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A Study of The Variations In The Growth of Blue Grama Grass From Seed Produced In Various Sections of The Great Plains Region

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A STUDY OF THE VARIATIONS IN THE GROWTH OF BLUE GRAMA GRASS FROM SEED PRODUCED IN VARIOUS SECTIONS OF THE GREAT PLAINS REGION

being

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INTRODUCTION

During the past 7 years the Great Plains Region, with its "dust bowl", has been the scene of unparalleled activity in the fields of range management and erosion control. The people of this short grass area are extremely conscious of the need for a sound, practical program of conservation that will revegetate the wasted pasture and cultivated land, which will aid materially in preserving the eroding soil. Many problems have arisen as the program of conserving the soil and the vegetation has progressed.

One of these problems pertains to the variations in the development of blue grama grass (Bouteloua gracilis), which is one of the dominant species of the short grass faciation of the Great Plains Region.

These variations have been puzzling to field men in making range reconnaissance surveys in that they have been led to believe that several species of grama had been encountered. Investigation, however, proved these variations to be within one species but modified by differences in climatic conditions.

Reconnaissance supervisors and grass specialists of the western and plains states have felt that there is a definite need for a detailed study of the variations of

blue grama grass from various regions of Western United States. This would acquaint the inexperienced taxonomist and range examiner with the variations that might be expected in the different regions and states.

One phase of this problem is whether these variations in the development of blue grama grass are hereditary or just the products of the environment. If the variations are due to environment and the blue grama plants from various regions are grown under the same environmental conditions, there should be little difference in their characteristics regardless of their origin. On the other hand, if the long period involved in establishing this grass in the various regions and localities has fixed its characteristics until they have become hereditary, then these characteristics should be retained fairly well in any environment permitting growth.

Another important phase of the problem is the effect of the source of seed upon the survival and normal growth of blue grama grass. Will the blue grama seed of plants native to one section of the Great Plains Region produce plants that will grow well in all the other sections? This is an important question to those purchasing the seed to plant in revegetation areas, or for erosion control. There is need for palatable, drought resistant grasses which will provide a permanent, erosion resisting cover in a relatively

short time. Blue grama, in its native environment, has many of these qualities but only experimentation can reveal how the grass will respond in sections to which it is not native.

In order to obtain information pertaining to these phases of this important problem a study has been made of the variations in growth of blue grama grass from seed produced in various sections of the Great Plains Region.

Related Studies

Most of the experimental work, relative to variations in growth, has been done with cereals or other domesticated crops. Miller (6) made a comparative study of the root systems and leaf areas of corn and sorghums. Percival (8), Taylor and McCall (11), and Webb and Stevens (14) in their several studies of wheat investigated the variations or differences found in varieties of that cereal. Each of their respective reports showed that differences in root and top growth were evident when the varieties were grown in the same environment. Weihing (15) found considerable variations in the root systems of small, medium, and large types of corn when grown together.

Anderson and Aldous (2) in working with the native grass, little blue stem, (Andropogon scoparius), found much variation in the period of anthesis and in the leaf areas

of plants grown on the same environment, but from seed which had come from different sources. The plants grown from southern seed blossomed later and produced more forage than those from central or northern sources, while the plants of northern origin came into flower earliest and made the least growth of the three. The observations which Savage (10) has made of several important native grasses of the Great Plains Region are in accord with the findings of Anderson and Aldous. To the author's knowledge, however, no detailed study has been made of the variations in growth of blue grama grass.

EXPERIMENTAL PROCEDURE

Obtaining and selecting seed

Early in March, 1938, a shipment of blue grama grass seed was obtained from D. A. Savage, Agronomist, Woodward, Oklahoma.

On March 25, these samples were prepared for a germination test. One hundred florets from each sample were placed between wet blotters in covered petri dishes and allowed to remain undisturbed until April 3. At this time the per cent of germination was computed, the results of which are contained in Table I.

