Forage Quality Evaluations of Twelve Grasses in Relation to Season for Grazing

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CONCEPTS AND CONCLUSIONS

Systems of forage production on farms and ranches can be improved by planned usage of cool season and warm season grasses to provide high-quality forage for season-long grazing. Adapted strains and varieties can be planted to improve existing pastures or ranges and to establish new pastures for added production or extension of the grazing season.

Time of year and length of season of the principal period of growth are important characteristics to be considered in the choice of a grass strain. These characteristics are built into the strain or cultivar from its genetic origins.

Strains of grasses with short seasons of growth have resulted from progressive natural selection following hybridization and migration from centers of origin into shorter seasons of higher altitudes or latitudes as shown by the distribution of strains in the warm season prairie grasses. Northern strains with long-day requirements, as well as the winter-susceptible strains from southern sources, are poorly adapted in the midlatitudes (8, 16, 17, 26, 34).

Variation in adaptation attributable to origins from different latitudes and/or elevations has also been found in the cool season grasses, such as in the introduced smooth bromegrass (24, 31), crested wheatgrass (Table 1), and in the endemic western wheatgrass (Table 2).

Forage quality evaluations of grasses and grass strains have emphasized the importance of time of year and length of season for their best grazing use. The crude protein content demonstrated the cyclic nature of early growth and regrowth of grasses in response to the seasonal changes of photoperiod and temperature, especially in the cool season grasses. Minimum requirements of protein for animal nutrition were usually met from grazing during the growth period, but protein content could be limiting from winter grazing or in late-cut hay, especially in the warm season grasses.

Percentages of digestibility by the method of IVDMD were practical measures of nutritional components of the forages, showing intrinsic value in relation to dry matter yield. Digestible dry matter yield measured the real value of forage. It is a weighted value (dry matter yield x IVDMD%) determined in these studies from two or more harvesting regimes, representative of different grazing managements.

The curve of accumulation of average yield of digestible dry matter provided information on the season of production of best-quality forage for grazing by each grass. The importance of timeliness of grazing in this growth period was shown by weighted digestibility estimates of forage quality from different harvesting sequences. A weighted quality (W Q) index estimated the forage quality for the season of production of each grass.

Forages which have the greatest potentials for forage quality and forage production may require careful management for maintaining that production. Unique combinations of grazing units providing pasture for different seasons are possible for each farm or ranch situation. Grazing units with overlapping periods of production allow for adjustment of stocking rate for obtaining optimum use while also maintaining the photosynthesis factory for forage production.

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L. C. Newell[1] and W. J. Moline[2]

INTRODUCTION

A study of forage quality in relation to seasonal yield of important perennial forage grasses was initiated to provide information and to promote a better understanding of their best use for grazing. This information should be particularly valuable in planning seasonal use of pure stands or mixtures of grasses.

A grazing system for a farm or ranch should provide adequate high-quality forage throughout the growing season. A planned system should integrate grazing of planted pasture, rangeland, and crop residues with feeding of harvested forage in emergency periods and during months of limited grazing. Knowledge of each grass component is essential for planning its management and season of use. This research deals with some interrelations of forage quality and forage yield of grasses which can be considered in developing plans for seasonal grazing.

Forage crops available for different purposes and management intensities vary with the critical limitations of soil and climate. In the mid latitudes, the production of high-quality forage may be balanced through the season by use of both cool season and warm

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season grasses. The dominant grasses of rangeland or existing pastures provide the basic resource for developing a grazing system.

Total forage production can be improved by planting suitable forages and making changes in management. A warm season annual or perennial may be planted for summer grazing to follow spring use of cool season pasture such as bromegrass; or a cool season pasture may be established to complement summer rangeland. A deteriorated range or pasture may be improved by interseeding. Grasses with different periods of growth provide greater latitude for management and a longer season for grazing.

Adapted and productive strains or varieties are necessary for the success of grass plantings. Adaptation to the total environment is the first requirement in the choice of a variety of perennial grass. It must exhibit acceptable levels of (a) stand establishment, (b) competition with other grasses and weeds, (c) tolerance to insects and diseases, and (d) persistence under prescribed use through recurring seasons. In addition to adaptation, a chosen variety must have potential for acceptable levels of forage quality and forage yield that can be achieved by proper management.

Objectives of these studies were, therefore, to characterize selected cool season and warm season grasses for forage quality and to determine the season of quality forage production of adapted strains of these grasses for use in grazing systems.

Strains and released cultivars resulting from programs of improvement and evaluation were available for study at the University of Nebraska Field Laboratory at Mead, Nebraska. The plantings were in small seed production fields or larger fields for the production of breeder or foundation seed. These strains were considered adapted representatives of that segment of each grass crop with potential for production in the region.

Six cool season grasses and six warm season grasses were chosen for field studies in a 3-year period, 1972–74. The selected grass strains were harvested through their season of growth to determine forage yields and forage quality. The seasonal variations in forage yields, crude protein, and dry matter digestibility of several strains, as available, were used to characterize each of the 12 grasses.

PREVIOUS WORK

A better understanding of the origin of variation in grasses has resulted from the development of natural classification systems. Gould (10)[3] included most of the forage grasses in three intra-related groups as subfamilies. He placed the largest proportion of the grasses adapted to the cool and cold climates of the world in one subfamily,

[3] Figures in parentheses refer to literature cited.

the *Festucoideae.* Its present abundance and distribution in North America is in northwest United States and Canada. In contrast, he presented natural classifications in two subfamilies of warm season grasses. The distribution of the *Panicoideae* is centered in the southeastern United States and the Caribbean area. The distribution and abundance of the *Eragrostideae* is centered in southwestern U.S. and Mexico.

Following the drought of the 1930s, crested wheatgrass and smooth bromegrass came into prominence from earlier introductions. Crested wheatgrass was introduced into the United States from Russian Turkestan in 1906, according to Dillman (7). The importance of both introduced and native wheatgrasses to the western states has been summarized by Rogler (30). Lyon (13) described the results of planting Hungarian bromegrass in Nebraska in 1897. The discovery of the so-called southern-type bromegrass in old fields of Nebraska, Kansas, and Iowa provided a new forage for the central latitudes. Numerous cultivars were developed and tested (20, 24, 31).

Effects of natural selection in the warm season prairie grasses have been shown by comparisons of strains collected from south to north in the midcontinent. Strains of sideoats grama *(Eragrostoideae)*, selected from different origins southwest to north in the Great Plains, show progressive changes: from apomixis to cross-fertilization as the mode of reproduction; from day-neutral to long-day requirements of photoperiod; and from winter susceptibility to cold tolerance for persistence (26).

Strain differences in switchgrass and the bluestems *(Panicoideae)* trace their migration from southern prairie northward and up river valleys with adaptation developed to long days and short seasons in peripheral environments (8). Strains found to be different in length of season of growth have been compared for adaptation and yield in different environments (16, 17, 18, 34). Improved strains have been developed by hybridization of selected clones, and cultivars have been released with recommended areas for their use (14, 19, 23, 25, 27).

Quality evaluation of forages has evolved slowly since the early interest in hay grades and complete chemical analyses of single harvests. Crude protein content has continued to provide valuable information for balancing feed rations. Effects of time of cutting prairie hay have been measured in terms of protein content, yield of hay, and animal performance in feeding trials (1).

Progress has been made in techniques of measuring forage quality characteristics. A two-stage technique for in vitro dry matter digestion of forages was developed by Tilley and Terry (32). Evaluation of numerous forages showed favorable comparisons of percent in vitro dry matter digestibility with previously determined percent in vivo digestibility by sheep. Their methods have been used for comparisons of animal feeds and the selection and improvement of forages. Contributions to a better understanding of forage quality have resulted from research on interrelations of quality characteristics associated with advances toward maturity in plants.

Pritchard *et al.* (29) studied the in vitro digestibility of timothy, orchard, brome, reed canary, tall fescue, and mountain bromegrass. They found decreases in the in vitro digestibility of these grasses at the rate of approximately 0.5% per day throughout the season.

Miller *et al.* (15) reported results of nylon-bag digestibility trials of pelleted bermudagrass harvested at 3-, 5-, and 7-week intervals. Over 95% of the variation was attributed to linear effects for dry matter, crude fiber, crude protein, ash, and nitrogen-free extract associated with forage age.

Burton *et al.* (3) screened varieties of bermudagrass from samples taken at intervals of 2, 3, 4, and 6 weeks. Significant differences were found in crude protein and nylon-bag dry matter digestibility, which decreased as the age of forage increased.

From studies of pearl millet, Hart (11) showed a positive correlation between whole-plant digestibility and leafiness and a negative correlation of digestibility with age at harvest. Burton *et al.* (4) reported that protein content of leaves, stems, and heads decreased as the cutting interval of pearl millet was increased. Generally, the crude fiber content increased with longer intervals between harvests.

Trends of dry matter, digestible dry matter, and digestible protein from the spring growth of smooth bromegrass were reported by Wright *et al.* (35) for the northeastern states. From four first harvests in a 46-day period between prejoint to past bloom (in Maine, New York, and Maryland), the protein content decreased from 24% to 5%. Yields increased from less than 0.50 T/A to 1.50 T/A digestible dry matter in comparison with 2.75 T/A total dry matter for this most productive period. Response to nitrogen fertilization and delay of first harvest increased yields, but first harvests made later than heading decreased in quality.

Junk and Austenson (12) concluded that variability in quality characteristics was greater among locations than among cultivars. Significant differences in crude protein, crude fiber, in vitro digestibility, ether extract, and mineral analysis were found among cultivars of bromegrass, but only in crude fat, in vitro digestibility, and crude fiber for crested wheatgrass.

Peterson (28) compared 10 hard red winter wheat varieties and one variety of *Triticale* for forage characteristics from regional performance nurseries at the University of Nebraska Field Laboratory at Mead, Nebraska. Total plant samples were collected from discard rows of replicated grain plots at weekly intervals from April 21 to June 25, 1971. Significant differences were found among varieties for in vitro dry matter digestibility, crude protein, acid detergent fiber, and cellulose. Percentages of crude protein and *in vitro dry matter* digestibility decreased through the sampling period and were positively correlated (r = 0.90). The estimates of digestibility (decreasing) were negatively correlated with the characteristics (increasing) associated with advancing maturity.

Burzlaff (5) compared forage quality of three range grasses in plantings at Ft. Robinson, NE. Stands were obtained by transplanting clonal material from the natural grasslands of northwestern Nebraska. He found higher percentages of crude protein and in vitro dry matter digestibility in sand bluestem than in prairie sandreed and little bluestem. There was a high correlation between percentages of crude protein and digestibility estimates in their decrease through the season with advance toward maturity.

Gilbert (9) reviewed the literature on growth and development of numerous range grasses. In a 2-year study, he compared the forage quality trends of four warm season grasses under rangeland conditions in the sandhill region of northcentral Nebraska. Leaves were usually higher than stems in crude protein content and estimates of dry matter digestibility. Because of rapid plant development, switchgrass declined most rapidly through the season in these qualities. The estimates of digestibility were higher in sand bluestem than in the other three grasses. Switchgrass and sand bluestem produced larger yields of crude protein and digestible dry matter than sand lovegrass or little bluestem.

METHODS OF EVALUATION

Replicated field-plot trials for selection of promising grass strains were conducted at the University of Nebraska Field Laboratory at Mead, NE. Seed production fields sampled for forage yields and quality were in adjacent sections of land. These plantings were established in rows with approximately one meter spacing between centers. Stands were maintained without irrigation and with a minimum of cultivation. Weed control was aided by spring burning of residues as warranted.

Forage harvests, representing different managements, were made by hand clipping from two to four series of randomly selected, triplicate plots (2 m of row) in each field. The plot series were numbered in sequence of first harvest. First harvests of Series 1 plots of cool season grasses representing early grazing were in early May; those of the warm season grasses were in mid-May or early June. First harvests of Series 2 plots were begun at least two weeks later than those of Series 1. Additional harvests were made from regrowth as warranted or a new series was started. First growth harvests were lettered A and regrowth harvests were lettered B, C, or D from each series numbered 1, 2, etc., respectively. Sequence of harvests was by number and letter for each grass, as 1A-2A-1B, etc.

Frequent removal of forage by mowing or close clipping has been shown to limit subsequent yields of the tall prairie grasses (17). Height of clipping varied with season and type of growth. Harvests were at 8–12 cm for the midtall grasses (cool season grasses; sideoats grama, and little bluestem) Harvests of the tall prairie grasses were at increasing height of clipping from 8–12 cm in early season to regrowth clipping at 20–25 cm at the end of the season.

Forage from each of the triplicate plots was oven-dried at 75 to 85C, then weighed, and ground through a 1.0 mm screen in a Wiley mill. Subsamples from each plot harvest were bottled for analysis. The analyses were conducted by the Diagnostic Laboratory of the Agronomy Department, University of Nebraska, using standard procedures. Crude protein was calculated (Percent Nitrogen x 6.25). Estimates of forage dry matter digestibility were obtained by measurements of percent in vitro dry matter dsiappearance, using techniques developed by Tilley and Terry (32).

Protein percentages and yields of dry matter and digestible dry matter were obtained for each plot harvest. The digestible dry matter yield was a weighted estimate–the product of a dry matter yield and IVDMD percent. Protein percentages and accumulated yields were averaged from triplicate plot harvests for each date of harvest of each grass strain.

