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CONTENTS

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Performance Evaluation Of Some Warm-Season Prairie Grasses In Nebraska Environments

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INTRODUCTION

Objectives of these experiments were to study and compare establishment of stands, fertility responses, and forage yields of certain warm-season grass varieties and experimental strains in Nebraska locations which differed in soil and climatic conditions.

The perennial warm-season prairie grasses are an important part of the total forage resources which provide grazing in the Plains states. Revegetation of marginally productive land with these perennial prairie grasses is a part of present-day agricultural and conservation programs. Plantings are made for multiple uses in a diversity of soil types and climates. Different kinds and varieties of grasses are required for the wide range of environmental conditions encountered. Seed of unknown origin or grass strains obtained from distant sources frequently fail to establish stands in a different environment or to persist with adequate production under use. Accordingly, the need is met by varieties developed from prairie sources with adaptation to these particular environments.

Harlan (4) and Keim and Newell (6) have described the historical uses of the native prairie grasses for revegetation in the Great Plains. Comparisons of prairie vegetation before and after the drought of the 1930's have provided information for the selection of suitable kinds of grasses (Weaver *et al.* 25, 26). A part of the grass breeding program at the University of Nebraska is conducted with several of the most prominent warm-season

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Cooperative investigations of the Nebraska Agricultural Experiment Station and the Plant Science Research Division, Agricultural Research Service, U. S. Department of Agriculture.

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prairie grasses (12, 13, 14, 17). Grass strains are selected and developed for superior characteristics of seed quality, stand establishment, forage production, and adaptation to the central latitudes.

Management practices for obtaining superior yields of forage and seed have been studied for the warm-season side-oats grama by Smika and Newell (20). Production practices for western wheatgrass, a cool-season grass, were also studied (21). Effects of nitrogen fertilization and clipping management regimes were studied for two tall prairie grasses. Big bluestem and switchgrass strains collected from diverse origins in the Great Plains and adjacent prairies were compared at three locations in Nebraska in a four-year period (8). Although the response of these two grasses to nitrogen fertilization was not apparent early in the experiment, there were marked and significant cumulative yield effects over the years. Some establishment and yield responses to fertilization of grass strains compared in this experiment were given in a preliminary report (22).

Responses to fertilization under favorable conditions found on some subirrigated meadows or in a year of high precipitation are often in contrast to responses under unfavorable conditions of upland fertilization in dry years. Burzlaff *et al.* (1), in a study of western Nebraska range, found that an application of nitrogen fertilizer in one year increased yields and protein of forage but that the increased yields were not accompanied by major changes in development of underground parts. Russell *et al.* (19) and Ehlers *et al.* (3) found that combinations of nitrogen and phosphorus fertilizers on subirrigated meadows in Nebraska gave greater yield increases, increased forage ultilization and altered botanical composition more than either fertilizer applied alone. Associated changes in chemical composition of the hay were attributed to these changes in botanical composition.

Rogler and Lorenz (18) reported favorable responses to nitrogen fertilization of the western wheatgrass and other cool-season grasses in the natural vegetation of the Northern Great Plains. Nichols and McMurphy (15) found that largest increases in the yield of western wheatgrass in South Dakota resulted from applications of 120 lb. N/A in conjunction with 2 lb./A of 2,4-D for forb control. N-fertilization and forb control treatments were more effective together than either treatment alone. Effects were cumulative and persisted for several years.

In contrast, the fertilization of native pastures of warm-season grasses in one Oklahoma experiment increased annual weed production two to five times with little effect on yield of the warm-season perennial grasses (5). Owensby *et al.* (16) reported increased dry matter yields from nitrogen applied to plots

of upland bluestem ranges in Kansas in years of normal or above-normal precipitation. Nitrogen fertilization also increased crude protein of the forage and moisture-use efficiency was highest on the nitrogen plots but there was a shift in vegetative composition toward cool-season grasses, principally Kentucky bluegrass.

Klingman and McCarty (7) in studies of pasture management and weed control near Lincoln, Nebr., noted changes in botanical composition from warm-season to cool-season grasses or the reverse depending upon which were favored during critical growth stages by soil moisture conditions, intensity of grazing or mowing, application of 2,4-D, or nitrogen fertilization.[4] Weaver *et al.* (23, 24) studied changes in the true prairie in eastern Nebraska caused by the drought of 1934-1940 and noted the invasion of western grasses from the mixed prairie as a result of competition for limited soil moisture.

In regions of low rainfall the establishment and subsequent yields of new grass plantings are frequently limited by inadequate soil moisture. However, many controllable factors are involved in the establishment of good stands, such as the timing and manner of seedbed preparation, the proper time and method of planting, as well as the use of adapted, improved varieties. Such practices as weed control, time and frequency of mowing or grazing, and adequate fertility on problem sites are critical for the establishment and maintenance of stands and for profitable yields. Failure to consider any one factor may offset all other factors in the success of grass plantings.

LOCATIONS, MATERIALS, METHODS

Studies of establishment and subsequent forage evaluation of strains and varieties of warm-season prairie grasses were conducted at 12 locations in Nebraska from plantings made in a three-year period, 1961-1963. Observational and yield data were obtained in the ensuing years following planting, 1961 through 1969.

Test Locations

Test plots were established at 12 locations by Outstate Testing personnel of the Nebraska Agricultural Experiment Station. Four tests were established in each of the years 1961, 1962, and 1963 (Fig. 1). These tests were located from southwest and south central to northeast in Nebraska on typical problem sites where

[4]M. K. McCarty. Personal communication on the changes in botanical composition of pastureland resulting from nitrogen fertilization.

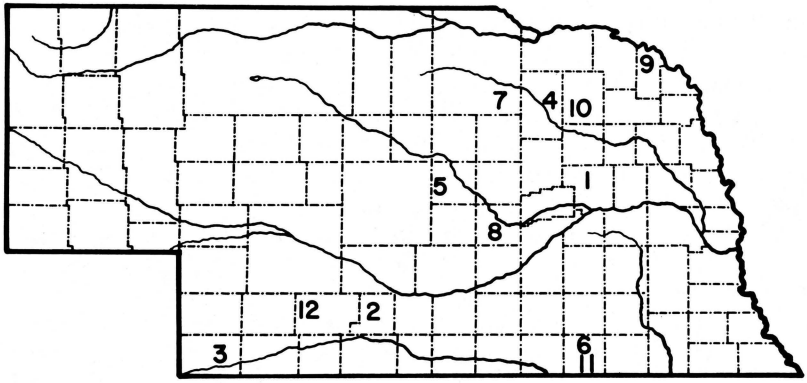

Figure 1.—County location of 12 Nebraska tests of warm-season prairie grasses: Planted in 1961 — 1, Platte; 2, Gosper; 3, Dundy; 4, Antelope. Planted in 1962 — 5, Valley; 6, Thayer 1; 7, Holt; 8, Howard. Planted in 1963 — 9, Dixon; 10, Pierce; 11, Thayer 2; 12, Frontier.

grass plantings are a part of recommended conservation programs.

The counties selected for tests were representative of a transition belt in the state with respect to soil type, average annual rainfall and length of season for growth. Annual rainfall averages for these locations range from 16 inches in Dundy County in the southwest to 23-24 inches in Pierce, Antelope, and Dixon Counties in the northeast; and to 27 inches in Thayer County in the south central area of the state.

Planting sites in each county were selected with the help of the County Agricultural Extension Agent and the Work Unit Conservationist of the Soil Conservation Service. Table 1 gives the county location, the year of planting, and the names and addresses of the cooperators. Planting sites were later characterized from the analyses of soil samples taken before planting and by soil type and slope.[5]

Strains and Varieties

The warm-season grasses evaluated were six named check varieties and certain grass strains developed in the breeding program of the Nebraska Agricultural Experiment Station in cooperation with the Plant Science Research Division, Agricultural Research Service, U. S. Department of Agriculture. Single entries in each of five cool-season grasses were also compared. The experimentals included selections and synthetic strains.

[5]The sites were classified in regard to soil type and slope by Dr. James Drew, Professor of Agronomy, University of Nebraska.

Table 1.—County and farm location and year of planting of the 12 grass test comparisons.

County location[a]		Year planted	Cooperator and address
1	Platte	1961	Marvin Rickert, Leigh
2	Gosper	1961	William Umberger, Elwood
3	Dundy	1961	Roy Dean Parker, Benkelman
4	Antelope	1961	Ferd F. Reinke, Neligh
5	Valley	1962	Orville Lueck, Arcadia
6	Thayer 1	1962	Carl and Roland Meyer, Hubbell
7	Holt	1962	Walter Fick, Inman
8	Howard	1962	Ted Prince, St. Paul
9	Dixon	1963	Dale Tracy, Ponca
10	Pierce	1963	August Nave, Pierce
11	Thayer 2	1963	Carl and Roland Meyer, Hubbell
12	Frontier	1963	Theo. Russell and Son, Maywood

[a]Number refers to location of the county shown in Figure 1.

Selections were entries from a single source, whereas synthetics were strains of divergent genetic make-up involving more than one source of parent stock.

Some changes in entries occurred each year of planting. New strains were introduced as seed became available and some entries included in the early plantings were discontinued. In the three years, a total of 30 warm-season grass strains were established at the different locations (Table 2). (See Appendix A for scientific names of grasses.) During the period of evaluation which followed, three of the experimental strains were named and released for seed and forage production.

The switchgrass entries were Nebraska 28 and seven experimental strains. Nebraska 28 is a moderately early variety arising from one generation of selection among spaced plants grown from a 1935 collection made in Holt County, Nebr. It is relatively small and fine-stemmed. The comparisons in these tests were part of the basis for release of Pathfinder switchgrass in 1967 (9). Pathfinder is a late-maturing variety which traces to clones selected from the 1953 Domestic Collections in Nebraska and Kansas.

The indiangrass entries were Holt and three late-maturing experimental strains. Holt was released in 1960 (11) from seed increase tracing to a collection in the Elkhorn Valley of Holt County. It was selected from comparisons among a large number

Table 2—Numbers of varieties and experimental strains of warm-season grasses planted in three years for comparisons in 12 Nebraska outstate grass tests.[a]

Variety or strain	Location in 1961[b]				Location in 1962[b]				Location in 1963[b]			
	1	2	3	4	5	6	7	8	9	10	11	12
Switchgrass												
Nebr. 28	1	1	1	1	1	1	1	1	1	1	1	1
Experimentals	7	7	7	7	5	6	4	5	6	6	5	5
Indiangrass												
Holt	1	1	1	1	1	1	1	1	1	1	1	1
Experimentals	3	3	3	3	3	3	2	3	3	3	3	3
Tall bluestems												
Pawnee	1	1	1	1	1	1	1		1	1	1	1
Kaw							1		1	1	1	1
Champ					1	1	1		1	1	1	1
Exp. Big Bluestem					1	1	1	1	1	1	1	1
Exp. Synthetic	3	3	3	3	3	3	2	3	3	3	3	3
Exp. Sand bluestem	2	2	2	2	1	2	1	1	2	2	2	2
Little bluestem												
Experimentals					3	4	3	3	4	4	4	4
Side-oats grama												
Butte	1	1	1	1	1	1	1	1	1	1	1	1
Trailway	1	1	1	1	1	1	1	1	1	1	1	1
Experimental	1	1	1	1	1	1	1	1	1	1	1	1

[a]Cool-season grasses planted in 1962 and 1963 for spring-planting comparisons included Lyon bromegrass, Nebr. 50 intermediate wheatgrass, and experimental strains of tall wheatgrass, crested wheatgrass, and western wheatgrass.

[b]Planting locations indicated by number refer to county locations: 1—Platte; 2—Gosper; 3—Dundy; 4—Antelope; 5—Valley; 6—Thayer 1; 7—Holt; 8—Howard; 9—Dixon; 10—Pierce; 11—Thayer 2; 12—Frontier.

of collections in the Nebraska Sandhills and adjacent areas. Holt matures seed early and is adapted for seed production in relatively short seasons. The experimental indiangrass strains were developed for late maturity from southern Nebraska and Kansas sources. One of these, Oto indiangrass, was released in 1970.

The tall bluestem entries included: the big bluestems, Pawnee, Kaw and one experimental selection; two experimental sand bluestems; and four synthetic strains of big bluestem and sand bluestem that included Champ. These entries traced to collections made by the Nebraska Agricultural Experiment Station with the exception of Kaw, a variety developd at the Kansas Agricultural Experiment Station. Pawnee and Champ were released in 1963 during the early period of these investigations (9). Pawnee is a big bluestem synthetic variety which traces to collections made in 1938 from typical prairie in Pawnee County, Nebr. Champ bluestem is an interbreeding population of divergent types in the taxon comprising big bluestem and sand bluestem (17). It is characterized as moderately late-maturing, and intermediate to parent types for characteristics such as basal spread, culm and glume color, foliage color, awn length, and villousness.

The little bluestem entries were six experimentals, only 3 or 4 of which were available for comparison in any one planting. These experimental strains were inclusive of Blaze which was released in 1967 with data from these tests contributing to the information for its release (9). Blaze was developed by hybridizing 15 clones derived from collections made in natural prairies of Nebraska and Kansas.