Table I - Results of Germination Tests on blue grama florets from Various States of the Great Plains Region.

Sample	Original Source	Year Collected	Germination per cent
1	Hays, Kansas	1937	5
2	Tulsa, County, Okla.	1937	3
3	Lincoln, Nebraska	1937	22
4	Lincoln, Nebraska	No Date	18
5	N. Platte, Nebraska	No Date	30
6	Colorado Springs, Colo.	1936	62
7	Galatea, Colorado	No Date	29
8	Galatea, Colorado	1937	10
9	Colorado Springs, Colo.	1937	12
10	Colorado	No Date	19
11	Colorado Springs, Colo.	1936	62
12	Douglas, Arizona	1937	0
13	Wilcox, Arizona	1937	3
14	Cheyenne, Wyoming	No Date	50
15	Killdeer, North Dakota	No Date	50
16	Albuquerque, N. Mexico	No Date	19
17	Farley, New Mexico	1937	20
18	Tucumcari, N. Mexico	1936	30
19	Mexican Springs, N. Mex.	1937	1
20	Hartley, Texas	1937	25
21	Dalhart, Texas	No Date	0
22	Montana Strain	No Date	29
23	Bozeman, Montana	1937	10
24	White Hall, Montana	1937	8

From the twenty-four samples tested, ten were selected for planting which were representative of blue grama grass from the southern, central, and the northern sections of the Great Plains Region. The states represented were: Arizona, New Mexico, and Texas from the south; Kansas, Nebraska (North Platte), Nebraska (Lincoln), and Colorado from the central section; and Wyoming, North Dakota, and

Montana from the north. These were also selected because the seed showed a satisfactory germination test.

Selection and Preparation of Seed Bed

The location selected for the plots was a well-drained tract of typical creek bottom soil. It had been cultivated for some years and was equipped with the Skinner system of irrigation (Fig. 1 and 2). In making the ground ready for planting, only the surface was disturbed. The weeds were removed and the crust kept pulverized but the soil was not tilled because as nearly pasture reseeding conditions as possible were desired.

Planting of Seed

On May 10, the samples were sown in plots. Each plot contained three rows, twenty-six feet long which ran at right angles to the slope of the land. Two of the rows in each plot were spaced nine inches apart and the third, eighteen inches from the nearest row to determine the effect of spacing of rows on root and top growth. A space of eighteen inches was allowed between the plots. The seed was sown one-fourth inch deep and boards were layed over the rows to prevent drying or baking of the soil until the plants came up. The seeds sprouted satisfactorily and all plots had a showing of seedlings seven days after

Fig. 1. A view of the east portion of the blue grama grass plots showing Skinner watering system, the rich loam soil and the comparative top growth of the various plots. The Kansas plot lies adjacent to the Nebraska plot and is not included in the photograph. Sept. 1, 1938.

Fig. 2. A view of the west portion of the plots of blue grama grass used in the investigation. Sept. 1, 1938.

sowing. At the end of the second week, germination was practically complete and a fair stand was obtained in most of the plots.

Care of Plants

Heavy rains, however, covered or washed out many seedlings and packed the soil, forming a hard crust. This was carefully broken and the weeds kept in check in order to give the seedlings opportunity for maximum growth. During the third week of growth the plants became distinctly more robust and had three or four leaves per plant. After every shower, the crust of the soil was broken and the weeds were removed. No addition of moisture was required until early in July, when several days of hot, dry weather removed the soil moisture to a depth of three to five inches. The plants in most of the plots were not growing and showed signs of wilting during the heat of the day. Careful examination revealed the fact that they were not able to send down their crown roots through the dry soil and each plant was subsisting for the most part on the moisture absorbed by its lone seminal root and two or three crown roots. These tiny crown roots were from 1 mm. to 10 mm. in length. On July 11 and 12, the plants were watered in order to promote uninterrupted growth and

prevent death among the seedlings from drouth. On July 16 the crown roots had grown to a depth of three to six centimeters showing an increase of 6 to 30 times their length in 4 days.