Seasonal trends of crude protein content and yields of digestible dry matter in comparison with total dry matter were estimated from the combined results of strains for each of the 12 grasses. These trends were analyzed and plotted by computer, with estimates of R^2 values indicating probability of fit of parabolic regressions.

Estimates of weighted digestibility were obtained from the ratio of accumulated yield of digestible dry matter to yield of total dry matter from harvests of each grass strain in each of two or more harvest plot series. These estimates were averaged for comparisons of management practices or groups of strains. The average weighted digestibility gave an estimate of forage quality (W Q index) for the grazing season for each of the 12 grasses.

RESULTS AND DISCUSSION

The Cool Season Grasses

1. The crested wheatgrass complex:

[*Agropyron cristatum* (L.) Gaertn.; and
Agropyron desertorum (Fisch. ex Link) Schult.]

Crested wheatgrass from the Russian Turkestan introductions spread rapidly in the northern Great Plains in the late 1930's and early 1940's. Commercial seed harvested from the large acreages came to be known either as standard type *(A. desertorum)* or as fairway

Table 1—Forage quality and yields of crested wheatgrass from June harvests. University of Nebraska Field Laboratory, Mead, Nebraska. 1972 and 1973.[1]

Strain	IVDMD[3]	Digestible dry matter[2]/[3]	Total harvest dry matter[3]
	%	MT/ha	MT/ha
Naturalized strains:			
Ruff (Nebr. 3576)	52.1 bcde	4.17 a	7.95 a
Nebr. 10a	48.9 f	3.98 ab	7.68 a
Synthetic strains:			
B D S, & (5 x 10a)	52.2 bcde	3.90 ab	7.30 ab
(123 x 10a) and (2 x 10b)H	52.5 bcde	3.47 bcd	6.79 bcd
(1 x 10b), (2 x 10b) and R(2 x 10b)	52.2 bcde	3.38 cde	6.56 cde
(1 x 10b)H and (7 x 102R)	51.6 de	3.05 ef	6.05 efg
Turkish types:			
Types (2 x 3)	54.0 ab	2.78 f	5.51 fgh
Type 1	54.9 a	3.05 ef	5.44 gh
Type 2	54.0 ab	2.98 f	4.95 h
Type 3	53.8 abc	2.80 f	5.17 h
Commercial	50.9 e	3.32 ef	6.27 def
Average (16)	52.4	3.36	6.42

[1] Two-year averages from harvests (June 25–27, 1972 and June 13–14, 1973) of 16 strains in four replications of a randomized block design.

[2] Average yields of digestible dry matter from the products of total dry matter yields and IVDMD percentages as estimates of digestibility.

[3] Results in columns followed by the same small letter (a-h) are not significantly different at $P = .05$.

type *(A. cristatum)* (30). The small seeded introduction had been increased separately, and it was the reputed parent source of the cultivar 'Fairway' selected in Canada (7).

Selections from these naturalized types were made from commercial sources at the Nebraska Experiment Station in the mid-1940's. Nebraska 1007 was developed from the standard bunch-type with large seed and Nebraska 3576 from the spreading decumbent-type with small seed. These selections were tested widely in the northern and western states. An awnless strain, N 10a, was later selected from N 1007.

Other strains available for testing traced to Siberian or Turkish origins (16). A strain, B D S (broad spikes, decumbent, spreading), was developed by synthesis of a Siberian strain with N 3576. Selections of intermediate type, tracing to Turkish introductions, included awnless strains (T1, T2, T3), strains with awned plants (T4, T5, T6, T7), and these in synthetic combinations with the naturalized N 10a.

Differences in forage quality, yield, and adaptation were shown in a comparison of crested wheatgrass strains in a randomized block design. In two years, the largest yields from annual harvests as hay crops in June were obtained from the two naturalized strains, N 3576

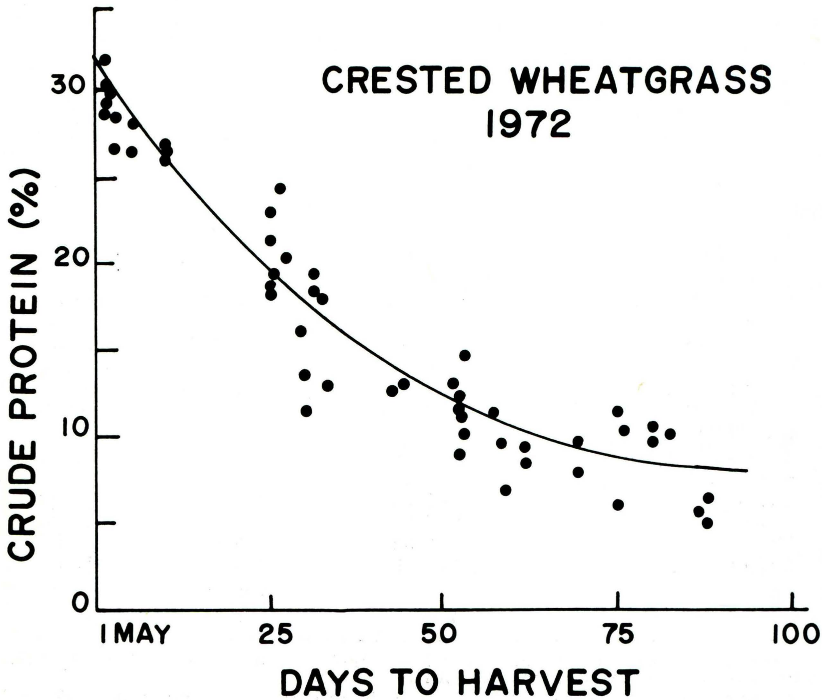

Fig. 1. Regression of crude protein content of crested wheatgrass in percent (Y) on length of season in days (X) to harvest date. Analyses of growth or regrowth in triplicate plots from four harvests of fourteen strains. (Equation, Table A1).

(later released as the cultivar 'Ruff') and N 10a, and their synthetic combinations B D S and T5 x N 10a (Table 1). The low-yielding Turkish selections rated the highest values for crude protein and IVDMD. These values were less important when interpreted in terms of digestible dry matter from IVDMD percentages and total yield, the ranking of strains being determined by total yields. The large-yielding strains, observed for four years, persisted with good stands. The unadapted low-yielding strains lost stands and were invaded by annual grasses and weeds.

Fourteen strains of standard and intermediate types and their synthetic combinations were sampled through the season by three series of triplicate plots in harvest sequence of 1A-2A-1B-3A. Dry matter content of first harvest 1A in early May was as low as 20%. Crude protein dropped rapidly from 31% in early May to readings as low as 5% in mid-July (3A). A linear trend was suggested by the earlier harvests but the plotted curve of a parabolic regression gave the best fit for the results with an R^2 value of 0.93 for the equation (Figure 1; Appendix Table A 1). A total of 168 analyses was involved (3 plots x 4 harvests x 14 strains).

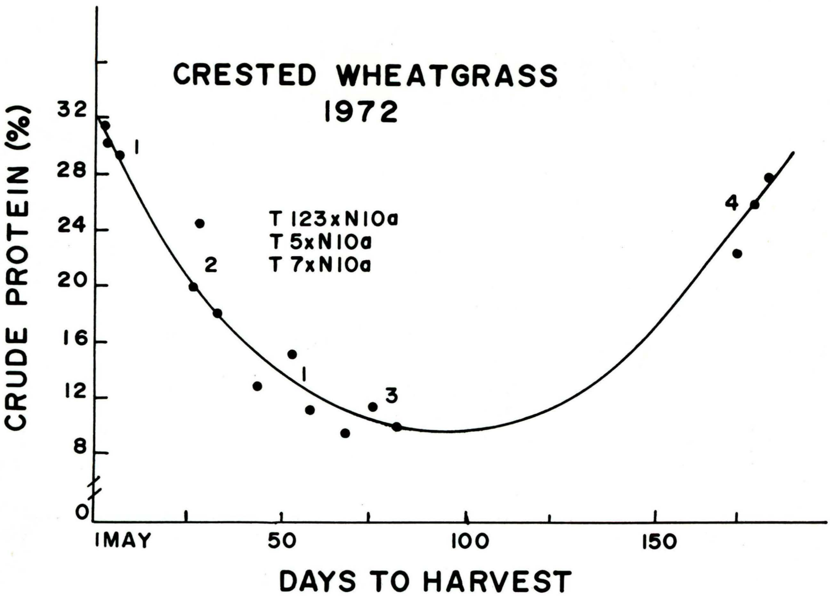

Fig. 2. Pattern of crude protein content of forage from three selected strains of crested wheatgrass, corresponding to seasonal changes in vegetative growth in a full season. Averages of analyses of growth or regrowth in triplicate plots (4 series) from five samplings of three strains. (Regression equation, Table A1)

Only three strains produced enough growth above combine-stubble height of 20 cm for sampling on October 20. These synthetic strains (T123 x N10a, T5 x N10a, and T7 x N10a) were chosen for further comparisons. The pattern of seasonal crude protein content characterized the cycle of vegetative growth response of the cool season grass to the short days and cool temperatures of the full season (Figure 2; Table 1A). Protein content of the three strains that averaged 30% in early May (1A), dropped to 10% in mid-July (3A), and returned to 25% in mid-October (4A). Harvests of each plot series are numbered on the graph. Estimates of forage digestibility indicated by IVDMD percentages averaged 68% in early May, dropped to 43% in mid-July, and returned to 69% for the regrowth in October.

The three selected strains gave excellent yields from row production, averaging 2.75 MT/ha (1.23 T/A) digestible dry matter relative to 5.18 MT/ha (2.31 T/A) total yield from the three Harvest Series. Harvest sequence was 1A-2A-1B-3A with 36 yields (3 plots x 4 harvests x 3 strains).

Increases in yield of digestible dry matter through the season were determined by the increases in weighting by dry matter yield. A comparison of seasonal trends of digestible dry matter to total yield shows the real value of the grass and indicates the length of

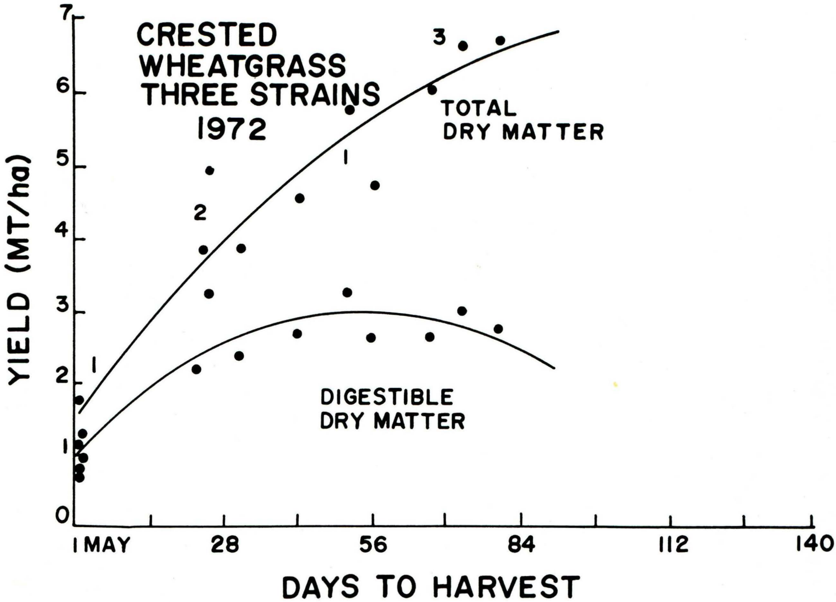

Fig. 3. Regressions of forage yields of crested wheatgrass in MT/ha (Y) on length of season in days (X) to harvest date. Comparison of yields of digestible dry matter and total dry matter produced in triplicate plots (3 series) from four harvests of three strains. (Equations, Table A1)

season for grazing (Figure 3; Table A1). Best grazing use must be in the seven to eight weeks of yield accumulation, before the increases in dry matter yield are offset by decreases in digestibility.

For comparisons, estimates of digestibility were obtained for the harvests of each plot series of each of the three strains. Yields of digestible dry matter from Series 1 plots were weighted (Yield x IVDMD %) and accumulated (1A + 1B). The ratio of digestible dry matter to total dry matter expressed as percent is a weighted digestibility estimate for Series 1. Weighted digestibility estimates for the three strains were 55.4%–54.8%–52.2%; for the three harvest series were 62.7% (2A) – 56.6% (1A + 1B) – 43.1% (3A), with an average of 54.1%. Since the yields from Series 2 and Series 3 plots were from single harvests, the better estimate of average quality was from average yields. The ratio of yields (2.75/5.18 = .531) gave a forage quality estimate of 53.1% as the W Q index for the 1972 grazing season of crested wheatgrass.

2. Western wheatgrass

[*Agropyron smithii* Rydb.]

Western wheatgrass is an important range and dryland pasture grass indigenous to the Great Plains and Intermountain regions of

Table 2—Tyo-year average forage yields of western wheatgrass from harvests in July, 1969 and 1970. Strains of western wheatgrass established on two planting dates in 1968. Lincoln, Nebraska.[1]/[2]

Strain	Plot establishment		Average yield
	Spring 1968	Fall 1968	
	MT/ha	MT/ha	MT/ha
From short-season sources:			
South Dakota	3.23 a	3.45 a	3.34
Colorado	3.09 a	3.36 a	3.22
From long-season sources:			
Nebraska Synthetic			
Generation 1	5.92 b	6.16 b	6.04
Generation 2	6.39 b	6.28 b	6.33
Generation 3	6.32 b	5.87 b	6.10
Mean	6.21	6.10	6.15
Kansas	6.48 b	6.45 b	6.46

[1] Yield averages from randomized block designs with four replications of each strain in each planting.