The side-oats grama entries were Butte and Trailway, both released in 1958 (10), and one experimental synthetic. Butte originated from two strains collected in Holt and Platte Counties. Butte is early maturing and has relatively large caryopses. Trailway traces to a hybrid population collected near O'Neill, Nebr. Trailway is later maturing than Butte. The experimental synthetic is an advanced generation hybrid developed from the two varieties.

Five cool-season grasses were included for general observation and comparisons in the April plantings in the 1962 and 1963 tests. The cool-season grasses included: Lyon bromegrass, Nebraska 50 intermediate wheatgrass and experimental strains of tall wheatgrass, crested wheatgrass, and western wheatgrass.

Planting, Fertilizing, Harvesting

Planting sites were selected with respect to seedbed provided by the previous crop. Seedbeds were in milo stubble at seven of the planting sites (Locations 1, 2, 3, 6, 8, 11, 12). In Antelope

Table 3.—The year and the rate of nitrogen fertilization given to blocks or replications of grass strains in the Nebraska Tests.[a]

		Follow-up nitrogen fertilization of 2 blocks originally fertilized at planting					Follow-up nitrogen fertilization on all four blocks at a location		
		1961	1962	1963	1964	1965	1966	1967	1968
1	Platte	planted		40	40				
2	Gosper	planted		30	30	30	30	30	
3	Dundy	planted		30	30	30	30	30	
4	Antelope	planted							
5	Valley		planted		40	40			
6	Thayer 1		planted			40			
7	Holt		planted		40				
8	Howard		planted		40				
9	Dixon			planted	40	40	40	40	40
10	Pierce			planted	40	40	40		
11	Thayer 2			planted		40	40	40	40
12	Frontier			planted					

[a]Figures of 30 and 40 refer to the approximate pounds per acre of nitrogen applied as ammonium nitrate fertilizer to replications of grass strains in the designated year.

County the previous crop was sorghum and in Pierce County it was corn. Sudangrass was the seedbed stubble at the sites in Valley, Holt, and Dixon Counties.

Seeding rates for all grass strains were calculated for planting approximately 30 viable seeds per square foot. Planting was in April each year with a belt seeder designed for uniform seed distribution. In 1961 and 1962 the plot size was 5 x 25 feet (6 rows, 10 inches apart) while in 1963 the plot size was 5 x 50 feet. At each planting site, all strains were planted in each of 4 blocks or replications which sampled different positions on the slope.

At planting time two of the four blocks of entries at each planting site were fertilized with ammonium phosphate (8 + 24 + 0 lb./A) applied with the seed. Beginning in 1963 or after stands of the grasses had been established at a location, ammonium nitrate fertilizer was applied in late May to the same blocks previously fertilized at planting (Table 3). In Gosper and Dundy the annual follow-up applications of nitrogen were applied at the rate of 30 lb. N/A, whereas 40 lb. N/A was applied as the follow-up treatment at the other locations. Two blocks of entries at each location received no fertilizer until 1966. Beginning in

1966, all four blocks at selected locations received the rate of nitrogen previously applied at that site (Table 3).

Forage harvests were obtained from Dixon, Pierce, Valley and Platte Counties in 1964 and in Gosper, Dundy, Dixon, Pierce and at two Thayer County locations in 1965. Only the plots in Dixon and Pierce were harvested for forage yield in 1966. Forage yields were taken at Gosper, Dundy, Dixon, and Thayer 2 locations in 1967 and the Thayer 2 plots were harvested again in 1968. Forage yields were obtained by mowing 16 square feet from two selected rows of each plot at each location except in 1966, 1967, and 1968 at the Thayer 2, Pierce, and Dixon locations. For these harvests an area of 60 square feet (3 feet x 20 feet) was mowed from each plot.

Evaluation Methods

Stands were evaluated by visual observation with a rating of 1 to 9 given to each plot in one or more years following planting. The rating indices were: 1 = excellent; 3 = good; 5 = average; 7 = fair, and 9 = poor; thus the lower numbers indicate the better stands produced. The ratings were averaged over locations for comparisons among entries and kinds of grass.

Forage samples from each harvest were oven-dried at approximately 185°F. for 3 days and weighed. Forage yields were calculated in tons per acre on a dry-weight basis. Average yields of strain entries were determined for the two soil fertility levels at each location for each harvest. Data were compiled and summarized in selected ways to determine averages of strains, fertility levels, and location environments; and to measure the significance of main effects and their interactions using the Analysis of Variance.

RESULTS OF EXPERIMENTS

The locations of tests represented typical problem sites for planting grass in selected counties from the southwest and south central to northeast Nebraska. These locations provided a broad range of environmental conditions, including differences in precipitation, soil slope, soil type, and soil fertility, as well as weed competition. All of these factors were important in evaluating the grasses.

Soil types ranged from fine sands to silty clay loams (Table 4). Slope of land varied from 1% to 12%. Soil tests taken prior to planting showed pH readings which ranged from 5.4 to 7.9. Available nitrogen in the topsoil ranged from 4 p.p.m. (very low)

Table 4. Soil characteristics of the grass test plots in 12 Nebraska counties.

Location[a]	Soil type	Slope	Sample Tests[b]							
			pH		N (p.p.m.)		P (p.p.m.)		K (p.p.m.)	
			Top	Sub	Top	Sub	Top	Sub	Top	Sub
1. Platte	Moody silty clay loam	4%	6.0	6.4	17 med.	3	15 low	3	320 high	215
2. Gosper	Colby silt loam	5%	7.8	7.9	8 v low	<3	8 low	8	440 high	455
3. Dundy	Colby silt loam	6%	7.3	8.1	9 v low	4	9 low	3	465 high	400
4. Antelope	Thurman fine sand	2%	6.1	6.0	4 v low	4	20 med.	12	115 med.	75
5. Valley	Holdrege silt loam	3%	6.1	6.5	13 low	<3	9 low	6	405 high	395
6. Thayer 1	Hastings silty clay loam	3%	5.8	6.0	12 low	<3	12 low	6	400 high	365
7. Holt	Elsmere loamy fine sand	1%	5.8	5.7	7 v low	<3	22 med.	19	140 med.	115
8. Howard	Thurman fine sand	3%	5.8	6.2	5 v low	<3	>30 v high	11	175 high	180
9. Dixon	Crofton silt loam	12%	7.8	7.8	[c] low		8 low	6	160 high	140
10. Pierce	Valentine loamy sand	3%	6.1	6.5	[c] low		17 med.	7	60 med.	45
11. Thayer 2	Hastings silty clay loam	2%	5.4	5.8	[c] low		14 low	14	285 high	263
12. Frontier	Holdrege silt loam	2%	—	—	[c] low		[c] low		[c] high	

[a]Number refers to the location in county as shown in **Figure 1.**
[b]Top; sample 0-6 inches; Sub: sample 6-12 inches.
[c]Estimate from other sources.

Table 5.—Precipitation during the establishment season and the resulting grass stands at 12 test locations.

	County location	Precipitation		Weed competition	Over-all stand
		April	Apr-Aug.		
		1961			
1	Platte	1.45	14.05	Severe	Good
2	Gosper	1.56	15.10	Little	Excellent
3	Dundy	1.38	15.78	Little	Excellent
4	Antelope	1.24	13.28	Moderate	Poor
		1962			
5	Valley	.89	24.01	Moderate	Excellent
6	Thayer 1	.62	14.35	Severe	Fair
7	Holt	1.35	20.21	Moderate	Fair
8	Howard	.68	19.66	Moderate	Poor
		1963			
9	Dixon	1.65	20.10	Moderate	Good
10	Pierce	1.66	15.27	Moderate	Excellent
11	Thayer 2	3.23	15.67	Moderate	Excellent
12	Frontier	.80	14.81	Moderate	Fair

to 17 p.p.m. (medium). Available phosphorus ranged from 8 p.p.m. (low) to 30 p.p.m. (very high) and available potassium ranged from 60 p.p.m. (low) to 465 p.p.m. (very high).

Variations in seasonal and total precipitation were important considerations in grass establishment and subsequent performance. Records showed that average annual precipitation ranged from 16 to 27 inches for the planting sites. In the years of planting, the April rainfall affecting germination and seedling emergence varied from 0.62 to 3.23 inches on the Hastings silty clay loams of the Thayer County sites and from 0.68 to 1.24 inches on Thurman fine sands in Howard and Antelope, in contrast to April rainfall of 1.66 inches for a Valentine loamy sand in Pierce County (Table 5). Seasonal precipitation (April-August) affecting establishment varied from 13 to 24 inches for the 12 sites.

Precipitation for June, July, and August during years of forage harvest ranged from a low of 6.28 for Dundy County in 1967 to a high of 16.91 inches for Thayer 2 in the summer of 1968. (Table 6).

Table 6.—Precipitation for the season of growth of the harvest year for grass test plots harvested in 1964-1968.

Location of test		Inches of rainfall during year of harvest			
		June	July	August	Total
			1964 Harvests		
1	Platte	4.09	1.09	5.70	10.88
5	Valley	4.87	3.54	4.04	12.45
9	Dixon	3.89	5.14	5.20	14.23
10	Pierce	7.55	4.97	3.60	16.12
			1965 Harvests		
2	Gosper	5.44	6.17	3.12	14.73
3	Dundy	4.77	5.22	4.34	14.33
6	Thayer 1	10.31	4.93	1.43	16.67
9	Dixon	4.20	3.16	2.35	9.71
10	Pierce	4.93	4.62	2.79	12.34
11	Thayer 2	10.31	4.93	1.43	16.67
			1966 Harvests		
9	Dixon	5.18	4.74	3.97	13.89
10	Pierce	4.56	2.47	4.86	11.89
11	Thayer 2	1.83	3.66	2.84	8.33
			1967 Harvests		
2	Gosper	7.93	6.36	2.00	16.29
3	Dundy	3.15	2.12	1.01	6.28
9	Dixon	7.58	2.07	2.62	12.27
11	Thayer 2	7.68	1.11	1.62	10.41
			1968 Harvest		
11	Thayer 2	2.62	4.46	9.83	16.91

Stand Establishment

Differences in local precipitation and soil types undoubtedly influenced establishment conditions. After the grass stands were well established they were evaluated in the 6-row plots (Fig. 2). Good to excellent stands were obtained at 7 of the 12 locations (Table 5). At the Gosper, Dundy, Dixon, and Pierce locations the

Figure 2.—Relative success of stand establishment in planted rows was evaluated for 6-row plots.

good to excellent stands resulted from timely precipitation during the establishment season. Poor stands resulted on the sandy soils in Antelope and Howard Counties. On the silty clay loams of Thayer 1 and Platte sites the weed competition was critical even though initial grass stands were fair to good (Table 5). Even at locations with generally poor stands a few grass strains later became established and produced good stands.

There were no significant benefits from planting-time fertilization (8 + 24 + 0 lb./A) on establishment of any of the grasses as shown by averages of the stand ratings. The average stands obtained from all plots in 10 outstate locations were used to evaluate the different grasses (Table 7). Certain grasses produced superior stands at all locations. Among the tall prairie grasses, switchgrass and indiangrass averaged better initial stands than the bluestems. Of the midgrasses, better initial stands were produced by side-oats grama than by little bluestem. However, important differences occurred among strains of each grass. Early and late maturing strains of switchgrass and indiangrass produced contrasting stands (Table 7 and Fig. 3). Similar trends were evident in the other grasses. Superior initial seedling vigor and continued growth through the summer of the late-maturing grass strains were important in their competition with weeds and thus they produced better stands than early-maturing strains.

Table 7. Relative stands of warm-season grasses obtained in ten Nebraska outstate tests planted in three years.[a]

Variety or strain	Stand ratings[b]			
	4 tests in 1961	3 tests in 1962	3 tests in 1963	Mean 10 tests
Switchgrass				
Nebraska 28	3.9	7.2	4.9	5.7
1 Late Selection	4.5	6.6	5.6	5.6
3 Late Experimentals	3.1	4.1	3.2	3.5
Indiangrass				
Holt	3.8	4.9	5.4	4.7
1 Late Selection	3.8	4.2	4.9	4.3
2 Late Experimentals	3.3	2.0	3.2	2.8
Big bluestem				
Kaw			5.8	
1 Selection			5.3	
Pawnee	4.7	5.2	4.5	4.8
Bluestem Synthetic				
Champ		6.1	5.8	
2 Experimentals	4.7	5.1	4.9	
Sand bluestem				
1 Early Experimental	4.8	7.0	6.4	6.1
1 Late Experimental			5.2	
Little bluestem				
3 Experimentals		4.9	6.9	
Side-oats grama				
Butte	4.5	6.0	4.8	5.1
Trailway	4.6	5.0	3.9	4.5
1 Experimental	4.1	5.1	3.9	4.3

[a]Location of tests:
1961—Antelope, Dundy, Gosper, Platte
1962—Howard, Thayer 1, Valley
1963—Dixon, Pierce, Thayer 2

[b]Averages of comparative ratings from four replications of plots at each location of test in the first and/or second year after planting. Stand ratings expressed in numerals 1 to 9: 1, excellent; 3, good; 5, average; 7, fair; 9, poor.

