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L. C. Newell

R. D. Staten

E. B. Jackson

E. C. Conard

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by

L. C. Newell
R. D. Staten
E. B. Jackson
E. C. Conard

Nebraska Agricultural Experiment Station
In Cooperation with Agricultural Research Service
U. S. Department of Agriculture

University of Nebraska College of Agriculture
The Agricultural Experiment Station
E. F. Frolik, Dean; H. H. Kramer, Director

Foundation seed field of Trailway side-oats grama on the Foundation Seed Farm, Waterloo, Nebr., August, 1958.

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# SUMMARY

Six strains of side-oats grama obtained from different sources were grown in field experiments to evaluate their adaptation to mid-latitude conditions and to discover their suitability for seed increase as varieties. Their responses to photoperiod were also determined under controlled greenhouse conditions to aid interpretation of field results.

Only adapted varieties of side-oats grama should be planted in the latitude of the Central Plains. Northern strains moved southward are low in production, whereas winter hardiness is a critical factor in the choice of southern varieties or strains. Two Nebraska strains and one Oklahoma strain were found to be adapted in parts of the Central Plains.

Butte (Nebraska 37) and North Dakota 97 exhibited typical growth and reproduction as long-day plants. They were relatively earlier in maturity than more southern strains and were winter hardy. Butte was found best adapted for sites low in soil moisture or fertility in the northern central Plains, whereas North Dakota 97 was too low in production. Only Butte and Trailway (Nebraska 52) survived winter conditions in Nebraska, Wyoming, and Dakota comparisons with strains of more southern origin.

Trailway and El Reno received an intermediate classification as to photoperiod and adaptation, since short days inhibited and long days retarded their inflorescence development. They produced good forage yields and utilized most of the growing season in the mid-latitudes. Trailway is a productive, leafy, winter-hardy variety with forage characteristics intermediate between northern and southern types. It was found adapted for forage production in pure stands and mixtures on good soils with favorable moisture conditions in eastern and southern parts of the region. El Reno was winter susceptible in the Nebraska comparisons, but gave good results in the Kansas trials.

In photoperiod studies, Oklahoma Tucson and New Mexico Vaughn (A-3603) initiated the reproductive phase in shorter days than other varieties with which they were compared. In field studies, they flowered earlier in the summer than the varieties of the central group, but continued comparable growth throughout the summer. Such varieties and strains from southern sources were winter susceptible in all northern comparisons.

Yields of seed spikes and pure live seed of side-oats grama were increased with a moderate application of nitrogen (30 lbs. of N per acre), but higher rates failed to give significant additional yields under non-irrigated conditions. Effects of phosphorus were negligible in these tests. Caryopses were larger when more nitrogen was applied under favorable moisture conditions but applying nitrogen decreased quality and seed set with limited moisture. Moderate, timely irrigation improved the yield of spikes and the quality of caryopses.

Caryopses of side-oats grama of good quality may be described as varying from 550,000 to 750,000 per pound, based on average performance of Trailway and Butte in two years. Average quality of the two varieties in a season favorable to seed production on non-irrigated land was approximately 600,000 per pound. As commercial seed is composed of a mixture of whole and broken seed spikes, yields were calculated on the basis of pure live seed produced per acre. A suitable rate of planting was illustrated on the basis of average caryopses quality assuming 191,000 seed units per pound containing viable caryopses. On this basis a selected rate of planting of 4½ pounds of pure live seed per acre would plant 20 viable seed units per square foot.

Side-oats grama grows well in mixtures with other warm-season grasses to produce maximum forage for summer use. It is an important component of mixtures to be planted on fine-textured, upland soils for conservation and forage.

# Side-Oats Grama in the Central Great Plains[1]

**L. C. Newell, R. D. Staten,**

**E. B. Jackson, and E. C. Conard[2]**

## INTRODUCTION

Side-oats grama, *Bouteloua curtipendula* (Michx.) Torr., is a warm-season grass distributed widely in the native grasslands of continental United States. It has long been considered a valuable forage grass. Its habit of growth and favorable seed-producing qualities have suggested its suitability for domestication as a pasture crop.

Investigations which contributed to the domestication of side-oats grama were conducted at the Nebraska Agricultural Experiment Station in a 12-year period, 1948 to 1960. Field trials were carried on to evaluate forage and seed yields of selected strains and varieties from

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[1] Cooperative investigations of the Nebraska Agricultural Experiment Station and the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture.

[2] L. C. Newell is Professor of Agronomy, University of Nebraska, and Research Agronomist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, in charge of grass breeding and improvement at the Nebraska Experiment Station.

E. C. Conard is Associate Professor of Agronomy in charge of pasture investigations at the Nebraska Experiment Station.

R. D. Staten and E. B. Jackson were formerly graduate Research Assistants in Agronomy at the University of Nebraska. Dr. Staten is Associate Professor of Agronomy, Department of Soil and Crop Sciences, Texas A. and M. College, College Station, Texas; Dr. Jackson is Assistant Agronomist, Yuma Branch Station, University of Arizona at Yuma, Arizona.

different regions. The photoperiodic responses of these strains were studied under controlled conditions to develop possible explanations of differences in strain adaptation. Two varieties were developed for use in the latitudes of the Central Plains region as a result of these investigations. Studies were initiated also to determine suitable cultural methods for stand establishment and utilization and for the production of seed of the adapted varieties. The purposes of this bulletin are to present the results of these experiments and to recommend practices for production and use of side-oats grama.

## PREVIOUS WORK

Side-oats grama is one of the native grasses noted by forage investigators in western states at an early date. Lyon and Hitchcock (13) reported favorably on the first experimental planting of side-oats grama by the Nebraska Experiment Station in 1897. Hay yields of two and four tons per acre were reported for the first two seasons of production from this planting. From another planting made in 1900 seed crops were obtained on August 21 and October 16, 1901. They considered this grass very promising for the dry regions of Nebraska, where as a native plant it was excellent for pasture and promised well for hay. They suggested that side-oats grama would be most useful in mixtures with other grasses.

Experimental or practical developments from these early studies did not materialize until mid-century. This was because there was an abundance of unplowed native grasslands in the early period and attention was focused on the development of cash crops. The droughts of the 1930's changed this viewpoint and interest in adapted native grasses was revived. Harvests of large quantities of grass seed from native stands has become the common practice in recent years of favorable seed set.

Fults (4) studied the chromosome complements of side-oats grama plants from 32 seed sources in the central and southern Great Plains. He classified and described five biotypes. Chromosome numbers were hexaploid and near-hexaploid complements of 42 and 40 chromosomes, but the biotypes were not found to have distinctly characteristic chromosome number or morphology.

Olmstead (16) working with several species of *Bouteloua,* reported that side-oats grama was sensitive to photoperiod. Garner and Allard (7) first announced the discovery of the principle of photoperiodism in 1920. Since then, numerous investigators have studied the effect of the relative lengths of day and night on initiation of sexual reproduction in many kinds of plants.

Garner (5) classified plants into three groups according to their photoperiodic response with reference to flowering and fruiting. Reproductive activity in a short-day plant is expressed in a relatively short photoperiod, while a long-day plant responds with heading and flowering in a relatively long photoperiod. Short-day plants flower and fruit through a range of day lengths up to, but not above, a certain maximum known as their critical photoperiod, while long-day plants reproduce through a range of photoperiods down to, but not below, their critical photoperiod.

Photoperiodic classification of plants depends on whether the critical photoperiod marks the lower or upper limit of day length conducive to reproductive activity. Plants which flower readily in either a long or short photoperiod are designated as day-neutral and have no critical photoperiod.

Evans and Allard (3), working with timothy, *Phleum pratense L.*, showed that marked differences frequently exist in the critical photoperiods of otherwise closely related varieties. They stated that in any locality earliness or lateness of different strains is almost entirely dependent upon the response of the strains to photoperiod.

Larsen and Olmstead (12) grew strains of little bluestem, *Andropogon scoparius Michx.*, ranging in source from Texas to North Dakota and from Montana to Connecticut, under controlled greenhouse conditions. The photoperiodic responses of these strains indicated that those of northern origin are long-day types, while the southern strains are either intermediate in response or short-day types.

Plant growth and development commonly is influenced by temperature in association with the effects of photoperiod. According to Garner (6), light requirements of a plant may be modified by differences in temperature.

Allard and Evans (1), studying the photoperiodic responses of several species of grasses, concluded that the different responses represented inherent strain differences.

Purvis (19) and McKinney and Sando (14) found that winter and spring cereals have very definite light and temperature requirements. The early stage of flower development in winter cereals is delayed by long days but subsequent development is favored. Spring cereals respond favorably at all stages to long days. Vernalization of winter cereals, however, causes them to respond like the spring types with regard to day-length.

Steinberg and Garner (21) reported a definite change in critical photoperiod for early, medium, and late maturing varieties of soybeans with slight changes in temperature treatment.

Roberts and Struckmeyer (20) stated that the effects of other environmental factors as well as temperature indicated that blossoming results directly from the nature of the internal condition of the plant rather than from any specific external environment.

Olmstead (17, 18) found that strains of side-oats grama from northern latitudes were essentially long-day plants, and strains from southern Texas and southern Arizona consisted almost entirely of short-day plants; whereas certain Oklahoma and New Mexico strains contained plants which showed more diversity of response to short or intermediate critical photoperiods.

Harlan (9) reported that growth habit, leaf and stem characters, etc., found in variable populations of side-oats grama can be shifted toward a desired plant type and fixed to a reasonable degree in a few generations of selection.

## DESCRIPTION OF STRAINS AND VARIETIES

Experiments with side-oats grama from widely different origins were conducted in the greenhouse and in field plots during the period 1948 to 1955. Sources of the strains ranged from North Dakota to Oklahoma and New Mexico. Brief descriptions of origin of these plant materials are presented to aid in the interpretation of the early comparisons.

North Dakota 97 resulted from a bulk field collection made in 1934 near Mandan, N. D. Seed was furnished for the experimental studies by George A. Rogler from a rod-row increase made at the Northern Great Plains Field Station. This material was only one generation removed from the original, and one of the better accessions for conditions prevailing in North Dakota.

Nebraska 37 and Nebraska 52 were developed at the Nebraska Experiment Station in cooperation with the Agricultural Research Service and the Soil Conservation Service, U. S. Department of Agriculture. Nebraska 37 is representative of the best endemic strains of side-oats grama found throughout central and northern Nebraska. This strain was produced from a composite of two high yielding collections made in Holt and Platte Counties by the Soil Conservation Service. It was released cooperatively in 1958 for seed production and certification under the variety name of Butte.

