used. Ranges among the parent selections in 1955 were greater than those among progeny lines, as might be expected from the results with protein.

Leaves had 1.8 times the ash, 2.5 times the calcium, 1.5 times the phosphorus and 2.3 times the crude

Table 8.—Average leaf percentages and crude protein percentages in leaves and stems of samples taken from sand bluestem selections and their open-pollination progenies at first anthesis in 1954 and 1955.

Selection number	Parents			Progenies		
	% Leaf	% Protein leaf	% Protein stem	% Leaf	% Protein leaf	% Protein stem
1	39.7[1]	7.72[1]	4.70[1]	48.8	7.54	4.14
2	36.7	7.90	3.72	52.2	7.70	3.72
3	48.7	8.50	4.01	57.1	8.15	3.84
4	47.4	8.82	3.84	54.8	8.04	4.59
5	50.0	9.32	4.71	53.5	8.61	3.38
6	33.6	8.08	3.40	54.9	8.26	3.58
9	44.9	7.06	3.90	58.9	8.50	3.79
10	38.8	6.44	3.15	54.5	7.98	3.69
11	59.9	6.36	3.16	35.5	8.40	3.48
12	44.2	6.88	3.04	49.4	8.12	3.78
13	41.0	7.16	2.96	42.6	9.34	4.08
14	64.3	7.22	2.96	48.3	8.42	3.90
16	39.0[1]	4.48[1]	1.68[1]	38.0[1]	7.58[1]	4.09[1]
17	38.6	6.81	2.90	46.5	8.59	4.34
18	42.2	6.42	3.09	36.4	9.00	4.30
19	41.2	6.92	2.86	56.6	8.04	3.42
20	38.6	6.37	3.24	43.3	8.18	4.62
21	39.2	5.56	2.78	54.8	7.78	3.60
22	39.8	8.26	2.62	57.5	7.61	3.98
23	54.2	6.52	3.48	48.8	8.06	4.02
24	52.1	6.99	2.72	42.7	8.88	3.83
25	37.0	5.86	3.92	51.6	7.63	4.01
26	47.6	5.90	3.75	65.7	7.68	4.04
29	36.8[1]	4.73[1]	2.49[1]	35.0	8.88	4.15
30	48.2	6.04	2.74	41.4	8.61	3.90
31	43.0	6.27	3.28	38.4	8.62	3.98
32	39.5[1]	7.63[1]	5.50[1]	50.0	9.26	4.10
33	47.8	6.42	3.03	54.6	9.28	4.22
34	33.6	7.70	3.44	57.0	8.32	3.80
35	35.3[1]	8.84[1]	4.06[1]	35.5	9.90	3.98
36	32.2	6.62	3.27	50.6	8.60	3.82
Average	43.1	6.96	3.37	47.4	8.37	3.94
L.S.D. .05	14.7	1.79	N.S.	N.S.	1.13	N.S.

[1] One year's data only, L.S.D. does not apply.

fat that the stems had. Crude fiber was lower and nitrogen free extract about the same.

Inter-relationships Among Characters

As part of another study, individual plants of the sand bluestem progeny lines sampled for chemical analyses were measured for height, diameter, and green weight yield shortly after sampling. Correlations between protein percentage and line averages for height, diameter, and yield were all less than .3 and not significant. Protein percentage was correlated with phosphorus and calcium percentages. The correlation between protein percentage and calcium percentage was .505 using leaf data and .620 with figures from stems. The correlations

Table 9.—Ash, calcium and phosphorus percentages in leaves and stems of samples taken from sand bluestem selections and their open-pollination progenies at first anthesis in 1955.