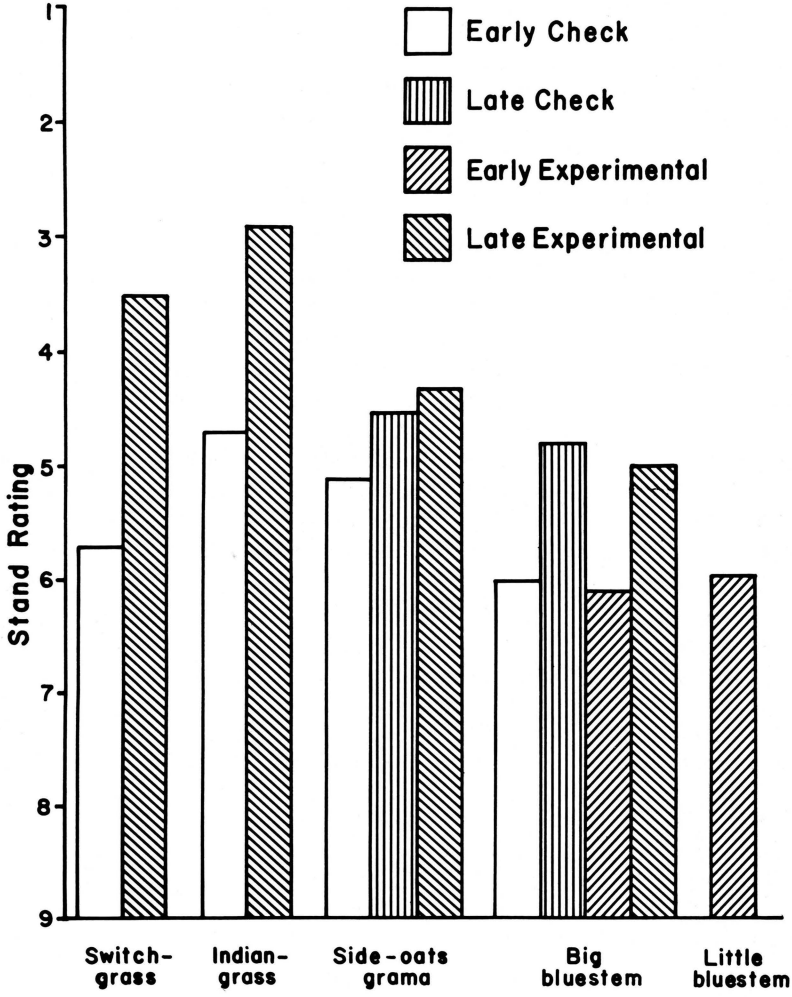

Figure 3.—Average stand ratings of selected check varieties and experimental strains of warm-season grasses planted on problem sites.

The cool-season grasses produced relatively good stands from spring planting although the period for establishment before hot weather was short. Bromegrass, intermediate wheatgrass, and western wheatgrass produced the best initial stands and had the advantage of spread by rhizomes as compared to crested wheatgrass and tall wheatgrass.

Because there were only single entries planted of each of these cool-season grasses, no comparative data were taken. The

plantings demonstrated the relative establishment and competition among cool-season and warm-season grasses from spring establishment but also suggested that comparisons should be made from fall established plots of cool-season grasses in certain areas.

Effects of Location and Fertilization

Average forage yields for each location showed the responses of these warm-season grass strains to applied fertilizer in relation to the age of stand and the environmental conditions imposed by inherent soil fertility and effective precipitation.

The forage yields from fertilized and nonfertilized plots were obtained from harvests in eight of the locations in the two years, 1964 and 1965, to show the effects of early fertilization following establishment of the grasses. The deferred nitrogen fertilization, imposed in 1966 on the previously nonfertilized plots at five of these locations, permitted comparisons of fertility levels of the initial and deferred fertilization regimes from the harvests after 1965. Stand differences among the varieties at four locations (Holt, Howard, Antelope, and Frontier) precluded meaningful forage harvests.

Platte County. Grass test plots in Platte County planted in 1961 were located on a Moody silty clay loam near the top of a hill on a 4% slope. Rainfall was favorable but weed competition was severe during the establishment period (Table 5). Additional nitrogen fertilizer at 40 lb. N/A was applied in May of 1963 and 1964 to the first and third blocks of replications of grass strains which had previously received starter fertilization at planting time (Table 3). Rainfall in the harvest year 1964 was poorly distributed, low in July and normal in June and August (Table 6).

The best comparisons of the effect of fertilization on the 1964 harvests were provided by 12 strains representing 4 grasses. Switchgrass produced the largest average yields (Table 8). Indiangrass and side-oats grama gave the greatest percentage increases from fertilization. For the four grasses, the average increase in the 1964 forage yields resulting from planting time and follow-up N-fertilization compared with no fertilization was 176%.

Valley County. The Valley County test planted in 1962 was on a Holdrege silt loam at the top of a hill on a 3% slope. Rainfall in April was low but a total of 24 inches from April to August provided for excellent stand establishment (Table 5). Weed competition was moderate. Nitrogen fertilizer was applied

Table 8. The 1964 forage yields of warm-season grasses from fertilized and non-fertilized plots established in 1961 in Platte County, Nebraska.

Kind of grass	Fertilization level			Increase from fertilization
	Starter plus 40 lb. N/A in 1963-64[a]	Not fertilized	Av.	
	T/A	T/A	T/A	%
Switchgrass (5 entries)	3.44	1.13	2.28	204
Indiangrass (4 entries)	2.73	0.78	1.76	250
Big bluestem (1 entry)	1.56	1.00	1.28	56
Side-oats grama (2 entries)	1.32	0.35	0.84	277
Average of 4 grasses	2.26	0.82	1.54	176

[a]Starter fertilization with ammonium phosphate (8 + 24 + 0 lb./A) at planting time in 1961 plus ammonium nitrate of 40 lb. N/A in 1963 and 1964.

to replications 1 and 3 in 1964 and 1965. Plots were harvested only in 1964 following the summer period with rainfall totaling 12.45 inches (Table 6).

Switchgrass and indiangrass strains produced the largest forage yields (Table 9). Average increase in forage yields attributed to fertilization was 44% (0.82 to 1.18 T/A). Switchgrass

Table 9. The 1964 forage yields of grasses from fertilized and non-fertilized plots established in 1962 in Valley County, Nebraska.

Kind of grass	Fertilization level			Increase from fertilization
	Starter plus 40 lb. N/A in 1964[a]	Not fertilized	Av.	
	T/A	T/A	T/A	%
Switchgrass (5 entries)	1.38	0.82	1.10	68
Indiangrass (4 entries)	1.60	1.20	1.40	33
Side-oats grama (2 entries)	1.03	0.65	0.84	58
Big bluestem (1 entry)	1.05	0.75	0.90)	38
Tall bluestems (6 entries)[b]	0.98	0.72	0.85)	
Little bluestem (3 entries)[b]	0.89	0.75	0.84	18
Average of 5 grasses	1.18	0.82	1.00	44

[a]Starter fertilization with ammonium phosphate (8 + 24 + 0 lb./A) at planting time in 1962 plus 40 lb. N/A in 1964.
[b]Not included in the analyses of data combined with other locations.

had the largest increase (68%) and little bluestem the smallest (18%).

Thayer 1. The test plots planted in 1962 at the Thayer 1 location were on a hillside with a 3% slope. The soil type was a Hastings silty clay loam. Spring rainfall was meager and only fair stands were obtained, as weed competition was severe (Table 5). A follow-up nitrogen fertilization of 40 lb. N/A was applied in 1965 to the blocks of replications 1 and 3. Forage yields were taken in 1965. The average increase in total forage yield, attributed to the nitrogen fertilization, was 0.87 ton or 54% (1.62 to 2.49 T/A) (Table 10). Yields from the fertilized plots of indiangrass, switchgrass, tall bluestems, and little bluestem exceeded two tons per acre. Side-oats grama gave the lowest yields but the greatest percentage increase from fertilization.

Gosper County. The Gosper County Test planted in 1961 was on a 5% slope of a previously cropped field adjacent to roughly rolling rangeland. The soil type was a Colby silt loam. Excellent initial stands were obtained on this problem site as the rainfall was timely and weed competition was minor (Table 5). Sheet erosion and the resulting poor soil fertility and low soil moisture contributed to poor yields in the early years.

Annual nitrogen fertilizer at 30 lb./A was applied in late May each year, 1963-1965, on the first and third blocks or replications of grass entries. These sets of grass strains gave rapid response in deeper green color of leaves. Although the color differences

Table 10. The 1965 forage yields of grasses from fertilized and non-fertilized plots established at Thayer County 1 in 1962.

Kind of grass	Fertilization level			Increase from fertilization
	Starter plus 40 lb. N/A in 1965[a]	Not fertilized	Av.	
	T/A	T/A	T/A	%
Switchgrass (5 entries)	2.96	1.94	2.45	53
Indiangrass (4 entries)	3.07	2.04	2.55	50
Tall bluestems (7 entries)	2.81	1.92	2.36	46
Side-oats grama (3 entries)	1.25	0.73	0.99	71
Little bluestem (2 entries)	2.38	1.46	1.92	63
Average of 5 grasses	2.49	1.62	2.05	54

[a]Starter fertilization with ammonium phosphate (8 + 24 + 0 lb./A) at planting time in 1962 plus 40 lb. N/A in 1965.

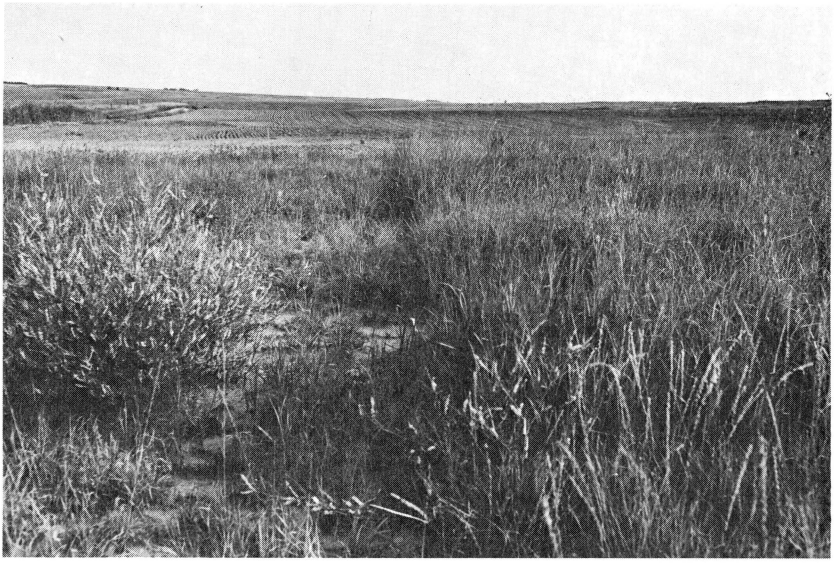

Figure 4.—Test plots at the Gosper County location in June 1965, showing the improved stands and production on fertilized plots (right) compared with plots receiving no fertilization (left) where loss of stands, weed invasion, and soil erosion occurred.

were striking, there were no large yield differences in the first year between the fertilized and non-fertilized blocks. By midsummer of 1965, large differences developed from continued annual fertilizer applications. On the one hand good grassland had been developed on the fertilized plots; whereas on the other hand, losses of stand, weed infestation, and erosion had set in (Fig. 4). Sweetclover was also an invader in the non-fertilized plots.

Although initial stands were excellent, forage yields were not taken until 1965. Average forage yields increased by 229% (0.48 to 1.58 T/A) from the planting time and follow-up fertilizations as compared to no treatment (Table 11). Switchgrass, indiangrass, and bluestem produced relatively good yields with the significant responses to fertilization. Side-oats grama was the lowest yielding grass but it gave the greatest percentage increase from nitrogen fertilization.

In 1966 the plots were mowed at the end of the season but yields were not taken. Yields were again measured in 1967. Rainfall was suitable in June and July but low in August that year (Table 6). Applications of 30 lb. N/A similarly to all four replications in 1966 and 1967 brought the 1967 average forage yields of the grasses to comparable levels for the different fertility practices. However, the switchgrass entries which received fertilizer in each of five years produced 35% larger forage yields than the

Table 11. The 1965 and 1967 forage yields of grasses from different fertilization practices on plots established in 1961 in Gosper County, Nebraska.