Removal of Roots

In order to study the growth habits and to make drawings of the grass roots, it was necessary to carefully extract them from the soil. Two methods were employed in this operation. During the period of time the plants were small and the roots were shallow, a narrow ditch, exceeding the roots in depth, was dug around the plant to be removed. The ball of earth, containing the roots, was then removed and the soil carefully soaked away from them. After carefully washing the soil from their roots, the plants were placed in a shallow pan and floated in water over colored graph paper to facilitate drawing the leaves and roots.

Later in the season when the roots became too deep to extract by the above method, a trench was dug beside the plants to be removed. It was excavated far enough from them to prevent injuring the roots and made wide enough to permit working without being cramped. The trench was made deeper than the extent of the roots in order to provide a

place for the dirt and water which fell into the trench while the roots were being extracted. After the trench was completed, an ice pick and a pressure spray were used to uncover the roots. The pick was used to loosen the dirt about the root while a jet of water from the spray was directed on the loose earth to wash it away from the root and leave it exposed. When the root had been exposed throughout its length, it was measured and drawn to scale on graph paper, along with the top which had previously been sketched (7). After the roots and tillers became numerous, only a portion of them could be placed on the drawings which made the numbers only approximate.

Vegetative Growth

The tops were drawn to scale, three plants from each plot being removed and drawn where the number of plants in the plot was great enough to permit it. Beginning with May 19, the plants of the various plots were extracted and drawings made each week until June 18. With the increase in size and number of tillers above the ground and the number and depth of the roots below, the task became so great that the plants were removed and sketched every two weeks during July. The last digging was made the first

week in August. The extractions were then discontinued until after the first killing freeze, which occurred on October 23. All the plants which were extracted and drawn were pressed and retained for later study and photographing.

On June 25, ten plants in each plot were marked for observations regarding vegetative growth and seed production. These observations were made every two weeks beginning June 29, and ending the first week in August. One more observation was made September 16. These observations consisted of counting the number and obtaining the measurements of tillers, stems, leaves, and heads.

Seed Production

A record was kept of the date of the emerging of the first heads and the daily increase in heads on each plot from June 25, when the first flower stalks appeared until the seventh of August. A weekly record was made from then until August 29. A last count was taken September 13 to determine the greatest number of heads produced in each plot. In addition to this, observations were made on those plants staked for vegetative growth records to determine the number of spikes per plant and per head; and the average length of the peduncle of the heads.

Seed collections were made shortly before frost and after the first freeze. Six representative plants in each plot were used to supply the seed collected and a brief description of each plant was listed on the packet with its seed.

LIFE HISTORY

This study is primarily concerned with the variations to be found in the growth of the blue grama grass plants grown from seed produced under various soil and climatic conditions. It seems logical, however, that the early life history of the plants should be described to give a foundation for the study of these variations. Little variation occurs in the plants from the various sections during the early stages of their growth so the history or the early development of blue grama may be applied to all of them.

Germination

The blue grama seed began to germinate in about 3 days to 2 weeks (12) after being planted in warm, moist, well aerated soil at a depth of one fourth to one half inch. Several hours after planting, the palea and lemma enclosing the caryopsis became soft and pliable as

moisture penetrated them. The caryopsis began to swell as moisture was absorbed through the pericarp and the embryo showed white through the thin, tightly stretched seed coat. After the moisture content within the seed had reached the proper amount (8) (5) the epicotyl and coleorhiza became active and began to elongate. The coleorhiza pushed through the pericarp, and the primary or seminal root (15) elongated within the coleorhiza filling it and subsequently penetrating the protective wall. About this time, or shortly thereafter, the coleoptile emerged and rapidly elongated, pushing toward the surface of the soil (5).