Selection number	Parents						Progenies					
	Ash		Calcium		Phosphorus		Ash		Calcium		Phosphorus	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
1	----	---	--	--	---	---	6.82	3.81	.33	.14	.162	.074
2	13.26	6.98	.62	.21	.163	.118	7.30	4.16	.40	.12	.143	.082
3	9.74	5.58	.45	.20	.254	.166	7.09	3.62	.37	.12	.159	.085
4	10.80	---	.55	--	.188	---	7.52	3.85	.42	.11	.159	.082
5	11.22	6.81	.30	.13	.163	.120	7.08	4.36	.36	.15	.145	.075
6	10.91	5.01	.57	.19	.244	.083	7.07	3.74	.35	.13	.162	.075
9	10.75	5.55	.37	.12	.164	.120	7.85	4.64	.37	.13	.150	.085
10	12.14	5.01	.36	.14	.152	.114	7.35	4.63	.37	.18	.138	.092
11	10.85	4.95	.38	.17	.240	.136	8.15	4.24	.38	.12	.172	.120
12	10.73	5.23	.38	.15	.106	.084	7.72	4.94	.34	.16	.161	.130
13	12.26	5.44	.43	.09	.163	.128	8.73	5.16	.34	.16	.158	.101
14	11.44	6.18	.39	.14	.224	.128	7.97	4.25	.34	.15	.140	.076
16	8.92	---	.31	--	.154	---	8.07	5.23	.40	.14	.128	.104
17	13.40	---	.49	--	.188	---	8.18	5.04	.39	.13	.173	.120
18	12.12	6.40	.27	.11	.202	.168	9.12	5.37	.39	.11	.149	.116
19	10.24	5.31	.38	.12	.210	.160	8.14	4.35	.40	.10	.147	.072
20	9.02	5.56	.23	.09	.156	.142	8.77	5.12	.40	.17	.145	.110
21	11.22	---	.41	--	.163	---	8.12	5.14	.38	.20	.149	.094
22	10.30	---	.35	--	.208	---	7.66	4.34	.35	.16	.135	.084
23	9.19	5.15	.32	.15	.202	.147	8.82	5.88	.40	.19	.153	.110
24	10.54	---	.38	--	.206	---	8.71	5.78	.44	.18	.149	.145
25	9.70	---	.28	--	.184	---	7.93	5.50	.41	.17	.131	.118
26	10.03	---	.46	--	.240	---	7.82	3.39	.43	.13	.110	.063
29	10.65	5.62	.44	.14	.216	.152	9.45	4.82	.43	.16	.135	.102
30	9.36	4.26	.39	.14	.183	.176	8.82	6.78	.49	.15	.137	.096
31	10.05	5.33	.43	.17	.209	.106	9.74	6.09	.41	.21	.165	.108
32	----	---	--	--	---	---	9.13	3.86	.38	.15	.164	.079
33	10.49	3.50	.37	.13	.209	.126	9.28	4.24	.40	.13	.120	.083
34	----	5.65	--	.11	---	.115	8.51	3.32	.40	.13	.135	.047
35	----	---	--	--	---	---	9.58	5.31	.39	.16	.151	.083
36	9.15	3.99	.42	.08	.112	.066	9.29	4.22	.37	.13	.139	.092
Average	10.68	5.38	.40	.14	.189	.128	8.25	4.68	.39	.15	.147	.094

between protein percentage and phosphorus percentage were negative, contrary to expectation (8, 25). They were -.511 for the leaves and -.227 for the stems. All of the above figures except the last are significant at the one percent level.

The correlation between protein in the leaves and that in the stems was .645 for the 62 sand bluestem comparisons in table 8. For the bromegrass data in tables 2 and 3 it was .845. Calculated from data on orchard grass given by Fagan and Jones (10) the same correlation would be .617.

Correlations between leaf and stem values for phosphorus and for calcium were .660 and .656 respectively, similar to the figures for protein. With crude fat the figure was .358 and not significant. The limited data on crude fiber indicate a general relationship between leaf and stem values, with some discrepancies. Nitrogen free extract values were about the same for the two parts of the plant.

Discussion

Although forage yield should always be one of the prime considerations in grass breeding, quality of forage can make wide differences in animal production. Willhite, et al. (28) found that beef heifers fed hay from mountain meadows gained in accordance with the protein percentage in that hay, consumption being a complete fill daily in every case. The correlations between protein percentage and animal gains were .946 and .962 in successive years. The data obtained in the present studies indicate that appreciable genetic differences in protein percentage exist in smooth bromegrass, sand lovegrass, blue grama, and sand bluestem. The blue grama yield data and the low correlation between yield and protein percentage in the sand bluestem progenies indicate that both high yield and high quality can be obtained by appropriate selection. Kneebone (18) and Pickett (21) obtained similar results with smooth bromegrass.

In order to obtain lines with high quality, first attention should be placed on leafiness. From the data on protein percentage, fat, calcium, phosphorus and crude fiber, it is evident that any increase in leafiness would mean an increase in forage quality. In both smooth bromegrass and sand bluestem, distinct quantitative differences in leafiness were demonstrated. Selection for leafiness is, of course, almost axiomatic and results of previous selections were evident in the sand bluestem.

Faster progress in breeding for particular chemical constituents would be obtained if chemical analyses were made. Since leaves form, when possible, the bulk of the grazing animal's diet and since contents of protein, calcium, and phosphorus in leaf and stem are correlated it might be worthwhile to sample only leaves for such analyses. The more uniform samples obtained in this way would tend to give more consistent results and more accurate evaluations of breeding potential. Visual selection for leafiness, coupled with chemical studies of the leaves, with particular

Table 10.—Ash, calcium, phosphorus, crude fat, crude fiber, and nitrogen free extract percentages in leaves and stems of samples taken from open-pollination progenies of sand bluestem selections at first anthesis in 1954.