Kind of grass	1965				1967			
	Starter plus 30 lb. N/A 1963-64-65[a]	Not fertilized	Av.	Increase from fertilization	Starter plus 30 lb. N/A 1963-67[a]	30 lb. N/A 1966 & 67 only[b]	Av.	Difference
	T/A	T/A	T/A	%	T/A	T/A	T/A	T/A
Switchgrass (6 entries)	1.82	0.57	1.19	219	2.14	1.58	1.86	0.56
Indiangrass (4 entries)	1.61	0.52	1.07	210	1.88	1.86	1.87	0.02
Tall bluestems (5 entries)	1.85	0.59	1.22	214	1.47	1.65	1.56	—0.18
Side-oats grama (3 entries)	1.04	0.26	0.65	300	0.71	0.89	0.80	—0.18
Average of 4 grasses	1.58	0.48	1.03	229	1.55	1.50	1.52	0.05

[a]Starter fertilization with ammonium phosphate (8 + 24 + 0 lb./A) at planting time in 1961, plus 30 lb. N/A annually.

[b]Ammonium nitrate at 30 lb. N/A applied to plots previously not fertilized.

same entries which had been fertilized only in the last two years. The other grasses produced comparable yields for the two fertility regimes.

Dundy County. The Dundy County test planted in 1961 was near the top of a large hill on a 6% slope. The soil type was a Colby silt loam. Previous cropping and sheet erosion had contributed to low soil fertility (Table 4). This site was in the lowest average rainfall area of the tests and was considered one of the more severe problem sites from the standpoint of soil moisture. However, the environmental conditions during establishment exceeded expectations with timely rainfall and minor competition from weeds (Table 5).

Plots in Dundy were managed similarly to those in Gosper. Fertilizer at 30 lb. N/A was applied in late May each year, 1963-65, to two blocks of replications. Non-fertilized plots in Dundy gave similar average yields of grasses in 1965 to those in Gosper but the forage yields from fertilized plots were not as large (Table 12). The forage yield in 1965 was increased 181% by the planting-time and follow-up fertilization as compared to no fertilization. Switchgrass produced the largest yields.

Rainfall for three summer months of 1967 in Dundy (6.28 in.) was 10 inches less than in Gosper (16.29 in.) (Table 6). Total forage yields in 1967 were understandably smaller in Dundy than in Gosper (Table 12). The applications of 30 lb. N/A equally to all four replications of grass strains in 1966 and 1967 brought the 1967 average yields of replications fertilized in the two years to one ton per acre or only 74% of the average yield of 1.35 T/A for the replications which had received additional nitrogen in the five-year period. The largest differences in average yields remaining between the two fertilizer practices were for switchgrass and indiangrass (Table 12).

Antelope County. A Thurman fine sand was selected for the fourth planting in 1961. The plots were on a long 2% slope. There was moderate competition from annual weeds and a droughty condition prevailed. Only poor stands were obtained. Switchgrass and indiangrass produced the best initial stands and there was some seedling establishment in the second year from dormant seed. With some natural reseeding a sufficient stand was obtained after a few years for the cooperator to incorporate the test area into his pasture system. Stand differences among varieties made forage harvests of little value. Follow-up nitrogen fertilizer was not added.

Holt County. The Holt County plantings in 1962 were on generally flat meadowland in the Elkhorn Valley. The site was an Elsmere loamy fine sand with a 1% slope. This area had a

Table 12. The 1965 and 1967 forage yields of grasses from different fertilization practices on plots established in 1961 in Dundy County, Nebraska.

Kind of grass	1965				1967			
	Starter plus 30 lb. N/A 1963-64-65[a]	Not fertilized	Av.	Increase from fertilization	Starter plus 30 lb. N/A 1963-67[a]	30 lb. N/A 1966 & 67 only[b]	Av.	Difference
	T/A	T/A	T/A	%	T/A	T/A	T/A	T/A
Switchgrass (6 entries)	1.57	0.54	1.05	191	1.71	1.14	1.42	0.57
Indiangrass (4 entries)	1.35	0.60	0.98	125	1.49	1.11	1.30	0.38
Tall bluestems (5 entries)	1.11	0.47	0.79	136	1.42	1.24	1.33	0.18
Side-oats grama (3 entries)	0.81	0.11	0.46	636	0.80	0.52	0.66	0.28
Average of 4 grasses	1.21	0.43	0.82	181	1.35	1.00	1.18	0.35

[a]Starter fertilization with ammonium phosphate (8 + 24 + 0 lb./A) at planting time in 1961 plus 30 lb. N/A annually.

[b]Ammonium nitrate at 30 lb. N/A applied to plots previously not fertilized.

relatively high water table in the spring months, favoring plants with roots suited to these depths. Only fair stands were obtained. Initial weed competition appeared moderate but since the weed population included cool-season annual grasses the competition may have been more severe than initially estimated. Nitrogen fertilizer was applied in 1964 but the plots were not harvested for forage because of weeds. The response to fertilizer was similar to reports of fertilization of subirrigated meadows by Russell *et al.* (19).

The test area was mowed for hay in late June of 1963, a critical time for warm-season grasses. The period of spring growth on the cool, wet soil had also given all the advantage to the cool-season weeds. Yields were not taken and in subsequent years the test area was included for harvest in the August mowing of the adjacent meadow for hay.

Howard County. A Thurman fine sand was selected for a planting in Howard County in 1962. The site, on a 3% slope between two grass-covered sandhills, had been in cultivated crops and was subject to wind erosion. Only two experimental indiangrasses produced good stands. Some other strains produced fair stands while many produced very poor stands. Drought was the main factor contributing to the poor establishment. Since stands were variable forage yields were not taken.

In subsequent years a suitable stand was produced from delayed germination of the initial seeding and by reseeding of some of the grasses, so that the cooperator incorporated the test area into his pasture system.

Pierce County. Plantings at the Pierce County location in 1963 were on a Valentine loamy sand near the top of a low hill on a 3% slope. Excellent stands were obtained on this sandy site by timely precipitation (Table 5). Weed competition was moderate. Follow-up nitrogen fertilizer at 40 lb./A was applied in 1964 and 1965 to replications 1 and 3 for the comparisons with no fertilization. In 1966, the 40 lb. N/A was applied to all four replications. Both fertility and rainfall were limiting factors on this sandy soil in the three years of harvest, 1964-1966. Rainfall was considered below normal either in July or in August in these years (Table 6).

The 1964 forage yields in the first year after planting were understandably low. Strain entries of four grasses averaged 35% larger yields from fertilized replications than from those receiving no fertilization (Table 13). Yields of little bluestem were not included in this comparison as the stands remained variable and forage yields reflected no difference between fertilization practices. Switchgrasses gave the largest yields. Strains of the

Table 13. Forage yields of grasses in three years from different fertilization practices on plots established in 1963 in Pierce County, Nebraska.

Kind of grass	1964			1965			1966		
	Starter + 40 lb. N/A 1964[a]	Not fertilized	Increase from N	Starter + 40 lb. N/A '64 & '65[a]	Not fertilized	Increase from N	Starter + 40 lb. N/A 3 yrs. [a]	40 lb. N/A 1966 only[b]	Difference
	T/A	T/A	%	T/A	T/A	%	T/A	T/A	T/A
Switchgrass (7 entries)	0.66	0.54	22	1.59	1.29	23	1.83	1.48	0.35
Indiangrass (4 entries)	0.56	0.41	37	1.29	0.88	47	1.17	0.80	0.37
Tall bluestems (9 entries)	0.23	0.10	130	1.40	1.04	35	1.12	1.18	—0.06
Side-oats grama (3 entries)	0.38	0.29	31	0.53	0.51	4	0.82	0.51	0.31
Average of 4 grasses	0.46	0.34	35	1.20	0.93	29	1.23	0.99	0.24

[a]Starter fertilization with ammonium phosphate (8 + 24 + 0 lb./A) at planting time in 1963 plus 40 lb. N/A annually.

[b]Ammonium nitrate at 40 lb. N/A to plots previously not fertilized.

tall bluestems were the lowest yielding in 1964 but they produced yields second to switchgrasses in 1965. Average yields in 1965 were more than double those of 1964; fertilized replications of the four grasses produced 29% larger yields than those not fertilized.

Average yields in 1966 were similar to those in 1965. Switchgrass again produced the largest yields and increased in yield each year on this sandy site. Side-oats grama increased in yield each year from the repeated fertilization but indiangrass and bluestems attained their best production in 1965.

Dixon County. Plantings at the Dixon County location in 1963 were on a Crofton silt loam with a 12% slope. Good stands were obtained as precipitation was very timely and weed competition was only moderate. Follow-up nitrogen fertilizer at 40 lb./A was applied in 1964 and 1965 to replications 1 and 3 for comparisons with no treatment.

Only the switchgrass and indiangrass entries were harvested in 1964 (Table 14). Both grasses produced larger yields attributable to fertilization (switchgrass from 0.32 to 0.66 T/A and indiangrass from 0.79 to 1.30 T/A). In 1965 all grasses were harvested with the indiangrasses producing the largest yields. The tall bluestems and switchgrasses gave the largest responses to fertilization. Forage yields of little bluestems were not included in this comparison of fertility responses because yields of the young stands reflected differences in stands instead of fertility practices.

The low fertility of the Crofton silt loam is demonstrated by the large response to the planting-time fertilization and follow-up nitrogen fertilizations in 1964 and 1965. In 1965, switchgrass and big bluestem strains gave the largest average responses to fertilization (Table 14). Average yields of the four grasses were increased 80% by the fertilization practice.

Applications of 40 pounds nitrogen per acre were made to all four replications in 1966 to 1968. Each of the four grasses increased in yield each year. Indiangrass produced the largest yield.

Thayer 2. A Hastings silty clay loam with a 3% slope was chosen and planted in 1963 for a second test in Thayer County. Timely precipitation and limited competition from weeds aided in establishment of excellent stands. Nitrogen at 40 lb./A was applied to replications 1 and 3 in late May, 1965, and forage yields were obtained in early September (Table 15). Switchgrass, bluestem, and side-oats grama produced some increases from the added fertility. The average increase from fertilization at planting time and in the harvest year of 1965 was only 9% (2.19 to 2.39 T/A), inasmuch as the soil was already relatively fertile.

Table 14. Forage yields of grasses in four years from different fertilization practices on plots established in 1963 in Dixon County, Nebraska.

Kind of grass	1964			1965			1966			1967		
	Starter + 40 lb. N/A 1964[a]	Not fertilized	Increase from N	Starter + 40 lb. N/A '64, 65[a]	Not fertilized	Increase from N	Starter + 40 lb. N/A '64, 65, 66[a]	40 lb. N/A 1966[b]	Difference	Starter + 40 lb. N/A 4 yrs.[a]	40 lb. N/A 66-67[b]	Difference
	T/A	T/A	%	T/A	T/A	%	T/A	T/A	T/A	T/A	T/A	T/A
Switchgrass (7 entries)	0.66	0.32	106	0.98	0.36	172	1.19	0.63	0.56	1.84	1.59	0.25
Indiangrass (4 entries)	1.30	0.79	64	1.50	1.09	38	1.83	1.08	0.75	2.80	1.93	0.87
Tall bluestems (9 entries)	—	—	—	0.96	0.44	118	1.47	0.82	0.65	2.20	1.75	0.45
Side-oats grama (3 entries)	—	—	—	0.90	0.49	84	1.04	0.51	0.53	1.29	0.69	0.60
Average of four grasses	0.98	0.56	75	1.08	0.60	80	1.38	0.76	0.62	2.03	1.49	0.54

[a]Starter fertilization with ammonium phosphate (8 + 24 + 0 lb./A) at planting time in 1963 plus 40 lb. N/A.

[b]Ammonium nitrate at 40 lb. N/A to plots previously not fertilized.

Table 15. Forage yields of grasses in three years from the 1963 plantings in Thayer County, Nebraska.

Kind of grass	1965			1967			1968		
	Starter + 40 lb. N/A 1965[a]	Not fertilized	Increase from N	Starter + 40 lb. N/A '65, 66, 67[a]	40 lb. N/A '66 & '67[b]	Difference	Starter + 40 lb. N/A '65, 66, 67, 68[a]	40 lb. N/A '66, 67, 68[b]	Difference
	T/A	T/A	%	T/A	T/A	T/A	T/A	T/A	T/A
Switchgrass (6 entries)	2.99	2.56	17	3.02	2.28	0.74	1.99	1.84	0.15
Indiangrass (4 entries)	3.30	3.21	3	1.89	1.73	0.16	3.02	3.42	—0.40
Tall bluestems (9 entries)	2.22	1.99	12	2.03	2.17	—0.14	1.15	1.41	—0.26
Side-oats grama (3 entries)	1.45	1.20	21	1.47	0.82	0.65	0.94	0.70	0.24
Little bluestem (4 entries)	2.00	2.00	0	1.56	1.60	—0.04	1.63	1.32	0.31
Average of 5 grasses	2.39	2.19	9	1.99	1.72	0.27	1.75	1.74	0.01

[a]Starter fertilization with ammonium phosphate (8 + 24 + 0 lb./A) at planting time in 1963 plus 40 lb. N/A.

[b]Ammonium nitrate at 40 lb. N/A to plots previously not fertilized.

The order of average yields was from indiangrass, switchgrass, big and little bluestems to side-oats grama.