Nebraska 52 was produced by selection and recombination within a naturally occurring hybrid population found in northern Nebraska. The original collection was made by L. C. Newell along an old wagon trail northwest of O'Neill, Nebr. Selection in subsequent generations grown in nurseries at Lincoln, Nebr., was directed toward improved leafiness, late maturity, and rust resistance. After six generations of selection, Nebraska 52 exhibits a vegetative growth that is characteristic of side-oats grama obtained from much farther south than Nebraska. Nebraska 52 was released cooperatively in 1958 by the Nebraska Station for seed production and certification as the variety Trailway.

The variety El Reno originated from an old field near El Reno, Okla. Seed was harvested from this field by B. F. Kiltz of the Nursery Division of the Soil Conservation Service and was increased at Manhattan, Kan. In 1937, the Oklahoma Experiment Station at Stillwater received seed of El Reno side-oats grama from the Manhattan nurseries. The variety has been used throughout central and western Oklahoma and in Kansas for range and pasture seedings.

New Mexico A-3603 was obtained for these studies from C. G. Marshall of the Soil Conservation Service nursery at Albuquerque, N. M. This strain was originally collected near Vaughn, N. M. It has been used for range reseeding throughout Utah, Colorado, and the northern half of New Mexico and Arizona. It is used under the variety name Vaughn.

Oklahoma Tucson resulted from selection of the best plants in a nursery of Arizona Tucson, grown at Stillwater, Okla. It is a variety reproduced by apomixis (8). The original collection of Tucson was made by C. R. Proctor near Douglas, Ariz., in 1935. It was grown in a nursery at Tucson, Ariz., under the number A-2405 and later sent to Woodward, Okla., by way of the Soil Conservation Nursery at Lincoln, Nebr.

## COMPARISONS IN CONTROLLED ENVIRONMENTS

Greenhouse experiments were conducted at Lincoln to study varietal responses of side-oats grama to different photoperiods. Since reaction to photoperiod is a critical factor in adaptation, it is desirable to know the environmental factors which activate the reproductive phase, and to be able to control the factors responsible for the production of a maximum number of flowers and an adequate pollen supply. Preliminary tests, on locally adapted clonal material, indicated that a 16-hour photoperiod and temperatures of 75° to 85° F. favored flower production on these plants.

Two experiments were conducted to compare the development of the several varieties grown under natural short days with their development under daily photoperiods of 16 hours.

Seedlings were grown in four-gallon crock water-coolers filled with sand. The crocks were drained from the bottom through approximately three inches of gravel. Plants were watered daily with one pint of nutrient solution per crock and crocks were flushed occasionally with tap water to remove excess salts.

The nutrient solutions were made with technical grade salts and commercial fertilizers. Separate stock solutions of the following four salts were maintained.

| Salt | Grade | Grams per liter |
|---|---|---|
| Ammonium nitrate (32% N) | Fertilizer | 32 |
| Treble superphosphate (42% $P_2O_5$) | Fertilizer | 10 |
| Potassium sulfate (N-free) | Technical | 20 |
| Magnesium sulfate (N-free) | Technical | 8 |

Plants were watered with a solution composed of 10 cc. of each stock solution per liter of tap water. The fertilizers were considered to contain sufficient minor elements for the growth and development of side-oats grama.

Light was controlled with black sateen curtains arranged between the natural and 16-hour photoperiod treatments. The long photoperiod of 16 hours was obtained by the use of 200-watt incandescent bulbs in large reflectors arranged approximately three feet apart and operated automatically to extend the natural photoperiod.

## Varietal Responses to Increasing Photoperiod

Seed of five strains of side-oats grama was planted on December 11, 1948, and 10 seedlings of each strain were transplanted into each of 6 crocks of sand on January 1, 1949. Three replicates of these plants were then placed under each of two photoperiod treatments, a naturally increasing day and a continuous 16-hour photoperiod.

The varieties were classified, according to origin and their responses to short days, into three rather distinct groups. These groups were northern, including North Dakota 97 and Nebraska 37 (Butte); central, composed of Nebraska 52 (Trailway) and El Reno, and southwestern, represented by New Mexico A-3603 (Vaughn).

Relationships among the five varieties, with regard to height of leaves and height of flowering culms are presented in Table 1. The northern group grew little under conditions of short days and produced few flowering culms during the short period in which they were

**Table 1.—Average top-growth characteristics of five varieties of side-oats grama grown in sand cultures and subjected to different greenhouse photoperiod treatments, January 1 to June 1, 1949.[a]**

| Variety and source | Photoperiod | Height: Leaves | Height: Flowering culms | Total culms | Flowering culms |
|---|---|---|---|---|---|
| | | In. | In. | No. | No. |
| North Dakota 97 | Natural[b] | 8 | 14 | 204 | 8 |
| | 16-hour | 14 | 42 | 221 | 79 |
| Nebraska 37 (Butte) | Natural | 12 | 18 | 223 | 13 |
| | 16-hour | 21 | 50 | 294 | 77 |
| Nebraska 52 (Trailway) | Natural | 19 | 34 | 336 | 44 |
| | 16-hour | 25 | 50 | 298 | 88 |
| Oklahoma El Reno | Natural | 19 | 35 | 270 | 49 |
| | 16-hour | 26 | 46 | 236 | 45 |
| New Mexico A-3603 (Vaughn) | Natural | 23 | 42 | 480 | 105 |
| | 16-hour | 25 | 52 | 413 | 165 |

Mean squares from analyses of variance.[c]

| Source of Variation | D. F. | M. S. | M. S. | M. S. | M. S. |
|---|---|---|---|---|---|
| Varieties (V) | 4 | 179** | 336** | 49842** | 9103** |
| Photoperiods (P) | 1 | 288** | 2803** | 750 | 16521** |
| V x P | 4 | 14** | 158** | 4442 | 1342 |
| Error | 20 | 2 | 11 | 2562 | 553 |

[a] Averages of three replications of 10 plants each.
[b] The natural photoperiod was the normal short day which increased during the period of growth.
[c] The double asterisk indicates F values which exceed the 1 per cent level of significance.

exposed to long spring days in the natural photoperiod treatment. The southwestern strains grew relatively well under the short days and reproduced much ahead of other types. The other two varieties were intermediate in growth and reproductive responses under these conditions (Figure 1). The leaves of the central group were 7 to 11 inches taller and the leaves of the New Mexico strain were 12 to 16 inches taller than the two northern varieties. Similarly, the flowering culms of the central group were 16 to 20 inches taller and the culms of the New Mexico strain were 24 to 28 inches taller than the northern group. In general, the more southern the variety the greater the number of tillers and flowers produced under the natural, increasing photoperiod.

The growth responses of all varieties were improved by the 16-hour photoperiod (Figures 2 and 3). Differences among varieties in their responses to the longer photoperiod were varied, but the same general relationships among the northern and southern varieties were apparent. The greatest contrast between treatments was shown by the northern varieties which responded markedly to the 16-hour photo-

**Figure 1.—Characteristic growth of side-oats grama grown in sand cultures with the natural increasing photoperiod from January 1 to June 1. Left to right: New Mexico A-3603 (Vaughn), El Reno, Nebraska 52 (Trailway), Nebraska 37 (Butte), and North Dakota 97.**

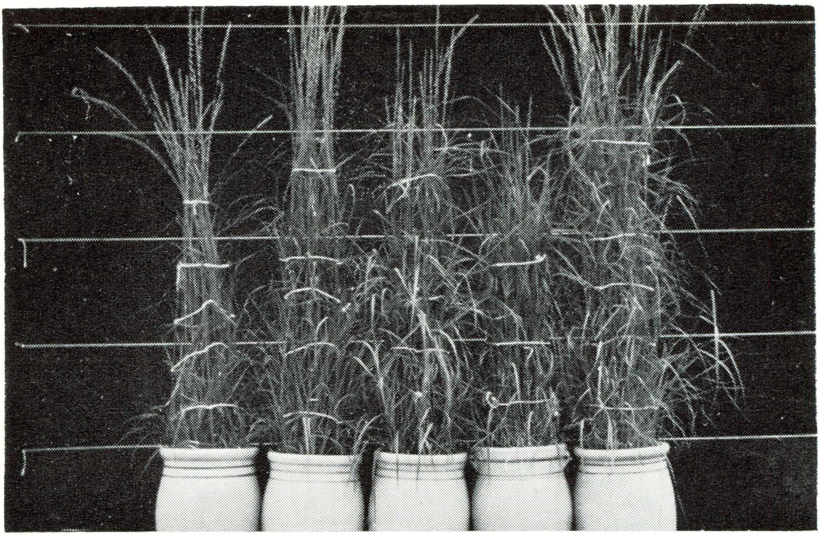

Figure 2.—Characteristic growth of side-oats grama grown with a continuous 16-hour photoperiod, January 1 to June 1. Left to right: North Dakota 97, Nebraska 37 (Butte), Nebraska 52 (Trailway), El Reno, and New Mexico A-3603 (Vaughn).

Figure 3.—Growth responses of side-oats grama subjected to naturally increasing short photoperiod compared with responses under a 16-hour photoperiod, January 1 to June 1, 1949. Two crocks of seedlings for each variety occur together: left, the 16-hour photoperiod and right, the natural photoperiod. Left to right: New Mexico A-3603 (Vaughn), Nebraska 52 (Trailway), and North Dakota 97, representing southwestern, central, and northern regions of adaptation in the Great Plains.

period in both vegetative and reproductive growth, whereas long days retarded other varieties in total number of culms produced (Table 1).

The average yields of dry matter and the relationships between top growth and associated root development are given in Table 2. Plants of side-oats grama from the northern sources produced smaller yields of both tops and roots than the more southern varieties, under naturally increasing day-lengths. With the extension of the natural days to a 16-hour photoperiod, forage and root yields were increased. Top-root ratios, however, proved to be wider with artificially long days than with the natural days.

North Dakota 97 and Nebraska 37 produced smaller yields of forage than the more southern varieties. Nebraska 52, El Reno, and New Mexico A-3603 not only produced larger yields of tops but also produced more roots than the northern varieties. However, the relationship of the amount of top growth to that of roots was markedly different for each variety.