Development of Seminal Root

After the root had broken through the coleorhiza wall, it penetrated the soil, elongating at the rate of about five tenths of a centimeter a day for four or five days. The young root was covered with root hairs. It reached a length of two or three centimeters in five to seven days. Lateral roots appeared at this time and the single seminal root continued to elongate (12). With the appearance of the lateral roots, the root hairs on the primary roots ceased to function except near the tips, where for a space of from one to four centimeters, no laterals had yet developed. There were eight to ten

lateral rootlets on each centimeter of the seminal roots with the exception of the tip region, and as these increased in length, tertiary rootlets, covered with root hairs, developed on them usually five to ten days after the laterals started elongating. Only one seminal root, or that root, (8) "belonging initially to the embryo, or, which later develops from or near the hypocotyl", was produced in the blue grama seedling development. It grew to a length of six to fourteen centimeters in the plants observed and remained active for four to six weeks. It was .15 millimeter in diameter throughout most of its length when young and growing, but decreased slightly in diameter as it became less active. A few seminal roots were observed undecayed at the end of one season of growth, but their primary function, it appears, is the absorption of water necessary for growth of the young plants before the crown roots elongate. It has been observed (3) that seminal roots of wheat remain functional throughout the life of the plant. Great difficulty was experienced in trying to locate the seminal root of a large blue grama plant among the hundreds of roots present and only when the seed coat had remained attached to the root could one be certain of the identity.

Coleoptile and plumule

The coleoptile began to elongate (5) from the basal node which was located at the juncture of the hypocotyl and epicotyl. The coleoptile formed a protective sheath over the delicate plumule which was one of the cotyledons diverging from the caulicle. The plumule became the first seed leaf while the scutellum, which was the other cotyledon, remained in the caryopsis. The coleoptile elongated rapidly by growth of the meristematic tissue just above the coleoptile's attachment to the basal node. The enclosed plumule elongated also within the coleoptile sheath, a brief space intervening between the tip of the plumule and the apex of the coleoptile (5). As soon as the tip of the coleoptile emerged above the soil surface, it was apparently retarded by the sunlight, while the plumule elongated rapidly and broke through the protecting sheath which had ceased to grow, its work having been finished. The white plumule began to turn a purplish-green and, as elongation continued, the compact shoot unrolled or unfolded to form the first blade or foliage leaf (4). The sheath, supporting the leaf and enclosing the tiny culm, began to elongate and the leaf continued to grow. After about six or seven days, a definite change was noted in the plant. At the surface of the soil

or slightly below it a bulb-like enlargement appeared which was at the juncture of the stem and basal internode. Above it the stem became definitely thicker, while below it the subcrown internode appeared to slightly decrease in diameter. This enlargement was the first or crown node (14) from which the first foliage leaf grew. It formed the crown or the base for the erection of the second internode, which was very short, and the forming of the first crown or adventitious roots. The second leaf appeared at this time, giving evidence that the second node had been formed and under favorable conditions the third and even fourth leaf was added during the second week after the first leaf unfolded. With the addition of the third leaf, the first crown root was usually formed and began to elongate.

Crown Roots and Fillers

The first crown root made its appearance as an enlargement beneath the epidermis at the outer edge of the lower side of the crown node, and as a rule, directly beneath the midrib of the sheath of the first leaf of the plant. It broke through the epidermis and elongated usually at the rate of about one centimeter per day, under favorable conditions, until a depth of twenty or thirty

centimeters was reached. As the adventititious crown root began to elongate the first tiller bud (12) started to emerge from the axil of the first leaf (9) whose sheath was attached to the crown root, and apparently, slightly higher and following it, the second tiller emerged from the axil of the second foliage leaf. Under favorable moisture conditions, the plant continued to set down more adventitious roots throughout the growing season, the average being about one root for each tiller. It was observed, however, that if the top soil became dry for a few inches down, the crown roots broke through the epidermis but failed to elongate over about one centimeter into the dry soil (13). The tillers continued to increase until it taxed the few established roots to supply them with moisture and wilting occurred during that of the day. When moisture was supplied, the adventitious roots elongated rapidly, many reaching a length of six to eight centimeters in four days.

