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The Life History of Side-Oats Grama Grass and Variations In Its Growth At Hays, Kansas, When Grown From Seed Produced In Different Parts of The Great Plains Region

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THE LIFE HISTORY OF SIDE-OATS GRAMA GRASS AND
VARIATIONS IN ITS GROWTH AT HAYS, KANSAS, WHEN GROWN FROM
SEED PRODUCED IN DIFFERENT PARTS OF THE GREAT PLAINS REGION

being

A thesis presented to the Graduate Faculty
of the Fort Hays Kansas State College
in partial fulfillment of the requirements
for the Degree of Master of Science

by

Harold Hopkins, A.B.
Fort Hays Kansas State College

Approved
Major Professor

Date 5-27-41

Chmn. Graduate Council
ACKNOWLEDGMENTS

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INTRODUCTION

The recent great drought covering the plains area has caused a revolution in grassland research. A realization of the importance of the conservation of our soil and native plants has been brought clearly before the research workers as well as our entire population.

Overgrazing, depletion of soil moisture, continued tilling of pulverized soil, and the resultant blowing and dusting caused an enormous reduction in plant cover. Any one of these factors would have resulted in serious damage, and taken together they have literally cost the people of the nation millions of dollars. New soil conservation methods have been brought into use and with them has come a need for hardy soil binding plants which can be easily established on disturbed soil. These conditions have caused research workers in the area to turn their attention toward finding plants with which to revegetate the stricken areas and methods of getting these plants established.

Quadrat studies, as well as general observations, show that side-oats grama grass (*Bouteloua curtipendula*) is more drought resistant than its associate, little bluestem grass (*Andropogon scoparius*). Before the drought little bluestem covered the hillsides of the mixed prairie association; at the present time, however, it has been almost completely replaced by side-oats grama grass (Albertson, 1938). This indicates that side-oats grama is a drought resistant plant and may have possibilities as a plant for revegetation purposes.
Side-oats grama is a good forage producer and shows capabilities of improvement by selection and crossing. It is the one species of *Bouteloua* which might make a favorable plant for domestication (Range Plant Handbook, 1957). The rhizomatous nature of the species together with its tough fibrous root system makes it a good soil binder, in spite of the fact that it is not a sod former. Its habit of growing in slightly favored spots suggests that this would be an excellent grass for roadside ditches, dam spillways, terrace outlets, etc.

Side-oats grama is an easily adaptable plant as is shown by its widespread distribution covering much more territory than any of the other species in the genus. It occurs from Connecticut and New Jersey to Tennessee and Alabama, and from Montana and Utah to California and Texas; also through Mexico south into South America (Range Plant Handbook, 1957). It is nearly always present in the true prairie, is an important species in the mixed prairie, and is found in favored spots in the short grass disclimax (Weaver, 1920).

Agriculturists have long had the opinion that seed for their crops would produce better if it were obtained from another locality perhaps of a slightly different climate (Smith, 1937). If this is true of cultivated crops perhaps it is also true of native grasses. If so, then we must know what locality produces seed most likely to do well in the particular climate of mid-western Kansas.

This study, which covered a period of two years, was originated in order to learn more of the merits and faults of side-oats grama grass as a revegetation and soil conservation plant in the Great Plains Region. It was suggested by the fact that there is a definite need for more
knowledge about the native grasses which are potential revegetation plants of the Great Plains. An attempt was made to find as many growth habits of the species as possible, and a comparison was made in the growth, development, and forage production of plants grown from seed produced in different climatic areas in the Great Plains.

Related studies

Until the last few years, when its importance became more apparent, there had been very little work done on any one species of native grass. Life history research has received considerable attention, but this has dealt more with introduced species than with native grasses.

Love and Hanson (1932) discuss the life history of crested wheat grass (*Agropyron cristatum*), an important species in the Northern Great Plains. Evans (1927) goes into some detail in his studies with timothy (*Phleum pratense*), a hay grass of the Eastern United States. Riegel (1940) has made a very thorough investigation of the life history and variations in the growth of blue grama grass (*Bouteloua gracilis*) when grown from seed collected in different climatic regions. He found as did Savage (1938) in Oklahoma and Rogler (unpublished) in North Dakota that strains of various species from the north were low in forage production and strains from the south were lacking in winter hardiness. Webb (1941) worked out the life history of buffalo grass (*Buchloe dactyloides*), an important species sharing dominance in the short grass disclimax with blue grama. Hase (1941) studied the effect of clipping and weed competition on the establishment, growth, and root development of three native grasses.

