Establishment and Yield Responses of Warm-Season Grass Strains to Fertilization[1]

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Highlight

Effects of nitrogen and phosphorus fertilization on stand establishment and yield of 5 warm-season prairie grasses were observed on 12 problem sites in Nebraska. Annual nitrogen fertilization after the establishment year maintained superior stands and increased forage yields of the experimental varieties. Proper timing and rate of nitrogen fertilization produced vigorous growth of the planted grasses which in turn controlled soil erosion and reduced weed invasion; whereas untimely mowing and fertilization increased cool-season weeds. Late-maturing strains of the warm-season grasses produced better stands than early-maturing strains. Where not limited by soil moisture or shortness of season, the late-maturing strains of switchgrass, indiangrass, and big bluestem produced larger yields than early-maturing strains of these grasses.

The objectives of this study were to determine the effects of nitrogen and phosphorus fertilization on stand establishment and yields of certain warm-season prairie grasses and to evaluate and characterize selected experimental strains of these grasses for possible use in variety improvement for their respective areas of adaptation.

Harlan (1962) and Keim and Newell (1962) have described the historical uses of the native grasses in the Great Plains. Perennial warm-season prairie grasses are an important part of the total forage resources which provide grazing in summer in the Plains states. The need is best met by the use of adapted varieties of these grasses developed from prairie sources. Objectives of variety development include superiority of seed quality and production, stand establishment, and range of adaptation to diverse environments.

In regions of low rainfall the success of 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 stands, such as proper time for planting, use of adapted superior varieties, and suitable practices for seedbed preparation. Such practices as weed control, time and frequency of mowing or grazing, and adequate added fertility are critical for the establishment and maintenance of stands and for profitable yields. Failure to consider any one factor may offset any or all attention given to other factors in the success of grass plantings.

Management practices for forage yield and seed yield have been reported for side-oats grama by Newell et al. (1962) and Smika and Newell (1965). Effects of nitrogen fertilization and clipping management regimes were studied for two tall prairie grasses (Newell, 1968). 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. Although the response of these grasses to nitrogen fertilization was not apparent early in the experiment, there were marked and significant yield effects, cumulative over years for both grasses. Unless curtailed by shortness of season or limited soil moisture, southern strains usually gave larger yields than strains of local or northern origin.

Conflicting interpretations have been given to the effects of fertilizing rangeland. Responses on some subirrigated meadows or in a year of high precipitation are often contrasted with upland fertilization in dry years. Russell et al. (1965) found that combinations of nitrogen and phosphorus fertilizers on Nebraska subirrigated meadows gave greater yield

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[1] Contribution of the Nebraska Agricultural Experiment Station and the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture. Published with the approval of the Director as Paper No. 2379 Journal Series, Nebraska Agricultural Experiment Station. Received August 8, 1968; accepted for publication December 11, 1968.

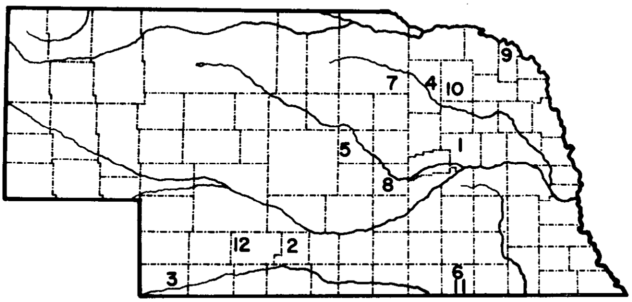

FIG. 1. Location of 12 Nebraska tests of warm-season prairie grasses: Planted in 1961–1, Platte. 2, Gosper. 3, Dundy. 4, Antelope. Planted in 1962–5, Valley. 6, Thayer 1. 7, Holt. 8, Howard. Planted in 1963–9, Dixon. 10, Pierce. 11, Thayer 2. 12, Frontier.

increases, increased forage utilization, and altered botanical composition more than either fertilizer applied alone. The application of fertilizer changed the chemical composition of the forage by affecting the botanical composition of the meadow. Conard and Youngman (1965) and Klingman and McCarty (1958) noted changes in botanical composition from warm-season to cool-season grasses or the reverse depending upon which were favored during critical plant stages by soil moisture conditions, nitrogen fertilization, intensity of grazing or mowing, and application of 2, 4–D.