North Dakota 97 and Nebraska 37 had relatively narrow top-root ratios of 2.00 and 1.88, respectively. These ratios and the wider ratios of 3.16 and 3.12 for Nebraska 52 and El Reno represent the extremes in top-root relationships. New Mexico A-3603 had an intermediate ratio of 2.53, indicating a good balance between roots and tops under the short-day treatment. The development of the above-ground portion of the plants of the central group increased at a more rapid rate than their root systems when subjected to the long photoperiod. Thus their

**Table 2.—Yields of tops in grams and top-root ratios of five varieties of side-oats grama grown in sand cultures and subjected to different greenhouse photoperiods, January 1 to June 1, 1949.[a]**

| Variety and source | Photoperiod | Green Weight Tops | Dry Weight Tops | Top-Root Ratio |
|---|---|---|---|---|
| North Dakota 97 | Natural[b] | 39 | 10 | 2.00 |
| | 16-hour | 189 | 58 | 2.76 |
| Nebraska 37 (Butte) | Natural | 105 | 27 | 1.88 |
| | 16-hour | 321 | 102 | 3.11 |
| Nebraska 52 (Trailway) | Natural | 272 | 69 | 3.16 |
| | 16-hour | 452 | 134 | 3.94 |
| Oklahoma El Reno | Natural | 231 | 59 | 3.12 |
| | 16-hour | 379 | 107 | 4.22 |
| New Mexico A-3603 (Vaughn) | Natural | 256 | 69 | 2.53 |
| | 16-hour | 448 | 151 | 3.62 |
| Mean squares from analyses of variance.[c] | | | | |
| Source of Variation | D. F. | M. S. | M. S. | M. S. |
| Varieties (V) | 4 | 66092** | 5592** | 2.09** |
| Photoperiods (P) | 1 | 235845** | 30656** | 7.34** |
| V x P | 4 | 1227 | 351 | .09 |
| Error | 20 | 3251 | 545 | .32 |

[a] Averages of three replications of 10 plants each.
[b] The natural photoperiod was the normal short day which increased during the period of growth.
[c] The double asterisk indicates F values which exceed the 1 per cent level of significance.

top-root ratios are even wider than described for the shorter photoperiod.

Characteristic flowering responses of the side-oats grama in the natural, increasing photoperiod and in the continuous 16-hour photoperiod are contrasted in Table 3. Their characteristic flowering responses indicate the large differences among these strains, which have evolved in widely different environments.

New Mexico A-3603, when subjected to the short photoperiod of winter and early spring, required only 87 days from date of seeding to date of first flower formation. El Reno and Nebraska 52 required 96 and 120 days to flower, while Nebraska 37 and North Dakota 97 required 159 and 164 days, respectively. As the source of these strains became progressively more northern, it took a greater number of days for the plant to reach the flowering stage under the natural, increasing photoperiod.

This phenomenon associates the flowering response to a critical photoperiod somewhat shorter than that indicated at the time of first flowering, since some time elapsed between flower initiation and its expression.

The flowering responses of the seedlings in the 16-hour photoperiod showed a different pattern than in the other treatment. North Dakota 97, Nebraska 37, Nebraska 52, and El Reno required 111, 120, 138 and 148 days, respectively. The order of flowering for these four strains was reversed from that during naturally increasing photoperiods. North Dakota 97 and Nebraska 37 flowered readily under a 16-hour photoperiod but both vegetative and reproductive development were delayed under natural winter and spring days until the daily period of light reached a critical point between 14 and 15 hours. El Reno and Nebraska 52 required a minimum of 12 and 13 hours of light to initiate their reproductive phase. A 16-hour photoperiod retarded their flowering. The New Mexico strain, on the other hand,

**Table 3.—Flowering responses of five varieties of side-oats grama to artificial long-day and natural, increasing photoperiods, January 1 to June 1.**

| Variety and source | Photoperiod | First Flowers Produced | Days to First Flowering | Photoperiod on Date of First Flowering |
|---|---|---|---|---|
| | | Date | No. | Hrs.: Min. |
| North Dakota 97 | Natural | May 24 | 164 | 14:45 |
| | 16-hour | April 1 | 111 | |
| Nebraska 37 | Natural | May 19 | 159 | 14:35 |
| (Butte) | 16-hour | April 10 | 120 | |
| Nebraska 52 | Natural | April 10 | 120 | 13:05 |
| (Trailway) | 16-hour | April 28 | 138 | |
| Oklahoma | Natural | March 17 | 96 | 12:00 |
| El Reno | 16-hour | May 8 | 148 | |
| New Mexico | Natural | March 8 | 87 | 11:35 |
| A-3603 (Vaughn) | 16-hour | March 29 | 108 | |

required only 108 days to produce its first inflorescence under long days. It flowered readily under short days of 11½ hours, and also developed comparatively rapidly under a 16-hour photoperiod. This strain exhibited a low minimum photoperiod for initiation of inflorescences and produced flowers through a wide range of photoperiods.

## Varietal Responses to Decreasing Photoperiod

Seed of six strains of side-oats grama was planted on May 7, 1949, and 10 seedlings of each strain were transplanted into each of 6 crocks of sand on June 2, 1949. Three replicates of seedlings were subjected to naturally decreasing lengths of day, and their responses compared with those obtained with three replicates under a 16-hour photoperiod. Varieties used in this study included Oklahoma Tucson and the five strains previously tested.

Since the lengths of photoperiod that occur naturally during June and early July at Lincoln are between 15 and 16 hours, the two photoperiod treatments at the beginning of the experiment were similar. The growth responses under the two treatments are, therefore, not greatly different. Table 4 presents average growth characteristics obtained with these treatments. It shows trends in development among the strains similar to those in the previous experiment which support the information obtained from plants subjected to the natural, increasing photoperiods.

**Table 4.—Average top-growth characteristics of six varieties of side-oats grama grown in sand cultures and subjected to artificial, long-day and natural decreasing photoperiods, May 7 to September 1, 1949.[a]**

| Variety and source | Photoperiod | Height: Leaves | Height: Flowering culms | Total culms | Flowering culms |
|---|---|---|---|---|---|
| | | In. | In. | No. | No. |
| North Dakota 97 | Natural[b] | 13 | 35 | 212 | 84 |
| | 16-hour | 15 | 38 | 229 | 91 |
| Nebraska 37 (Butte) | Natural | 19 | 47 | 208 | 61 |
| | 16-hour | 19 | 44 | 219 | 53 |
| Nebraska 52 (Trailway) | Natural | 25 | 50 | 212 | 74 |
| | 16-hour | 25 | 51 | 208 | 66 |
| Oklahoma El Reno | Natural | 26 | 54 | 224 | 71 |
| | 16-hour | 26 | 53 | 226 | 74 |
| New Mexico A-3603 (Vaughn) | Natural | 31 | 59 | 300 | 99 |
| | 16-hour | 32 | 57 | 255 | 62 |
| Oklahoma Tucson | Natural | 32 | 59 | 248 | 114 |
| | 16-hour | 32 | 56 | 229 | 62 |
| Mean squares from analyses of variance.[c] | | | | | |
| Source of Variation | D. F. | M. S. | M. S. | M. S. | M. S. |
| Varieties (V) | 5 | 294** | 403** | 3703** | 853 |
| Photoperiod P) | 1 | 0 | 7 | 367 | 1804* |
| V x P | 5 | 1 | 7 | 773 | 928 |
| Error | 24 | 2 | 12 | 751 | 403 |

[a] Averages of three replications of 10 plants each.
[b] The natural photoperiod was the normal long day which decreased during the period of growth.
[c] The single and double asterisk indicate F values which exceed the 5 and 1 per cent levels of significance, respectively.

The average height of leaves for the two southern strains was 6 to 7 inches more than for the varieties of the central group and 13 to 19 inches more than for the two northern varieties. Similar responses were noted regarding the height of flowering culms. There was a tendency for an increase in tillering of the northern varieties and a decrease in tillering of the southern varieties, resulting from artificially long days. The longer periods of light had no great effect on tillering of the central varieties.

Production of inflorescences by the most northern strain was favored by a 16-hour period of light, but the flower production of the strains from the most southern sources was sharply retarded under continuous, long days. These data lend support to the hypothesis that North Dakota 97 and Nebraska 37 react as long-day plants, Nebraska 52 and El Reno are favored by intermediate photoperiods, and the Oklahoma Tucson and New Mexico A3603, especially the latter, responded as short-day plants.

Relationships among the varieties were similar to those in the previous experiment. Varieties differed significantly in height of leaves and flowering culms, and total number of culms but did not differ significantly in number of flowering culms (Table 4). The more southern the origin the greater the yields of both tops and roots (Table 5). Top-root ratios were higher for all strains during the summer growth period than during the previous winter and spring period, but the relationships among varieties are apparent. North Dakota 97 and Nebraska 37 had the narrowest top-root ratios, while Nebraska 52 and El Reno had the widest. The two southwestern strains had ratios which were intermediate between the other two groups.

A comparison of the varieties again shows that side-oats grama strains from different regions of adaptation exhibited variable responses when subjected to a given photoperiod. In this widely variable species, strains adapted to different environments fall logically into different classifications in response to photoperiod (Table 6).

With the naturally decreasing photoperiod of summer days at Lincoln, the two northern strains produced their initial flowers 2 to 3 weeks earlier than the two southern strains and 3 to 4 weeks earlier than the central group. First flower production was somewhat earlier with a continuous 16-hour photoperiod than for the natural days for North Dakota 97, Nebraska 37, Nebraska 52, and El Reno; whereas the first flower production of Oklahoma Tucson and New Mexico A-3603 was later with the continuous, long photoperiod than for natural days.

## FIELD TRIALS OF VARIETIES

### Forage and Seed Yields at Lincoln

Field plots of the six strains of side-oats grama were established in the spring of 1949 to evaluate them for forage production and seed

**Table 5.—Yields of tops in grams and top-root ratios of six varieties of side-oats grama grown in sand cultures and subjected to artificial, long-day and natural, decreasing photoperiods, May 7 to September 1, 1949.**[a]

| Variety and source | Photoperiod | Green Weight Tops | Dry Weight Tops | Top-Root Ratio |
|---|---|---|---|---|
| North Dakota 97 | Natural[b] | 116 | 37 | 3.27 |
| | 16-hour | 143 | 52 | 4.46 |
| Nebraska 37 (Butte) | Natural | 156 | 51 | 4.07 |
| | 16-hour | 160 | 52 | 4.52 |
| Nebraska 52 (Trailway) | Natural | 224 | 77 | 5.86 |
| | 16-hour | 202 | 71 | 6.03 |
| Oklahoma El Reno | Natural | 246 | 87 | 5.70 |
| | 16-hour | 241 | 92 | 6.07 |
| New Mexico A-3603 (Vaughn) | Natural | 314 | 119 | 5.12 |
| | 16-hour | 255 | 107 | 4.96 |
| Oklahoma Tucson | Natural | 283 | 120 | 5.81 |
| | 16-hour | 292 | 115 | 5.87 |

Mean squares from analyses of variance.[c]

| Source of Variation | D. F. | M. S. | M. S. | M. S. |
|---|---|---|---|---|
| Varieties (V) | 5 | 25618** | 5631** | 4.03** |
| Photoperiods (P) | 1 | 536 | 0 | 0.82 |
| V x P | 5 | 1327 | 137 | 0.95 |
| Error | 24 | 1251 | 131 | 0.63 |

[a] Averages of three replications of 10 plants each.
[b] The natural photoperiod was the normal long day which decreased during the period of growth.
[c] The double asterisk indicates F values which exceed the 1 per cent level of significance.