The larger part of this cited work has been done since the beginning of the great drought, which caused a realization of our lack of knowledge
of native grasses. The object of a large part of the recent grassland research has been to find suitable methods, species, and strains for various types of revegetation work.

**METHOD OF STUDY**

Obtaining and selecting seed

Early in the spring of 1939, 25 small packets of side-oats grama grass seed were received from various individuals over the Great Plains. The seed was tested for germination on the basis of 100 florets. Every floret, however, did not contain a caryopsis. The range of viability was from 0% to as high as 55%. In selecting the seed for the problem, the germination test results, the amount available, and the locality from which they were received were all considered. The samples chosen for the study represented three localities each in the northern, Central, and Southern Great Plains (Fig. 1).

One of the localities represented, (Gage County, Nebraska,) is located outside the Great Plains Region and has an annual precipitation of almost twice that of the northern localities and a growing period only two weeks shorter than those of the southern localities (Table I). As a consequence of these conditions, the plants from seed of Gage County, Nebraska were more similar to plants from southern grown seed than to plants from seed of any other region.

The mean annual temperature of the localities represented, ranges from 40.5° F. in North Dakota with a growing period of 154 days, to 59.5° F. in Vaughn, New Mexico, with a growing period of 200 days. The greatest
amount of rainfall is received in the central region, with an average of 20.49 inches per year (exclusive of Gage County, Nebraska), slightly less in the south with 20.02 inches, and the least amount in the northern Great Plains with 15.43 inches.

Selection, preparation, and planting of seed bed

The plot selected for the study was on clay loam creek bottom soil near irrigation facilities. It has been previously occupied by sand dropseed (*Sporobolus cryptandrus*) and pigweed (*Amaranthus retroflexus*). The ground was hoed deeply, irrigated, and hoed again after weed seed had germinated.

The seed was left in the spikes and planted fairly thick about one-fourth inch below the surface of the ground. It was planted in plots of three rows each, which were 24 inches apart and 25 feet long. Old boards were then placed over the rows to keep the surface of the soil moist until germination had taken place (fig. 2).

Care of plants

As soon as the seed germinated, the boards were removed but kept close by in order that they might be used in case of hail. Water was sprinkled on the plot every morning until the roots had become established. After that irrigation was relied upon only when necessary to prevent wilting. Weeds were hoed from between the rows and pulled from among the plants. An effort was made not to disturb the soil in the vicinity of the roots.
Fig. 1. Map of the plains states with an outline of the Great Plains Region showing the localities from which seed was secured for this investigation.
<table>
<thead>
<tr>
<th>Locality</th>
<th>Annual temperature (degrees F)</th>
<th>Annual rainfall (inches)</th>
<th>Length of growing period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaughn, New Mexico</td>
<td>59.5</td>
<td>14.34</td>
<td>Apr. 11 to Oct. 28 (200 days)</td>
</tr>
<tr>
<td>Amarillo, Texas</td>
<td>56.3</td>
<td>20.59</td>
<td>Apr. 17 to Oct. 31 (187 days)</td>
</tr>
<tr>
<td>Woodward, Oklahoma</td>
<td>56.4</td>
<td>24.14</td>
<td>Apr. 11 to Oct. 28 (200 days)</td>
</tr>
<tr>
<td>Hays, Kansas</td>
<td>52.5</td>
<td>22.59</td>
<td>Apr. 29 to Oct. 13 (176 days)</td>
</tr>
<tr>
<td>North Platte, Nebraska</td>
<td>48.3</td>
<td>18.29</td>
<td>May 2 to Oct. 2 (153 days)</td>
</tr>
<tr>
<td>Gage County, Nebraska</td>
<td>50.6</td>
<td>27.77</td>
<td>Apr. 14 to Oct. 6 (185 days)</td>
</tr>
<tr>
<td>Mandan, North Dakota</td>
<td>40.5</td>
<td>16.34</td>
<td>May 11 to Sept. 22 (134 days)</td>
</tr>
<tr>
<td>Cannonball, North Dakota</td>
<td>40.5</td>
<td>16.34</td>
<td>May 11 to Sept. 22 (134 days)</td>
</tr>
<tr>
<td>Miles City, Montana</td>
<td>44.3</td>
<td>18.79</td>
<td>May 2 to Oct. 2 (155 days)</td>
</tr>
</tbody>
</table>
Fig. 2. General view of the experimental plot after the seed had been planted and before germination had taken place. The boards are to help retain moisture and protect the young plants.
Vegetative growth

Three permanently staked plants from each row or nine plants from each plot were studied every two weeks during the first season to determine length of leaves, width of leaves, height, number of tillers, and number of leaves per tiller. Since the leafy part of the plant is that preferred by stock, the area of leaf surface is one of the most important factors of quality. Leaf areas were calculated by multiplying the average length, times the average width, times the average number of leaves per tiller, times the total number of tillers. This is not expected to be absolutely accurate but gives comparative values. In order that the plants might be readily studied during the second year, the entire plot was clipped after the first year of growth.