Methods and Materials

Experimental strains of warm-season grasses planted for this study were developed in the grass improvement program of the Nebraska Agricultural Experiment Station. Included were selected strains and synthetic varieties of switchgrass (*Panicum virgatum* L.), indiangrass (*Sorghastrum nutans* (L.) Nash), side-oats grama (*Bouteloua curtipendula* (Michx.) Torr.), big bluestem (*Andropogon gerardi* Vitman), and little bluestem (*Andropogon scoparius* Michx.), as well as certain released varieties as checks. In 1961 and 1962 the number of grass strains planted was 20 while in 1963 the number planted was 25.

Test plots were established at 12 locations by Outstate Testing personnel of the Nebraska Experiment Station. Four test locations 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 grass plantings are a part of recommended conservation programs.

Seeding rates for all grass strains were calculated for planting 30 viable seeds/ft^2. Planting was in April each year with a belt seeder designed for uniform seed distribution. In 1961 and 1962 the plot was 5×25 ft (6 rows, 10 inches apart) while in 1963 the plot size was 5×50 ft. All strains were planted in each of four blocks at each location.

At planting time two blocks of entries were fertilized with ammonium phosphate (8+24+0 lb/acre) applied with the seed. After a stand of grass had been established at a location, ammonium nitrate fertilizer was applied in May to the same blocks of plots previously fertilized at planting. In Gosper and Dundy the follow-up applications of nitrogen were applied at the rate of 30 lb N/acre, whereas 40 lb N/

Table 1. Location, soil type, and year of planting of Nebraska Outstate Grass Test plots.

County location*		Year planted	Soil type
1.	Platte	1961	Moody silty clay loam
2.	Gosper	1961	Colby silt loam
3.	Dundy	1961	Colby silt loam
4.	Antelope	1961	Thurman fine sand
5.	Valley	1962	Holdrege silt loam
6.	Thayer 1	1962	Hastings silty clay loam
7.	Holt	1962	Elsmere loamy fine sand
8.	Howard	1962	Thurman fine sand
9.	Dixon	1963	Crofton silt loam
10.	Pierce	1963	Valentine loamy sand
11.	Thayer 2	1963	Hastings silty clay loam
12.	Frontier	1963	Holdrege silt loam

* Number refers to order of planting and location in Fig. 1.

acre was applied each year at the other locations. Two blocks of entries at each location received no fertilizer at planting or in succeeding years.

Stands were evaluated by visual observation with a rating of 1 to 9 given to each plot and averaged from each of 12 locations. The rating indices were: 1 = excellent, 3 = good, 5 = average, 7 = fair, and 9 = poor; thus, the lower numbers indicate the better stands produced.

Forage yields were obtained by mowing 16 ft^2 from two selected rows of each plot at each location. The harvested forage was ovendried and yields determined. Forage yields in 1964 were obtained from Dixon, Pierce, Valley, and Platte counties. In 1965 the forage yields were taken at Gosper, Dundy, Dixon, Pierce, and two Thayer county locations. Stand differences among varieties precluded forage harvest from the Holt, Howard, Antelope, and Frontier locations.

Results and Discussion

Differences in local precipitation and soil fertility provided a broad range of environmental conditions for evaluation of the grasses. Soil types varied from fine sands to silty clay loams (Table 1). Soil tests taken prior to planting showed pH readings which ranged from 5.4 to 7.8. Available nitrogen in topsoil ranged from 4 ppm (very low) to 7 ppm (medium). Available phosphorus ranged from 8 ppm (low) to 30 ppm (very high) and available potassium ranged from 60 ppm (low) to 465 ppm (very high).