The secondary or lateral roots appeared on the crown root about seven to ten days after it began to elongate, and tertiary rootlets emerged on the secondary roots about a week after the appearance of the secondary roots (12). Lateral secondary roots were not found, usually, closer than five or six centimeters to the root tip of the crown

root and tertiaries were, as a rule, about the same distance back from the tip of the secondary.

RESULTS

Variations in top growth

The plants of the nine plots increased in height at about the same rate from the middle of May until July 16 (Fig. 3-4-5). Then (Table II) on August 1, the Montana plot measured twenty-three centimeters and the Colorado and Nebraska plots, each twenty centimeters, the greatest growth in height among the plots. On September 1, measurements showed the plants in the Arizona plot to be the

Table II. Height (in centimeters) of blue grama grass in the various plots on progressive dates during the first year's growth from seed.

Plot	May 9	Jun 4	Jun 18	Jul 2	Jul 16	Aug 1	Sept 1	Oct 1	Oct 28
Ariz.	2	3	4.5	12	15	18	28	45	60
N. Mex.	1.5	3	7	10	12	18	25	33	38
Tex.	1.5	3	7	10	15	16	24	32	38
Kans.	1.5	3.5	4	5.5	11	19	20	25.5	26
Neb.	1.5	3.5	4	5	12	20	20	28	28
Colo.	1.5	3.5	6	13	14.5	20	26	32	32
Wyo.	1.5	2.5	3	7	9	16	24	27	28
N. Dak.	1.5	2.5	5	9	11	16	22	24	25
Mont.	1.5	2.5	6	9	14	23	24	24	24

tallest with a height of twenty-eight centimeters, Colorado and New Mexico plots followed with heights of twenty-six and twenty-five centimeters respectively. The Montana plot was twenty-four centimeters in height, only one centimeter greater than on August 1, while all the other plots grew several centimeters during August. This was apparently due to early maturing qualities of the Montana grass. By October 1, the plots of the southern group were equal to or exceeding the other plots in height, the Arizona grass measuring forty-five centimeters, New Mexico thirty-three centimeters, and Texas thirty-two centimeters. The Texas grass was equalled by the Colorado plot. The plots of the northern group showed little or no increase in height during the month of September as they apparently had reached maturity.

The height of the plants in the plots was checked for the final time on October 28 after a killing frost had brought the growing season to a close. The southern group showed the greatest growth in height for the season, the Arizona grass having a height of sixty centimeters, New Mexico and Texas each with thirty-eight centimeters. The central group with the exception of Kansas, was next tallest, Colorado being thirty-two centimeters, Nebraska twenty-eight centimeters, and Kansas twenty-six centimeters in height. Wyoming of the northern group exceeded Kansas

with a height of twenty-eight centimeters. North Dakota grew twenty-five centimeters tall and Montana twenty-four centimeters during their first seasons, placing the northern grasses as the shortest of the three groups. The southern group of plants grew vigorously until frozen.

The plants of the central group grew very little after October 1, although conditions were favorable for growth.

The northern group, coming from regions with relatively short growing seasons and limited rainfall, matured early. They remained green but grew very little after September 1.

Variations in foliage

The foliage characteristics observed were average width of blade, average length of blade, and area of leaf surface.