Underground growth

Once each week for the first month and thereafter every two weeks until August 20, two plants from each plot were completely extracted from the soil and their roots and tops drawn to scale on graph paper. Counts and measurements were made on the roots and rhizomes. During the first part of the season before the roots were very deep, a one-foot square core of earth containing the entire plant was taken up and soaked away exposing the roots. After this, however, it became necessary to dig a trench by the side of the plant and remove the soil from the roots by means of an ice pick and water under pressure (Fig. 3). The extracted plants were preserved for future reference.
Fig. 5. View of bisect which was used in studying the root systems.
Seed production

A careful record was kept of the date the plants of each plot flowered and of the approximate date of seed maturity during both years of the study. At the end of each season counts were made to determine the number of seed heads per plant and the number of spikes per head. Caryopses counts were made on the seed produced during the second year.

Forage production

At the end of the growing season, five plants from each locality were clipped, air-dried, and weighed in order to find comparisons in the amount of forage produced. A clipping experiment was set up at the beginning of the second season. Three individual plants from each plot were clipped one-half inch above the ground every two weeks throughout the season and the forage produced was weighed air-dry. Determinations were also made as to the effect of clipping on root and tiller growth.

RESULTS

Life history

Germination

The time required for germination, other things being equal, is dependent upon temperature. Seed started in the laboratory under favorable conditions germinated in 12-24 hours. When the seed was planted directly in the field, it generally took from 5-30 days for this process to take place. The first sign of germination was a noticeable swelling of the
caryopsis in the region of the embryo.

Coleorhiza and coleoptile

The appearance of the coleorhiza after breaking through the pericarp at the end of the caryopsis, was the first outward sign of germination. About 2-3 hours later the coleoptile appeared at the approximate center of the seed (Fig. 4a). Within 3-6 hours after the appearance of the coleoptile, the pericarp was split to the base of the seed by the swelling embryo, exposing the entire young embryo. At this time the cellular structure of the embryo was very distinct and the coleoptile, hypocotyl, and coleorhiza were easily differentiated. The plumule could be seen as a yellow line within the semi-transparent coleoptile. The coleorhiza reached its greatest length of not over 1-2 mm. in 12-24 hours after its appearance. The coleoptile continued to grow and emerged from the soil during this same 12-24 hour period.

Radicle and plumule

The first actual growth of the plant was on the part of the radicle or seminal root originating from the coleorhiza anywhere from the tip end to its point of juncture with the hypocotyl. It extended rapidly into the soil. The coleorhiza then completely stopped growth and the plumule, slightly slower than the radicle, could be seen drawing closer to the apex of the coleoptile (Fig. 4b).

Light seems to be an important factor in the development of the plumule. It took seven days after germination started for the plumule to emerge when they were kept in the dark in the laboratory; however, when planted outside, the plumule broke through the coleoptile in less than
Fig. 4. Stages in the development of the young plant. 

a. just after coleoptile and coleorhiza have broken through the pericarp. 
b. radicle has broken through the coleorhiza but plumule has not emerged. 
c. secondary roots starting to develop on the primary root system and coleoptile has just emerged. 
d. fully developed seed plant about 3 weeks old showing well developed seminal root, starting of 2 crown roots, and the leaves numbered in the order of their appearance.
one day after appearing through the ground. Like the coleorhiza, the coleoptile stopped growing as soon as it was ruptured by the plumule. The seminal root soon became covered with root hairs, and a few longer hair-like roots, which later became the secondary roots of the primary root system, were evident (Fig. 4c).

When the plants were about 5 days old, the second leaf emerged from a node and within the sheath of the first leaf. A third leaf then emerged in a similar fashion and between the other two. The fourth leaf came from a node at the base of the plant at about the same time that the fifth leaf arose from within the sheath of the third. Within another week a sixth leaf appeared at the base of the plant and on the opposite side from the fourth leaf (Fig. 4d). However, not all of the seedling leaves developed in every case. When the soil was fairly dry, the basal leaves died back and the plant was thus left with only 4 or 5 leaves.