Applications of 40 lb. N/A were made equally to all four replications in 1966 to 1968. No forage harvest was made in 1966 as summer rainfall was only half as much as in the previous year (Table 5). April rainfall in 1967 and August rainfall in 1968 were favorable but average forage yields were smaller in 1967 and 1968 than in 1965 (Table 15). Average yields in 1968 from the two fertilization regimes were nearly comparable.

Frontier County. The plantings in Frontier County in 1963 were on a Holdrege silt loam with a 2% slope. Only fair stands were initially obtained because of weed competition and inadequate spring rainfall. Follow-up nitrogen fertilizer was never applied to the variable stands and no forage yields were taken. In later years some plots of the switchgrasses, indiangrasses, and bluestems became very productive. Open stands of other plots were invaded by seedlings of side-oats grama and little bluestem.

Variety and Strain Responses

The test locations from southwest and south central to northeast Nebraska provided a diversity of problem sites for evaluating grass strains. For comparisons of the main effects and interactions, the forage yields from test locations were combined for each of four areas: southwest, east central, south central, and northeast. Varieties and strains were compared also over several years at certain locations .

Yield comparisons at different locations increased the precision by repetition of the strain or variety comparisons (main effects of strains). Average yields also measured similarities and differences among the environments (location effects). Responses to levels of management or fertilization disclosed the variety potentials (treatment effects). Significant changes in relative responses among entries were also measured by interactions (strain x location, strain x fertility level, and strain x year).

Before a variety can be recommended for production in an area, consideration must also be given to competitive growth for establishment, to season of growth and forage quality, and to relative persistence under the management given. Tolerance or resistance to diseases and insects, as well as adequate potential for seed production, are important evaluations over locations and years. Suitability to the purpose for which the planting was made is of prime importance in assuring proper management and the resulting persistence of the planting.

Table 16. The average 1964 forage yields of grass strains harvested in Platte and Valley Counties in east central Nebraska.[a]

Grass strain and relative maturity	Platte (est. 1961)	Valley (est. 1962)	Average yield
	T/A	T/A	T/A
Switchgrass			
Nebraska 28 (early)	1.76	0.70	1.23
1 Selection (late)	2.42	0.98	1.20
3 Experimentals (late)	2.41	1.28	1.84
Mean of 5 strains	2.28	1.10	1.69
Indiangrass			
Holt (early)	2.10	1.36	1.73
3 Experimentals (late)	1.64	1.41	1.53
Mean of 4 strains	1.76	1.40	1.58
Big bluestem			
Pawnee (late)	1.28	0.90	1.09
1 Selection (late)	.....	0.87	.....
Bluestem Synthetic			
Champ (m late)	.....	0.97	.....
Little bluestem			
3 Experimentals (late)	.....	0.84	.....
Side-oats grama			
Butte (early)	0.85	0.86	0.86
1 Experimental (m early)	0.82	0.76	0.79
Trailway (m late)	[b]	0.90	.....
Mean of 3 strains		0.84	
Average of grasses	1.54	1.02	1.30
LSD at P=.05			
Between means of strains	0.55	0.42	0.36
Between mean of 1 strain and a mean of 3 strains	0.45	0.31	0.29

[a]Average yields from 2 fertilized and 2 non-fertilized plots at each location. Refer to Appendix Table 1 for statistical analysis of yields of the 12 strains harvested from both tests.

[b]Plots destroyed.

East Central Nebraska (Platte and Valley, 1964). The 1964 average forage yields in Platte County slightly exceeded 1.5 tons per acre, whereas the 1964 yields in Valley County averaged only a ton per acre (Table 16). The planting in Platte was a year older and was favored by better soil moisture than the Valley

planting. Yield differences in the Platte and Valley tests were highly significant for location effects, fertility levels and differences among strains (Appendix Table 1). The strains responded differently to the different ages of stand and environments at the two locations (S X L) and to the different levels of fertility (S X Fl).

Switchgrass and indiangrass were the outstanding grasses in these tests (Table 16). The average yields of switchgrass in Platte were more than twice those of Valley County, reflecting the age advantage and relatively favorable environment of the Platte site. The three late-maturing experimental switchgrasses, which included the variety later released as Pathfinder, produced larger average forage yields than the earlier maturing Nebraska 28 variety. Indiangrass also gave larger yields from the older stands in Platte. Although Holt gave larger yields than the three experimental strains in Platte, the differences were not significant in Valley County. There were no significant differences among yields of strains of bluestems or side-oats grama in these comparisons.

South Central Nebraska (Thayer 1 & 2, 1965). The plantings of grass strains in Thayer in 1962 were initially regarded as a failure because of poor stands. Plantings were repeated in 1963 on an adjacent section of land with excellent initial stands. Differences in rate of establishment were attributed to differences in rainfall in the two years (Table 5). With the favorable soil moisture situation in 1963, the two sets of plots developed at similar rates. Plots were fertilized and harvested for forage yield comparisons in 1965.

Yields were combined from the two locations for variety comparisons at two fertility levels in one year, 1965 (Table 17). Average yields of the five grasses showed a half-ton per acre or 30% advantage attributable to added fertility. Analyses of variance of the combined yields showed a significant yield difference between fertility levels but no significance between the yields at the two locations with similar soil type and environment (Appendix Table 2).

Early-maturing strains of the grasses proved poorly adapted at the Thayer locations as shown by significantly low yields at both nitrogen fertility levels (Table 17). At this stage of their stand development there was no advantage from fertilization. On the other hand, the late-maturing strains produced larger yields from fertilized plots than from no-fertility treatment. The three late indiangrass experimentals were superior in average yield to the early maturing variety, Holt. Pawnee, Champ and Kaw gave the largest yields of the bluestems. Trailway side-oats

Table 17. Average 1965 forage yields of grass strains from the 1962 and 1963 plantings in south central Nebraska (Thayer 1 and Thayer 2).

Grass strain and relative maturity		Starter + 40 lb. N/A in 1965[a]	Not fertilized[a]	Average yield[b]
		T/A	T/A	T/A
Switchgrass				
Nebraska 28	(early	1.51	1.87	1.69
1 Selection	(late)	3.00	2.04	2.52
3 Experimentals	(late)	3.37	2.38	2.87
Mean of 5 strains		2.92	2.21	2.56
Indiangrass				
Holt	(early)	2.43	2.59	2.51
3 Experimentals	(late)	3.44	2.64	3.04
Mean of 4 strains		3.19	2.63	2.91
Big bluestem				
Pawnee	(late)	3.22	2.40	2.81
Kaw	(late)	3.09	2.02	2.56
1 Selection	(late)	2.23	1.91	2.07
Bluestem Synthetic				
Champ	(m late)	3.16	2.41	2.78
2 Experimentals	(m late)	2.53	2.14	2.33
Sand bluestem				
1 Experimental	(early)	0.81	0.98	0.90
1 Experimental[c]	(late)	1.98	1.16	1.57
Mean of 8 strains		2.45	1.90	2.17
Side-oats grama				
Butte	(early)	0.99	0.76	0.87
1 Experimental	(m early)	1.37	0.96	1.16
Trailway	(m late)	1.69	1.17	1.48
Mean of 3 strains		1.35	0.96	1.15
Little bluestem				
2 Experimentals	(late)	2.29	1.66	1.97
Average of 5 grasses		2.44	1.87	2.15
LSD at P=.05				
Between means of strains				0.48
Between a mean of 1 and a mean of 3 strains				0.33
Between a mean of 3 and a mean of 3 strains				0.28

[a]Mean yields from four replications, 2 from each location (see statistical analysis in Appendix Table 2).

[b]Mean yields from the eight replications in both tests.

[c]These yields were from only one location (Thayer 2). They were not included in the statistical analysis.

grama gave larger yields than Butte. The late-maturing switchgrasses yielded better than Nebraska 28. However, the late-maturing switchgrass and bluestem selections from single sources were inferior to the late-maturing synthetic strains in these groups.

Southwest Nebraska (Gosper and Dundy, 1965 & 1967). Stands of grasses in the southwest test locations were relatively slow in attaining large yields. Although both locations had periods of moisture stress, Dundy was the more severe site as judged by average yields of 0.82 T/A and 1.18 T/A for the two years, compared with 1.03 and 1.53 T/A for Gosper. Forage yields from the two locations were combined in each of 1965 and 1967 (Table 18). There were no significant yield differences between the locations in 1965 but the favorable yield increase in Gosper in 1967 was statistically significant over Dundy in location effect (Appendix Table 3). Differences in fertility levels from nitrogen fertilization were highly significant in 1965 and these differences persisted in 1967 in Dundy (Tables 11 and 12). Strain differences were highly significant in both years. Strain interactions with location and with fertility levels were highly significant in 1965 but not in 1967 (Appendix Table 3).

Three late-maturing synthetic strains of switchgrass gave larger yields than two early-maturing selections, as averages from the two locations in both years. The late-maturing selection was intermediate in yield between these groups. Likewise one of the long-season indiangrasses was lower yielding than the other two late-maturing strains. Holt was slow in establishment with low 1965 yields at both locations but it increased in yield in the 1967 harvest. There were persistent differences shown among strains of bluestems and side-oats grama.

Northeast Nebraska (Pierce & Dixon, 1965-1967). Forage yields from northeastern Nebraska test sites were summarized in two ways. Pierce and Dixon yields were combined for each of the years 1965 and 1966 and for each location the yields were combined from the two years with best yields. Average yields of the five grasses in Pierce were 1.09 and 1.12 T/A in 1965 and 1966, respectively (Table 19). Average yields of the five grasses in Dixon increased from 0.87 to 1.22 and 1.80 T/A in the three-year period 1965 through 1967 (Table 19).

Analysis of variance each year showed no significant differences in yields from the two locations or from different fertility regimes, because of large block errors from differences attributed to slope (Appendix Table 4). However, fertilizer was applied equally to blocks beginning in 1966. Because of early stand ir-

Table 18.—Forage yields of grass strains from the 1965 and 1967 harvests in two southwestern Nebraska counties.

Grass strain and relative maturity	Gosper		Dundy		2 Locations		Average yield
	1965[a]	1967[b]	1965[a]	1967[c]	1965[d]	1967[e]	
	T/A	T/A	T/A	T/A	T/A	T/A	T/A
Switchgrass							
Nebraska 28 (early)	0.94	1.50	0.61	1.08	0.78	1.29	1.03
1 Experimental (early)	0.88	1.46	0.88	1.18	0.88	1.32	1.10
1 Selection (late)	1.09	1.81	1.00	1.48	1.04	1.64	1.34
3 Experimentals (late)	1.42	2.13	1.28	1.60	1.34	1.86	1.60
Mean of 6 strains	1.19	1.86	1.05	1.42	1.12	1.64	1.38
Indiangrass							
Holt (early)	0.62	1.79	0.70	1.28	0.66	1.53	1.10
1 Experimental (late)	1.18	1.54	0.92	1.09	1.05	1.31	1.18
2 Experimentals (late)	1.24	2.08	1.14	1.41	1.19	1.74	1.46
Mean of 4 strains	1.07	1.87	0.98	1.30	1.02	1.58	1.30
Big bluestem							
Pawnee (late)	0.82	1.81	0.60	1.30	0.71	1.55	1.13
Bluestem Synthetic							
2 Experimentals (m late)	1.30	1.61	0.80	1.30	1.05	1.45	1.25
Sand bluestem							
2 Experimentals (early)	1.34	1.39	0.88	1.39	1.11	1.39	1.25
Mean of 5 strains	1.22	1.56	0.79	1.33	1.00	1.45	1.22
Side-oats grama							
Butte (early)	0.49	0.84	0.30	0.48	0.40	0.66	0.53
1 Experimental (m early)	0.81	0.75	0.47	0.75	0.64	0.75	0.69
Trailway (m late)	0.66	0.82	0.60	0.75	0.63	0.78	0.70
Mean of 3 strains	0.65	0.80	0.46	0.66	0.55	0.73	0.64
Average of 4 grasses	1.03	1.53	0.82	1.18	0.92	1.35	1.13
LSD at P=.05							
Between means of strains					0.26	0.38	.....
Between a mean of 1 strain and a mean of 3 strains					0.21	0.31	.....

[a]Average 1965 yields from four replications: 2 non-fertilized and 2 fertilized plots of each strain. Refer to Appendix Table 3 for statistical analysis.

[b]Average 1967 yields for three replications of plots fertilized similarly in 1966-67.

[c]Average 1967 yields from four replications of plots fertilized similarly in 1966-67.

[d]Average of 1965 yields from eight replications.

[e]Average of 1967 yields from seven replications.

Table 19.—Comparisons of forage yields of grass strains from harvests in Pierce and Dixon Counties in northeastern Nebraska.