Establishment of these warm-season grasses was dependent upon the distribution of precipitation during the establishment season. Good stands at the Dixon and Pierce locations resulted from timely, adequate precipitation during the establishment season (Table 2). Nitrogen fertilizer was applied the year following seeding. Poor stands resulted where untimely precipitation occured the first year on sandy soils as in Antelope and Howard counties, and fertilization was not warranted even 4 years following seeding. On the heavier silty clay loams of the Platte and Thayer sites the weed competition

Table 2. Precipitation during establishment season and resulting grass stands at each of the 12 locations of tests.

County location	Precipitation (in) April	Precipitation (in) Apr–Aug	Weed competition	Over-all stand
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
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
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

was critical even though initial grass stands were good. Accordingly, nitrogen fertilization was withheld until the planted grass dominated the stand (Table 3).

There was no significant benefit from planting-time fertilization (8+24+0) on grass establishment as shown by averages of the stand ratings. At some locations nitrogen fertilization was detrimental by favoring the growth of weeds which competed with the warm-season grass seedlings.

Certain grasses produced superior stands at all 12 locations. Among the tall prairie grasses, switchgrass and indiangrass had better initial stands than big bluestem (Fig. 2). Of the shorter growing grasses, side-oats grama produced better stands than little bluestem.

Early- and late-maturing strains of the same grass produced constrasting stands (Fig. 2). Superior seedling vigor of these late-maturing grass strains was important in their competition with weeds and

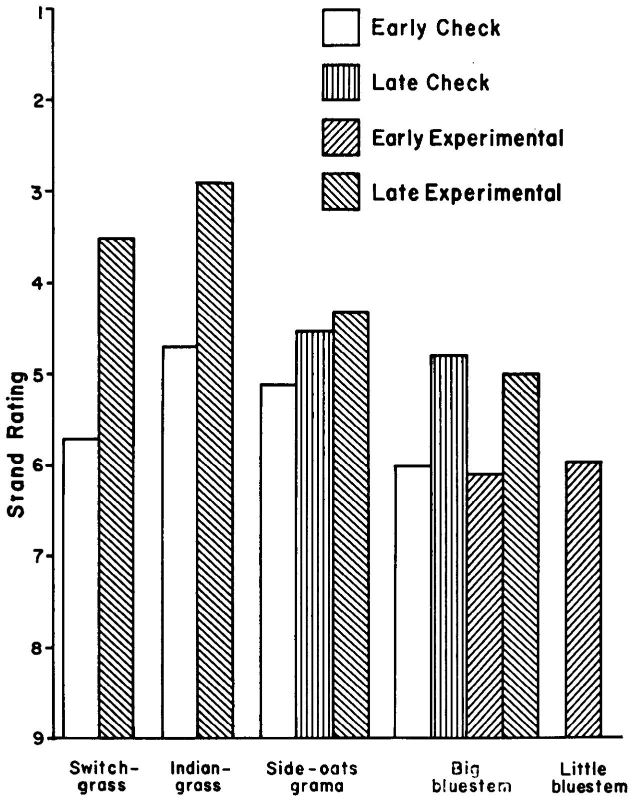

FIG. 2. Stand comparisons of selected check varieties and experimental strains of warm-season grasses planted on problem sites in 12 Nebraska tests. Ratings: 1 = excellent, 3 = good, 5 = average, 7 = fair, 9 = poor.

thus they produced better stands than the early-maturing strains.

Average forage yields for each location showed the response of these warm-season grass strains to the applied fertilizer (Table 4). The amount of response was related to soil fertility, number of years after establishment of grass, and moisture conditions during the year of forage harvest.

Table 3. Rates and dates of nitrogen and phosphorus fertilization on problem sites in 12 Nebraska tests.

County location	Planting-time fertilization: Year planted	Planting-time fertilization: Fertilization rate, lb/acre	Follow-up N fertilization: Years applied	Follow-up N fertilization: Rate per year, lb/A
1. Platte	1961	8+24+0	1963–64	40
2. Gosper	1961	8+24+0	1963–64–65	30
3. Dundy	1961	8+24+0	1963–64–65	30
4. Antelope	1961	8+24+0	Poor stands	None
5. Valley	1962	8+24+0	1964	40
6. Thayer 1	1962	8+24+0	1965	40
7. Holt	1962	8+24+0	1964	40
8. Howard	1962	8+24+0	Poor stands	None
9. Dixon	1963	8+24+0	1964–65	40
10. Pierce	1963	8+24+0	1964–65	40
11. Thayer 2	1963	8+24+0	1965	40
12. Frontier	1963	8+24+0	Poor stands	None

Table 4. Effect of fertilizer on the average forage yield of 20 grass strains from 8 Nebraska locations in 1964 and 1965.