The seminal root continued to function until the crown roots had become well established, and then it ceased to grow and gradually disintegrated. By the end of the season remnants of it were very hard to find (Fig. 5).

Growth

The first crown root and sometimes the second emerged at the base of the plant from a bulb-like enlargement above the seed when the plant was about 18 days old and at about the same time that the fourth leaf appeared at the base of the plant. A few days later a tiller originated from the base of the plant and within the sheath of the fourth leaf,
Fig. 5. Further stages in the development of the plant. (left) about 40 days old; note the disintegration of the seminal root as compared to fig. 4d. (center) when about 2 months old showing first flowering head and rhizome. (right) at the end of the first growing season.
and another crown root was put down. By the time the plants had reached the age of 40 days, they had about 6 tillers and 9 crown roots (Fig. 5). Each tiller had one crown root and the original plant had several. The basal leaf usually preceded the tiller which arose from a node within its sheath. A tiller, however, did not always arise within the sheath of a basal leaf.

A new tiller seems to be the product of the parent tiller and is dependent upon it for some time. New tillers apparently did not send down their own crown roots until they had stored some reserve food from their parent tillers. After the crown root was established, another tiller was developed. This leads one to believe that there is no interdependence among the tillers of a mature plant but rather a series of independent plants.

When the plants were about 50 to 60 days old, rhizomes appeared at the base of the culm about one-half inch below the surface of the ground. During the first two weeks they grew from one to three cm. in length and some of them put down a root from a node during this time. By the end of the year these rhizomes were from three to nine cm. in length; the longer ones were well branched, had a well developed root system, and accounted for a large number of the tillers. They grew at every angle from the base of the plant and were intermingled with the roots. They characteristically turned up on the end, and those near the surface of the soil sent out tillers from the apex.

During the 7-10 day period in which the first rhizome appeared, a flowering head emerged from the top leaf sheath of one of the older tillers (Fig. 5). The first flowering heads produced only 8-20 spikes per head. Later, however, from 35-50 spikes per head were produced.
There are indications that a tiller never flowers but once, after which its life cycle has been completed. For example, in the spring of the second year, each plant first greened up around the margin of the clump. Many of the center tillers which had flowered the first year appeared dead. A few weeks later, however, new tillers emerged from the crowns at the base of these dead tillers.

The plants began to grow fairly rapidly after the first head appeared and soon reached their full development (Fig. 5).

Variations in growth

Height

There was only slight variation in the height of the plants during the first month of growth; although the northern plants were slightly ahead of those from the south (Fig. 6a). By August 15, when about 2 months old, plants grown from Mandan, North Dakota, seed were 39.5 cm. tall while those from New Mexico seed, although taller than any of the other southern plants, were only 13 cm. in height (Table II). Apparently the northern plants, whose ancestors complete their year's growth in a short time, were taking advantage of the mild spring weather, which was still too cold for vigorous growth on the part of the southern plants (Fig. 6b).

As the days became still warmer, however, the weather was ideal for the southern plants to continue their growth, while the northern plants had already completed their most vigorous activity. At the end of the growing season, the New Mexico plants had an average height of 65.3 cm.
Fig. 6. a. Side-oats grama plants grown from Texas, Kansas, and North Dakota seed after a little more than one month old. b. Same plants one month older.
<table>
<thead>
<tr>
<th>Locality</th>
<th>Jul 14</th>
<th>Aug 1</th>
<th>Aug 15</th>
<th>Oct 30</th>
<th>May 4</th>
<th>Oct 10</th>
</tr>
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<tbody>
<tr>
<td>Vaughn, New Mexico</td>
<td>8.4</td>
<td>13.8</td>
<td>18.0</td>
<td>65.3</td>
<td>10.0</td>
<td>96.0</td>
</tr>
<tr>
<td>Amarillo, Texas</td>
<td>4.5</td>
<td>10.0</td>
<td>13.5</td>
<td>62.6</td>
<td>12.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Woodward, Oklahoma</td>
<td>6.6</td>
<td>10.0</td>
<td>14.8</td>
<td>51.2</td>
<td>12.5</td>
<td>59.0</td>
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<tr>
<td>Hays, Kansas</td>
<td>6.5</td>
<td>9.6</td>
<td>14.0</td>
<td>50.6</td>
<td>10.0</td>
<td>66.0</td>
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<tr>
<td>North Platte, Nebraska</td>
<td>8.5</td>
<td>20.3</td>
<td>29.0</td>
<td>39.5</td>
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<td>55.0</td>
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<td>52.1</td>
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<td>65.0</td>
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<td>Cannonball, North Dakota</td>
<td>8.7</td>
<td>25.0</td>
<td>36.5</td>
<td>50.5</td>
<td>15.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Miles City, Montana</td>
<td>4.5</td>
<td>9.0</td>
<td>30.2</td>
<td>50.5</td>
<td>15.0</td>
<td>62.0</td>
</tr>
</tbody>
</table>