Grass strain and relative maturity	Pierce yields[a]			Dixon yields[a]			
	1965	1966	65-66 Av.	1965	1966	1967	66-67 Av.
	T/A	T/A	T/A	T/A	T/A	T/A	T/A
Switchgrass							
Nebraska 28 (early)	1.32	1.49	1.40	0.62	0.88	1.75	1.31
1 Experimental (early)	1.29	1.46	1.37	0.48	0.77	1.47	1.12
1 Selection (late)	1.23	1.63	1.43	0.66	0.70	1.28	0.99
4 Experimentals (late)	1.56	1.76	1.66	0.75	1.01	1.87	1.44
Mean of 7 strains	1.44	1.66	1.55	0.68	0.91	1.71	1.31
Indiangrass							
Holt (early)	0.94	1.09	1.01	1.19	1.36	2.60	1.98
3 Experimentals (late)	1.13	0.95	1.04	1.33	1.49	2.29	1.89
Mean of 4 strains	1.08	1.02	1.03	1.29	1.46	2.37	1.92
Big bluestem							
Pawnee (late)	1.16	0.96	1.06	0.84	1.10	2.64	1.87
Kaw (late)	1.33	0.99	1.16	0.73	1.10	1.61	1.36
1 Selection (late)	1.08	1.03	1.05	0.63	0.95	1.60	1.28
Bluestem Synthetic							
Champ (m late)	1.45	1.30	1.37	0.66	1.22	2.20	1.71
3 Experimentals (m late)	1.27	1.28	1.28	0.72	1.57	2.09	1.83
Sand bluestem							
1 Experimental (early)	0.89	1.01	0.95	0.47	1.06	1.85	1.45
1 Experimental (late)	1.25	1.27	1.26	0.78	1.16	1.77	1.46
Mean of 9 strains	1.22	1.16	1.19	0.70	1.26	1.99	1.62
Side-oats grama							
Butte (early)	0.43	0.53	0.48	0.67	0.66	1.06	0.86
1 Experimental (m early)	0.53	0.80	0.66	0.81	0.91	0.93	0.92
Trailway (m late)	0.60	0.66	0.64	0.60	0.76	0.77	0.76
Mean of 3 strains	0.52	0.66	0.59	0.69	0.78	0.92	0.85
Little bluestem							
1 Experimental (early)	1.37	1.46	1.41	0.78	1.61	2.16	1.88
3 Experimentals (late)	1.14	0.98	1.06	1.02	1.75	1.96	1.85
Mean of 4 strains	1.20	1.10	1.15	0.96	1.72	2.01	1.86
Average of 5 grasses	1.09	1.12	1.10	0.86	1.22	1.80	1.51
LSD at P=.05							
Between means of strains			0.35				0.47
Between a mean of 1 with a mean of 3 strains			0.25				0.38
Between a mean of 3 with a mean of 3 strains			0.20				0.27

[a]Average yields across fertility levels from four replications at each location in each year of harvest. Refer to Appendix Tables 4 and 5 for statistical analyses.

regularities at the Pierce location, the comparisons of yields of little bluestem were omitted from the 1965 analysis. Differences among the strains and the strain by location interaction were highly significant in both years. Switchgrass strains produced larger yields in Pierce than in Dixon in 1965 and in 1966 whereas indiangrass and side-oats grama produced larger yields in Dixon than in Pierce for those years (Table 19). The trend of average yields of the tall bluestems was for larger yields in Pierce than in Dixon in 1965 but not in 1966. Yields of most strains were larger in 1967 in Dixon than previous yields at either location.

Analysis of variance of yields in two years at the same location showed differences among strains were highly significant for both Pierce and Dixon yields (Appendix Table 5). There were no significant differences between the average yields in the two years in Pierce but the grasses continued to increase significantly in yield in Dixon through 1966 and 1967. The large variation in average yields among blocks or replicates of strains in Pierce was present in the two years whereas in Dixon the block error was smaller than in Pierce.

Fertility regimes remained significantly different in 1966 and 1967 in Dixon (Appendix Table 5) since yields continued to improve through additions of fertilizer over the four-year period as compared to additions only in the last two years (Tables 14 and 19). Strains of grasses gave similar yields at different fertility levels and in different years as shown by low mean squares for these interactions (S X Fl and S X Y) in both Pierce and Dixon analyses (Appendix Tables 4 and 5).

At the Pierce location switchgrasses outyielded other grasses (Table 19). Four experimental synthetics gave larger two-year average yields than two early-maturing switchgrasses. Champ and one experimental little bluestem gave the largest yields among the bluestems.

As an average of the 1966-67 yields in Dixon the indiangrasses gave the most production followed by the bluestems (Table 19). Pawnee big bluestem, the four bluestem synthetics as a group and four little bluestems produced significantly larger yields than the variety Kaw. No significant differences were shown among strains in indiangrass, switchgrass, or side-oats grama in this test.

Eastern Nebraska (Dixon, Pierce, & Thayer 2, in 1965). The 1965 yields from 1963 plantings in the three eastern Nebraska locations were combined for a comparison of strains and interactions. Average yields indicated that the Dixon County site (0.87 T/A) was more severe for establishment and early production than the Pierce site (1.09 T/A) and the Thayer 2 location (2.29 T/A) (Table 20).

Table 20.—Comparison of the 1965 forage yields of grass strains from the 1963 plantings in three eastern Nebraska counties.[a]

Grass strain and relative maturity		Dixon	Pierce	Thayer (2)	Average yield
		T/A	T/A	T/A	T/A
Switchgrass					
Nebraska 28	(early)	0.62	1.32	1.74	1.23
1 Selection	(late)	0.66	1.23	2.56	1.48
4 Experimentals	(late)	0.75	1.56	3.08	1.80
Mean of 6 strains		0.71	1.46	2.77	1.65
Indiangrass					
Holt	(early)	1.19	0.94	2.90	1.68
3 Experimentals	(late)	1.33	1.13	3.37	1.94
Mean of 4 strains		1.29	1.08	3.25	1.87
Big bluestem					
Pawnee	(late)	0.84	1.16	2.95	1.65
Kaw	(late)	0.73	1.33	2.35	1.47
1 Selection	(late)	0.63	1.08	2.03	1.25
Bluestem Synthetic					
Champ	(m late)	0.66	1.45	2.83	1.65
3 Experimentals	(m late)	0.72	1.27	2.17	1.39
Sand bluestem					
1 Experimental	(early)	0.47	0.89	0.70	0.69
1 Experimental	(late)	0.78	1.25	1.57	1.20
Mean of 9 strains		0.70	1.22	2.10	1.34
Side-oats grama					
Butte	(early)	0.67	0.43	0.98	0.69
1 Experimental	(m early)	0.81	0.53	1.45	0.93
Trailway	(m late)	0.60	0.60	1.54	0.91
Mean of 3 strains		0.69	0.52	1.32	0.84
Little bluestem[b]					
4 Experimentals		0.96	1.20	2.00	1.39
Average of 5 grasses		0.87	1.09	2.29	1.41

LSD at P=.05	
Between means of strains	0.34
Between a mean of 1 strain with a mean of 3 strains	0.28
Between a mean of 3 strains with a mean of 3 strains	0.20

[a]Average yields across fertility levels from four replications at each location.

[b]Yields of little bluestem not included in the statistical analysis of Appendix Table 6.

The strain by location interaction was previously shown to be low and not significant for the two Thayer locations but significant for Dixon-Pierce (Appendix Tables 2 and 4). Analysis of variance of data from the three locations (Appendix Table 6) show a highly significant S X L interaction similar to that for the two locations (Appendix Table 4). There were highly significant differences among locations and among strains. Fertility levels differed at the 10% level of significance.

Differences in strain responses at the three sites caused the strain by location interaction. Indiangrasses led in average yields of first harvests from plots in their third year but were second place to switchgrasses in the sandy soil of Pierce. Switchgrasses were highest in average yields in Pierce but second to indiangrass in Dixon and Thayer. Late-maturing strains were relatively more productive than early-maturing strains in Thayer than they were in Dixon and Pierce. Outstanding in these comparisons of average over-all yields were the late-maturing switchgrass experimentals including Pathfinder which gave yields significantly larger than the late selection from one source and the early-maturing variety.

South Central Nebraska (Thayer 2—1965, 1967, 1968). The 1963 planting in Thayer produced some of the largest yields of the grasses. The initial harvest in 1965 gave the best average yields (Table 21). Yields were maintained at a relatively high level by fertilization of all plots in each succeeding year but average yields were smaller in later harvests.

The combined yields showed significant differencs in production for the three years (Appendix Table 7). The differences in inherent fertility among replicates treated alike was large, causing a significantly large block error. Differences among blocks were minimized by equal application of fertilizer to all blocks in 1966, 1967, and 1968. Differences in yield of strains were highly significant but there was considerable variation in response of the grasses in different years and at different levels of fertility (Appendix Table 7).

Based on the three-year average, indiangrass and switchgrass gave the largest yields as groups of strains; side-oats grama the lowest yield. The late-maturing switchgrasses and indiangrasses gave significantly larger forage yields at this location than the early-maturing varieties, Nebraska 28 and Holt. This generalization regarding relative maturity classes also applies to the yields of late-maturing versus early-maturing strains of sand bluestem and to Trailway versus Butte side-oats grama. Pawnee and Champ bluestems gave significantly larger yields than Kaw or the selected strains and experimentals. Sand bluestem and

Table 21.—Yield comparisons of 26 strains of warm-season grasses harvested in three years from plots established in 1963 in Thayer County, south central Nebraska.[a]

Grass strain and relative maturity		Annual harvested yield			Average Yield
		1965	1967	1968	
		T/A	T/A	T/A	T/A
Switchgrass					
Nebraska 28	(early)	1.74	2.34	1.52	1.87
1 Selection	(late)	2.56	2.44	1.74	2.24
4 Experimentals	(late)	3.08	2.78	2.06	2.64
Mean of 6 strains		2.77	2.65	1.92	2.44
Indiangrass					
Holt	(early)	2.90	1.59	3.05	2.51
3 Experimentals	(late)	3.37	1.88	3.28	2.84
Mean of 4 strains		3.25	1.81	3.22	2.76
Big bluestem					
Pawnee	(late)	2.95	2.10	1.55	2.20
Kaw	(late)	2.35	1.95	1.26	1.85
1 Selection	(m late)	2.03	1.89	1.45	1.79
Bluestem Synthetic					
Champ	(m late)	2.83	2.82	1.61	2.42
3 Experimentals	(m late)	2.17	2.04	1.17	1.80
Sand bluestem					
1 Experimental	(early)	0.70	1.40	1.15	1.09
1 Experimental	(late)	1.57	2.66	1.07	1.77
Mean of 9 strains		2.10	2.10	1.28	1.83
Side-oats grama					
Butte	(early)	0.98	0.99	0.78	0.92
1 Experimental	(m early)	1.45	1.15	0.92	1.17
Trailway	(m late)	1.54	1.29	0.77	1.70
Mean of 3 strains		1.32	1.14	0.82	1.09
Little bluestem					
4 Experimentals		2.00	1.58	1.48	1.69
Average of 5 grasses		2.29	1.86	1.74	1.96
LSD at P=.05					
Between means of strains					0.32
Between means of 1 and 3 strains					0.26
Between means of 3 and 3 strains					0.19

[a]Average yields across fertility levels from four replications each year of harvest. Refer to Appendix Table 7 for statistical analysis.

little bluestem were lowest in yield among bluestems. The late-maturing switchgrass experimental synthetics inclusive of Pathfinder outyielded the late-maturing selection from one source.

Persistence of Stands

After initial establishment, the grass strains and varieties differed greatly in improvement or maintenance of stands. These responses resulted from differences in rate and amount of vegetative spread or in the reseeding characteristics of the strains, as well as from differences in their competition with weeds. The rate of stand development was controlled by the availability of soil moisture and soil fertility.

Maintenance and persistence of stands are as important as establishment. Switchgrass and indiangrass exhibited vigorous rhizome development and the most rapid spread among the warm-season grasses. The tall bluestems were next in order in vegetative development. The midgrasses, side-oats grama and little bluestem, were slow in vegetative spread from initial rows or sparse stands.

By 1965 the 1961 plantings in Dundy and Gosper Counties were losing stands in plots which had not been fertilized. At this fertility level all plantings remained in definite rows, showed nitrogen deficiency, and did not compete with weeds. Plots which had received nitrogen fertilization in each of three years had good top-growth of grasses and erosion was checked. In the Gosper plantings, weeds and sweetclover had invaded the non-fertilized grasses but there were few weeds and no sweetclover observed in the fertilized plots (Fig. 4). However, by 1968, good stands resulted from improved soil moisture and applied nitrogen fertility. Switchgrass, indiangrass, and big bluestem exhibited vigorous rhizome development and the rows spaced 10 inches apart at planting had spread together to form solid stands in plots where soil moisture and nitrogen fertility were sufficient (Fig. 5).

The plantings in Holt County were fertilized with additional nitrogen but the grass strains were not harvested for forage yields because of cool-season weeds. Hay harvests in early summer and N-fertilization practices on this sub-irrigated soil combined unfavorably for the maintenance of warm-season grasses in pure stands. In all tests the annual total production was removed after frost from plot borders and plots not previously harvested for forage yield. The earlier maturing varieties and strains, which escaped drought and frost, matured viable seed which shattered into nearby areas. A few years after the original planting of plots in 10-inch spaced rows, it was frequently noted

Figure 5.—Plots of warm-season grasses at the Dundy County site in June 1968. Solid stands were established by vegetative spread from 10-inch row plantings. Foreground plots received 30 lb N/A in each of 5 years, 1963-67; background plots received 30 lb N/A in 2 years, 1966-67.

that open stands of some of the grass plots were invaded by seedlings of side-oats and/or little bluestem. The reseeding characteristics of these two grasses were first noted in the open initial stands in Frontier County (Fig. 6).