[2] Yields in each column followed by the same letter are not significantly different at P = .05.

North America. Dewey (6) describes its probable origin as an allo-octoploid (2n = 56) derived from the hybridization of two tetraploid grasses (2n = 28), thickspike wheatgrass and beardless wildrye.

Nebraska Synthetic western wheatgrass (later released as the cutlivar 'Flintlock') traces to intercrossing of 100 clones derived from 30 collections made in 1957 in natural grasslands of central Nebraska and northwest Kansas. The Nebraska variety was compared with strains from commercial seed harvested in South Dakota and Colorado, and with a variety from west-central Kansas, later released as Barton.

Differences in yield and adaptation were shown from spring- and fall-established plots in randomized block designs. In the first two years, the average yields of strains of Nebraska and Kansas origins were significantly larger than the yields of strains originating from shorter seasons in South Dakota or Colorado (Table 2). There were no significant differences in yields among the three generations of the Nebraska Synthetic variety. Strains from Colorado and South Dakota made acceptable early growth in eastern Nebraska, but matured vegetatively more rapidly than the other strains and were subject to rust. In the third and fourth years, loss of stands occurred and these unadapted strains were subject to invasion by annual and perennial grasses and weeds.

Yield and quality determinations in two years were from the breeder seed field of the Nebraska cultivar at a low level of production in 1972 and from a higher level of forage production in 1974. Sequence of harvests from triplicate plots of two series in 1972 was 1A-2A-1B-2B. The sequence in 1974 from four series was 1A-2A-1B-

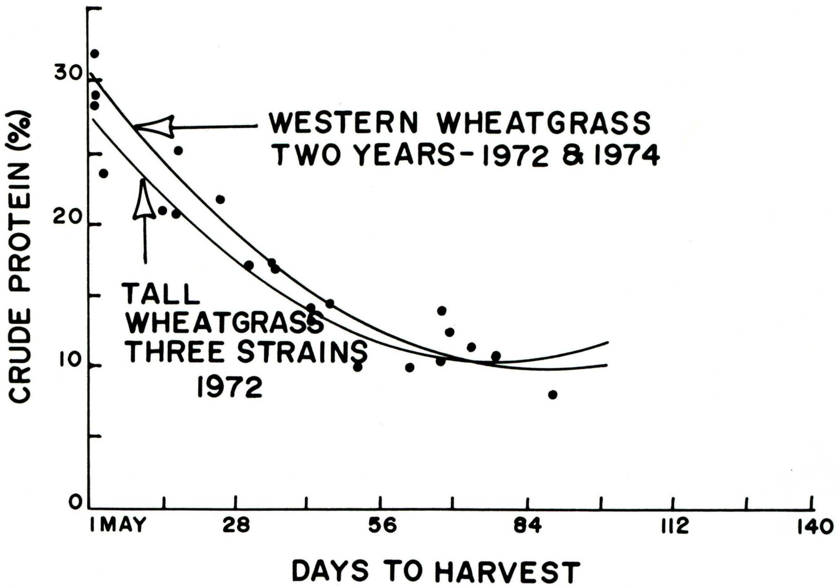

Fig. 4. Regressions of crude protein content in percent (Y) on length of season in days (X) to harvest date; comparison of western wheatgrass (10 harvests in two years) and tall wheatgrass (4 harvests of 3 strains). Averages of analyses from triplicate plots. (Equations, Table A1)

3A-2B-4A. Results were from 30 plot-harvest determinations (triplicate plots x 10 harvests).

Crude protein content in 1972 was 31.6% in early May, decreasing to 13.6% for regrowth 2B in early July. In 1974, protein content in mid-May was 20.8% (1A), decreasing in regrowth to 12.2% (2B) and from late first harvests to 9.8% (3A) in early July and 7.9% (4A) in late July. The trend of decrease in protein content of western wheatgrass with its R^2 value of 0.92 (Figure 4; Table 1A) was similar to the decrease made by crested wheatgrass (Figure 1).

The IVDMD determinations were relatively high for western wheatgrass in comparison with other grasses. Initial harvests (1A) averaged 74.5% in early May 1972 and 76% in mid-May 1974. Regrowth harvests 1B and 2B were both at 60% in 1972 and 68% and 58% in 1974. Determinations from late first harvests in 1974 were 59% (3A) in early July and 54% (4A) in late July.

The average trend of seasonal production was plotted from the accumulated yields of dry matter and digestible dry matter from the 10 dates of harvest in the two years (Figure 5; Table 1A). These results show a relatively large yield of digestible dry matter in relation to yield of total dry matter and longer season of production for western wheatgrass than found for crested wheatgrass. The graph suggests

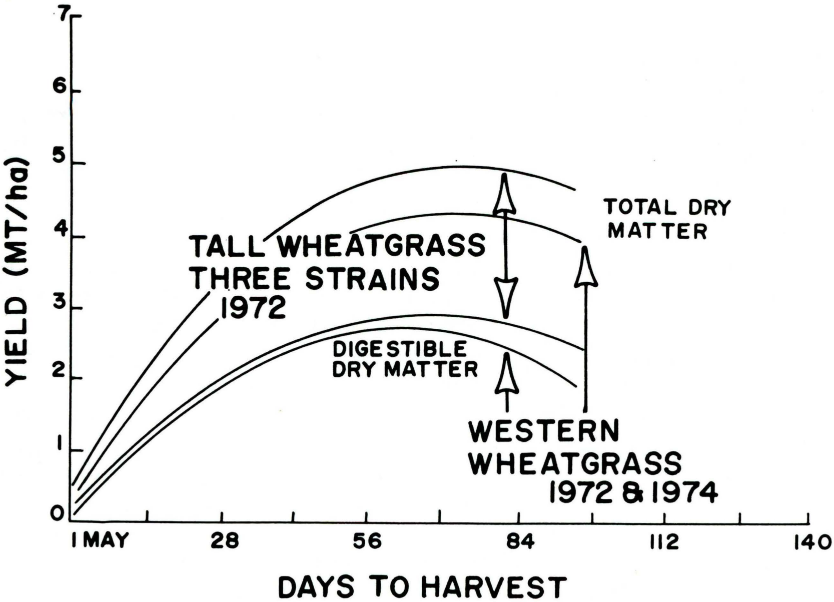

Fig. 5. Patterns of accumulating forage yields and seasons of maximum growth, comparing western wheatgrass and tall wheatgrass (Regression equations, Table A1)

a potential season for grazing high-quality forage extending 10 weeks after May 1.

Estimates of weighted digestibility were calculated from the ratio of accumulated yields for each of the Harvest Series and from average annual yields. From 1972 results, the estimates of weighted digestibility for the two Harvest Series were 61.2% (1A + 1B) and 64.8% (2A + 2B), averaging 63.0%. Average yield of digestible dry matter was 1.91 MT/ha (0.85 T/A) relative to the total yield of dry matter, 3.03 MT/ha (1.35 T/A). The ratio of these yields was .630, giving a W Q index of 63.0% for the 1972 grazing season.

From 1974 results, the estimates of weighted digestibility for the four Harvest Series were 73.3% (1A + 1B) – 68.0% (2A + 2B) – 59.5% (3A) – 54.5% (4A), averaging 63.8%. Two of these estimates were from single harvests. The average yield of digestible dry matter was 2.84 MT/ha (1.27 T/A) relative to the total yield of 4.47 MT/ha (1.99 T/A). The ratio of these yields gave 63.5% as the W Q index for the 1974 grazing season of Flintlock western wheatgrass.

3. Tall wheatgrass

[*Agropyron elongatum* (Host) Beauv.]

'Platte' tall wheatgrass was released for certified seed production by the Nebraska Agricultural Experiment Station in 1969. Its two parental strains and their first generation synthetic combination provided information in 1972 from three fields on two different soil types. Fields of the two parental strains were in close proximity to the fields of western wheatgrass and one strain of the synthetic crested wheatgrasses. The three fields of tall wheatgrass were sampled by two series of triplicate plots each with two harvests in harvest sequence 1A-2A-1B-2B. Results are reported from 36 determinations (3 plots x 4 harvests x 3 strains).

Similarities of adaptation and potential use suggested comparisons of cultivated row production of the bunch-type tall wheatgrass with the normally spreading western wheatgrass on the same graph.

Crude protein content averaged 26.2% (1A), 19.7% (2A), 11.8% (1B), and 10.7% (2B) for the four harvests, showing a similar trend to that of western wheatgrass but with lower percentages in early season (Figure 4; Table A1). The IVDMD determinations averaged 63.4% (1A), 63.6% (2A), 59.6% (1B), and 54.5% (2B), also lower than those for western wheatgrass in early season.

The average yield of digestible dry matter from the three fields of Platte was 2.83 MT/ha (1.26 T/A) relative to the average total yield of dry matter 4.75 MT/ha (2.12 T/A). The ratio of these yields was .596 or 59.6%. The trend in seasonal production of tall wheatgrass was similar to that of western wheatgrass, but the yield trend for digestible dry matter was sustained somewhat longer in the season (Figure 5; Table A1), suggesting a potential grazing period of 11 to 12 weeks for grazing. Estimates of weighted digestibility for the two Harvest Series were similar: 60.1% (1A + 1B) and 59.1% (2A + 2B), these averaging 59.6% as the W Q index for the 1972 grazing season for Platte tall wheatgrass.

4. Intermediate wheatgrass

[*Agropyron intermedium* (Host) Beauv.]

Introductions of wheatgrasses now classified as intermediate wheatgrass and pubescent wheatgrass were widely distributed to different environments in the United States. The early introductions were frequently mixtures and contained segregating populations, making classification difficult. Attributing adaptation based on few characteristics is often misleading. However, a 1953 survey of the increase and use of early introductions showed large acreages of intermediate wheatgrass centered in low elevations of the Plains states, whereas pubescent wheatgrass was widely distributed at higher elevations in Foothill and Intermountain states. Present emphasis can be placed only on the extremes of variation and adaptation in the intermediate wheatgrass complex.

Strains developed for the desired characteristics of intermediate wheatgrass for the mid latitudes traced to three sources. 'Nebraska 50', a cultivar selected for blue-green leaves and reduced glume pubescence, traces to PI 98568 from low elevation (600 ft.) between the Black and Caspian Seas in central Eurasia. This introduction had great variability in visible characters and was also the parent source of 'Ree', 'Oahe', and 'Greenar'. 'Amur' traces to PI 131532 from eastern Asia. 'Slate' (21) was developed from selected strains of Nebraska 50 and Amur. Caspian relates to a more recent introduction from east of the Caspian Sea in the USSR. These sources have provided cultivars with broad variation and yield potential.

Eight fields that were sampled in 1972 included five parent strains and three synthetic combinations of unrelated parent selections. The eight strains were: (a) the released synthetic variety Slate from parent strains; (b) Nebraska 50 Slate and (c) Amur Slate; the experimental synthetic (d) Blue, from (e) Nebraska 50 Erect Blue and (f) Amur Small Blue as parents; and (g) Caspian Synthetic from (h) Caspian and (b) Nebraska 50 Slate as parents. Parent strains and synthetic combinations had given large yields in replicated plot tests.

Initial and regrowth harvests from two series of triplicate plots were made in harvest sequence 1A-2A-1B-2B-1C. Regrowth contained only a few fine and short culms. Results are graphed from 120 plot harvest determinations (3 plots x 5 harvests x 8 strains).

Crude protein content was relatively high at 29.7% (1A) in early

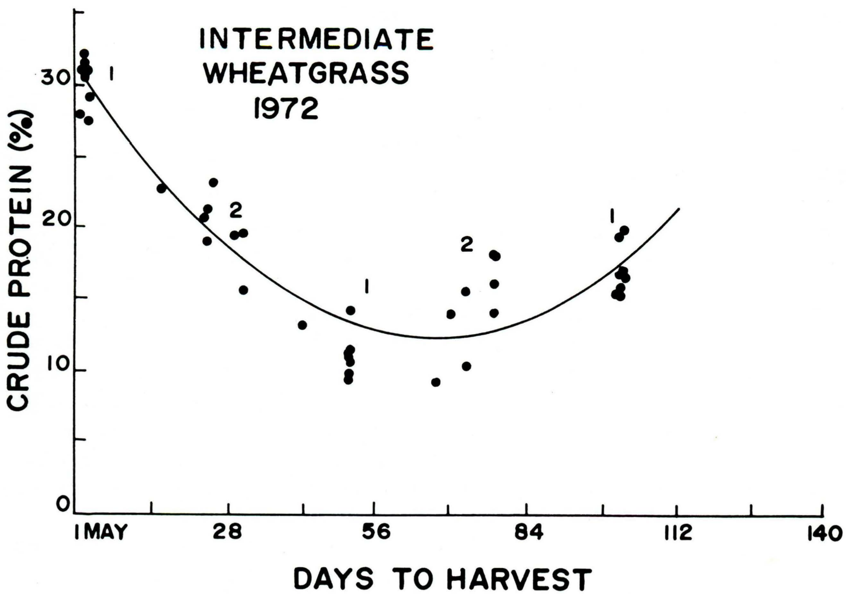

Fig. 6. Seasonal trend of crude protein content of intermediate wheatgrass shown by regression of crude protein in percent (Y) on length of season in days (X) to harvest date. Averages of analyses of growth or regrowth in triplicate plots (2 series), for 5 harvests of 8 strains. (Equation, Table A1).