**Table 6.—Flowering responses of six varieties of side-oats grama to artificial long-day and natural, decreasing photoperiods, May 7 to September 1, 1949.**

| Variety and source | Photoperiod | First Flower Produced | Days to First Flowering | Photoperiod on Date of First Flowering |
|---|---|---|---|---|
| | | Date | No. | Hrs.: Min. |
| North Dakota 97 | Natural | July 4 | 58 | 15:02 |
| | 16-hour | July 1 | 55 | |
| Nebraska 37 (Butte) | Natural | July 13 | 67 | 14:50 |
| | 16-hour | July 10 | 64 | |
| Nebraska 52 (Trailway) | Natural | Aug. 1 | 86 | 14:20 |
| | 16-hour | July 19 | 73 | |
| Oklahoma El Reno | Natural | Aug. 1 | 86 | 14:20 |
| | 16-hour | July 21 | 75 | |
| New Mexico A-3603 (Vaughn) | Natural | July 25 | 79 | 14:30 |
| | 16-hour | Aug. 1 | 86 | |
| Oklahoma Tucson | Natural | July 22 | 76 | 14:40 |
| | 16-hour | Aug. 1 | 86 | |

yields. Plot size was six drilled rows, 12 feet long, spaced at one-foot intervals. The plots were arranged in a randomized-block design with eight replications. Four replications were harvested at the flowering stage for hay. The remaining four were harvested at maturity for seed yields and total production. Yields were calculated from 10 feet of the four center rows.

**Comparisons in 1949.**—The plots of this experiment were not established until late May, but all strains made a remarkable growth during the succeeding three months. During that time the plots were kept weed-free. Figure 4 shows the characteristic summer growth produced in the first season. Table 7 shows that most of the strains produced two to three tons of hay per acre the first year and that seed yields ranged from approximately 100 to 360 pounds per acre.

The Oklahoma Tucson strain had the highest yield of hay, producing slightly over three tons per acre, while the North Dakota strain was the lowest yielding, producing only 0.63 ton of hay per acre, harvested September 1. The hay yields of the four remaining strains ranged from 2.03 to 2.48 tons per acre with small differences among their respective yields in their first season (Table 7).

By the time all the varieties had reached vegetative maturity, October 1, the production of forage ranged from 0.55 to 3.08 tons per acre for the varieties North Dakota 97 and Oklahoma Tucson, respectively. Forage yields for these strains were approximately the same as the September 1 hay yields. Yield relationships changed some from September 1 to October 1, the earlier maturing strains showing the disadvantage of the late harvest.

Yields of seed, in the year of establishment, were relatively large due to the plentiful supply of moisture, a fertile soil, control of weeds, and favorable weather conditions during pollination. North Dakota

**Figure 4.—Field planting of side-oats grama, ranging in source from North Dakota to New Mexico, at Lincoln. The Oklahoma Tucson strain can be distinguished by its light color. Plots planted May 20, 1949 and photographed *August 10, 1949.***

Table 7.—Yields of forage and seed of six varieties of side-oats grama grown in field plots at Lincoln in 1949.[a]

| Variety | Forage production per acre[b] | | Seed yield per acre[c] |
|---|---|---|---|
| | Cut for hay September 1 | Cut at maturity October 1 | |
| | Tons | Tons | Lbs. |
| North Dakota 97 | 0.63 | 0.55 | 97 |
| Butte (Nebr. 37) | 2.09 | 1.69 | 170 |
| Trailway (Nebr. 52) | 2.48 | 2.19 | 214 |
| El Reno | 2.25 | 2.78 | 361 |
| Vaughn (N. Mex. A-3063) | 2.03 | 2.60 | 201 |
| Oklahoma Tucson | 3.10 | 3.08 | 225 |
| Least significant differences between means of varieties | | | |
| P = .05 | 0.33 | 0.38 | 66 |
| P = .01 | 0.46 | 0.52 | 91 |

[a] Averages of four replications.
[b] Forage yields on an oven-dry basis.
[c] Seed yields are on the basis of approximately 80 per cent purity by weight.

97 was significantly lower in yield than any other strain, while yields of El Reno and New Mexico A-3603 were significantly higher. The two Nebraska strains and Tucson produced approximately 200 pounds of seed per acre with no great differences among them.

**Comparisons in 1950.**—The winter of 1949-50, at Lincoln, Nebr., was characterized by moderate temperatures and very little snow cover. Occasionally, plants were coated with ice from freezing rains, followed by short periods of cold weather with temperatures below 0° F. In spite of good establishment in 1949, Oklahoma Tucson was winter-killed approximately 95 per cent, and its yields were omitted from statistical analyses and varietal comparisons in the 1950 season. New Mexico Vaughn (A-3603) was so damaged that only a few stems emerged from old clumps the following spring. It was estimated to be about 50 per cent winter-killed. The protected undamaged portions of these plants tended to recover but gave low yields. Other strains were not affected.

Forage yields from two hay cuttings and the total hay production for the season are shown in Table 8 for comparison with yields of forage harvested at maturity. The forage yields for most strains were greater in 1950 than in 1949.

A comparison of the hay yields of the varieties at the two dates of harvest reveals that the amount of aftermath hay produced by the northern group of varieties was approximately one-half as large as the forage produced at the earlier cutting date. The varieties of the central group, on the other hand, produced aftermath yields that were approximately two-thirds as large as that at the first harvest. The hay yields for the southern group on these two dates were about equal. Thus, the more southern varieties produce a larger proportion of their total hay later in the season, whereas the northern varieties make most of their growth early. Butte, Trailway, and El Reno hay yields

Table 8.—Yields of forage and seed of six varieties of side-oats grama grown in field plots at Lincoln in 1950.[a]

| Variety | Forage production per acre[b] | | | | Seed yield per acre[c] |
|---|---|---|---|---|---|
| | Cut for hay | | | Cut at maturity | |
| | First cutting July 24 | Aftermath Oct. 2 | Total | | |
| | Tons | Tons | Tons | Tons | Lbs. |
| North Dakota 97 | 1.59 | 0.82 | 2.41 | 1.36 | 90 |
| Butte (Nebr. 37) | 4.15 | 2.09 | 6.24 | 4.69 | 244 |
| Trailway (Nebr. 52) | 3.92 | 2.60 | 6.52 | 4.53 | 118 |
| El Reno | 4.07 | 2.72 | 6.79 | 5.64 | 225 |
| Vaughn (N. Mex. A-3603) | 1.99 | 1.97 | 3.96 | 2.41 | 48 |
| Oklahoma Tucson[d] | 0.13 | 0.56 | 0.69 | 0.73[e] | 23[e] |
| Least significant differences between means of varieties | | | | | |
| P = .05 | 0.58 | 0.67 | 1.14 | 0.50 | 51 |
| P = .01 | 0.82 | 0.94 | 1.59 | 0.71 | 71 |

a Average of four replications.
b Forage yields on an oven-dry basis.
c Seed yields are on the basis of approximately 80 percent purity by weight.
d Omitted from statistical analyses due to approximately 95 percent winterkilling.
e Average of three replications.

totalled 6.24, 6.52, and 6.79 tons per acre, respectively. These yields were significantly greater than the yields of either the most northern or the most southern strains. Hay production for the combined cuttings was greater than total production taken once at maturity, for all the five varieties.

Forage yields of the varieties, cut at maturity, ranged from 1.36 to 5.64 tons per acre for North Dakota 97 and El Reno, respectively. In this comparison, the yield of El Reno was significantly greater than the yield of either of the two Nebraska strains and North Dakota 97 was significantly lower yielding among the five varieties. These relationships were similar to those which existed among these strains during the 1949 season. There was no significant difference between the yield of the Nebraska strains in either year.

Seed yields in 1950, for all varieties except Butte, were lower than in 1949. The North Dakota strain matured approximately three weeks earlier and Butte matured two weeks earlier than any of the other varieties. During their periods of maximum flower formation the weather was warm and dry. A period of frequent rains and cool, moist conditions prevailed later when other strains began to flower. Because of the better conditions for pollination in the earlier period, North Dakota 97 and Butte produced relatively large seed yields, while the yields of the other strains were materially reduced in comparison with the former year.

Plots were maintained in the third year but yields were not determined. El Reno winter-killed significantly in the second winter. Plots of winter-killed varieties became infested with seedlings from early-maturing strains and the North Dakota strain made such poor growth that the plots became weedy. The comparison was thus narrowed to the locally adapted varieties, Butte and Trailway. These varieties had responded differently in tests, but their average seasonal yields were very similar.

**Statistical interpretations.**—The analyses of variance of the forage and seed yields, produced by five varieties of side-oats grama during a two-year period are presented in Appendix Table A. Significant differences were found among varieties for forage production and the forage yields in 1950 proved to be significantly greater than in 1949.

The significant interaction, Variety x Years, indicates that the varieties responded differently in the two years both for forage cut at an optimum time for hay and for total yields at maturity. The cause of this interaction can be attributed, for the most part, to the responses of Butte. During the first year it produced relatively low yields, but it grew rapidly in the early part of the spring of the second year, whereas the more southern strains were delayed in their development. Thus, at the end of the second year this strain ranked as one of the highest yielding in forage.

Seed yields also proved to be different in the two seasons. The varieties responded differently in the two years, causing a highly significant interaction. This interaction was caused largely by the variable responses of Butte, Trailway, and El Reno to the environments of the two years. El Reno produced the highest seed yields in the first year, but in the second year Butte ranked first, followed by El Reno. Since seed yields of the other strains were generally smaller in 1950 than in 1949, they also contributed to this interaction.

## Yields in Kansas and Oklahoma

The growth responses of Butte and Trailway in the Nebraska tests were not fully interpreted until their responses under other conditions were noted. Comparative yields of varieties at two southern locations added much to an understanding of the effects of differences in photoperiod and temperature on growth response and adaptation.

**Manhattan, Kan., 1953 - 1955.**—Yields of eight strains of side-oats grama from different origins compared in 1953 and 1955 at Manhattan, Kan., were furnished through the courtesy of M. D. Atkins, of the Plant Materials Section, Soil Conservation Service (Table 9). In this comparison, El Reno, Trailway, and Hope were in the leading group of adapted productive varieties, whereas the more southern varieties dropped into a secondary group in their yield response. Trailway and Butte were separated significantly in different groups.