Arizona had the greatest average width of blade with .282 centimeter measured at the blade's widest part. New Mexico was next with .222 centimeter, followed by Nebraska with .22 centimeter. The North Dakota plot was narrowest being .163 centimeter in average width of blade. The plants of the other plots (Table III) had an average width of blades of .2 centimeter. The Arizona plot's average length of blade, measured from ligule to tip, was 7.5 centimeters. The other plots (Table III) ranged in

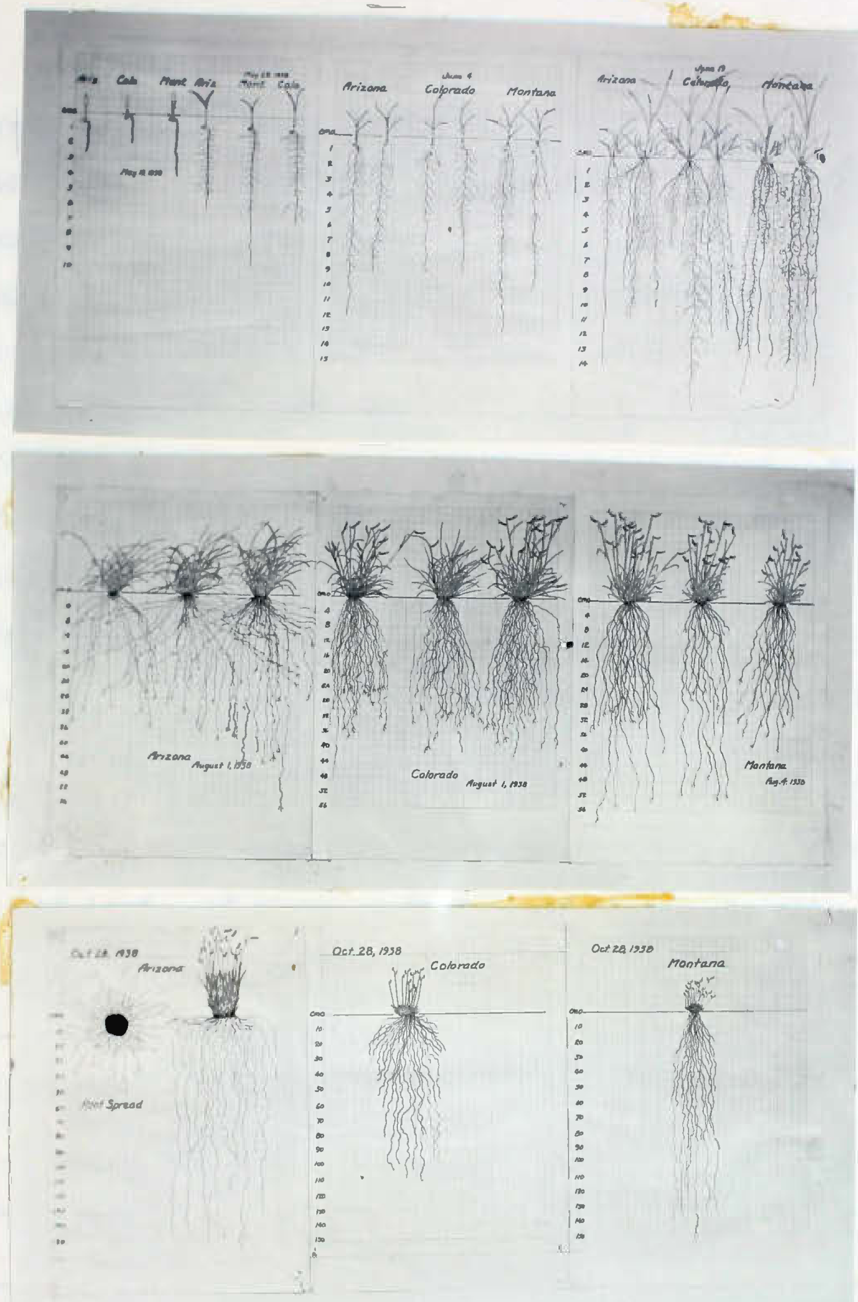

Fig. 3-4-5. The variations in growth of roots, and tops of blue grama grass seedlings, from May 19, to Oct. 23, 1938, of Arizona, Colorado, and Montana representing Southern, Central, and Northern regions, respectively.

average length of blade from 6 centimeters for Nebraska to 3.4 centimeters for North Dakota. The area of leaf surface is a fair index to the forage production of the plants of the various plots. This calculation was reached by multiplying the length of the blade by the width, then this result times the average number of leaves per plant for the plot at the close of the growing season. This figure was then multiplied by two so as to include both surfaces of the leaves. The southern group had the greatest area of leaf surface per plant (1), the Arizona plot being 11,285.6 square centimeters, New Mexico 3,553 square

Table III. Variations in plots with regard to phases of top growth at close of growing season, October 28, 1938.