By 1969 in the Dixon County test, little bluestem had developed solid stands between the rows of the four strains. The seedlings were attributed to the reseeding from one early-maturing strain which had produced notably good seed crops in Dixon as well as superior forage yields in the Pierce tests (Table 19). In other environments, reseeding by indiangrass strains produced competitive seedlings in open stands of the initial plantings. On low fertility sandy soil in Antelope County the delayed establishment of both switchgrass and indiangrass from dormant and shatter seed contributed greatly to a productive grass cover.

The spreading characteristics of the cool-season rhizomatous grasses were noted, especially in 1969. Ample spring moisture favored the spread of bromegrass and intermediate wheatgrass in the Thayer 2 plantings. But western wheatgrass with its rapidly spreading rhizomes, readily invaded the bunchgrasses, crested wheatgrass and tall wheatgrass, to a greater extent than intermediate wheatgrass did in the plot tests of the cool-season grasses.

Western wheatgrass and bromegrass frequently invaded the

Figure 6.—Seedling establishment of side-oats grama and little bluestem from natural reseeding into open stands of the Frontier County plots. Some of the adjacent parent plants are shown: little bluestem, left foreground and center background; a plant of side-oats grama showing seed stalks, right foreground. In June 1968.

plots of warm-season grasses from adjacent plots in the test plantings or from other plantings outside the plot area (Fig. 7).

DISCUSSION AND CONCLUSIONS

The warm-season prairie grasses provide a broad range of

Figure 7.—Encroachment of the cool-season western wheatgrass (dark color of spring growth) into a plot of warm-season big bluestem (light color of last year's growth) in Thayer 2 plantings, April 1969.

variation for the development of varieties adapted to particular environments and uses in the mid-continental areas characterized by summer rainfall. These studies have shown the potential variation available for the requirements of establishment and adaptation to critical planting sites encountered in range reseeding or in the regrassing of cropland taken from cash grain production. The protection of these lands with vegetative cover of adapted perennial grasses is essential.

Moreover, superior varieties of these warm-season grasses respond with proper management to provide improved range grazing. These varieties may also be used in systems of rotational grazing to provide warm-season pastures for use in conjunction with other grazing or forage resources.

Grasses are frequently planted on low fertility, sloping sites that have been cropped and are no longer well suited to cash grain production. Cropping practices and erosion have depleted the former soil productivity. For their restoration these sites need supplemental fertility and protection by vegetative cover. These studies of establishment of permanent and productive grass stands in such environments have shown the need for nitrogen fertilizer properly applied in relation to the development of the grasses planted.

Differences in yield responses to N-fertilization at different locations were attributable to differences in soil fertility and soil moisture of the planting site and to the yield potential and stage of development of each grass strain. Yields are expected to fluctuate with rainfall patterns. Average increases in yield of the five grasses measured from first year N-fertilization were comparatively low; in their 2nd season,—35% in Pierce and 75% in Dixon in 1964; in their 3rd season,—44% in Valley in 1964 and 9% in Thayer 2 in 1965; and in their 4th year,—54% at Thayer 1 in 1965. Also, relatively small increases in yield were obtained in 1965 from second-year fertilization in Pierce, 29%, and in Dixon, 80%, in their 3rd season.

In contrast to the above comparisons, the second-year N-fertilization on plots in the 4th year gave increases in yields of 176% in Platte in 1964; and third-year N-fertilization on 5th year plots in 1965 gave yield increases of 181% in Dundy and 229% in Gosper over yields from non-fertilized plots (Tables 8-15). The best responses were attained at a location when favorable soil moisture coincided with adequate soil fertility at a proper stage of the stand development of the grasses.

Improved yields from plots previously not fertilized were obtained by nitrogen fertilization after longer periods of grass establishment. However, the practice of deferred fertilization was

effective in producing yields equivalent to early and annual fertilization in only two instances. It took two years (1966-67) of the delayed practice of N-fertilization in Gosper to produce similar average yields to those from plots fertilized in five years (1963-67) at the rate of 30 lb. N/A (Table 11). One year of fertilization was not sufficient in Gosper, Dundy, Pierce and Dixon (Tables 11, 12, 13, 14); nor were two annual applications effective in Dundy and Dixon. And it took three years (1966-68) of application at 40 lb. N/A on plots previously not fertilized to produce yields comparable to those fertilized in four years in Thayer (1965-68) (Table 15). There is always the danger of loss of stand on critical sites, if N-fertilization is needed but deferred.

Nitrogen fertilization of warm-season grasses must necessarily be in an amount approximating the expected usage during the season of maximum growth in the early summer months. Nitrogen fertilization applied early in the season retards warm-season grass establishment and growth by increasing competition from weeds or cool-season grasses. The carryover of nitrates from large applications favors invasion of cool-season grasses in fall or spring seasons when moisture conditions are adequate.

Shifts in plant population from warm-season to cool-season grasses have been noted sufficiently to evaluate causes. Thus the shift to bluegrass, timothy, and redtop in subirrigated meadows of the sandhills as noted by Russell *et al.* (19) was favored by the availability of soil moisture in early spring, and especially with the addition of nitrate and phosphate fertilizers before the growth of warm-season grasses was initiated.

The invasion of western wheatgrass into true prairie, as described by Weaver *et al.* (23, 24) was favored by the accumulation of nitrates during the drought years and their ready availability on the return of favorable moisture conditions. Stands of prairie grasses weakened by drought were not competitive in early spring. Conard and Youngman (2) have shown the early seasonal depletion of soil moisture in the profile under pastures of cool-season grasses in comparison with moisture storage in the soil profile under pastures of warm-season grasses. Accordingly, the production of warm-season grasses in mixtures for summer grazing should not be complicated by inclusion of seed of cool-season grasses in the mixture at planting, if maximum production of either is expected.

The warm-season prairie grasses offer a wide choice for use in accomplishing different objectives. The choice of adapted varieties is very important to the success of planting. Adapted varieties of the more aggressive grasses may be used in pure stands or simple mixtures for maximum production. For perma-

nent plantings, mixtures containing several of the tall prairie grasses and mid-grasses may be chosen to include those with aggressive spread and reseeding characteristics.

Outstanding in the rate of seedling growth were the group of three late-maturing switchgrass strains, inclusive of Pathfinder switchgrass, and two late-maturing indiangrass experimentals inclusive of Oto indiangrass (Table 7). These strains were developed by synthesis of unrelated clones from different sources in contrast with late-maturing experimental selections increased from single sources. The growth of seedlings of the late-maturing synthetic strains throughout the summer season made them more competitive, especially with the warm-season annual grass weeds, as well as markedly superior to early-maturing varieties in rate of establishment.

The tall prairie grasses gave the largest initial yields. From initial harvests, the largest average forage yields were produced by switchgrasses and indiangrasses followed by the tall bluestems, as in Platte and Valley in 1964. Switchgrass and big bluestem averaged largest yields among entries in Gosper and Pierce in 1965. Indiangrass was most productive in Dixon and indiangrass and switchgrass gave larger average yields than the big bluestem in the two Thayer locations from first harvests.

Strains of warm-season grasses differed significantly in total forage yields (Appendix Tables). Strain by fertility interactions resulted in two ways. In the 1964 and 1965 harvests the smaller variation among yields was from non-fertilized plots, compared to fertilized plots. These differences in amount of variation and rank of yields contributed to a S X F1 interaction in Valley in 1964 (Appendix Table 1) and in Gosper and Dundy in 1965 (Appendix Table 3). The larger variation among strains was measured by the more favorable fertility regime when moisture conditions were favorable. These comparisons in amount of variation and rank of yields contributed to the S X F1 interaction in Platte and Valley (Appendix Table 1) and in Thayer over three harvests (Appendix Table 7).

The ranking of average yields in 1965-1966 from a Valentine loamy sand in Pierce was switchgrass, the tall bluestems, indiangrass and side-oats grama, in contrast with the 1966-1967 yields from a Crofton silt loam in Dixon which were in the order—indiangrass, the tall bluestems, switchgrass and side-oats grama (Table 19). The ranking of yields of these grasses on a Hastings silty clay loam at Thayer 2 in 1965 was indiangrass, switchgrass, the tall bluestems and side-oats grama. Such differences in rank provided meaningful S X L interactions in the comparison of Dixon and Pierce in yields in 1965 and in 1966 (Appendix Table

4) and in the comparison of yields from Dixon, Pierce and Thayer in 1965 (Appendix Table 6). Grass strains differed in relative yields in two-year periods in Dixon and Pierce (Appendix Table 5) and in a three-year period in Thayer (Appendix Table 7). These variations in yield ranking of the strains of the grasses in different years caused significant S X Y interactions.

The late-maturing synthetic strains of switchgrass, inclusive of Pathfinder switchgrass, were readily established, widely adapted, and usually produced larger yields than selections with limited genetic diversity. However, if a reseeding type is wanted, the greater probability of seed maturity of the earlier maturing strains should be considered for northern areas.

The late-maturing synthetic strains of indiangrass, inclusive of Oto indiangrass, were superior in stand establishment in all of the comparisons. Yield superiority was significant in southern Nebraska tests (Gosper, Dundy and Thayer). The full season for growth provided by these locations made possible the forage production of these strains late in the season. They gave the largest yields under conditions of adequate soil moisture and soil fertility. Hence the probabilities of superior yields are lessened if soil moisture, soil fertility, or short season are limiting factors. The reseeding characteristics of Holt indiangrass should be considered for permanent plantings in areas with short seasons similar to the central and northern test areas.

Pawnee and Champ bluestems are synthetic varieties which owe superiority to broad genetic diversity and to relatively full season growth for maximum production in the areas tested. They produced larger yields than other strains in which selection for specific characters had limited their aggressive production, and especially the entry which was a selection from a single source.

There were few significant differences shown in yields of the midgrasses. Late-maturing strains of little bluestem inclusive of Blaze gave total yields in Thayer similar to some of the tall bluestems and Nebraska 28 switchgrass (Table 21). An early-maturing strain produced notably good seed crops in Dixon and significantly larger total yields in Pierce than late-maturing strains (Table 19). Trailway and a synthetic strain of side-oats grama frequently gave larger yields than Butte but not always at significant levels. The reseeding characteristics of side-oats grama and little bluestem suggests their use in mixtures for range and conservation plantings.

SUMMARY

Strains and varieties of warm-season prairie grasses were evaluated in test plantings in 12 Nebraska counties in a 9-year period, 1961-1969. Locations were selected problem sites for grass plantings—varying in slope, soil type, soil fertility and average rainfall.

Comparisons of warm-season grasses included 30 strains and varieties of switchgrass, indiangrass, big and sand bluestems, side-oats grama and little bluestem. Cool-season grasses included single entry check varieties of bromegrass, intermediate wheatgrass, western wheatgrass, crested wheatgrass and tall wheatgrass. Grass strains were compared for early establishment from spring planting, for stand improvement and persistence and for yield responses to locations and imposed fertility levels.

Late-maturing synthetic strains of switchgrass and indiangrass gave superior initial stand establishment compared with short-season varieties and selections from single sources. Side-oats grama strains were easily established. Bluestem strains varied in rate of development of productive stands. There were no effects of starter fertilization (8 + 24 + 0 lb. N/A) on early establishment of stands or on initial yields. Annual nitrogen fertilization (30-40 lb. N/A) applied after grass establishment (2nd to 5th yr.) was cumulative over years in improvement of stands and yields and in reduction of runoff and soil erosion.

The proper time and rate of nitrogen fertilization in relation to stage of grass establishment and season of growth are important considerations in the management of warm-season grasses. Nitrogen fertility can seriously retard establishment and reduce yields of warm-season perennials when early spring N-fertilization or carryover of nitrogen fertility favors competition from cool-season grasses or weeds.

Increases in average forage yields of the warm-season grasses from first-year nitrogen fertilization of second-year or older stands ranged from 9 to 75% at different locations; and timely annual N-fertilization for two or more years gave increased yields ranging from 29% to 229% over yields of non-fertilized plots. Improvement in stands and yields from nitrogen fertilization reduced runoff and soil erosion on problem sites.

The tall prairie grasses, switchgrass, indiangrass, and the tall bluestems usually gave larger average yields in comparison with the midgrasses, little bluestem and side-oats grama. The tall grasses were characterized by aggressive vegetative spread in the development of stands, compared to the midgrasses which were characterized by reseeding as the primary method of propagation.

Certain late-maturing strains of the tall bluestems, switchgrasses, indiangrasses and side-oats grama were outstanding in forage yields in their respective groups. However, the probabilities of late-maturing strains of grasses being superior to early-maturing strains were lessened in some of the test environments by the limiting factors of soil moisture, soil fertility and/or shortness of season.