**Perkins, Okla., 1952-1955.**—Yields of eight strains of side-oats grama at Perkins, Okla., were reported by Professor Wayne W. Huffine, of the Oklahoma Agr. Exp. Station (Table 10). These comparisons showed Coronado, Hope, and Tucson to be the leading varieties in these tests, whereas El Reno and Trailway were in a secondary group, and Butte

Table 9.—Forage yields in tons per acre of side-oats grama varieties grown at Manhattan, Kan. (Compiled from data[a] furnished through the courtesy of M. D. Atkins, Soil Conservation Service.)

| Variety | 1953 | 1955 | Av. |
|---|---|---|---|
| El Reno | 2.96 | 3.28 | 3.12 |
| Hope | 2.39 | 3.33 | 2.86 |
| Trailway (Nebr. 52) | 2.48 | 2.93 | 2.70 |
| Vaughn | 2.12 | 2.58 | 2.36 |
| Commercial | 2.21 | 1.98 | 2.10 |
| Tucson | 1.95 | 2.18 | 2.06 |
| Coronado | 1.79 | 2.20 | 2.00 |
| Butte (Nebr. 37) | 1.35 | 0.82 | 1.08 |

[a] Averages of three replications of air-dry forage.

Table 10.—Forage yields in tons per acre of side-oats grama varieties grown at Perkins, Okla. (Compiled from data furnished through the courtesy of Professor Wayne H. Huffine, Okla. Agr. Exp. Sta.)

| Variety | 1952 | 1953 | 1955 | Av. |
|---|---|---|---|---|
| Coronado | 1.34 (1) | 1.93 (2) | 1.02 (3) | 1.43 |
| Hope | 1.05 (5) | 1.99 (1) | 1.22 (1) | 1.42 |
| Tucson | 1.07 (4) | 1.80 (4) | 1.07 (2) | 1.31 |
| El Reno | 1.16 (2) | 1.78 (5) | 0.80 (4) | 1.24 |
| Vaughn | 1.01 (6) | 1.92 (3) | 0.79 (6) | 1.24 |
| Trailway (Nebr. 52) | 1.08 (3) | 1.72 (6) | 0.72 (7) | 1.17 |
| Commercial | 1.18 (7) | 1.38 (7) | 0.80 (4) | 1.12 |
| Butte (Nebr. 37) | 1.08 (8) | 1.13 (8) | 0.25 (8) | 0.82 |

under these conditions even compared unfavorably with a commercial lot. The poor response of Butte is easily explained because of its requirement for the photoperiod-temperature relations of longer summer days. Obviously here its response was strikingly different from that of Trailway.

## Butte and Trailway Compared

In the six-year period, 1949 to 1954, experiments were conducted with the two Nebraska varieties at the Lincoln and North Platte Experiment Stations. These varieties were compared in connection with a larger experiment dealing with the responses of several grasses to nitrogen fertilization in the two environments.

**Lincoln, 1949-1953.**—Yields of forage produced by Butte and Trailway at two levels of nitrogen fertilization were obtained in a dry-land test at Lincoln during a five-year period (Table 11). Triplicate plots of each variety were compared in a split-plot design for nitrogen fertility. Ammonium nitrate fertilizer was applied to half of the plots annually at the rate of 50 pounds of N per acre before the period of most rapid growth of the grass in early June of each year. Yields were obtained each year from two harvests by mowing.

In these tests again the performance of the two varieties was somewhat similar with certain trends of dissimilarity. Trailway gave some-

Table 11.—Forage yields of Butte and Trailway side-oats grama, grown with and without nitrogen fertilization and harvested twice each season at Lincoln during the five-year period, 1949-1953.

| Year | Crop[b] | Yield of oven-dry forage, tons per acre[a] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Butte | | | Trailway | | |
| | | Fertilized[c] | Not fert. | Av. | Fertilized[c] | Not fert. | Av. |
| 1949 | First cutting | 1.31 | 0.91 | 1.11 | 1.67 | 0.95 | 1.31 |
| | Aftermath | .22 | .15 | .18 | .37 | .28 | .33 |
| | Total | 1.53 | 1.06 | 1.29 | 2.04 | 1.23 | 1.64 |
| 1950 | First cutting | 0.86 | 0.52 | 0.69 | 0.81 | 0.47 | 0.64 |
| | Aftermath | .33 | .11 | .22 | .46 | .20 | .33 |
| | Total | 1.19 | 0.63 | 0.91 | 1.27 | 0.67 | 0.97 |
| 1951 | First cutting | 1.31 | 0.40 | 0.85 | 1.24 | 0.39 | 0.82 |
| | Aftermath | .25 | .12 | .19 | .41 | .23 | .32 |
| | Total | 1.56 | 0.52 | 1.04 | 1.65 | 0.62 | 1.14 |
| 1952 | First cutting | 0.53 | 0.21 | 0.37 | 0.57 | 0.24 | 0.41 |
| | Aftermath | .55 | .13 | .34 | .78 | .24 | .51 |
| | Total | 1.08 | 0.34 | 0.71 | 1.35 | 0.48 | 0.92 |
| 1953 | First cutting | 0.79 | 0.22 | 0.51 | 0.78 | 0.23 | 0.51 |
| | Aftermath | .14 | .06 | .10 | .19 | .08 | .13 |
| | Total | 0.93 | 0.28 | 0.61 | 0.97 | 0.31 | 0.64 |
| Averages | | | | | | | |
| | First cutting | 0.96 | 0.45 | 0.71 | 1.01 | 0.46 | 0.74 |
| | Aftermath | .30 | .11 | .20 | .44 | .20 | .32 |
| | Total | 1.26 | 0.56 | 0.91 | 1.45 | 0.66 | 1.06 |

[a] Averages of three replications of fertilization treatments.
[b] First harvest was in mid-July and the aftermath harvest was in early October each year.
[c] Ammonium nitrate fertilizer was applied in early June each year at the average rate of 50 pounds of nitrogen per acre.

what larger yields than Butte, particularly with the nitrogen fertilization and in the second mowing. Although somewhat obscured by low yields in the years of low summer rainfall, the average performance of Trailway was superior to that of Butte in this planting.

**North Platte, Nebr., 1949-1954.**—An experiment similar to the one just described was conducted on non-irrigated land at the North Platte Experiment Station in the six-year period 1949-1954. Duplicate plots of each variety were compared at two levels of nitrogen fertility. Ammonium nitrate at the rate of 60 pounds of nitrogen was applied to half of the plots of Trailway and Butte in four of the years.

Forage yields were determined by mowing twice per year in the first two years and annually in the succeeding years (Table 12). The two grasses produced about equal yields. Butte had a small advantage in general performance under these conditions.

It is of interest to compare the yield response of Butte, a long-day variety, to the yields of varieties which responded differently to photoperiod. Apparently Butte should not be grown any further south than the latitude in which it has shown such good performance, i.e., approximately 42° North. In this latitude or further north it should be superior to the other varieties.

Table 12.—Forage yields of Butte and Trailway side-oats grama, grown with and without nitrogen fertilization on dryland at North Platte, Nebr., during the six years 1949-1954.

| Year | Date harvested | Yield of oven-dry forage, tons per acre[a] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Butte | | | Trailway | | |
| | | Fertilized[b] | Not fert. | Av. | Fertilized[b] | Not fert. | Av. |
| 1949 | June 27 | 0.71 | 0.49 | 0.60 | 0.58 | 0.49 | 0.53 |
| | October 15 | .60 | .36 | .48 | .42 | .23 | .33 |
| | Total | 1.31 | 0.85 | 1.08 | 1.00 | 0.72 | 0.86 |
| 1950 | July 26 | 0.53 | 0.25 | 0.39 | 0.49 | 0.18 | 0.33 |
| | October 5 | .37 | .03 | .20 | .58 | .07 | .33 |
| | Total | 0.90 | 0.28 | 0.59 | 1.07 | 0.25 | 0.66 |
| 1951 | August 15 | 2.35 | 0.64 | 1.50 | 1.93 | 0.79 | 1.36 |
| 1952 | July 2 | 0.46 | 0.30 | 0.38 | 0.29 | 0.30 | 0.30 |
| 1953 | July 23 | 0.18 | 0.15 | 0.16 | 0.17 | 0.16 | 0.16 |
| 1954 | July 28 | 0.11 | 0.07 | 0.09 | 0.07 | 0.07 | 0.07 |
| Average, total yields | | 0.89 | 0.38 | 0.63 | 0.76 | 0.38 | 0.57 |

[a] Yields are the averages of two replications of fertilization treatments.
[b] Ammonium nitrate fertilizer was applied in early June of four years, 1949-1951 and 1953, at the average rate of 60 pounds of nitrogen per acre. None was applied in 1952 and 1954.

## Tests in Wyoming and the Dakotas

Other tests of side-oats grama strains have been made in Wyoming, in South Dakota, and in North Dakota. Nebraska 37 (Butte) has been grown as far north as Mandan, N. D.

A comparative planting was made by Dr. Robert Lang at the Wyoming Experiment Station, Laramie, Wyo., in 1958 at an elevation of 7,150 feet. All of the southern varieties of side-oats grama winter killed completely in the first winter, whereas stands of Trailway and Butte were maintained. Although these varieties are not recommended for that elevation, they showed winter hardiness as predicted.

# COMPARISONS IN MIXTURES

A yield test comparing several grasses in pure stands and mixtures was conducted at Lincoln in 1950-1951.[3] In this study, Trailway side-oats grama was compared for forage yield with six other grasses, all grown in pure stands, and with simple mixtures of each of these grasses with Trailway. Plots were established by seeding on April 15, 1950, in a randomized-block design with three replications.

The grasses were planted in rows spaced one foot apart in plots 8 by 42 feet, both in pure stands and in the selected mixtures of two grasses. The grasses grown in mixtures were seeded in alternate rows. Plots were hand-weeded the first year and yields were obtained from

[3] Reported by R. Chase Allred. Effects of association on the responses of selected grasses grown in mixtures. Ph.D. Thesis. University of Nebraska. 1952.

Table 13.—Forage yields in tons per acre of Trailway side-oats grama compared with other grasses in pure stands from spring planting at Lincoln April 15, 1950.[a]

| Kind of grass | Total yield in pure stand[b] | |
|---|---|---|
| | First year, 1950 | Second year, 1951 |
| Warm-season grasses: | | |
| Side-oats grama | 2.02 | 3.31 |
| Sand lovegrass | 3.47 | 2.70 |
| Big bluestem | 2.41 | 4.32 |
| Cool-season grasses: | | |
| Russian wildrye | 0.30 | 1.20 |
| Crested wheatgrass | 0.67 | 2.43 |
| Slender wheatgrass | 1.03 | 3.23 |
| Bromegrass | 1.43 | 2.51 |
| L.S.D. at P = .05 | 0.36 | 0.58 |

[a] Data from R. Chase Allred. Effects of association on the responses of selected grasses grown in mixtures. Ph.D. Thesis. University of Nebraska. 1952.
[b] Average yields per acre on an oven-dry basis from three replications, harvested once in 1950 and twice in 1951.

the six center rows in 1950 and 1951. Each row was harvested separately by the use of an offset mower bar especially constructed on a Jari mower. The harvest of individual rows provided a method for obtaining yields of mixtures without the necessity of making separations of the vegetation. Each grass was harvested separately once at maximum production in 1950 and following anthesis and aftermath production in the second season.