Location and year planted		Ave. forage yield (tons/acre) Not fert.	Ave. forage yield (tons/acre) Fertilized	Increase from fert. (%)
1964 Harvests				
1. Platte	1961	.87	2.68	208
5. Valley	1962	1.02	1.48	45
9. Dixon	1963	.49	.86	76
10. Pierce	1963	.49	.62	27
1965 Harvests				
2. Gosper	1961	.51	1.75	243
3. Dundy	1961	.44	1.22	177
6. Thayer 1	1962	1.73	2.63	52
9. Dixon	1963	.64	1.00	56
10. Pierce	1963	1.05	1.30	24
11. Thayer 2	1963	2.25	2.47	10

Table 5. Precipitation during the 1964 and 1965 growing seasons of the harvest year at each of 8 Nebraska locations.

County location	Inches of rainfall during year of harvest			
	June	July	August	Total
1964 Harvest				
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 Harvest				
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

It is interesting to contrast the 243, 208, and 177% increases resulting from fertilization in Gosper, Dundy, and Platte counties with the smaller increases of 76% or less from other harvests. Gosper, Platte, and Dundy had one additional year of growth for contrasts in nitrogen fertility to become cumulative. This can be further demonstrated by comparing the 1965 harvests for Thayer 1 location with Thayer 2 location. Average fertilized yields were similar, but Thayer 1 had a yield of 1.37 T/acre without nitrogen fertilization compared with 2.25 T/acre for Thayer 2.

Dixon and Pierce had smaller percent increases from nitrogen fertilization in the 1965 harvests than from the 1964 harvests. A partial explanation appears to be the reduced precipitation in 1965 compared with 1964 at these two locations (Table 5). The Dixon location is on a steep slope and the Pierce planting is on a sandy soil, situations which require adequate rainfall throughout the growing season.

Some general benefits from fertilization in addition to forage yield were observed that have implications in maintaining stands of grass. In Dundy and Gosper counties the nonfertilized plots were losing stand due to soil erosion by runoff while fertilized plots had heavy topgrowth of grass which prevented erosion. The perennial rhizomatous grasses were still in rows nearly 10 inches apart in the nonfertilized plots whereas the grass in the fertilized plots was almost a solid cover. The grass in the nonfertilized plots showed nitrogen deficiency symptoms, lacked vigor, and did not compete with weeds. Erosion occurred in nonfertilized plots, and in the Gosper County plantings weeds and sweetclover invaded the five-year-old nonfertilized grass whereas no sweetclover plants were observed in the fertilized replications (Figure 3). Grass is often planted on land not suited to