In the cross-fertilized switchgrasses and tall bluestems, the synthetic varieties with broad genetic diversity were shown to be more broadly adapted and were more productive than strains developed by selection from a single source or by continued selection within a strain or variety.

The warm-season prairie grasses may be utilized for planting singly or in simple mixtures for maximum summer pasture production. The basic components of such plantings would be chosen from high yielding adapted varieties of the tall prairie grasses—the bluestems, switchgrass, and indiangrass.

Adapted varieties of tall grasses or midgrasses chosen for aggressive spread or reseeding characteristics may be added to mixtures for conservation or rangeland plantings.

LITERATURE CITED

1. Burzlaff, D. F., G. W. Fick and L. R. Rittenhouse.
1968. Effect of nitrogen fertilization on certain factors of a western Nebraska range ecosystem. J. Range Mgmt. 21: 21-24.

2. Conard, E. C. and V. E. Youngman.
1965. Soil moisture conditions under pastures of cool-season and warm-season grasses. J. Range Mgmt. 18: 74-78.

3. Ehlers, Paul, G. Viehmeyer, R. Ramig and E. M. Brouse.
1952. Fertilization and improvement of native subirrigated meadows in Nebraska. Nebraska Exp. Sta. Circ. 92.

4. Harlan, Jack.
1962. Chapter 46. Hay and pasture seedings for the southern Great Plains and the southwest. 12 p. *In* Forages. Hughes, Heath and Metcalfe. Iowa State Univ. Press.

5. Huffine, W. W. and W. C. Elder.
1960. Effect of fertilization on native pastures in Oklahoma. J. Range Mgmt. 13: 34-36.

6. Keim, F. D. and L. C. Newell.
1962. Chapter 44. Hay and pasture seedings for the northern Great Plains. 9 p. *In* Forages. Hughes, Heath and Metcalfe. Iowa State Univ. Press.

7. Klingman, D. L. and M. K. McCarty.
1958. Interrelations of methods of weed control and pasture management at Lincoln, Neb., 1949-55. USDA Tech. Bul. 1180. 49 p.

8. Newell, L. C.
1968. Effects of strain source and management practice on forage yields of two warm-season prairie grasses. Crop. Sci. 8: 205-210.

9. Newell, L. C.
1968. Registrations of Pawnee big bluestem (Reg. No. 1), Champ bluestem (Reg. No. 2), Blaze little bluestem (Reg. No. 3), Pathfinder switchgrass (Reg. No. 17). Crop Sci. 8: 514-516.

10. Newell, L. C. and E. C. Conard.
1963. Registration of Butte and Trailway side-oats grama (Reg. Nos. 2 and 3). Crop Sci. 3: 460-461.

11. Newell, L. C. and E. C. Conard.
1968. Registration of Holt indiangrass (Reg. No. 16). Crop Sci. 8: 515-516.

12. Newell, L. C. and S. A. Eberhart.
1961. Clone and progeny evaluation in the improvement of switchgrass, *Panicum virgatum* L. Crop Sci. 1: 117-121.

13. Newell, L. C. and L. V. Peters.
1961. Performance of hybrids between divergent types of big bluestem and sand bluestem in relation to improvement. Crop Sci. 1: 370-373.

14. Newell, L. C., R. D. Staten, E. B. Jackson and E. C. Conard.
1962. Side-oats grama in the central Great Plains. Nebraska Agr. Exp. Sta. Res. Bul. 207. 38 p.

15. Nichols, J. T. and W. E. McMurphy.
1969. Range recovery and production as influenced by nitrogen and 2,4-D treatments. J. Range Mgmt. 22: 116-119.

16. Owensby, C. E., R. M. Hyde and K. L. Anderson.
1970. Effects of clipping and supplemental nitrogen and water on loamy upland bluestem range. J. Range Mgmt. 23: 341-346.

17. Peters, L. V. and L. C. Newell.
1961. Hybridization between divergent types of big bluestem, *Andropogon gerardi* Vitman, and sand bluestem, *Andropogon hallii* Hack. Crop Sci. 1: 359-363.

18. Rogler, G. A. and R. J. Lorenz.
1957. Nitrogen fertilization on northern Great Plains rangeland. J. Range Mgmt. 10: 156-160.

19. Russell, J. J., E. M. Brouse, H. F. Rhoades and D. F. Burzlaff.
1965. Response of subirrigated meadow vegetation to application of nitrogen and phosphorus fertilizer. J. Range Mgmt. 18: 242-247.

20. Smika, D. E. and L. C. Newell.
1965. Irrigation and fertilization practices for seed production from established stands of side-oats grama. Nebraska Agr. Exp. Sta. Res. Bul. 218. 13 p.

21. Smika, D. E. and L. C. Newell.
1966. Cultural practices for seed production from established stands of western wheatgrass. Nebraska Agr. Exp. Sta. Res. Bul. 223. 15 p.

22. Warnes, D. D. and L. C. Newell.
1969. Establishment and yield responses of warm-season grass strains to fertilization. J. Range Mgmt. 18: 235-240.

23. Weaver, J. E.
1942. Competition of western wheatgrass with relict vegetation of prairie. Am. J. Bot. 29: 366-372.

24. Weaver, J. E. and R. W. Darland.
1944. Grassland patterns in 1940. Ecol. 25: 202-215.

25. Weaver, J. E. and W. W. Hanson.
1941. Native midwestern pastures. Their origin, composition and degeneration. Nebraska Univ. Conser. and Survey Div. Conser. Bul. 22. 93 p.

26. Weaver, J. E. and T. J. Fitzpatrick.
1934. The prairie. Ecol. Mono. 4:109-295.

APPENDIX A

Scientific names of Grasses cited by common name

Warm-Season Grasses

Big bluestem	*Andropogon gerardi* Vitman
Sand bluestem	*Andropogon hallii* Hack.
Little bluestem	*Schizachyrium scoparium* (Michx.) Nash *Andropogon scoparius* Michx.
Indiangrass	*Sorghastrum nutans* (L.) Nash
Side-oats grama	*Bouteloua curtipendula* (Michx.) Torr.
Switchgrass	*Panicum virgatum* L.

Cool-Season Grasses

Bromegrass, or smooth brome	*Bromus inermis* Leyss.

Bluegrass, or Kentucky bluegrass	*Poa pratensis* L.
Redtop	*Agrostis alba* L.
Timothy	*Phleum pratense* L.
Crested wheatgrass	*Agropyron cristatum* (L.) Gaertn.
Crested wheatgrass	*Agropyron desertorum* (Fisch.) Schult.
Intermediate wheatgrass	*Agropyron intermedium* (Host) Beauv.
Tall wheatgrass	*Agropyron elongatum* (Host) Beauv.
Western wheatgrass	*Agropyron smithii* Rydb.

APPENDIX B

Statistical Analyses

Table 1.—Analysis of variance of the 1964 forage yields of 12 grass strains from fertilized and non-fertilized plots in Platte and Valley Counties in east central Nebraska (Reference to Table 16).

Source of variation	Degrees of freedom	Mean square	F-value
Total	95	.....	.....
Location (L)	1	10.0233	**
Fertility level (Fl)	1	31.1452	**
Fl x L	1	11.2748	**
Block error	4	0.2214	
Strains (S)	11	1.2078	9.61**
S x L	11	0.5411	4.30**
S x Fl	11	0.3866	3.08**
Experimental error	55	0.1257	

Grand mean, 1.46 T/A; S.D.=0.35 ton; C.V.=24.3%

**F-value exceeds the .01 level of significance.

Table 2.—Analysis of variance of the 1965 forage yields of 21 grass strains from 1962 and 1963 plantings in Thayer County, Nebraska (Reference to Table 17).

Source of variation	Degrees of freedom	Mean square	F-value
Total	167	.....	.....
Location (L)	1	1.3375	NS
Fertility level (Fl)	1	13.2666	8.52*
Fl x L	1	4.8518	NS
Block error	4	1.5569	
Strains (S)	20	4.0201	10.5**
S x L	20	0.3840	NS
S x Fl	20	0.3702	NS
Experimental error	100	0.2369	

Grand mean, 2.27 T/A; S.D.=0.50 ton; C.V.=22.0%

* F-value exceeds the .05 level of significance.

**F-value exceeds the .01 level of significance.

NS Indicates no significance.

Table 3.—Analyses of variance of the 1965 and 1967 forage yields of grass strains combined from harvests in Gosper and Dundy Counties in southwestern Nebraska. (Reference to Table 18.)

Source of variation	1965 Yields			1967 Yields		
	Degrees of freedom	Mean square	F-value	Degrees of freedom	Mean square	F-value
Total	183-6	....	....	125-6	.....	.....
Location (L)	1	2.9202	NS	1	4.4796	*
Fertility level (Fl)	1	45.0846	**	1	3.2491	*
Fl x L	1	1.6796	NS	....	.....	
Block error	4	0.3829		4	0.2310	
Strains (S)	22	0.5882	8.82**	17	1.0098	8.07**
S x L	22	0.1339	2.01**	17	0.2256	NS
S x Fl	22	0.2017	3.03**	17	0.2201	NS
Experimental error	110-6	0.0666		68-6	0.1251	
Grand Mean		0.97 T/A			1.42 T/A	
Standard deviation		0.26 Ton			0.35 Ton	
Coefficient of variation		26.6%			24.8%	

* F-value exceeds the .05 level of significance
** F-value exceeds the .01 level of significance
NS indicates no significance

Table 4.—Analyses of variance of the 1965 and the 1966 forage yields of grass strains combined from harvests in Pierce and Dixon Counties in northeastern Nebraska. (Reference to Table 19.)

Source of variation	1965 Yields			1966 Yields		
	Degrees of freedom	Mean square	F-value	Degrees of freedom	Mean square	F-value
Total	183	.....	.....	215-6	.....	.....
Location (L)	1	6.6690	NS	1	0.0311	NS
Fertility level (Fl)	1	7.8107	NS	1	6.9589	NS
Block error	5	2.4291		5	4.0509	
Strains (S)	22	0.3501	3.93**	26	0.4020	2.00**
S x L	22	0.3659	4.11**	26	0.5708	2.84**
S x Fl	22	0.0619	NS	26	0.1649	NS
Experimental error	110	0.0891		124	0.2012	
Grand mean		0.98 T/A			1.19 T/A	
Standard deviation		0.30 Ton			0.44 Ton	
Coefficient of variation		30.3%			37.7%	

** F-value exceeds the .01 level of significance
NS indicates no significance

Table 5. Analyses of variance of forage yields of grass strains in Pierce and in Dixon Counties combined from harvests in two years. (Reference Table 19.)

Source of variation	Pierce Yields 1965-1966			Dixon Yields 1966-1967		
	Degrees of freedom	Mean square	F-value	Degrees of freedom	Mean square	F-value
Total	215	.....	.....	215-6	.....	.....
Years (Y)	1	0.0267	NS	1	25.3998	**
Fertility level (Fl)	1	2.4321	NS	1	11.7180	*
Block error	5	5.0127		5	1.1345	
Strains (S)	26	0.7914	6.33**	26	1.1532	5.15**
S x Y	26	0.0712	NS	26	0.2625	NS
S x Fl	26	0.0962	NS	26	0.2982	NS
Experimental error	130	0.1250		130-6	0.2241	
Grand mean		1.19 T/A			1.52 T/A	
Standard deviation		0.35 Ton			0.47 Ton	
Coefficient of variation		29.7%			30.9%	

* F-value exceeds the .05 level of significance

** F-value exceeds the .01 level of significance

NS indicates no significance

Table 6. Analysis of variance of the 1965 forage yields of grass strains from three eastern Nebraska locations (Reference to Table 20).

Source of variation	Degrees of freedom	Mean square	F-value
Total	263	.....	.....
Location (L)	2	60.6602	**
Fertility level (Fl)	1	8.7091	3.77+
Fl x L	2	0.4046	NS
Block error	6	2.3105	
Strains (S)	21	1.8558	10.12**
S x L	42	0.7405	4.04**
S x Fl	21	0.1636	NS
Experimental error	168	0.1834	

Grand mean = 1.46 T/A; S.D. = 0.43 T; C.V. = 29.3%

\+ F-value exceeds the .10 level of significance.
** F-value exceeds the .01 level of significance.
NS indicates no significance.

Table 7. Analysis of variance of forage yields of 26 strains of warm-season grasses in three years from plots in Thayer County, south central Nebraska.

Source of variation	Degrees of freedom	Mean square	F-value
Total	311	.....	.....
Years (Y)	2	10.1293	**
Fertility levels (Fl)	1	1.4107	NS
Fl x Y	2	0.5630	NS
Block error	6	0.832	**
Strains (S)	25	4.0625	25.6**
S x Y	50	0.8784	5.52**
S x Fl	25	0.5966	3.75**
Experimental error	200	0.1590	

Grand mean 2.01 T/A; S.D. = 0.40 T; C.V. = 19.6%

** F-value exceeds the .01 level of significance.
NS indicates no significance.