The yields per acre of side-oats grama in the first and second year of production are compared in Table 13 with two other warm-season grasses and with four cool-season grasses. With the hand weeding given the plots, the warm-season grasses produced large yields during the first season, whereas cool-season grasses established stands more slowly, particularly by the Russian wildrye and crested wheatgrass. Sand lovegrass yielded best in the first season of growth but decreased in yield in the second. All other grasses gave higher yields in the second year than the first.

In the first year side-oats grama produced larger yields than the cool-season grasses but was exceeded in yield by sand lovegrass and big bluestem. In the second year side-oats grama was exceeded in yield only by big bluestem.

The competitive effect of the several grasses is shown by their growth in mixtures in the two seasons (Table 14). In the first year, the yield of side-oats grama, 0.58 ton, was reduced when mixed with the rapidly established sand lovegrass as compared with yield of side-oats grama in pure stand, 1.01 tons. However, the mixture of side-oats grama and sand lovegrass had the best total yield, 3.19 tons. Side-oats grama gave additional yield when mixed with grasses which were slow in becoming established from spring planting.

**Table 14.—Forage yields in tons per acre of Trailway side-oats grama in pure stand and of mixtures of Trailway side-oats grama with five selected grasses grown at Lincoln, 1950-51.[a]**

| Components of the stand | Grass grown in association with side-oats grama | | | | | | | Average yields in mixture | Difference required for significance $P = 0.05$ |
|---|---|---|---|---|---|---|---|---|---|
| | Side-oats grama | Sand love-grass | Big blue-stem | Russian wild-rye | Crested wheat-grass | Slender wheat-grass | Brome-grass | | |
| **Forage yields, 1950[b]** | | | | | | | | | |
| Side-oats grama | 1.01 | 0.58 | 1.08 | 1.14 | 1.05 | 0.82 | 0.38 | 0.84 | 0.31 |
| Associated grass[c] | 1.01 | 2.61 | 1.44 | 0.12 | 0.22 | 0.52 | 1.16 | 1.01 | . . . |
| Total yield | 2.02 | 3.19 | 2.52 | 1.26 | 1.27 | 1.34 | 1.54 | 1.85 | 0.36 |
| **Forage yields, 1951[b]** | | | | | | | | | |
| Side-oats grama | 1.65 | 0.98 | 0.83 | 1.93 | 1.11 | 1.29 | 0.52 | 1.11 | 0.26 |
| Associated grass[c] | 1.66 | 2.02 | 3.30 | 0.61 | 1.64 | 1.99 | 1.99 | 1.92 | . . . |
| Total yield | 3.31 | 3.00 | 4.13 | 2.54 | 2.75 | 3.28 | 2.51 | 3.03 | 0.58 |

[a] Data from R. Chase Allred. Effects of association on the responses of selected grasses grown in mixtures. Ph.D. Thesis. University of Nebraska. 1952.
[b] Average yields per acre on an oven-dry basis from three replications, harvested once in 1950 and twice in 1951.
[c] Yields in this line are yields of the two alternate rows selected at random in the pure stands of side-oats grama, shown in the first column of figures, or the yields of the associated grass grown in mixture with it shown in the columns to the right.

In the second year, although reduced in yield in all mixtures as compared with the yield of 1.65 tons in pure stand, side-oats grama gave good yields, 0.83 and 0.52 ton, respectively, in mixture even with aggressive big bluestem and bromegrass, and larger yields with less competitive grasses. The largest total yield of mixture was 4.13 tons in combination with big bluestem, a yield approaching that of bluestem in pure stand, 4.32 tons (Table 13).

## SEED PRODUCTION EXPERIMENTS

The effects of several factors on seed yield in side-oats grama were studied at the Nebraska Experiment Station during the years 1952 to 1954. Established stands of the two varieties, Butte and Trailway, were fertilized and cultivated. The grasses had been planted initially in 40-inch rows and were maintained as sod strips approximately 12 inches wide.

The five replicates of Butte plots were on a gently rolling ridge of Sharpsburg silty clay loam. Of the four replicates of Trailway plots, two were on a lowland complex of Waukesha and Rokeby silty clay loams and two were on a west-facing 7 per cent slope of Sharpsburg and Judson silty clay loams (Figure 5). Major soil changes, therefore, were from replicate to replicate and could be largely accounted for in the analyses of variance.

**Figure 5.—The field of Trailway side-oats grama in which seed production studies were conducted at the Nebraska Agricultural Experiment Station at Lincoln, 1952-1953.**

There were 13 experimental treatments in a randomized-block design. Each plot consisted of three rows 24 feet long with 20 feet of the center row harvested for seed yield. Ten treatments were on plots burned in the spring and consisted of four rates of nitrogen alone, two residual nitrogen treatments, and a repetition of the four rates of nitrogen with phosphorus. The treatments on unburned plots were 60 pounds of nitrogen with phosphorus, a check mowed and cleaned off following seed harvest in the fall, and one unburned check with the stubble left standing.

The fertilizers were applied in early June, except in the case of the plots receiving only nitrogen for residual effect. In this instance the nitrogen was applied the first year and the year prior to the one in which the seed harvest was made for the next two years. Nitrogen was applied as ammonium nitrate broadcast at rates of 0, 30, 60, and 90 pounds of N per acre each year, 1952 to 1954. Nitrogen treatment for residual effects was applied at 75 pounds per acre. The phosphorus was similarly applied as 60 pounds of $P_2O_5$ in 1952 and 1953. The burning was done in early spring before the resumption of growth and at a time when the ground was damp.

Seed yields were obtained on the basis of whole spikes and later adjusted on the uniform basis of pounds per acre of pure live seed. The effects on seed production of high and low soil moisture during the period of seed development were compared in the dry summer of 1954 on four similar plots in the early-maturing Butte. Supplemental water was hauled and applied by sprinkling to two plots on July 8 and this irrigation was repeated at weekly intervals until August 1, when the first important rain came.

In this experiment, no effect was found from phosphorus fertilization either alone or in combination with nitrogen. There were no differences between burned and unburned checks nor between the residual nitrogen treatments. For reporting, the treatments involving nitrogen and phosphorus were considered as replications of the nitrogen treatments. Similarly, the two rates of nitrogen for residual effect were combined as one treatment, and the two unburned checks were combined for simplicity in presenting results.

## Response to Nitrogen Fertilization

During the three years of this experiment, the responses to nitrogen fertilization were largely dependent upon the availability of moisture during critical growth periods. Soil moisture was adequate throughout the growing season in 1952. Seed yields measured as whole spikes were substantially increased over non-fertilized checks by all rates of nitrogen application in both varieties of grama (Table 15). However, only the 90 pounds of nitrogen per acre gave yields significantly higher than those from 30 pounds of nitrogen.

Table 15.—The effects of nitrogen fertilization on seed yields in two varieties of side-oats grama.

| Fertilization treatment | Yield of whole spikes, pounds per acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Butte[a] | | | | Trailway[b] | | | | Grand average[c] |
| | 1952 | 1953 | 1954 | Av. | 1952 | 1953 | 1954 | Av. | |
| Check | 177 | 180 | 182 | 180 | 525 | 214 | 218 | 319 | 242 |
| 30 lbs. N | 236 | 228 | 180 | 215 | 642 | 318 | 514 | 491 | 338 |
| 60 lbs. N | 257 | 210 | 199 | 222 | 672 | 338 | 526 | 512 | 351 |
| 90 lbs. N | 273 | 207 | 233 | 238 | 709 | 332 | 492 | 511 | 359 |
| Residual[d] | 264 | 217 | 186 | 222 | 690 | 291 | 459 | 480 | 337 |
| Average | 241 | 208 | 196 | 215 | 648 | 299 | 442 | 463 | 325 |
| L.S.D., P = .05 | 29 | 29 | 35 | 17 | 67 | 47 | 68 | 42 | 28 |
| L.S.D., P = .01 | 39 | 38 | 47 | 23 | 90 | 62 | 91 | 56 | 38 |

a Averages of ten replications.
b Averages of eight replications.
c Weighted on the basis of 10 replications of Butte and 8 replications of Trailway.
d Yields in 1952 and 1953 were from plots fertilized with 75 pounds of nitrogen in 1952, yields in 1954 from plots fertilized in 1952 and 1953 with 75 pounds of nitrogen per acre.

With the drought conditions of 1953, the application of 60 and 90 pounds of nitrogen produced plant growth which depleted the soil moisture before seed maturity. Yields of whole spikes from the higher rates approximately equaled those from 30 pounds of nitrogen per acre.

In 1954, the early-maturing Butte grama again matured seed under drought conditions. The rains, which began August 1 and continued throughout the month for a total of 11 inches, fell within the flowering and fruiting period of the later-maturing Trailway grama. Yield of spikes, consequently, was much better in this variety than it was in Butte. However, a depressing effect was noted in the highest nitrogen level, resulting from the need of moisture before the rain came.

Over the three-year period nitrogen fertilization generally increased the yield of seed spikes of the two varieties of grama, but there was no appreciable advantage shown from the higher over the lower rates of application. Thirty pounds of nitrogen per acre was approximately equal to other nitrogen treatments in producing increased yields of spikes.

Under the favorable moisture conditions of 1952, nitrogen fertilization improved the quality of caryopses as shown by increased weight per thousand (Tables 16 and 17). However, both the number and the weight of caryopses per given weight of spikes showed a tendency to decrease with the increase in rate of nitrogen application in both varieties.

In the drought of 1953, the effects of nitrogen fertilization were somewhat different than they had been the preceding summer. The plots receiving the higher rates of nitrogen made abundant early growth which used up the reserve soil moisture very rapidly. The resulting moisture deficiency during the period of seed formation reduced the size of caryopses as well as the number of caryopses per

Table 16.—The effect of nitrogen fertilization on caryopsis development of Butte side-oats grama with favorable moisture conditions in 1952 as compared with drought conditions of 1953.[a]

| Treatment | Caryopses in one gram of spikes | | Weight of caryopses in one gram of spikes | | Weight of 1,000 caryopses | |
|---|---|---|---|---|---|---|
| | 1952 | 1953 | 1952 | 1953 | 1952 | 1953 |
| | No. | No. | Mg. | Mg. | Mg. | Mg. |
| Check | 246 | 277 | 199 | 174 | 808 | 627 |
| 30 lbs. N | 243 | 253 | 202 | 151 | 832 | 597 |
| 90 lbs. N | 215 | 219 | 180 | 129 | 838 | 588 |
| Average | 235 | 244 | 194 | 151 | 826 | 604 |
| L.S.D., P = .05 | ns | 37 | ns | 21 | ns | 28 |
| L.S.D., P = .01 | ns | ns | ns | 31 | ns | ns |

[a] Averages of three-gram samples of spikes from the plots of five replications.

weight of spikes in both varieties. Conversely, the plots with less available nitrogen made less growth, retained the soil moisture longer, and matured relatively larger caryopses.