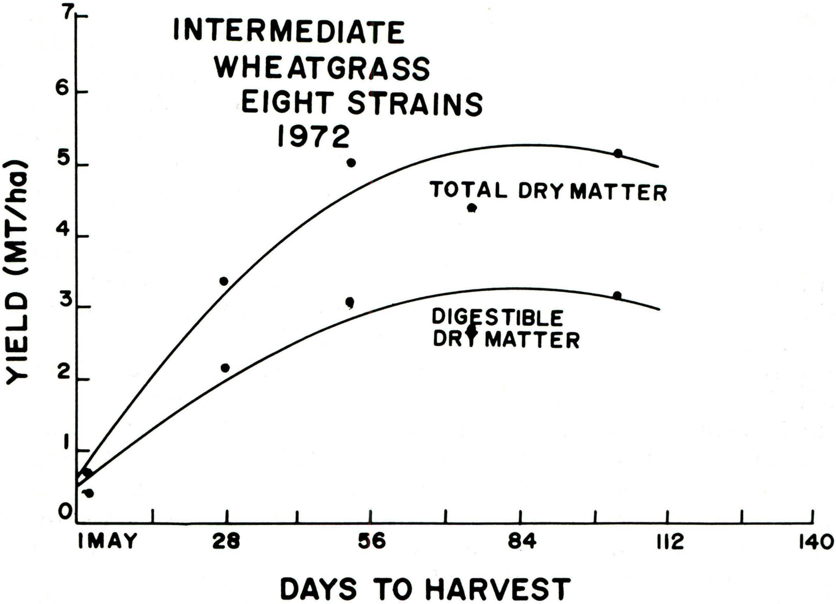

Fig. 7. Yield of digestible dry matter compared to total dry matter yield of intermediate wheatgrass. Regressions of average yields of eight strains (triplicate plots in 2 series) in MT/ha (Y) on length of season in days (X) to average harvest date for each of five harvests. (Equations, Table A1).

growth and continued through the summer with averages well above 10% (Figure 6; Table A1). The occurrence of lowest percentages of protein during long days and high temperatures characterized the vegatative cycle. Protein content increased with shorter days and cooler night temperatures to 17% in mid-August and reached 22% in early October from samples taken above combine-stubble height of 20 cm.

Excellent forage quality was also indicated by the averages of strains for IVDMD determinations. From first harvests, these were 70% (1A) in early May and 66.5% (2A) in late May. Estimates from regrowth were 58.6% (1B) in mid-June and 58.2% (2A) in mid-July, with a return of 61.6% (1C) for a third harvest in mid-August.

Forage yields of the eight strains, on several silt loam and sandy loam soils, were averaged for intermediate wheatgrass. Three harvests from Series 1 plots produced 5.17 MT/ha compared with two harvests from Series 2 plots for 4.24 MT/ha, these averaging 4.70 MT/ha (2.10 T/A). The products of dry matter yields and IVDMD percentages gave relatively large yields of digestible dry matter, averaging 2.92 MT/ha (1.30 T/A), in relation to total dry matter (Figure 7; Table A1). The ratio of yield of digestible dry matter to total yield of dry matter, 2.92 to 4.70 MT/ha, was .621 or 62.1%. The trends of accumulating yields showed a slow development toward maturity with excellent quality of forage for a long season of grazing, estimated at 14 to 15 weeks.

Estimates of weighted digestibility for the eight strains varied considerably in both Series of plot harvests, averaging at a high level of 59.0% to 65.2%. Estimates of weighted digestibility for the two Harvest Series, averaged from the eight strains as replications, were 60.0% (1A + 1B + 1C) and 64.2% (2A + 2B). These estimates also averaged 62.1% as the weighted digestibility or W Q index for the 1972 season of grazing of intermediate wheatgrass.

5. Pubescent wheatgrass

[*Agropyron trichophorum* (Link.) Richt.]

An early-maturing strain of pubescent wheatgrass of Siberian origin was increased through several generations. It was a small, low-yielding strain on upland soils, characterized by copiously pubescent glumes and easily observed stiff hairs on the upper surfaces of relatively long and narrow leaves. It segregated for dominant pubescent versus recessive glabrous glumes.

Three 2-strain synthetic combinations were produced in different fields from seed harvests of the pubescent strain grown in alternate rows with intermediate wheatgrass strains. The pollen parents were Slate, Nebraska 50 Erect Blue, and Caspian, representing the three different sources of intermediate wheatgrass. They were characterized by relatively smooth glumes and broad and smooth leaf surfaces.

Two plantings on fertile silt loam, bottomland soils provided harvests of first synthetic generations (hybrids and nonhybrids) for evaluation of the maternal parent. One field contained Siberian x Amur Slate; the other contained all three synthetic combinations. Hybrid vigor was evident from large yields and dominance of intermediate wheatgrass characters in the population.

Three series of triplicate plots in each of the two fields were required to measure production. Only Series 1 plots produced regrowth. Sequence of harvests was 1A-2A-1B-3A. Results reported are from 24 determinations (3 plots x 4 harvests x 2 strains). Because of similarities of soil fertility, forage yields, and sequence of harvests, the results for pubescent wheatgrass are presented on the same graphs with those for smooth bromegrass.

Early growth showed relatively high percentages of crude protein averaging 25.8% (1A) on May 5. Protein content dropped rapidly to 5% for 3A harvest on July 25 (Figure 8; Table A1). The IVDMD analysis for 1A was 72.0%, but the determinations decreased to an average of 43.5% in late July.

The two pubescent wheatgrass strains produced large yields of forage for row plantings, averaging 5.28 MT/ha (2.35 T/A) from the three Harvest Series. The rapid loss of forage quality caused a

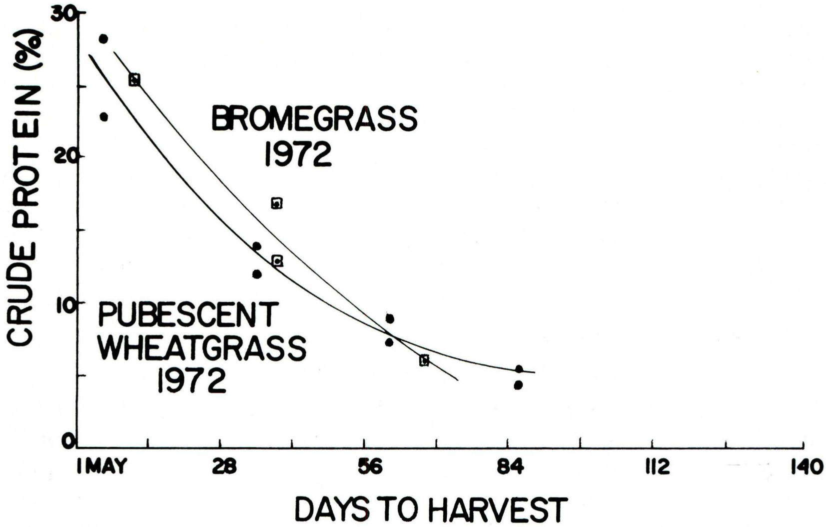

Fig. 8. Comparison of trends of crude protein content of smooth bromegrass and pubescent wheatgrass (2 strains). Regressions of crude protein in percent (Y) on length of season in days (X) to harvest date. Averages from analyses of triplicate plots. (Equations, Table A1).

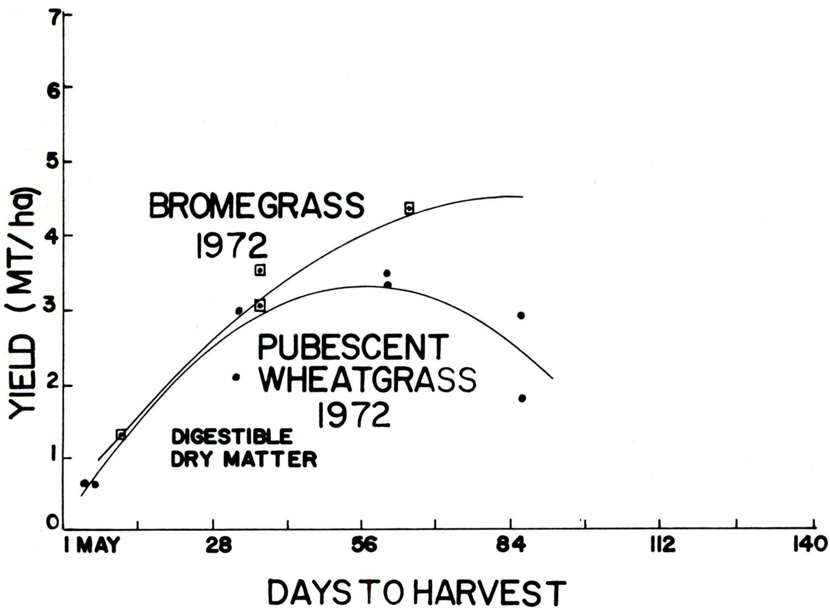

Fig. 9. Comparison of digestible dry matter yields of smooth bromegrass and pubescent wheatgrass (2 strains). Regressions of yield in MT/ha (Y) on length of season in days (X) to harvest date. Averages of triplicate yields. (Equations, Table A1).

sharp early decline in yield of available digestible dry matter, averaging 2.77 MT/ha (1.24 T/A), in contrast to the yield of digestible dry matter from intermediate wheatgrass (Figures 9 and 7; Table A1).

These characteristics of rapid development and early maturity were attributable to the pubescent wheatgrass maternal parent. A relatively short season of eight or nine weeks for grazing of quality forage was indicated for pubescent wheatgrass, comparable to the season for crested wheatgrass (Figures 9 and 3).

Estimates of weighted digestibility for the three Harvest Series were 60.1% (2A) – 54.8% (1A + 1B) – 43.5% (3A), averaging 52.8% A better estimate of quality for the season was obtained from the ratio of the average digestible dry matter yield to the average total yield. This ratio comparing 2.77 MT/ha with 5.28 MT/ha was .525 or 52.5% as the weighted digestibility or W Q index for the 1972 grazing season of pubescent wheatgrass.

6. Smooth bromegrass

[*Bromus inermis* Leyss.]

A solid stand planting of 'Lincoln' bromegrass was fertilized the previous fall with 90 kg/ha (80 lb/A) of N for production of foundation seed in 1972. Moisture conditions were favorable for early growth and development of the seed crop. Three series of triplicate plots were used to measure forage production in harvest sequence 1A-2A-1B-3A in 1972. Only the Series 1 plots produced enough regrowth for harvest. The field was sampled again in 1974, the total yields indicating a similar length of season, but the yields were low and the analyses were not completed. The season trends for smooth bromegrass for crude protein, digestible dry matter yields, and total dry matter yields from 12 determinations in 1972 were similar to those reported for Lincoln bromegrass by Wright *et al.* (35).

Soil moisture and fertility as well as sampling season were similar for a comparison of the bromegrass cultivar with the two pubescent wheatgrasses in 1972. Crude protein content of the bromegrass from first harvests was 25.4% (1A) on May 11, 16.1% (2A) on June 8, and 6% (3A) on July 7. Protein in regrowth was 12.9% (1B) on June 30. The trend for smooth bromegrass was similar to that of the two pubescent wheatgrasses (Figure 8; Table A1). The IVDMD determinations for bromegrass for first harvests ranged from 73.5% (1A) in early May to 54.9% in early June, and to 50% (3A) in early July, with regrowth at 58.9% (1B) in late June.

The fertilized bromegrass in solid stand produced the largest single yield among the grasses, exceeding yields in cultivated rows. The largest yield was 8.60 MT/ha (3.84 T/A) from Series 3A harvest compared with the 3A harvest 6.42 MT/ha (2.86 T/A) produced by pubescent wheatgrass.

Total dry matter yields of bromegrass from the three Harvest

Series were 4.62 (1A + 1B) – 6.30 (2A) – 8.60 MT/ha (3A), averaging 6.50 MT/ha (2.90 T/A) compared with the average yield for pubescent wheatgrass, 5.28 MT/ha. Yields of digestible dry matter for bromegrass for the three Series were 3.00 (1A + 1B) – 3.46 (2A) – 4.30 MT/ha (3A), averaging 3.59 MT/ha (1.60 T/A).

The trend of accumulation of digestible dry matter yield of smooth bromegrass in comparison with pubescent wheatgrass reflected the higher digestibility and indicated a longer season of grazing for the smooth bromegrass (Figure 9; Table A1). The graph indicates a potential length of season of 10 to 12 weeks as the period for best grazing. This period is longer for smooth bromegrass than for crested wheatgrass but somewhat shorter than that for intermediate wheatgrass.

Estimates of weighted digestibility from the ratio of yields for the three Harvest Series were 64.9% (1A + 1B) – 54.9% (2A) – 50.0% (3A), averaging 56.6%. Considering that the 2A and 3A estimates were from single harvests, a better estimate of quality for the season would be from the average yields. The ratio of average yield of diegstible dry matter to average yield of total dry matter (3.59 to 6.50 MT/ha) was .552 or 55.2% as the W Q index for the 1972 grazing season for smooth bromegrass.