TABLE II. Progressive development in height (centimeters) of plants from seed of each locality through two years' growth.
as compared to 50 cm. for those from North Dakota seed (Fig. 7). The southern plants made use of the latter weeks of the growing period and were stopped by frost before they were physiologically ready to go into dormancy. The northern plants on the other hand, had been semi-dormant for several weeks.

In the spring of the second year, plants from northern grown seed renewed growth about 10 days before the southern plants, which had been severely injured or even killed by the winter (Fig. 8). On July 22, 1940, all plants were in full head and had reached their greatest height. At this time, the Texas plants had a height of 100 cm.; Kansas plants, 66 cm.; and Mandan, North Dakota, plants, 55 cm. (Table II) (Fig. 9).

Root extent

The rate of root penetration corresponded in a general way to the other phases of development; the roots of the plants from northern seed grew faster at first and then slowed down before the end of the season as they reached maturity (Fig. 6). The results, however, were much more erratic than those of the other phases of growth. At the end of the first growing season, there was very little variation in root extent (Table III) (Fig. 7). The roots of all the plants had penetrated about 6 feet into the soil. Had they not been stopped by frost, the southern grasses would probably have extended deeper into the soil before reaching maturity.

During the second year the plants continued their penetration due to an abundance of moisture in the subsoil all season. Both the Texas and Oklahoma plants attained a root depth of 315 cm. or 10 feet 6 inches.
Fig. 7. Side-oats grama plants grown from Texas, Kansas, and North Dakota seed at the end of the first growing season.
Fig. 8. View of plants from northern grown seed (left) and southern grown seed (right) a few weeks after they had started growth in the spring. Note the more robust appearance of the northern plants and evidence of winterkilling in the southern plants.
Fig. 9. Representative plants from Texas, Kansas, and North Dakota seed (left to right) after they had completed their second year's growth.
Table III. Progressive rate of root penetration (centimeters) of the plants from seed of each locality through the first growing season and at the end of the second.

<table>
<thead>
<tr>
<th>Locality</th>
<th>Jul 14</th>
<th>Aug 1</th>
<th>Aug 15</th>
<th>Oct 30</th>
<th>Oct 10</th>
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<td>Vaughn, New Mexico</td>
<td>24.8</td>
<td>53.4</td>
<td>61.0</td>
<td>182.0</td>
<td>270.0</td>
</tr>
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<td>Amarillo, Texas</td>
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<td>51.1</td>
<td>54.1</td>
<td>182.0</td>
<td>315.0</td>
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<td>Mandan, North Dakota</td>
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<td>85.0</td>
<td>184.0</td>
<td>270.0</td>
</tr>
<tr>
<td>Cannonball, North Dakota</td>
<td>24.8</td>
<td>68.5</td>
<td>69.5</td>
<td>177.0</td>
<td>280.0</td>
</tr>
<tr>
<td>Miles City, Montana</td>
<td>28.0</td>
<td>29.0</td>
<td>83.0</td>
<td>178.0</td>
<td>310.0</td>
</tr>
</tbody>
</table>
The North Platte, Nebraska, plants had the shallowest root system, having penetrated to a depth of 205 cm. or less than 7 feet.

**Number of tillers and roots**

There seemed to be no definite ratio between the number of tillers and roots. At the end of the first growing season, the northern plants had a few more roots than tillers, while the southern plants had more tillers than roots. Representative plants from New Mexico seed had 98 tillers and 75 roots, while plants from Cannonball, North Dakota, seed had 71 tillers and 99 roots (Table IV). On May 31, 1940, after being badly injured by the winter, the New Mexico plants only had an average of 14 live tillers as compared to Cannonball, North Dakota, plants having 177 tillers (Fig. 8).