	Av.width of leaf cm.	Av.length of blade cm.	Area of leaf surface sq.cm.	Av.length of stem cm.	Greatest height of plant cm.	Air dry wt. of forage per plant. grms.
Ariz.	.222	7.5	11285.6	10	60	79.5
N. Mex.	.222	5.5	3553.0	7	38	47.4
Tex.	.2	5.5	3088.8	8	38	29.1
Kansas	.2	4.	1142.4	4	26	26.8
Neb.	.22	6.	2098.8	5	28	24.5
Colo.	.2	4.5	1539.0	5	32	29.8
Wyo.	.2	4.1	1402.2	4	28	26.1
N. Dak.	.163	3.4	1020.6	3	25	18.1
Mont.	.2	4.2	1377.0	4	24	15.1

centimeters and Texas 3088.8 square centimeters. The central group, with the exception of Kansas, exceeded the northern group of plots (Table III). North Dakota had the least upper leaf surface of any of the nine plots with 1020.6 square centimeters.

In average length of stem which was measured from the crown to the top node of the culm of the plant, the southern group exceeded both the central and northern group. The plants of the southern group were the shortest stemmed of the three groups (Table III). The average length of stem varied from ten centimeters for Arizona to three centimeters for North Dakota.

In general, the southern group of plots produced the most and the coarsest foliage, with the longest stems, while the northern group of plots grew the least and the finest textured foliage, with the shortest stems.

Variations in Forage

The southern states ranked first in forage production, (Table III), Arizona producing 79.5 grms. (air dry wt.) per plant, New Mexico 47.4, and Texas 29.1 grms. The central states exceeded the northern group, as a whole, Montana having 15.1 grms. per plant for the lightest forage production of any plot in the investigation.

Variation in Tillering

Little variation was observed in the number of tillers produced by the plants of the various plots until August 4. At that time the southern group showed greatest number of tillers per plant and the central group the least (Table IV). Through June and the early part of July, the plants from the northern sections showed an average slightly above those from the south and central sections in tiller increase.

The final count was made October 28, after growth had ceased. The southern group of plants had the greatest increase of tillers for the season. Arizona had 756 tillers, New Mexico 485, and Texas 468. The northern plants exceeded those from the central sections slightly, North Dakota having 307 tillers per plant for the largest number in the northern group, while Colorado had 285 tillers per plant exceeding the other plots of the central group.

Table IV. Average increase in number of tillers and roots on blue grama seedlings in each of 9 plots on various dates throughout the growing season of 1938.

Average number plants observed tiller count-13 root count-3		Jun 4.	Jun 11.	Jun 18.	Jul 4.	Jul 18.	Aug 4.	Oct 28
Ariz.	tillers	1	2	4	16	42	142	756
	roots	2	3	3	7	33	68	709
N.Mex.	tillers	1	3	6	20	34	132	485
	roots	2	4	6	6	17	67	492
Tex.	tillers	2	3	6	25	43	125	468
	roots	3	3	5	7	22	60	478
Kans.	tillers	1	3	4	10	23	80	238
	roots	2	3	4	6	11	45	229
Nebr.	tillers	2	4	5	20	33	77	265
	roots	2	4	5	9	14	67	241
Colo.	tillers	1	3	4	20	44	127	285
	roots	2	4	4	8	30	66	289
Wyo.	tillers	2	3	5	15	37	116	285
	roots	2	3	3	7	35	65	262
N. Dak.	tillers	2	3	6	19	36	86	307
	roots	3	4	5	6	30	42	292
Mont.	tillers	2	4	7	17	41	119	270
	roots	2	4	7	7	35	68	269