The importance of adequate moisture at crucial periods in the formation and development of seed was further illustrated in 1953. Butte had set seed just before soil moisture became a limiting factor. Seed set of Butte as measured by the number of caryopses per gram of spikes consequently compared well with seed set in the preceding summer when soil moisture was plentiful (Table 16). On the other hand, the number of caryopses per gram of spikes produced by the late-maturing Trailway was much reduced in 1953 as compared with 1952 (Table 17). Caryopses of both varieties matured under the influence of a soil moisture deficiency with the result that caryopsis weight per thousand was much reduced in 1953 as compared with 1952.

## Seed Viability and Purity

Average purity of Butte ranged from 107 to 111 thousand caryopses per pound of harvested spikes in 1952 and 1953, respectively, as calculated from Table 16. Actual purity on the basis of the weight of cary-

Table 17.—The effect of nitrogen fertilization on caryopsis development in Trailway side-oats grama, with favorable moisture conditions in 1952 as compared with drought conditions of 1953.[a]

| Treatment | Caryopses in one gram of spikes | | Weight of caryopses in one gram of spikes | | Weight of 1,000 caryopses | |
|---|---|---|---|---|---|---|
| | 1952 | 1953 | 1952 | 1953 | 1952 | 1953 |
| | No. | No. | Mg. | Mg. | Mg. | Mg. |
| Check | 323 | 271 | 218 | 142 | 676 | 524 |
| 30 lbs. N | 305 | 169 | 212 | 83 | 694 | 490 |
| 90 lbs. N | 273 | 149 | 194 | 73 | 712 | 491 |
| Average | 300 | 196 | 208 | 99 | 694 | 502 |
| L.S.D., P = .05 | ns | 36 | ns | 19 | 20 | 21 |
| L.S.D., P = .01 | ns | 54 | ns | 29 | ns | ns |

[a] Averages of three-gram samples of spikes from four replications.

opses in one gram of spikes was 19 and 15 per cent for 1952 and 1953, respectively. Butte has characteristically large caryopses. Based on the weight per 1,000 caryopses, average quality of Butte caryopses was 550,000 and 750,000 per pound in 1952 and 1953, respectively, or an average of 650,000 caryopses per pound. The heavier caryopses produced in the favorable year may offset, by an increase in the percentage of seedling establishment, the reduction in number below the averages used in the calculation of seeding rates on a weight basis.

Average purity of Trailway ranged from 136,000 to 88,000 caryopses per pound of spikes in 1952 and 1953, respectively, as calculated from Table 17. Actual purity by weight was 21 and 10 per cent in the two years, respectively. The caryopses of Trailway in 1952 were of average size, 655,000 per pound; but because of the unfavorable moisture situation for maturing seed of the late variety in 1953, the caryopses were very small, 910,000 per pound. Although seeding rates are based on average weights, it is likely that a larger than average number of small caryopses is necessary to offset failure of small seed in establishing seedlings.

Seed of side-oats grama normally found on the market consists of either whole spikes or individual florets, or mixtures of these, which vary highly in their content of germinable seed. For this reason, seeding rates must be computed on a basis of purity and viability. Purity analyses of side-oats grama are complicated by the inclusion of adhering glumes and spike fragments as a part of the seed piece. Accordingly, percentages of naked caryopses by weight are not comparable to purity percentages determined by separating spike fragments containing caryopses from the rest of the sample.

A mechanical method of ascertaining the purity of chaffy-seeded grasses, including side-oats grama, has been proposed by Harlan (10). It involves the mechanical determination of the percentage by weight of caryopses or grain in the sample and the conversion of this percentage to a purity analysis comparable to present official standards by means of factors. The conversion factor determined for side-oats grama was 3.2.

Estimates of average quality of seed of side-oats grama were calculated from the data for the two varieties grown in the two years (Table 18). The estimate of average seed set was 120,000 caryopses per pound of spikes in 1952 and 103,000 in 1953. Actual purities on the basis of weight of caryopses were 20 per cent and 12.8 per cent for 1952 and 1953, respectively. Purities on the basis of spike fragments were estimated by caryopsis weight times the empirical factor, 3.2, to be 64 per cent and 41 per cent for the two years. The average seed quality of the two varieties was 592,000 and 814,000 caryopses per pound for 1952 and 1953, respectively, or an average of 703,000 per pound.

Seeding rates for commercial seed are computed from the seed analyses on the basis of pounds of pure live seed required to furnish

**Table 18.—Average effects of nitrogen fertilization on caryopsis development of side-oats grama in two years varying in moisture availability.**[a, b]

| Treatment | Caryopses in one gram of spikes | | Weight of caryopses in one gram of spikes | | Weight of 1,000 caryopses | |
|---|---|---|---|---|---|---|
| | 1952 | 1953 | 1952 | 1953 | 1952 | 1953 |
| | No. | No. | Mg. | Mg. | Mg. | Mg. |
| Check | 280 | 275 | 207 | 159 | 749 | 581 |
| 30 lbs. N | 271 | 215 | 206 | 121 | 770 | 549 |
| 90 lbs. N | 241 | 188 | 187 | 104 | 782 | 545 |
| Average | 264 | 226 | 200 | 128 | 767 | 558 |
| L.S.D., P = .05 | ns | 24 | ns | 13 | 17 | 17 |
| L.S.D., P = .01 | ns | 33 | ns | 19 | 24 | 23 |

[a] Averages of three-gram samples of spikes from each of four replicate plots of Trailway and from five replicate plots of Butte.
[b] The growing season in 1952 had more favorable soil moisture conditions than the dry conditions in 1953 at Lincoln, Nebr.

a given number of viable seeds per square foot. Assuming 191,000 viable seed units per pound, approximately 4½ pounds would be required to plant at a proposed rate, viz., 20 viable seed units per square foot. To translate this figure into terms of pounds of seed material to be planted per acre, one may use the formula:

$$\frac{\text{Designated pounds of pure live seed per acre}}{\text{Purity percentage x germination percentage}} = \text{pounds of seed material to be planted}$$

For example, if 5 pounds of pure live seed are needed from seed material testing 50 per cent purity and 50 per cent germination, 20 pounds of the material should be planted; at 50 per cent purity and 80 per cent germination, only 12.5 pounds should be planted.

Commercial pure seed of side-oats grama has been computed on the basis of whole spikes or seed clusters containing one or more caryopses estimated at 125,000 per pound; or 500,000 separate pieces at 30 per cent purity (11). From the latter, a pound of spike fragments would include approximately 150,000 units containing caryopses. Cooper *et al.* (2) listed a similar figure of 140,000 units per pound contained in "seed" of 70 per cent purity. An average figure given in the Seed Chart, 1948 Yearbook of Agriculture (p. 745), is 191,000 "seed" units.

The 1952 average figures for Butte and Trailway appeared to be representative of seed production in a normal year (Table 18). An estimate of 64 per cent purity (3.2 x 20 per cent purity by weight of caryopses) for the average of the varieties in 1952 was used to estimate an average number of seed pieces in a gram by dividing the number of caryopses per gram of spikes, 264, by .64 and multiplying by 100. This calculation gave 412 per gram, or approximately 187,000 seed units per pound, a close approximation of the 191,000 estimate previously quoted for commercially processed seed.

Approximately 420 seed units per gram (191,000 per pound) was therefore used as an estimate of average "pure seed units" of side-oats grama which will provide a proper seeding rate at $4\frac{1}{2}$ pounds of pure seed units per acre. The hypothetical figure of 191,000 may thus also be chosen as the total number in a pound of "pure-live-seed units," assuming 100 per cent germination.

For some experimental purposes a direct method of testing seed quality meets the need for the analyses of both germination and purity (15). This "direct test" can be used even though there is contamination of the seed lot with other grass seed if the seed pieces are germinated on top of the germination medium or between blotters, so that the analyst can see the origin of each sprout.

The direct test involves the germination of a weighed sample and the computation of the number of viable seed units per pound of seed material directly from this test. Seeding rates may then be determined according to the number of viable seed units desired per unit of area to be sown. This method eliminates the conversion of rough seed weights into numbers of viable seeds per pound. It also reduces expense as compared with conventional germination and purity analyses.

New seed of side-oats grama has a high degree of dormancy which gradually disappears as the seed ages. To determine the effect of this dormancy by the direct test, germination trials were begun January 1, 1955, on seed harvested in late August of 1954, and continued at intervals until December, 1955. The results showed a steady increase in shoots per gram of spikes with the increase in time after harvest until around the first of May. At this point the dormancy appeared to be gone and the number of shoots per gram of spikes held rather constant throughout subsequent germination trials. This finding indicates that germination tests should be delayed until at least seven or eight months after harvest or until shortly before the time of planting.

## Seed Yields on a Pure-live-seed Basis

Since the interacting influences of soil moisture and soil fertility affected seed set and seed size as well as yield of spikes, the yields of spikes shown in Table 15 do not give a complete picture of the results of nitrogen fertilization under the conditions of this experiment. Accordingly, yields from the two strains for the three years were adjusted to a uniform quality of pure live seed using the direct method for quality analysis (Table 19). Plot yields were adjusted to uniform quality by multiplying the yields of spikes from each plot by a percentage factor. This factor was obtained by dividing the number of shoots per gram of spikes for each plot by 420, the average number of caryopses in one gram of material which contains approximately 191,000 caryopses per pound.

Adjustment reduced the original yield weights from the treatments of 60 and 90 pounds of nitrogen relatively more than it did those from the check, the 30 pounds of nitrogen, and the residual nitrogen. However, pooling the data from the two strains for the three-year period

**Table 19.—Effects of different rates of nitrogen fertilization on the average yields of seed from Butte and Trailway side-oats grama, adjusted on the basis of pure live seed produced in pounds per acre.**[a]

| Nitrogen Treatment | Pure live seed yield per acre[b] | | | |
|---|---|---|---|---|
| | 1952 | 1953 | 1954 | Av. |
| Check | 212 | 90 | 71 | 124 |
| 30 pounds of N per acre | 252 | 107 | 134 | 164 |
| 60 pounds of N per acre | 255 | 86 | 133 | 158 |
| 90 pounds of N per acre | 272 | 85 | 131 | 163 |
| Residual from 75 pounds of N per acre[c] | 256 | 99 | 105 | 153 |
| Average | 249 | 93 | 115 | 152 |
| L.S.D. at the .05 level | 35 | 16 | 23 | 14 |
| L.S.D. at the .01 level | 49 | ... | 31 | 19 |

[a] Yields of pure live seed per acre are based on direct tests per plot estimating the percentage of germinating seed in 191,000 filled seed units per pound. Seeding rates of 4½ lbs. pure live seed per acre were estimated to plant 20 seeds per square foot.
[b] Average yields from ten replications of Butte and eight replications of Trailway side-oats grama.
[c] Yields in 1953 are from plots fertilized in 1952 and yields in 1954 from plots fertilized in 1952 and 1953.

brings out two important points: (1) on the whole, nitrogen fertilization gave significant increases in yield of viable seed; (2) under the weather conditions prevailing during the period of this experiment, the low rates of nitrogen, 30 pounds per acre and the residual from 75 pounds per acre, were as effective as either of the higher rates. In the drought of 1953, the low rates gave significant yield increases not given by the higher rates.