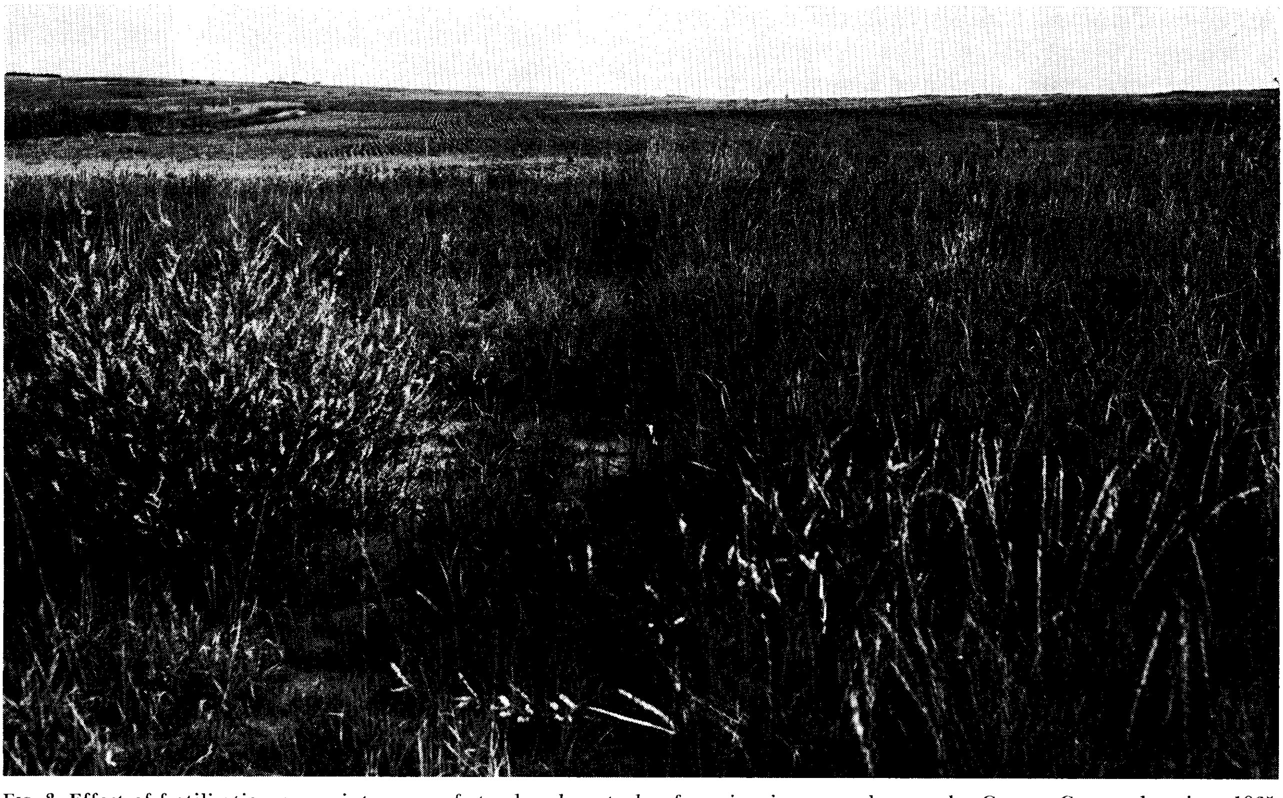

FIG. 3. Effect of fertilization on maintenance of stand and control of erosion in grass plots at the Gosper County location, 1965. Left: Nonfertilized; Right: Fertilized.

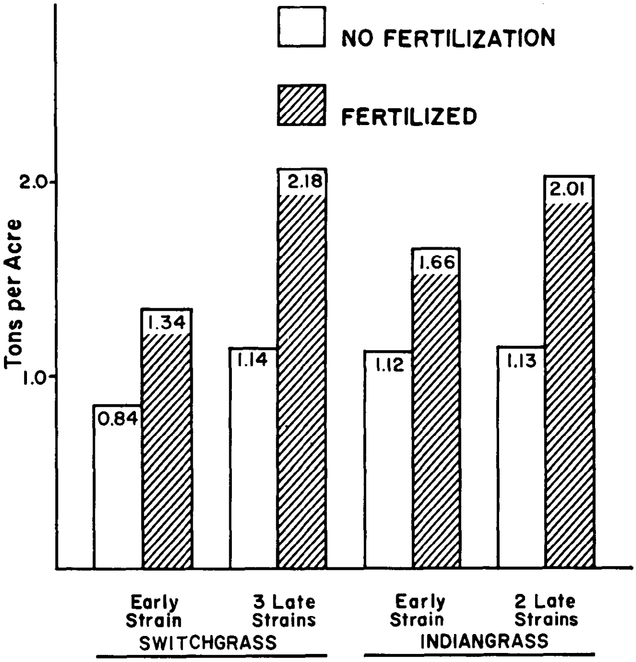

FIG. 4. Average forage yields of check varieties and selected experimental strains of warm-season grasses from 8 Nebraska locations.

cash crops because of the erosion hazard. Thus prevention of erosion by keeping the grass growing vigorously would be a very important benefit from fertilization. Savings in the cost of weed control also could be considered a profitable result of fertilization.