Utilization of Cool Season Grasses

Strains and varieties of cool season grasses varied in length of

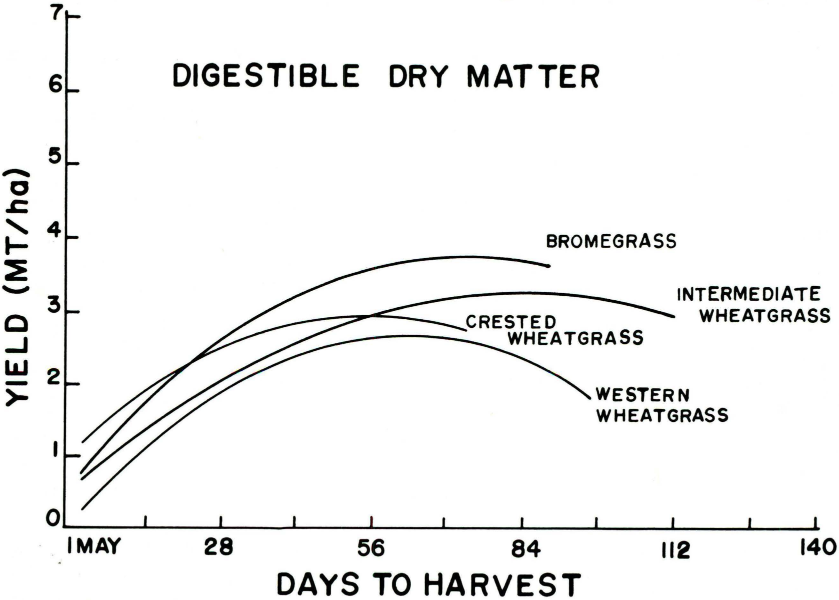

Fig. 10. Principal season of forage production for grazing of four cool season grasses, as indicated by accumulation of yields of digestible dry matter.

season for grazing from 8 to 15 weeks in the period of early May to mid-August (Figure 10; Table A1). Progress of forage production on farms and ranches may be greatly improved in different ways by the planting of adapted varieties of cool season grasses. They serve the double purpose of early grazing and spring deferment of rangeland or pasture for its improvement.

Crested wheatgrass is an important short-season grass in the middle and high elevations of the Great Plains. Its role in early grazing and deferment of natural grasslands is well known (30). Its use on rights-of-way attests to its prominence. Other short-season grasses developed in environments of the Northern Great Plains may have similar potentials. Evidence is accumulating to indicate that many short-season grasses of the cool season group were once more prominent in the natural grasslands (2, 10).

Western wheatgrass and tall wheatgrass offer choices of improved cultivars on favored sites of lower slopes and valleys in the semi-arid environments. In addition to early-season grazing, western wheatgrass is important for its role in conservation practices and roadside plantings. Both grasses are adapted to floodplains and saline soils for pasture and hay.

Smooth bromegrass and intermediate wheatgrass are leading representatives of the cool season grasses for nonirrigated and irrigated pasture production. Such grasses provide for spring deferment of summer rangeland. Grazing should be rotated from cool-season pasture to warm-season pasture. Some fall grazing can be obtained from cool-season pastures with favorable conditions of soil moisture and fertility.

The high protein content of forage of the cool season grasses suggests judicious grazing in early season to provide maximum use of the protein, balanced by feeding lowest quality hay left over from winter supplies. Heavy stocking of cool season grasses early in the season depletes the photosynthetic factory with a decrease in yield and length of season for grazing—and at great cost for the lowered yields obtained. Near the end of the season, too heavy stocking decreases fall regrowth and future yields. None of these grasses alone can provide profitable season-long grazing.

Warm Season Grasses

7. Switchgrass

[*Panicum virgatum* L.]

Full-season, late-maturing strains of switchgrass were developed from clone selections derived from the 1953 Domestic Collections[4] in

[4] Collections of grass and legume seed from natural grasslands were made possible in 1953 by grant funds to the Kansas and Nebraska Experiment Stations from the Division of Plant Introduction and Exploration of the U.S. Department of Agriculture. Seed supplies derived from these collections were exchanged widely with experiment stations of other states and countries.

the natural grasslands of Nebraska and Kansas. Early comparisons showed superiority in yield from the more southern or lower elevation collections compared with strains originating in shorter seasons (8, 23).

Germplasm pools were developed from selected clones grouped by plant type and maturity class in isolated crossing blocks. The original clones were designated Types a, b, c, d, e, f, and g, in order of average seed maturity ranging from mid-August to early October. Only strains a and b from northern and western Nebraska remained early maturing through advanced generations. The other strains became late maturing from the dominance of an increasing number of late-maturing maternal clones in the original groups. These late-maturing strains were found to be superior to early-maturing strains in seedling vigor, early growth, stand establishment, and yield on critical planting sites of outstate tests (33, 34) as well as on fertile soils.

Advanced generations of these selected strains of switchgrass in seed production fields included six strains, c x d, d, ey, ff, ed, and ed x ff. The strain ff was an advanced generation of the released cultivar 'Pathfinder' (14, 19).

First harvests were begun in early June 1973. The three series of triplicate plots provided eight harvests in harvest sequence 1A-2A-1B-3A-2B, and late harvests 3B-1C-2C. Regrowth was harvested above stubble height increasing from 20 to 25 cm at last harvest. Only a few

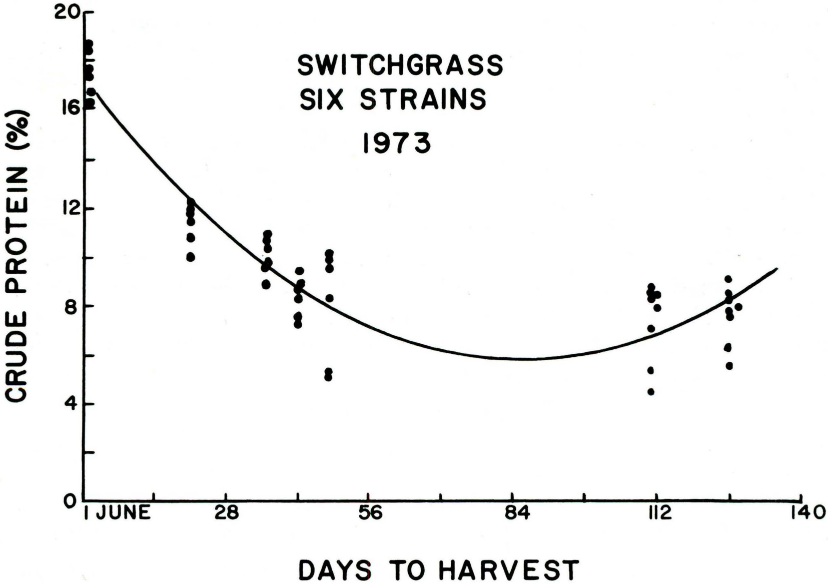

Fig. 11. Regression of crude protein content of switchgrass in percent (Y) on length of season in days (X) to harvest date. Averages of analyses of forage from triplicate plots, for six strains in eight harvests. (Equation, Table A2).

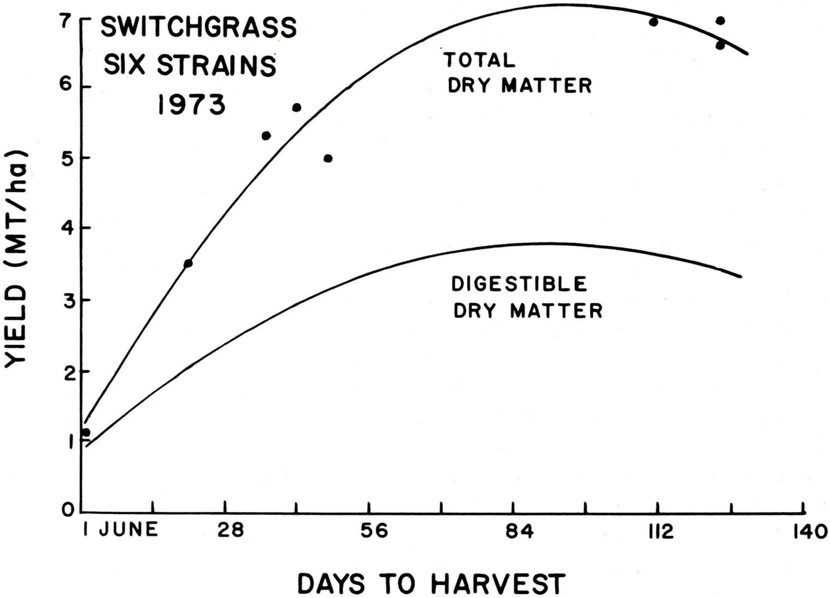

Fig. 12. Regressions comparing digestible dry matter and total dry matter yields of switchgrass. Averages of yields of six strains from triplicate plots for eight harvests. (Equations, Table A2).

short culms with immature panicles were evident in any of the forage harvests. Results presented were obtained from 144 plot harvests (3 plots x 8 harvests x 6 strains).

Crude protein from first harvests averaged 17.5% (1A) in early June, 11.4% (2A) in late June, and 8.4% (3A) in mid-July. Regrowth harvests decreased in protein content from 10% (1B) in early July to 8% (2B) in mid-July, reaching a low of 7.2% (3B) in mid-September, with determinations from the late harvests in early October maintained at 7.3% (1C) and 8.4% (2C) (Figure 11; Table A2).

The IVDMD determinations averaged 68.6% (1A) in early June, decreased to 59.8% (2A) in late June, and to 51.0% (3A) in mid-July. Regrowth analyses were 53.2% (2B) in mid-July, decreasing to 40% (3B) in mid-September and to 34% from the late harvests of early October (1C and 2C).

Relatively large yeilds of 7.08, 6.58, and 6.98 MT/ha were obtained from the row production by the 3, 3, and 2 harvests of Harvest Series 1, 2, and 3, respectively. The yields averaged 6.88 MT/ha (3.06 T/A). The six strains, considered to have equal potential for yield, ranked in three groups for yields from different sites. Strain d on a silt loam and strain ey on a fine sandy loam ranked first and second and averaged 7.98 MT/ha, with the largest production from early June harvest (1A) and continued growth. Strains c x d and ff on loamy sands ranked third and fourth and averaged 7.12 MT/ha, with smallest first harvest yields (1A) but with good sustained yields. The lowest-yielding groups were strains ed and ed x ff averaging 5.53 MT/ha from plantings adjacent to the highest-yielding pubescent wheatgrass and bluestems on fertile bottomland, silty clay loam.

Yields of digestible dry matter from Harvest Series 1, 2, and 3 were 3.75, 3.45, and 3.43 MT/ha, respectively, averaging 3.54 MT/ha (1.58 T/A). Strains ranked in the same order as for total dry matter yields. The rapid decrease of IVDMD percentage to the low 50's as early as mid-July was reflected in the curve of accumulating yield of digestible dry matter. A comparison of the accumulating yields suggests the best grazing use of switchgrass to be in the 12- to 13-week period from early June to early September (Figure 12; Table A2).

Estimates of weighted digestibility were calculated from accumulated yields of the three Harvest Series for each of the six strains. An analysis of variance was used to compare differences among averages of estimates for strains and for Harvest Series.

Although strains differed significantly in yield, there were no significant differences in weighted digestibility among the six strains, ranging from 50.1% to 52.2%, averaging 51.4%.

Estimates of weighted digestibility from the accumulated yields of 3, 3, and 2 harvests of Series 1, 2, and 3, respectively, were 53.0%, 52.3%, and 49.0%, respectively. The differences comparing Series 1 or Series 2 with Series 3 were highly significant, suggesting a selection of the earlier-starting Harvest Series 1 or 2 in the season for grazing. The low estimate, 49.0, resulted from higher weighting by yield for 3B as compared with 1C or 2C. The average of the estimates for the three harvesting regimes gave a W Q index of 51.4% for the 1973 season of grazing for these strains of switchgrass.

8. Big bluestem

[*Andropogon gerardi* Vitman]

9. Sand bluestem

[*Andropogon hallii Hack.*]

The big bluestem complex is a continuum of genetic variability ranging from the big bluestem types in true prairie through intergrading populations of sandy plains and sandhill meadows to the peripheral types of sand bluestem found on sandy plains, choppy sands, and sand dunes. Plant characters of typical big bluestem and the extremes in sand bluestem have been described (27). There is no clearcut differentiation of characters for classification of intermediate populations of inter-crossing genotypes often found in intermediate environments. Previous work has shown that cross-fertilization results from overlap in pollination even between diverse populations (25, 27).

Hybridization of selected genotypes from diverse origins has produced populations similar to natural strains collected in intermediate environments. For the forage quality studies, bluestem strains developed in a breeding program were grouped according to origins and classification of parent clones.

'Pawnee' big bluestem, a released cultivar tracing to 1938 collections in true prairie of southeast Nebraska, was the basic parent source of selected strains of the big bluestem group (14, 19). For this group, three sets of results were obtained (a) from averages of results from old stands of Pawnee Purple (glume color) and Pawnee Brown Pubescent on silt loam soils; and (b) from Pawnee Purple growing on fertile bottomland silty clay loam in alternate rows for backcrossing with (c) Bluegray (leaves, glumes), an advanced generation synthetic strain of Pawnee Purple outcrossed to a white villous sand bluestem from Oklahoma. Bluegray was included with the big bluestem group for initial comparisons.

The sand bluestem group included three yellow villous bluestem strains tracing to parentage from the 1953 collections in western and northern Nebraska sandhills: (d) the released cultivar 'Goldstrike' sand bluestem (WSY x NSY) growing on a fine sandy loam; (e) one of its parent strains, WSY growing on a loamy fine sand; and (f) Bluegold (leaves, glumes), an advanced generation synthetic strain of WSY outcrossed to Pawnee Brown Pubescent big bluestem. The Bluegold strain was included with the sand bluestem group for initial comparison since it was similar to its sand bluestem parent in observable characters.