## Effect of Burning on Seed Yield

The effect of burning was shown by comparing seed yields from two levels of fertility in plots burned in the spring with yields from the same fertility levels in plots which were not burned. These data were summarized over a three-year period (Table 20). Burning was done just prior to the initiation of first growth each year. Although the results showed consistently larger yields from both levels of fertility under the burning treatment, the differences were not statistically significant. This finding, however, is of interest because it indicates

**Table 20.—Effects of spring burning on seed yields of side-oats grama grown with two levels of fertility.**

| Treatment | Yield per acre in pounds of pure live seed[a] | | |
|---|---|---|---|
| | Unfertilized | 60 Lbs. N | Average |
| Burned | 125 | 155 | 140 |
| Unburned | 114 | 148 | 131 |
| Difference[b] | 11 | 7 | 9 |

[a] Averages from five replications of Butte and four replications of Trailway over the three-year period, 1952-1954.
[b] Differences not found significant by the analysis of variance.

that proper burning, if not too late in the spring, does not cut seed yields. The practice, therefore, is useful in the management of side-oats grama for seed production in some years. It is a simple method of cleaning the field for the new seed crop. After the stubble has served as winter cover, burning it just before growth begins in the spring may also help control weeds and disease.

## Effect of Irrigation on Seed Yield

Drought effects were beginning to show in the plots on July 8 when the first water was supplied in the irrigation test. Water was hauled to the areas and applied by hand sprinkler to the small plots. By July 15, the reserve moisture was becoming depleted in the non-irrigated plots to a depth of three to four feet. Temperatures were generally high and there was no effective precipitation until August 1.

Butte began flowering about June 27 and matured its seed during this dry period. As shown in Table 21, both the yield of spikes and the number of filled florets were increased by irrigation. Part of this increase was due to a marked increase in uniformity of maturity. Flowering in side-oats grama usually occurs over a period of two to three weeks. By the time late blooming spikes are mature many of the early blooming spikes have dropped from the culms. Any practice, therefore, which brings about a more uniform maturity over the field materially improves both the yield and quality of seed.

**Table 21.—Comparison of seed yields of Butte side-oats grama produced at two levels of soil moisture.**

| Treatment | Yield of spikes per acre[a] | | Seed set[b] | | Adjusted yield per acre[c] | |
|---|---|---|---|---|---|---|
| | Lbs. | Pct. | Shoots/ gram | Pct. | Lbs. | Pct. |
| Non-irrigated | 221 | 100 | 202 | 100 | 106 | 100 |
| Irrigated | 332 | 150 | 224 | 111 | 176 | 166 |

[a] Averages of two plots per treatment in 1953.
[b] Shoots per gram were determined by germinating three samples of whole spikes from each plot.
[c] Yields were adjusted on the basis of pure live seed produced per acre, estimated at 191,000 viable seed units per pound.

# ADAPTATION AND UTILIZATION

Side-oats grama is an important component of grass mixtures recommended for upland grassland plantings on fine-textured, non-irrigated soils. It is a palatable and nutritious grass which may be grown with blue grama and buffalograss on certain critical planting sites or planted in mixtures with bluestems, switchgrass, and sand lovegrass in the more favorable situations of soil moisture and fertility. Such mixtures of warm-season grasses may be used for summer grazing in systems which provide spring and fall grazing of cool-season grasses. Side-oats grama may be grown for seed in cultivated rows, and will respond to timely fertilization and irrigation.


**Figure 6.—Seed harvest of Butte side-oats grama at Lincoln in 1958.**

## Seed Sources

Winter-hardy strains or varieties of side-oats grama must necessarily be used in the Central Plains Region since varieties and native strains from southern sources will not survive severe winter conditions. Thus, variety or source of seed are important. Experiment stations and Crop Improvement Associations should be consulted for latest information on seed sources of certified adapted varieties.

Butte is recommended on sites critical for soil moisture and fertility. Its relatively large caryopses and good seedling vigor aid in establishment where adapted. It has given best results in plantings in the northern and western areas of the Central Plains. In Nebraska, it is recommended for plantings on fine-textured soils in areas surrounding the Nebraska sandhills.

Trailway combines winter hardiness with some of the desirable vegetative characteristics of the southern types. It may be grown to advantage in upland-pasture mixtures on sites where favorable moisture conditions prevail in eastern and southeastern areas of the Central

Plains. In Nebraska it is recommended for pasture plantings in eastern and southern cropping districts.

El Reno is grown in the southern part of the Central Plains, although susceptible to winter injury, as shown in the Nebraska and Wyoming tests. It is recommended for utilization as far north as Kansas.

## Planting for Forage Production and Conservation

The general recommendations for upland grass plantings apply to side-oats grama. The objective is to get the right amount of pure live seed uniformly distributed and covered with soil on a very firm seedbed. Side-oats grama can be planted with any drill that will handle the small, light seed. However, when using a drill, care must be taken to keep the seed flowing. For drilling through trash or in stubble, disk furrow openers equipped with depth bands are preferred. The seed should not be planted deeper than ½ inch in heavy soils or ¾ inch in light soils.

Weed control during establishment is the biggest problem with warm-season grasses such as side-oats grama. This fact should influence every operation involved in establishing stands, whether for upland pastures or for seed production. Controlling weeds either before or after planting conserves soil moisture and nutrients and allows sunlight to reach the young grass seedlings.

Land should be cropped and well managed in the year prior to seeding so surface tillage will prepare a seedbed. Spring plowing brings dormant weeds near the surface where they continue to germinate throughout the summer. In addition to being weed-free, the seedbed should be firm with enough mellow topsoil to cover the seed. It should also have sufficient residue from a former crop on the surface to protect the seedlings and minimize wind and water erosion and evaporation of moisture.

The best seedbed is a stubblefield of closely spaced drill-rows of a forage sorghum or similar crop. If the stubble is free of weeds, grass seed can be drilled directly into it without further preparation. Planting may be done as soon as the danger of frost is past—to give the seedlings a chance to compete with weeds which may come later. When early spring weeds must be killed in such a field, it should be worked with a subtiller in order to leave the stubble on the surface. Litter that is too heavy to harrow should be worked with a treader.

Stands may be obtained by broadcasting. An ordinary fertilizer spreader is ideal for broadcast seeding. It can be calibrated to drop the seed uniformly at the desired planting rate. If the seedbed has been disked and harrowed or treaded, the seed can be broadcast and rolled. This is sufficient to cover it ¼ to ½ inch deep.

## Planting for Seed Production

Seed can best be produced on good crop land. Planting procedure differs from that above in that the grass is usually planted in rows spaced 36 to 42 inches apart, so it can be cultivated and irrigated. If seedbeds are prepared by plowing and harrowing as for other crops, they should be irrigated and harrowed to sprout and kill weed seeds that have been brought to the surface. If the grass is to be planted in rows for seed production, last year's corn or sorghum rows may be followed if cultivation has left the surface nearly level. Putting in temporary rills at the time of planting for gravity-flow irrigation is desirable but care should be taken not to build up ridges where the rows are to be.

# DISCUSSION

Responses of side-oats grama in photoperiod studies and field trials demonstrated that they differ markedly according to geographic origin not only in their requirements for activation of the reproductive phase but also in vegetative development. Northern strains required long photoperiods for both vegetative growth and for floral initiation. Strains from southern sources required shorter periods of light for floral initiation than those from northern sources and were retarded in floral initiation by long photoperiods. Thus, varieties differed in their reactions throughout a wide range of photoperiods. Temperature also was a factor in regulating rapidity of growth. Differences in strain responses determined the relative vigor of early spring growth and the amount of late summer production. It should be emphasized, therefore, that source of seed or variety of side-oats grama must be known before the photoperiod response and adaptation can be assumed.

Butte and North Dakota 97 from the Northern Great Plains required relatively long photoperiods for vegetative and reproductive development. In the latitude of Nebraska the photoperiod-temperature relation during May and June is such that these northern strains made rapid vegetative growth and matured seed ahead of southern strains.

Trailway and El Reno of the central group made rapid vegetative growth in the long days of early summer and continued to grow well in the shorter days of late summer until frost. Reproductive development of these strains, however, was retarded by long days and inflorescences were produced late in the season. Much of their forage is produced in late summer, making these strains particularly valuable for summer grazing.

Oklahoma Tucson and New Mexico Vaughn, which originated in the southwest, exhibited the lowest requirements for length of photoperiod in these studies. In mid latitudes these strains matured seed earlier in the season than Trailway and El Reno of the central group but continued their vegetative growth late in the season like the central group. El Reno and the southern strains lacked cold hardiness.

These results were in accordance with those of Olmsted (17, 18), who found that strains from southern Arizona and southern Texas contained the more typical short-day plants, whereas strains from Oklahoma (El Reno) and New Mexico were intermediate between the typical short-day plants of the most southern latitude and the long-day plants from Montana and North Dakota.

Thus, a knowledge of the effects of photoperiod on the vegetative and reproductive development of strains from different latitudes proved essential in interpreting variations in growth habit and adaptation and selecting and developing varieties for the mid latitudes. Also, answers to problems of cold hardiness, seed yields, seed processing, seed quality evaluation, seeding rates, and stand etablishment were important in developing varieties of side-oats grama for utilization in the Central Plains.

## APPENDIX

**Table A.—Analyses of variance of forage and seed yields of five varieties of side-oats grama in the two-year period 1949 and 1950.[a]**

| Source of Variation | Degrees of Freedom | Forage Cut for Hay | Forage Cut at Maturity | Seed Yield |
|---|---|---|---|---|
| | | Mean Square | Mean Square | Mean Square |
| Replications | 3 | 0.5418 | 0.5875** | 1,704 |
| Varieties (V) | 4 | 13.3534** | 11.8765** | 48,437** |
| Error a | 12 | 0.4047 | 0.0798 | 870 |
| Years (Y) | 1 | 107.5184** | 31.0641** | 40,704** |
| V x Y | 4 | 3.4543** | 3.8732** | 18,179** |
| Error b | 15 | 0.1835 | 0.0905 | 1,364 |

**Indicates an F value which exceeds the 1 per cent level of significance.
[a] Yields of the Oklahoma Tucson strain were omitted from the analyses because of severe winter killing during the first winter.

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