Selection number	Ash		Calcium		Phosphorus		Crude fat		Crude fiber		Nitrogen free extract	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
17	9.48	5.25	.54	.23	.116	.069	3.48	1.77	29.29	39.58	48.59	48.92
18	10.34	5.63	.46	.22	.112	.073	4.13	2.23	29.86	39.92	46.14	47.52
19	9.02	5.81	.40	.20	.108	.067	4.05	2.40	29.92	39.19	48.35	48.12
20	8.75	5.51	.46	.20	.112	.086	4.30	2.35	30.37	38.68	48.05	48.06
21	9.38	5.53	.44	.21	.100	.064	3.71	1.46	29.48	40.85	48.99	48.19
22	9.37	5.25	.52	.20	.104	.066	3.20	1.67	30.08	36.92	49.29	51.46
23	9.17	5.18	.48	.22	.116	.067	3.72	1.88	29.78	38.05	48.42	50.89
24	9.39	5.75	.52	.20	.106	.076	3.74	1.93	29.69	40.51	47.90	48.17
25	8.74	4.94	.44	.18	.120	.096	3.45	1.44	34.12	38.53	45.79	50.93
26	8.42	6.12	.42	.23	.144	.114	3.49	1.46	35.28	35.12	44.43	52.86
29	9.10	5.28	.47	.21	.124	.100	3.46	1.26	30.24	40.32	48.20	48.72
30	9.70	4.71	.54	.30	.128	.075	3.97	1.09	30.26	41.49	47.23	48.82
31	9.33	5.28	.54	.20	.108	.065	3.86	1.48	31.95	42.57	46.58	46.95
32	9.62	5.52	.52	.24	.128	.106	4.08	1.37	29.56	39.35	46.71	48.44
33	9.78	5.30	.50	.23	.134	.106	3.63	1.02	29.36	39.28	48.02	49.51
34	9.63	5.71	.47	.21	.097	.109	4.09	1.61	32.09	39.48	45.72	48.11
35	9.78	5.31	.54	.21	.151	.108	4.24	1.25	28.74	41.38	47.24	47.81
36	9.80	4.84	.43	.19	.129	.091	3.12	1.29	29.89	42.49	48.18	47.41
Average	9.38	5.38	.48	.22	.118	.085	3.76	1.61	30.55	39.65	47.44	48.94

emphasis placed on progeny testing and use of adequate replication in well planned experiments should be very rewarding.

The levels in protein, calcium, and phosphorus percentage of sand bluestem at various sampling dates were in fair agreement with those found by Savage and Heller (22) when sampling native range stands. The variations found in this study among lines though, emphasize that categorical statements about chemical content of any given forage should be qualified by statements about the source or origin of the samples analyzed. Calcium and phosphorus levels in the stems were at borderline levels or below minimum standards for beef cattle set by the Committee on Animal Nutrition of the National Research Council. Leafy strains might not only be valuable but even essential for efficient and high levels of animal production on pastures seeded with sand bluestem.

According to most previously published results (8, 22, 24), selection for high protein would automatically mean selection for high phosphorus since the two are directly correlated. The negative correlation in the sand bluestem data may reflect sampling error. Results obtained in this study do suggest that more information on the interrelationship of protein and phosphorus is needed.

Differences observed among selections in the drop in protein percentage as material matured are of particular interest. Maintenance of relatively high nutrient levels at all stages of growth would be a particularly valuable asset in a forage grass. In the southern Great Plains, standing cured forage of sand bluestem and other native grasses is grazed during the winter. Higher nutrient levels at that time could be of extreme importance. The data obtained from sand bluestem indicate that strains could be developed with greater winter grazing value. Again, leafiness would be the most important selection criterion. The smooth bromegrass data suggest that as plants mature, leaves lose protein percentage less rapidly than do stems, possibly because of additional carbohydrates, predominantly of low digestibility, deposited in the stems.

Summary

Studies were made of protein percentage among selected plants, individual plant progenies, and strains of smooth bromegrass, sand lovegrass, blue grama, sideoats grama, and sand bluestem.

Significant differences in protein percentage among selections and among lines were demonstrated in all species except sideoats grama.

In the smooth bromegrass, significant differences in percentage dry matter were demonstrated among selections at the same stage of maturity.

Separations of leaf and stem with chemical analyses of each portion were made for smooth bromegrass and sand bluestem. Significant differences in leaf percentage and in protein percentage of leaves and of stems were demonstrated among selections of each.

Sand bluestem leaves had 2.1 times the protein, 1.8 times the

ash, 2.5 times the calcium, 1.5 times the phosphorus, and 2.3 times the crude fat percentages that the stems had. Protein percentage in leaves of smooth bromegrass was 1.8 times that in the stems.