**Rhizome development**

As far as rhizome studies were carried out, there were no constant variations in their number, length, diameter, nor extent of branching. Observations indicated, however, that the rhizome system was generally better developed in the southern than in the northern plants. Much difficulty was experienced in making counts and measurements on the rhizomes because of the difficulty in determining which of the shoots had their origin from rhizomes and which were tillers coming directly from the base of the culm.
TABLE IV. Comparative number of roots and tillers produced on plants of various localities through the two growing seasons.

<table>
<thead>
<tr>
<th>Locality</th>
<th>1939</th>
<th>1940</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jul 14</td>
<td>Aug 1</td>
</tr>
<tr>
<td>Vaughn, N. Mex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tillers</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>roots</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Amarillo, Texas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tillers</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>roots</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Woodward, Okla</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tillers</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>roots</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Hays, Kansas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tillers</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>roots</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>North Platte, Neb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tillers</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>roots</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Gage Co., Neb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tillers</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>roots</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Mandan, N. Dak</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tillers</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>roots</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Cannonball, N. Dak</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tillers</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>roots</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Miles City, Monta</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tillers</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>roots</td>
<td>2</td>
<td>19</td>
</tr>
</tbody>
</table>
Plants from seed of Mandan, North Dakota, were the first to produce flowers; some of which were out on July 17. The remainder of the northern plants all flowered before the end of the month. The last plants to come into flower were those from Texas seed which began flowering on August 20. Plants from Oklahoma and Kansas seed were only one and two days earlier respectively (Table V).

The second year there was not quite so much variation in the period of flowering. The Texas and New Mexico plants were a little late because they were forced to overcome the damage done by winterkilling before starting active growth.

Seed production

During the first year the greatest number of florets were produced by the Oklahoma plants and the least by the North Platte, Nebraska, and Montana plants. The following year, after the plants had become well established, there was a definite increase in the number of flower producing tillers and in the number of spikes per head on all the plants.

There was very little seed produced the first year. What little seed was produced by the northern plants was poorly developed while the southern plants did not mature any seed.

Caryopses counts of seed produced the second year showed that the northern plants produced slightly more caryopses than did the southern or central plants (Table V).
**TABLE V. Development and production of flower parts of the plants from seed of each locality at the end of each growing season.**

<table>
<thead>
<tr>
<th>Locality</th>
<th>Date</th>
<th>Date of flowering</th>
<th>Number of heads per plant</th>
<th>Per cent tillers with heads</th>
<th>Number of spikes per head</th>
<th>Per cent caryopses in flora</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaughn, New Mexico</td>
<td>1939 Aug 12</td>
<td>52</td>
<td>52</td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amarillo, Texas</td>
<td>1939 Aug 20</td>
<td>52</td>
<td>43</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woodward, Oklahoma</td>
<td>1939 Aug 18</td>
<td>61</td>
<td>52</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hays, Kansas</td>
<td>1939 Aug 17</td>
<td>52</td>
<td>41</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Platte, Nebraska</td>
<td>1939 Jul 29</td>
<td>24</td>
<td>20</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gage County, Nebraska</td>
<td>1939 Aug 7</td>
<td>50</td>
<td>48</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mendan, North Dakota</td>
<td>1939 Jul 17</td>
<td>32</td>
<td>60</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cannonball, North Dakota</td>
<td>1939 Jul 29</td>
<td>27</td>
<td>38</td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miles City, Montana</td>
<td>1939 Jul 22</td>
<td>24</td>
<td>36</td>
<td>22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Texas and Oklahoma plants started to flower on May 19th, but were not fully headed out until June 20th while the northern plants started on May 25th and were well in head by June 4th.*
Leaf area

There was considerable variation in leaf width and length. The widest leaves were on the Oklahoma plants, which had an average leaf width of .676 cm. The narrowest leaves and also the longest were those of the Vaughn, New Mexico, plants which were .384 cm. wide and 13.21 cm. long. North Platte, Nebraska, plants had the shortest leaves, which were only 2.86 cm. long (Table VI).

Forage production and the effect of clipping

At the end of the first year of growth the southern plants had produced approximately twice as much air-dry forage per plant as had the central plants and four times as much as had the northern plants (Table VII).

Hase (1941) in his studies on the effect of clipping on the development of seedlings of side-oats grama grass found that clipping caused a reduction in the amount of forage produced and also reduced the root extent and development. As a follow-up to this work, representative side-oats grama plants from each plot, representing different localities of the Great Plains, after being allowed uninterrupted growth during the first year, were clipped every two weeks during their second year of growth. In every case, with the exception of the New Mexico plants, more forage was produced when the plants were clipped every two weeks than when they were not clipped until the end of the season (Table VII).