Eight harvests were obtained from three series of triplicate plots of each strain in a harvest sequence of 1A-2A-1B-3A-2B, and late harvests 3B-1C-2C, beginning June 11 and ending in early October. Results presented for the six strains were obtained from 144 plot harvests (3 plots x 8 harvests x 6 strains).

Seasonal trends of crude protein content were very similar for the big bluestem and sand bluestem groups of three strains (Figure 13; Table A2). First harvest averages for the big bluestem group were 14.4% (1A) on 6/11, 10.6% (2A) on 6/25, and 8.7% (3A) on 7/12; for the sand bluestem group, 15.1% (1A), 9.9% (2A), and 7.5% (3A). End-of-season harvests in early October (3B, 1C, and 2C) averaged 7.0% and 7.1% for the two groups. Although there was considerable variation among strains within groups for some harvests, the differences were not sufficiently consistent to suggest a better grouping.

Each group of bluestems included both high- and low-yielding strains. In paired rows, Pawnee big bluestem (1st) produced a larger yield, 7.05 MT/ha, than Bluegray (2nd) yielding 5.87 MT/ha on the fertile bottomland soil. Old stands of Pawnee strains averaged

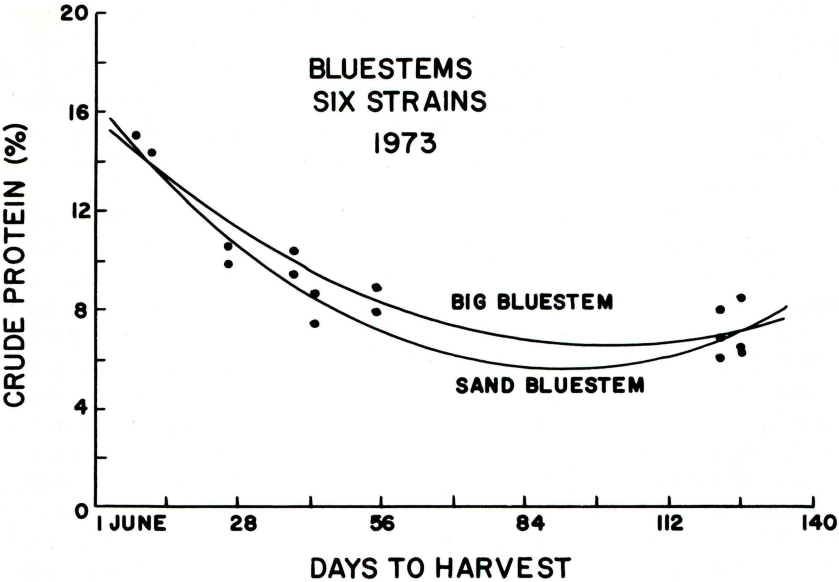

Fig. 13. Seasonal trends of crude protein content of big bluestem and sand bluestem. Regressions of analyses of forage growth or regrowth from triplicate plots of three strains of each bluestem group, for eight harvests. (Equations, Table A2).

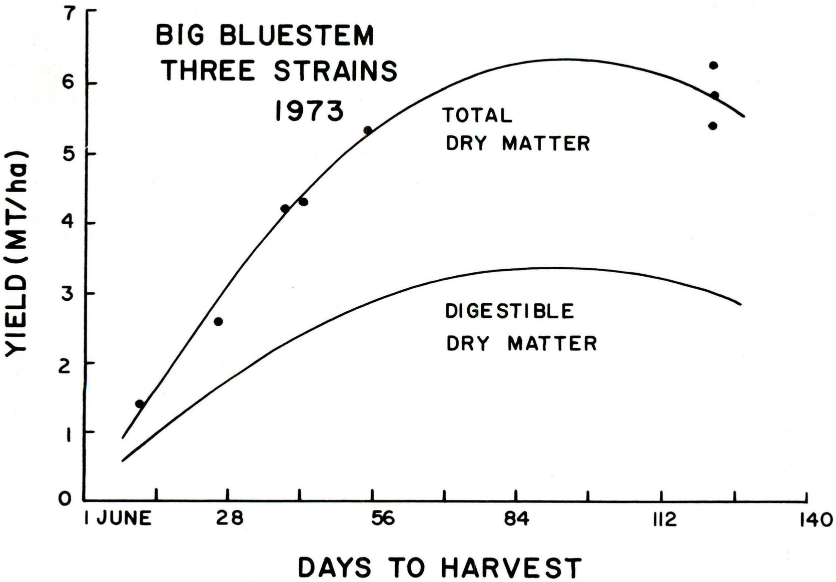

Fig. 14. Comparison of yields of digestible dry matter and total dry matter produced by strains of the big bluestem group. Average yields of three selected strains from triplicate plots, for eight harvests. (Regression equations, Table A2).

4.54 MT/ha (5th). In the sand bluestem group, Bluegold (3rd) at 5.09 MT/ha outyielded in paired rows its parent strain WSY (6th) at 3.45 MT/ha. Goldstrike at 5.08 MT/ha paired with Bluegold (3rd).

Largest total yields of bluestems were obtained from harvest series begun earliest in the season. Strains of the big bluestem group harvested from Series 1, 2, and 3 yielded 6.24, 5.82, and 5.40, respectively, averaging 5.82 MT/ha (2.60 T/A). Strains in the sand bluestem group from Series 1, 2, and 3 gave yields in that order, 5.14, 4.46, and 4.06, averaging 4.55 MT/ha (2.03 T/A). The trends in accumulation of yields were plotted from the results of the eight harvests in the three harvesting regimes (Figures 14, 15; Table A2).

The downward trends in IVDMD percentages were at different levels for three groups of strains. The two outcrossed synthetic strains averaged intermediate in digestibility between the two big bluestems and the two sand bluestems. Averages for the two big bluestems at first harvest (1A) in mid-June were 62.2% progressively decreasing through the season with last harvests (3B, 1C, 2C) averaging 34.9% in early October. Bluegray and Bluegold averaged 64.7% (1A) decreasing in last harvests to 38.9%. Goldstrike and WSY averaged 66.8% (1A) decreasing to 45.2%. The IVDMD percentages for Goldstrike exceeded those for Pawnee big bluestem by 5.1% at first harvest (1A), averaged 2.5% higher in the next four harvests, and were 11.4%

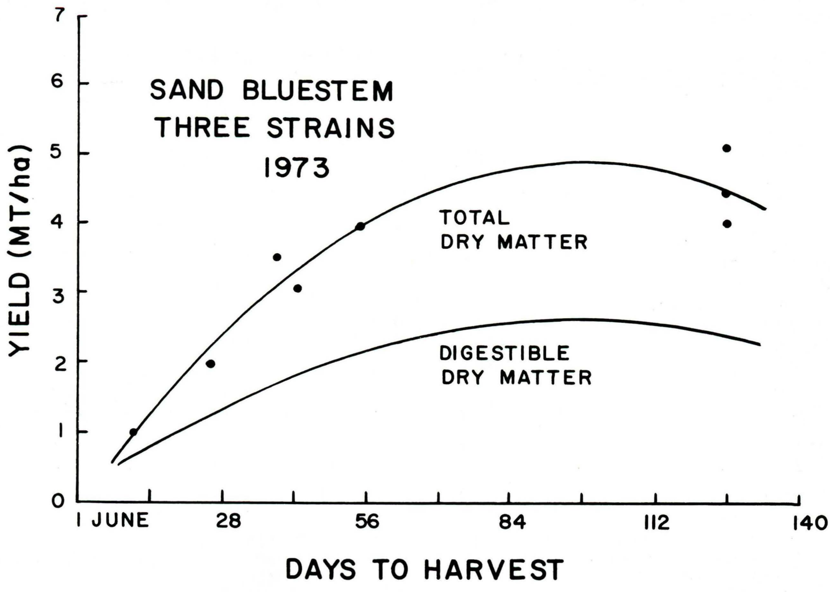

Fig. 15. Comparison of yields of digestible dry matter and total dry matter produced by strains of the sand bluestem group. Average yields of three selected strains from triplicate plots, for eight harvests. (Regression equations, Table A2).

higher as an average of the three harvests at the end of the season.

Correlations were calculated to determine the relation of yield at any harvest on comparisons of IVDMD percentages among strains. Significant negative correlations at the 5% level of probability were found between yield and IVDMD determinations in only the two lowest-yielding harvests, the first harvest (1A) and the last harvest (1C) of the early starting Series 1. Correlations in the other six harvests varied widely, but none was significant.

Strain yields of digestible dry matter ranked in the same order as for total dry matter yields except that Goldstrike ranked third over Bluegold fourth. The plotted yields of digestible dry matter showed a difference in rate of maturity associated with different digestibility of the two groups of strains. The accumulation of digestible dry matter by the strains of big bluestem continued through a season of 12 to 13 weeks from mid-June to mid-September. The accumulation of digestible dry matter by the sand bluestem group was through a season from late June extending to late September, estimated at 13 to 14 weeks (Figures 14, 15).

For comparisons, the digestible dry matter yields and rank of strains are shown with estimates of weighted digestibility calculated from the yields of the three Harvest Series for each strain (Table 3). A first overview shows the range of weighted digestibility percentages narrowed considerably compared with IVDMD percentages. Each

Table 3—Yields of digestible dry matter and weighted digestibility estimates from three harvest sequences for 6 strains in the big bluestem complex.

Strain	Digestible dry matter[1] yield		Weighted digestibility estimates[2] harvest series 1A, B, C	2A, B, C	3A, B	Average of estimates
	MT/ha	Rank	%	%	%	%
Big bluestems:						
Pawnee Purple	3.65	1	50.6	53.0	51.6	51.7
Pawnee selections	2.32	5	50.9	53.9	48.1	51.0
Outcrossed synthetics:						
Bluegray	3.07	2	53.1	54.5	48.8	52.1
Bluegold	2.60	4	51.5	52.2	49.4	51.0
Sand bluestems:						
Goldstrike	2.81	3	55.1	56.9	53.6	55.2
WSY	1.87	6	54.9	53.7	51.8	53.5
Avg. of first 3	3.01		51.5	53.8	49.5	51.6
Avg. of last 3	2.43		53.8	54.3	51.6	53.2
Avg. of first 4	2.91		51.5	53.4	49.5	51.5
Avg. of last 2	2.34		55.0	55.3	52.7	54.3

[1] Averages of accumulated digestible dry matter yields from three harvest management series of triplicate plots of each strain.

[2] Weighted digestibility estimates from the ratio of accumulated digestible dry matter yield to total dry matter for each of the three harvest management series:

Series 1 harvested (A) 6/11, (B) 7/9, (C) 10/5
Series 2 " (A) 6/26, (B) 7/25, (C) 10/5
Series 3 " (A) 7/13, (B) 10/5

weighted digestibility estimate reflects the IVDMD percentages of harvests in relation to the accumulation of digestible yield for the management practice. The average of the three estimates gives equal weight to the three harvest sequences which sample differently the downward trend of digestibility for the season.

An analysis of variance of the three weighted digestibility estimates for Harvest Series over the six strains was used to study the suitability of grouping of strains for forage quality comparison. Harvest Series differed at the .01 level of probability. There was no significant difference found between averages of weighted digestibility for the two groups of three strains (Table 3).

A more realistic grouping is a 4-to-2 comparison of groups of the unrelated strains—a group of four big bluestems including both of the outcrossed synthetic strains versus a group of two sand bluestems. Despite three generations of selection toward sand bluestem characters, Bluegray and Bluegold exhibited combinations of identification characters that were attributable to their remote parents, Pawnee Purple and Pawnee Brown big bluestems. The digestibility estimates of these synthetic strains from second and fourth ranking yields were similar to the digestibility estimates of the Pawnee big bluestem strains with first and fifth ranking yields. The two sand bluestems averaged significantly higher in digestibility estimates than the average of the other four and with consistency of estimates sampling the season.

This grouping of strains is not to be considered as an attempt to disprove the proposition of the continuum, which the synthetic strains support. The weighted digestibility estimates for the group of four strains of big bluestems were 51.5%-53.4%-49.5%, averaging 51.5% as the W Q index for a broad grouping of strains with dominant big bluestem characteristics. The weighted digestibility estimates for the group of two sand bluestems were 55.0%-55.3%-52.7%, averaging 54.3% as a W Q index representing a narrow selection for sand bluestem (Table 3). These results could not represent the broad array of the sand bluestem peripheral components of the continuum. They do agree with other favorable comparisons of sand bluestem with other grasses (5, 9) and suggest potentials for improvement.

10. Little bluestem

[*Schizachyrium scoparium* (Michx.) Nash = Andropogon scoparius (Michx.)]

Two midtall prairie grasses, little bluestem and sideoats grama, were evaluated in the relatively dry summer of 1974. 'Blaze' and 'Camper' little bluestem are released varieties derived from the seed increase of selected clones tracing to the 1953 Domestic Collections in Nebraska and Kansas (14, 19).