Parent-progeny correlations for smooth bromegrass and for sand bluestem were very low and not significant, indicating low heritabilities.

Protein percentage was significantly correlated with calcium percentage but not with height, diameter or yield in sand bluestem.

Protein, calcium, and phosphorus contents of the leaves were correlated with those of the stems.

Appendix Table 1.—Crude protein percentage in sideoats grama selections. Group 1.

Selection	July 1953	Oct. 1953	July 1954	Oct. 1954	Average
12	7.44	8.98	7.28	---	7.90
10	7.09	8.84	7.47	6.07	7.62
14	9.05	8.65	7.18	5.44	7.58
11	8.88	6.82	6.78	7.52	7.50
9	7.59	7.22	7.80	7.02	7.41
13	8.31	8.12	6.87	5.13	7.11
15	6.84	8.45	6.57	6.57	7.11
21	8.00	5.70	6.28	5.20	7.05
19	8.27	4.47	6.78	5.82	6.98
23	6.69	5.10	6.71	5.40	6.92
8	6.47	7.55	6.96	6.58	6.89
4	7.38	6.79	7.60	5.52	6.82
7	6.97	8.22	6.43	5.43	6.76
18	8.38	6.00	8.68	4.85	6.75
3	8.25	6.88	6.13	5.35	6.65
17	8.40	6.03	6.81	4.96	6.55
16	7.91	6.86	5.50	5.68	6.49
2	7.91	5.88	6.30	5.69	6.44
5	6.47	7.35	6.33	5.46	6.40
20	7.41	6.82	6.56	7.41	6.34
22	7.58	5.86	7.53	6.72	6.30
6	7.56	6.29	6.66	4.50	6.25
1	7.64	6.44	5.85	4.82	6.19
24	8.47	4.84	8.39	5.00	5.98

Appendix Table 2.—Crude protein percentage in sideoats grama selections. Group 2.

Selection	July 1953	Oct. 1953	July 1954	Oct. 1954	Average
28	8.91	7.69	7.25	7.97	7.96
37	8.56	9.01	9.74	3.93	7.81
32	9.59	8.55	7.08	5.83	7.76
30	8.59	7.16	7.04	6.46	7.31
29	8.05	7.22	7.75	5.40	7.10
41	8.38	9.21	5.78	4.93	7.08
31	8.44	6.79	7.09	5.82	7.04
33	8.06	8.22	6.32	5.16	6.94
47	8.78	7.19	7.22	4.53	6.93
26	7.98	7.25	6.99	5.43	6.91
38	8.41	6.99	7.06	5.08	6.88
40	8.06	7.44	6.25	5.67	6.86
25	8.11	6.16	7.32	5.57	6.79
27	7.69	7.78	6.09	5.02	6.64
39	7.50	7.62	6.30	4.60	6.50
34	7.78	7.22	5.78	5.10	6.47
35	8.28	6.99	6.16	4.29	6.43
46	8.59	5.66	6.78	4.46	6.37
42	8.56	5.33	6.39	3.57	5.96
45	8.19	6.86	4.69	3.88	5.90
43	6.50	6.82	6.88	2.91	5.78
44	9.03	3.25	6.81	4.02	5.78
36	7.06	5.53	5.81	4.13	5.63
48	8.28	4.07	6.02	3.63	5.50

Appendix Table 3.—Crude protein percentage in sideoats grama selections. Group 3.

Selection	July 1953	Oct. 1953	July 1954	Oct. 1954	Average
59	7.94	8.94	6.43	5.12	7.11
58	6.94	7.62	7.81	5.85	7.06
52	7.44	6.82	8.96	4.85	7.02
64	8.81	8.18	6.31	4.25	6.89
53	7.91	7.95	6.77	4.33	6.74
49	7.72	5.70	7.69	5.28	6.60
55	7.63	6.59	7.09	5.01	6.58
51	7.59	5.66	7.08	5.71	6.51
56	7.19	7.85	6.38	4.49	6.48
50	7.09	5.80	7.13	5.63	6.41
63	7.97	---	6.13	4.88	6.33
69	7.41	6.36	7.00	4.53	6.32
61	8.63	6.00	6.19	4.30	6.28
66	7.78	6.82	6.31	4.22	6.28
62	8.25	5.76	6.47	4.60	6.27
71	6.53	6.00	6.25	5.82	6.15
57	7.37	7.39	5.19	4.42	6.09
72	7.34	3.80	8.74	4.19	6.02
67	7.19	4.54	7.63	4.63	6.00
65	6.17	7.19	5.22	5.00	5.90
60	6.78	6.07	5.63	4.63	5.78
68	7.78	4.37	6.75	4.10	5.75
70	7.06	4.30	5.88	5.25	5.62
54	6.75	4.07	5.94	4.07	5.21

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