Test plots in Holt County were also fertilized in 1965 but were not harvested because of cool-season weeds. This test area was subirrigated and responded similarly to the observations of wet meadows reported by Russell et al. (1965). Late June of 1963 was a critical period to mow warm-season grasses for hay since it encouraged cool-season weeds and grasses. Additional mowing in early August of 1964 and 1965 continued to encourage cool-season weeds and grasses.

Individual grass strains gave different relative yield responses at the 1965 harvested locations and also between different fertility levels at the same location. Variety × location and variety × fertility interactions were highly significant from the 1965 harvests, except for the similar variety response in the comparisons from the two Thayer County locations which differed chiefly in age of planting. These two locations were about 0.5 mile apart and the soil and moisture conditions were similar. The interaction of individual strains with location and/or fertility showed that some strain responses were superior at one or two locations but not at other locations. Other strains appeared to be superior at most all of the locations.

Experimental varieties of switchgrass and indiangrass developed for late maturity were compared with early-maturing check varieties in their responses to fertilization (Fig. 4). The three late-maturing switchgrasses were superior in yield to early-maturing Nebraska 28 even without added fertility. The increase due to fertilization from the three experimentals were 1.04 T/acre although Nebraska 28 increased only 0.5 T/acre. The two late-maturing indiangrasses without fertilization produced yields similar to Holt, an early-maturing variety. With fertilization the two late-maturing indiangrass varieties were much superior in yield to the early-maturing variety.

Conclusions

Experimental warm-season grass strains were tested at all locations with presently available varieties of each grass as checks. Some strains produced superior stands and yields at all locations, while other strains were superior at one or two locations but not at other locations. Such knowledge of specific or broad adaptation is valuable to the plant breeder in developing new varieties. Superior seedling vigor of late-maturing strains produced stands superior to earlier maturing strains. The late-maturing strains also produced larger yields than the early-maturing strains.

In these studies there was no significant benefit from planting-time fertilization (8+24+0) on establishment of warm-season grasses. Nitrogen fertilization at planting of warm-season grasses for spring and summer establishment is usually not desired as it may deter stand development by increasing weed competition. Indiscriminate use of follow-up nitrogen fertilizer also can be serious by increasing the competition from cool-season grasses while warm-season grasses are dormant.

Proper fertilization is necessary for full success on problem soil sites with low organic matter, eroded slopes, or nutrient deficiencies. Nitrogen fertilizer may be applied after the desired grass is established as dominant in the stand. Timely applications of fertilizer at proper rates will not only improve forage yields of the planted grass but also thereby reduce erosion and improve weed control.

LITERATURE CITED

CONARD, E. C., AND VERN E. YOUNGMAN. 1965. Soil moisture conditions under pastures of cool-season and warm-season grasses. J. Range Manage. 18: 74–78.

HARLAN, JACK. 1962. Chapter 46. Hay and pasture seedings for the Southern Great Plains and the Southwest. 12p. *In* FORAGES. Hughes, Heath, and Metcalfe. Iowa State Univ. Press.

KEIM, F. D. AND L. C. NEWELL. 1962. Chapter 44. Hay and pasture seedings for the Northern Great Plains. 9p. *In* FORAGES. Hughes, Heath, and Metcalfe. Iowa State Univ. Press.

KLINGMAN, DAYTON L., AND M. K. MCCARTY. 1958. Interrelations of methods of weed control and pasture management at Lincoln, Nebraska, 1949–55. USDA Tech. Bull. 1180. 49p.

NEWELL, L. C., R. D. STATEN, E. B. JACKSON, AND E. C. CONARD. 1962. Side-oats grama in the Central Great Plains. Nebr. Exp. Sta. Res. Bull. 207. 38p.

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.

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 Manage. 18: 242–247.

SMIKA, D. E., AND L. C. NEWELL. 1965. Irrigation and fertilization practices for seed production from established stands of side-oats grama. Nebr. Exp. Sta. Res. Bull. 218. 13p.