In spite of the fact that forage production was increased by clipping, the actual numbers of roots and tillers was reduced by one-half or
TABLE VI. Variations in foliage and forage as determined at the end of the first growing season.

<table>
<thead>
<tr>
<th>Location</th>
<th>Ave. width of leaves (cm.)</th>
<th>Ave. length of leaves (cm.)</th>
<th>Ave. area per leaf (sq. cm.)</th>
<th>Ave. leaf area per plant (sq. cm.)</th>
<th>Forage produced per plant (gms.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaughn, New Mexico</td>
<td>.334</td>
<td>13.21</td>
<td>5.07</td>
<td>1987.4</td>
<td>26.02</td>
</tr>
<tr>
<td>Amarillo, Texas</td>
<td>.480</td>
<td>12.30</td>
<td>6.19</td>
<td>2947.3</td>
<td>27.30</td>
</tr>
<tr>
<td>Woodward, Oklahoma</td>
<td>.376</td>
<td>9.20</td>
<td>6.30</td>
<td>2948.4</td>
<td>27.04</td>
</tr>
<tr>
<td>Hays, Kansas</td>
<td>.620</td>
<td>7.33</td>
<td>4.85</td>
<td>2444.4</td>
<td>16.78</td>
</tr>
<tr>
<td>North Platte, Nebraska</td>
<td>.320</td>
<td>2.86</td>
<td>0.91</td>
<td>436.3</td>
<td>4.46</td>
</tr>
<tr>
<td>Gage County, Nebraska</td>
<td>.311</td>
<td>12.00</td>
<td>7.33</td>
<td>2019.9</td>
<td>18.38</td>
</tr>
<tr>
<td>Mandan, North Dakota</td>
<td>.420</td>
<td>6.86</td>
<td>2.88</td>
<td>725.7</td>
<td>6.10</td>
</tr>
<tr>
<td>Cannonball, North Dakota</td>
<td>.435</td>
<td>8.00</td>
<td>3.48</td>
<td>988.3</td>
<td>6.36</td>
</tr>
<tr>
<td>Miles City, Montana</td>
<td>.440</td>
<td>7.01</td>
<td>3.08</td>
<td>813.1</td>
<td>5.34</td>
</tr>
</tbody>
</table>
Table VII. Average amount of air-dry forage (grams) produced by one plant from each locality at the end of each season and the combined weight of forage produced by one plant when clipped every two weeks during the second year's growth.

<table>
<thead>
<tr>
<th>Locality</th>
<th>Forage produced per plant 1939</th>
<th>Forage produced per plant 1940</th>
<th>Forage produced per clipped plant 1940</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaughn, New Mexico</td>
<td>26.02 gms.</td>
<td>102.0 gms.</td>
<td>90.6 gms</td>
</tr>
<tr>
<td>Amarillo, Texas</td>
<td>27.30</td>
<td>66.6</td>
<td>37.4</td>
</tr>
<tr>
<td>Woodward, Oklahoma</td>
<td>27.04</td>
<td>76.2</td>
<td>102.8</td>
</tr>
<tr>
<td>Hays, Kansas</td>
<td>16.78</td>
<td>55.6</td>
<td>82.0</td>
</tr>
<tr>
<td>North Platte, Nebraska</td>
<td>4.46</td>
<td>11.2</td>
<td>24.1</td>
</tr>
<tr>
<td>Gage County, Nebraska</td>
<td>13.63</td>
<td>60.4</td>
<td>66.0</td>
</tr>
<tr>
<td>Mandan, North Dakota</td>
<td>6.10</td>
<td>13.9</td>
<td>27.1</td>
</tr>
<tr>
<td>Cannonball, North Dakota</td>
<td>6.96</td>
<td>13.2</td>
<td>22.3</td>
</tr>
<tr>
<td>Miles City, Montana</td>
<td>4.94</td>
<td>18.1</td>
<td>28.2</td>
</tr>
</tbody>
</table>
more in the northern plants and one-fourth or more in the southern plants. Clipping seemed to prolong the growing period of the southern plants which were still actively growing after the unclipped ones were mature. However, the clipped and unclipped plants grown from northern seed passed into dormancy at about the same time.