Blaze, tracing to selected clones derived from collections in southeast Nebraska and eastern Kansas, reaches seed maturity late in the

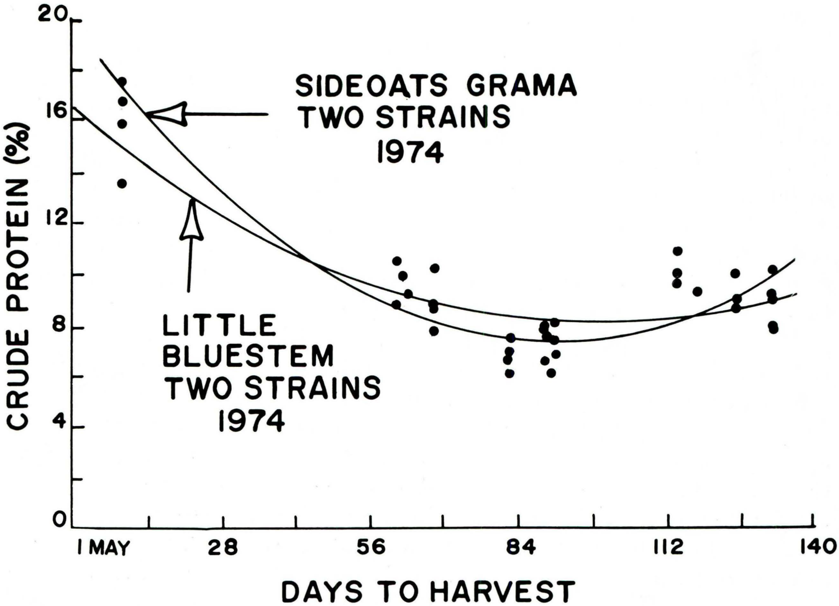

Fig. 16. Crude protein content of sideoats grama and little bluestem. Regressions of analyses of forage growth or regrowth from triplicate plots of two strains of each grass for nine harvests. (Equations, Table A2).

season at average frost dates in early October. Camper was increased from seed of a sister strain of Blaze hybridized with an early-maturity strain from central Nebraska. It matures seed for harvest in late September, 10 days to 2 weeks earlier than Blaze. Both of these varieties are more leafy and productive than earlier-maturing strains originating in shorter seasons.

Foundation seed fields of the two cultivars were sampled by nine harvests from triplicate plots in a harvest sequence of 1A-2A-1B-3A-2B-1C and late harvests 2C-3B-1D, giving 54 determinations for forage yield and quality.

Crude protein from first harvests averaged 15.1% (1A) on 5/10, 9.1% (2A) on 7/1, and 7.9% (3A) on 7/26. Regrowth averaged 9.4% for harvest 2C on 8/25, leveling to 8.8% (3B) and 9.2% (1D) on 9/10 (Figure 16; Table A2). Unweighted averages of crude protein content for the harvests of Series 1, 2, and 3 were 10.5%, 9.1%, and 8.2%, respectively.

The IVDMD determinations of first harvests were 65.1% (1A) on 5/10, 58.8% (2A) on 7/1, and 51.8% (3A) on 7/26. Regrowth dropped to 52.8% (2C) in late August. The low readings of 48.7% (3B) and 45.4% (1D) on 9/10 were evidence of the early advance to maturity at the end of the season, suggesting a maximum length of season of 12 to 13 weeks, similar to the big bluestems strains.

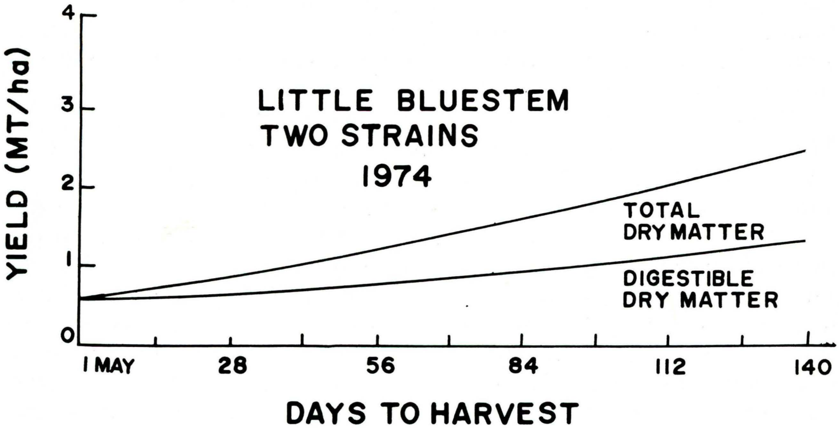

Fig. 17. Comparison of yields of digestible dry matter and total dry matter produced by two strains of little bluestem. Regressions of average yields of two strains from triplicate plots for nine harvests. (Equations, Table A2).

Low reserves of soil moisture were not sufficient for large yields. The return of more favorable moisture conditions in late summer favored most regrowth on plots of Series 1 with four harvests and Series 3 with two harvests. Average yields of the two varieties of little bluestem from plots in Series 1, 2, and 3 were, respectively, 2.75, 2.16, and 2.44 MT/ha and averaged 2.45 MT/ha (1.09 T/A). The long-season adaptation of both varieties made possible the continuation of regrowth which was shown by the trend of increasing yields to the end of the season (Figure 17; Table A2).

The ratio of accumlated yields of digestible dry matter to the total dry matter yields gave weighted digestibility estimates of 55.5%-56.1%-50.6% for the Harvest Series 1, 2, and 3, respectively, with a range of 5.5 percentage points. The early starting Series 1 harvests produced the best yield and acceptable forage quality. Despite some differences in yield, there was a difference of only 0.7% in weighted digestibility between the two varieties. The average of the three estimates gives 54.1% as the W Q index for the late-maturing varieties of little bluestem in 1974.

11. Sideoats grama

[*Bouteloua curtipendula* (Michx.) Torr.]

In common with many grasses of the *Eragrostoideae,* sideoats grama exhibits characteristics of persistence under conditions of drought and close grazing as well as stand increase and migration by self-seeding after drought.

Sideoats grama produces seed crops earlier in the summer season than the long-season *Panicoid* grasses. The characteristics of 'Butte' and 'Trainway' which make them adapted to the central plains have been described elsewhere (22, 26). Butte is the earlier-maturing variety adapted farther north. Trailway has produced larger forage yields in some environments (14, 34).

Foundation seed fields of the two varieties were sampled in 1974 from three series of triplicate plots by nine harvests in sequence of 1A-2A-1B-3A-2B-1C, and late harvests 2C-3B-1D. These harvests provided 54 determinations for forage yields and quality.

There were only small differences between varieties in crude protein content of forage from each of the nine harvests. Averages ranged from 17.8% (1A) on 5/10 to 6.3% (2B) on 7/29. Protein of second regrowth (2C) on 8/20 was 10.6%. Both varieties showed marked early increase in protein following the August seed production period (Figure 16; Table A2). Unweighted averages of crude protein content of forage from Harvest Series 1, 2, and 3, respectively, were 10.3%, 8.9%, and 8.2%. High quality of forage was indicated by crude protein for the full season.

The IVDMD determinations for sideoats grama from first harvests were 63.5% (1A) on 5/10, 59.6% (2A) on 7/2, and 57.6% (3A) on 7/22. Readings on regrowth ranged upward from a low of 53.8% (2B) on 7/29, to 57.7% (2C) on 8/23, and 56.6% (1D) on 9/16.

The Butte field, in its early years of seed production in cultivated rows, gave larger forage yields than the older established Trailway that had not been cultivated for several years. Yields of both varieties were limited by low soil fertility and summer drought in 1974.

Series 1 plots with four harvests (5/1, 7/8, 7/31, and 9/10) gave largest yields of 1.81 MT/ha (0.80 T/A). Series 3 plots with two har-

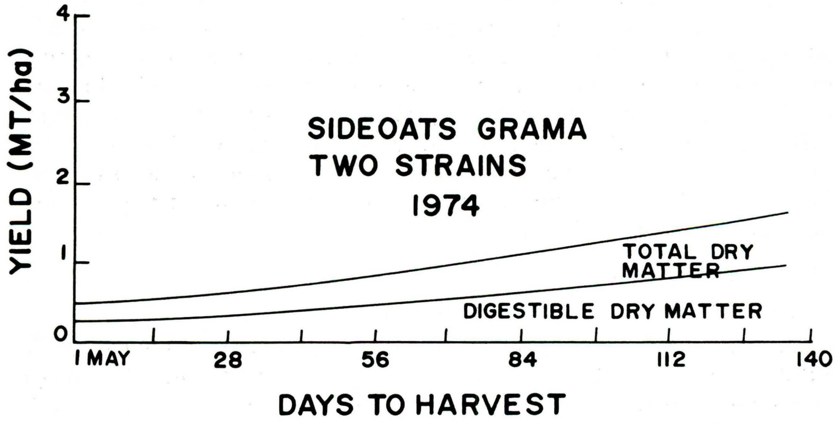

Fig. 18. Comparison of yields of digestible dry matter and total dry matter produced by two strains of sideoats grama. Regressions of average yields of two strains from triplicate plots for nine harvests. (Equations, Table A2).

vests (7/12 and 9/3) ranked second in yield (1.40 MT/ha) with the larger yield in regrowth (3B) contributed chiefly by the late vegetative growth of Trailway. Average yields of accumulated digestible dry matter increased through the full season (Figure 18; Table A2).

Estimates of weighted digestibility were very similar from the 4, 3, and 2 harvests of Series 1, 2, and 3, respectively. They were 57.8%-57.6%-57.7%, as averages for the two cultivars which differed in average weighted digestibility by only 0.6%. The average of the three estimates gives 57.7% as the W Q index for the 1974 grazing season of sideoats grama.

12. Indiangrass

[*Sorghastrum nutans* (L.) Nash]

Indiangrass is a tall prairie grass which is closely related to the bluestems but with its natural occurrence and abundance favored on more fertile and moist soils of lower slopes and subirrigated valleys. 'Holt', 'Nebraska 54', and 'Oto' are recommended cultivars in the central latitudes (14, 19, 21). Holt originated in northeast Nebraska and is recommended farthest north. It is earliest in maturity with seed harvests in early to mid-September. Nebraska 54 was developed from southern Nebraska selections; Oto was from selected clones tracing to southeast Nebraska and eastern Kansas. These two varieties are late in maturity, with seed harvests near late frost dates in southeast Nebraska.

Foundation seed fields of Holt and Oto indiangrass were sampled in 1974 from 3 series of triplicate plots, with a total of 9 harvests in sequence of 1A-2A-1B-3A-2B-1C and 2C-3B-1D, providing 54 determinations for forage yield and quality.

The Oto field was an old established stand that had been fertilized for seed production the previous year. Holt was in the third year of seed production with a relatively poor stand on soil of low fertility.

The crude protein content of the harvested forage reflected the difference in soil fertility of the two fields. The Oto field gave notably higher percentages in six of the nine harvests, but the seasonal trends for the two varieties were similar. The pattern of crude protein for indiangrass shown as the averages of harvests for the two varieties was similar to those for the bluestems (Figure 19 and Figure 13). The highest average protein content of the two varieties was 15.4% (1A) in mid-May; the lowest was 7.6% (2B) in late July. Later regrowth was 9.3% (2C) on 8/23, 7.8% (3B) on 9/3, and 9.7% (1D) on 9/10. Unweighted average protein contents from Harvest Series 1, 2, and 3 were, respectively, 10.6%, 8.8%, and 8.9%, indicating excellence of forage quality through the full season.

Average IVDMD analyses for the two indiangrasses ranged from 67.1% for first harvest 1A to 54.4% for last harvest 1D. These meas-

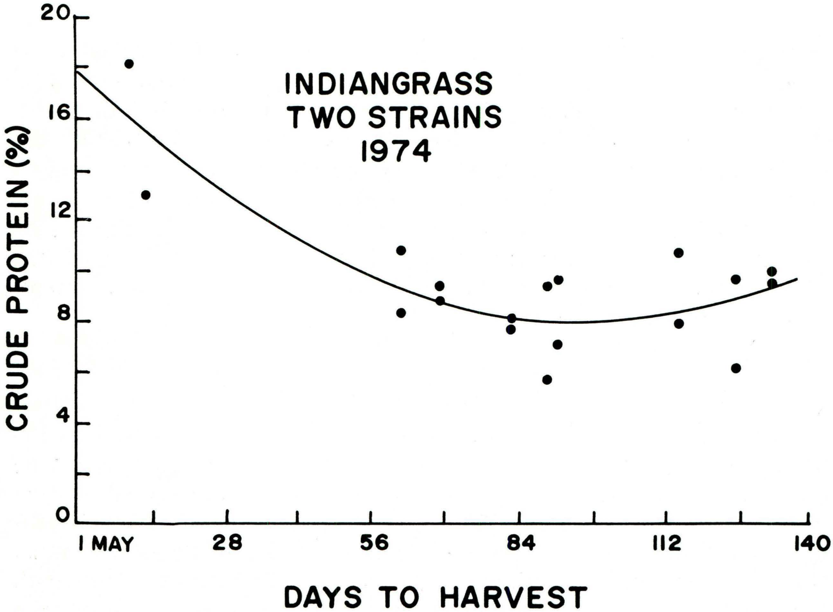

Fig. 19. Seasonal trend of crude protein content of indiangrass. Regression of crude protein in percent (Y) on length of season in days (X) to harvest date. Averages of analyses of growth or regrowth from triplicate plots, for two strains in nine harvests. (Equation, Table A2).