The roots of the unclipped northern plants penetrated the soil from 2 to 4 feet deeper than did the clipped plants and those of the unclipped southern grasses were found to extend 1 to 2 feet deeper than those of the clipped plants. It was difficult to determine the exact depth of the roots of the clipped plants, since they were taken at random in the plot and the roots of all plants were intermingled. However, dead partially disintegrated roots were very evident among the roots of the clipped plants. Many dead rhizomes were also present especially in the northern grasses.
Fig. 10. General view of the plot after two years of growth.
The experience of the people in the Great Plains Region has shown that the permanent prosperity of the area will never come from an extensive program of wheat farming. More likely it will come from a program of diversified farming with major emphasis upon the raising of cattle. This means that thousands of acres of denuded land must be returned to its former state of grassland. This study is only a small part in the great drive taking place to find suitable methods and species for revegetating the former grazing lands.

Seed was obtained from different localities representing the northern, central, and southern Great Plains. Careful studies were made of the plants throughout two seasons of growth. The vegetative parts were counted and measured at regular intervals as were the roots, which were completely removed from the soil. A record of seed and forage production was also kept.

The rate of germination and early growth were very definitely influenced by soil and air temperature varying with different dates of planting. The coleorhiza was the first part of the germinating seed to break the pericarp; it was closely followed by the coleoptile. The radicle or seminal root broke through the coleorhiza in a short time. A few hours later the plumule or first leaf appeared. It is obviously necessary that the first root be fairly well established before a transpiring leaf is placed out in the atmosphere. A dry soil at this particular phase of development is the cause of a large part of seedling mortality. As soon as the crown roots became established, the seminal
root gradually disintegrated, and by the end of the season even traces of it could seldom be found. The date of appearance of the rhizomes coincided fairly well with the time that the first flowering heads emerged. The presence of these scaly rootstocks is a distinct asset in enabling side-oats grama to maintain its place among the important range plants.

Two important factors in the study of any plant for conservation purposes are the length of its active growing period and the time of year that the most active growth takes place. The northern plants grew and matured fast in the comparatively warm climate of mid-western Kansas. As the season progressed and the weather became warmer, the southern plants started growing faster and soon exceeded in size the northern plants, which were beginning to reach maturity. By the end of the season, the southern grasses were still actively growing while those produced from northern seed had been semi-dormant for some time. When stopped by frost, the southern plants were physiologically not ready to go into dormancy. This may account for the large per cent of winter-killing.

The height of the New Mexico plants at the end of the first season was 65.3 cm., while it was only 50.5 cm. for the Montana plants. The southern plants also had more tillers and a greater leaf area than any of the other plants. Since the southern plants had a greater area of transpiring leaf surface, they would tend to be less drought resistant than the northern plants, which had a proportionately greater amount of absorbing surface. Water was not applied artificially during the second year of growth and the southern plants also developed a more extensive
root system in proportion to their top growth. Each plant from southern grown seed produced approximately 27 grams of air-dry forage as compared to an average of 6 grams produced by the northern plants and 16 grams by the central plants. It should not be construed, however, that the forage of the southern plants was proportionately more palatable than that of the northern grasses. The southern grasses were considerably more coarse and stemmy and consequently weighed the most; but cattle would probably relish the finer textured northern plants much more. The best rhizome development was found in the southern grasses, but the development of the underground stems did not vary so much as did the vegetative parts of the plants.

Under the conditions of this experiment, it has been found that plants grown from northern-produced seed, do not produce enough forage to be valuable; and plants from southern grown seed winterkill badly. As far as material gathered in this study indicates, it seems that the most promising plants can be grown from seed produced in an area not too far south of the locality in which it is to be planted.
BIBLIOGRAPHY


Compares quadrat studies before and after several years of drought.


Discusses variations in the growth of little bluestem.


A very detailed study of this important hay grass.


Gives the effect of clipping on top and root development.
   Attempted to find best methods of seedling treatment.

   Contains a few facts about side-oats grama grass.

   An excellent study of the early history of this species. Involves methods which can be applied to studies of other species.

   Shows how root extent and top extent influence drought resistance.
A complete study with practical aspects.

Contains studies of effect of source of seed on growth.

Short history of the idea that seed from different climate produces better than locally grown seed.

Contains statements about side-oats grama grass.

Defines certain necessary terms.
Gives habit of growth of side-oats grama grass and its distribution.

Explains reasons for seedling mortality.

Found many variations in the growth of the species.

Experimented on effect of planting and environmental factors on root development.

Worked on root development in crop plants.

Description and drawings of rice seedlings.