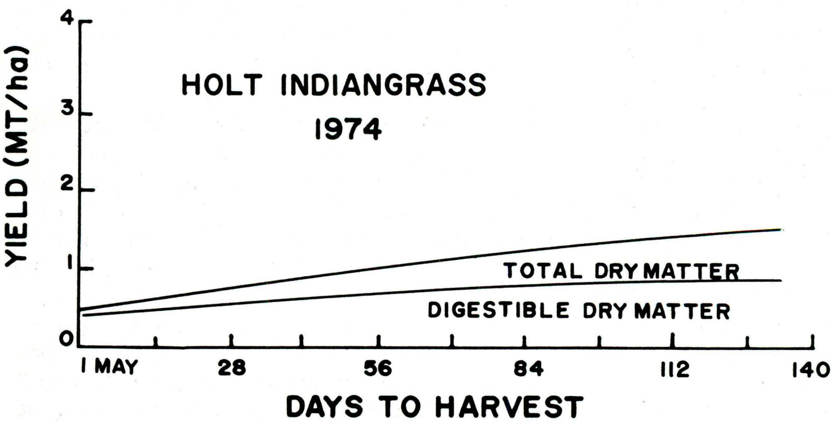

Fig. 20. Comparison of yields of digestible dry matter and total dry matter produced by Holt indiangrass. Average yields of forage growth and regrowth from triplicate plots for nine harvests. (Regression equations, Table A2).

urements were relatively high for the entire season compared with the bluestems and switchgrass. Variety differences were evident. Oto ranged in IVDMD determinations from 69.4% (1A) to 58.5% (3A) to a low of 57.3% (2B) on 7/29 with a return to 61.7% (2C) on 8/23 and 60.8% (3B) on 9/3. Holt ranged from 64.8% (1A), was 2.5% higher than Oto on 7/8, then to lows of 51.2% (3B) on 9/3 and 51.7% (1D) on 9/10.

Holt gave its best yields, 1.57 MT/ha, from three harvests of Series 2 plots and 1.41 MT/ha from two harvests from Series 3. Lowest yield was 1.38 MT/ha from four harvests of Series 1, in which early and late harvests were relatively low. Average yield was 1.45 MT/ha (0.65 T/A). Despite the advance to maturity evidenced by decrease in digestibility, yields continued to increase to the end of the season. The accumulated yields of digestible dry matter averaged relatively high in relation to total dry matter yield (Figure 20; Table A2).

Oto gave its largest yield, 5.04 MT/ha, from four harvests of Series 1, followed by 4.10 MT/ha from three harvests of Series 2, and 3.33 MT/ha from two harvests of Series 3 plots, averaging 4.16 MT/ha (1.86 T/A). The variety was productive through the season with relatively large yields of digestible dry matter in relation to total dry matter yields (Figure 21; Table A2).

Forage quality of the two varieties can be compared best from averages weighted by the forage production through the season. The

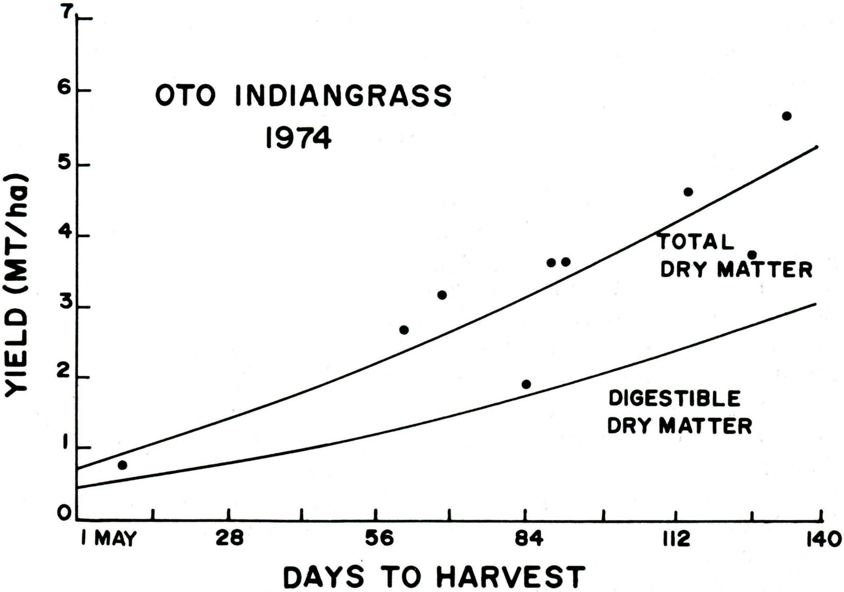

Fig. 21. Comparison of yields of digestible dry matter and total dry matter produced by Oto indiangrass. Average yields of growth and regrowth from triplicate plots, for nine harvests. (Regression equations, Table A2).

estimates of weighted digestibility of the forage of 4, 3, and 2 harvests, in that order, from the early-to-late starting Harvest Series 1, 2, and 3 were, respectively, 61.6%-56.7%-55.3%, averaging 57.9% for the season for Holt, and 60.7%-61.9%-59.5%, averaging 60.7% for the season for Oto. The range among these harvests was 6.3% for Holt and 2.4% for Oto. The difference of 2.8% in average digestibility of the two cultivars can thus be attributed to the progressive decrease in digestibility from Series 2 and 3 for Holt as compared with the relative uniformity of forage digestibility from Harvest Series 1, 2, and 3, respectively, for Oto.

For comparison of indiangrass with other grasses, the quality estimate was obtained from the average of results for the two representative varieties as described. The weighted averages of digestibility from Harvest Series 1, 2, and 3 were, respectively, 61.2%-59.3%-57.4%, giving a W Q index of 59.3% for the 1974 grazing season for indiangrass. This estimate was the largest of the W Q indices obtained for the warm season grasses.

Utilization of Warm Season Grasses

Warm season grasses have their peak of forage production in the long days and high temperatures of June, July, and August. They differ in rate of early growth and time of maturity.

Early-maturing strains of such grasses as switchgrass, big bluestem, sand bluestem, and indiangrass are the prairie grasses of hay meadows and summer rangelands of the sandhill regions. Mixtures of these grasses are used for improvement of rangeland by interseeding or they are planted on adjacent land for supplemental summer pasture. Cool season grasses on favored sites or under irrigation provide early grazing.

The late-maturing strains of switchgrass produced the largest average total forage yields of these experiments. They made rapid growth early in June and provided forage for 12 to 13 weeks or a 3-month period. Because of this rapid growth and accompanying decrease in digestibility early in the period, these switchgrasses can be managed best in pure stand with early stocking to keep up with growth (see comparison of Harvest Series 1 and 2 vs. 3).

Late-maturing strains of big bluestem and little bluestem provided for 12 to 13 weeks of grazing from mid-June to mid-September. The grazing period for sand bluestem extended for a period of 13 to 14 weeks from late June to late September. Sideoats grama and late indiangrass maintained high quality of forage for grazing from late June until frosts.

Pastures of these warm season grasses make possible a change of grazing from the cool season wheatgrasses or bromegrass to forage of high quality for midsummer grazing. The timing of such change

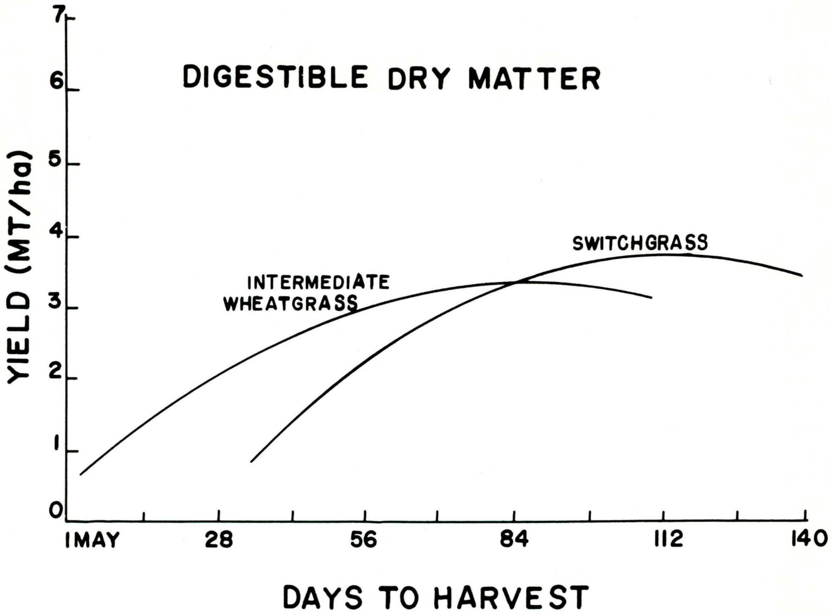

Fig. 22. Overlap and extension of season of forage production for grazing by combined use of cool season and warm season grasses.

becomes obvious with the decrease of quality of short-season early grasses.

Opportunities as well as problems are shown by overlap of season of production (Figure 22). The shift of livestock from cool season bromegrass or wheatgrass to warm season grasses should be at the right stage of growth to take advantage of animal acceptance of good forage quality. The summer pasture should be stocked at a suitable rate for its initial use. Additional use of the cool season grasses could continue with decreased stocking rate. However, any residual growth protects the soil and improves reserves for fall grazing or for future yields. Similarly, the shifting of livestock from warm season pastures to the fall regrowth of cool season grasses, or to crop residues, improves the reserves for future yields of the warm season grasses.

APPENDIX TABLES

Table A1—Regression equations for seasonal trends of crude protein[1] and accumulating forage yields[2] of six cool season grasses.

Graph	Figure no.	Parabolic regression	R^2 value
Crested wheatgrass			
Crude protein	1	$Y = 31.8 - .530X + .0030X^2$	.93
Crude protein	2	$Y = 30.8 - .473X + .0030X^2$	.95
Total dry matter	3	$Y = 1343 + 102X - .48X^2$	.93
Digestible dry matter	3, 10	$Y = 894 + 74X - .66X^2$	.86
Tall wheatgrass			
Crude protein	4	$Y = 27.4 - .430X + .0030X^2$	.94
Total dry matter	5	$Y = 270 + 128X - .89X^2$	.97
Digestible dry matter	5	$Y = 193 + 79X - .57X^2$	.97
Western wheatgrass			
Crude protein	4	$Y = 20.4 - .471X + .0027X^2$	.92
Total dry matter	5	$Y = 13 + 122X - .86X^2$	.81
Digestible dry matter	5, 10	$Y = 52 + 87X - .70X^2$	.78
Intermediate wheatgrass			
Crude protein	6	$Y = 30.8 - .553X + .0040X^2$	.88
Total dry matter	7	$Y = 616 + 107X - .62X^2$	.74
Digestible dry matter	7, 10, 22	$Y = 463 + 65X - .38X^2$	.73
Pubescent wheatgrass			
Crude protein	8	$Y = 28.0 - .52X + .0030X^2$	.95
Total dry matter	..	$Y = -7 + 181X - 1.36X^2$	.91
Digestible dry matter	9	$Y = 93 + 111X - .98X^2$	.88
Smooth bromegrass			
Crude protein	8	$Y = 30.4 - .47X + .0016X^2$	.97
Total dry matter	..	$Y = 15 + 158X - .48X^2$	.94
Digestible dry matter	9, 10	$Y = 268 + 98X - .57X^2$	.98

[1] Parabolic regressions for crude protein content (Y) in percent, on number of days (X) to harvest date.

[2] Parabolic regressions for forage yields of dry matter (Y) in kilograms per hectare, on number of days (X) to harvest date.

Table A2—Regression equations for seasonal trends of crude protein[1] and accumulating forage yields[2] of six warm season grasses.

Graph	Figure no.	Parabolic regression	R^2 value
Switchgrass			
Crude protein	11	$Y = 17.3 - .265X + .0015X^2$	.85
Total dry matter	12	$Y = 1150 + 128X - .67X^2$	.96
Digestible dry matter	12.22	$Y = 870 + 65X - .36X^2$	.93
Big bluestem			
Crude protein	13	$Y = 15.9 - .191X + .0010X^2$	.91
Total dry matter	14	$Y = -162 + 137X - .72X^2$	.97
Digestible dry matter	14	$Y = 52 + 73X - .40X^2$	.94
Sand bluestem			
Crude protein	13	$Y = 16.4 - .244X + .0014X^2$	.89
Total dry matter	15	$Y = -150 + 104X - .53X^2$	.93
Digestible dry matter	15	$Y = 82 + 53X - .27X^2$	.88
Little bluestem			
Crude protein	16	$Y = 16.9 - .169X + .0008X^2$	.86
Total dry matter	17	$Y = 584 + 10.3X - .0351X^2$	.79
Digestible dry matter	17	$Y = 386 + 6.53X - .0078X^2$	.69
Sideoats grama			
Crude protein	16	$Y = 20.5 - .287X + .0016X^2$	.87
Total dry matter	18	$Y = 336 + 6.15X - .0255X^2$	.39
Digestible dry matter	18	$Y = 218 + 3.08X - .0171X^2$	.37
Holt indiangrass			
Crude protein	19	$Y = 14.8 - .158X + .0008X^2$	.73
Total dry matter	20	$Y = 373 + 10.2X - .0139X^2$	.88
Digestible dry matter	20	$Y = 261 + 5.40X - .0064X^2$	.89
Oto indiangrass			
Crude protein	19	$Y = 20.1 - .225X + .0011X^2$	.93
Total dry matter	21	$Y = 796 + 20.5X - .0512X^2$	.77
Digestible dry matter	21	$Y = 568 + 12.2X - .0276X^2$	.72

[1] Parabolic regressions for crude protein content (Y) in percent, on number of days (X) to harvest date.

[2] Parabolic regressions for forage yields of dry matter (Y) in kilograms per hectare, on number of days (X) to harvest date.

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