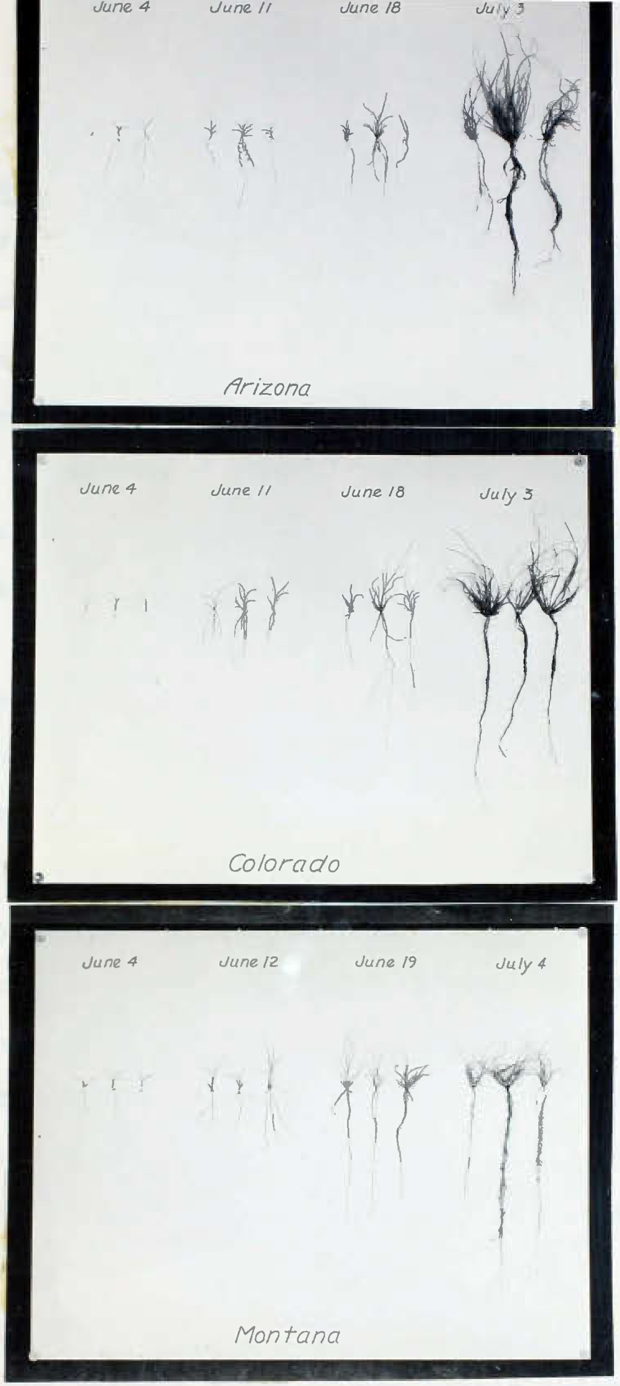

Fig. 6-7-8. Blue grama grass seedlings showing growth made during first month. Little variation occurred between the plants of the representative plots.

Variations in root growth

The fibrous system of roots of the blue grama grass plant consists of the primary crown or adventitious roots, the laterals or secondaries branching from the primary roots, and the tertiary rootlets which are attached to the secondaries.

Variations were noted in several phases of root growth throughout the plots as the roots were extracted and observed.

The southern group of plants produced primary crown roots with the greatest diameter at both the base and the tip ranging from .70 mm. to .63 mm. in base diameter, .50 mm. to .30 mm. in tip diameter (Table V). The northern group of plants all produced primary crown roots with a diameter of .60 mm. at the base, while their tip diameter was the smallest of the groups, measuring from .23 mm. to .20 mm. The primary crown roots of the plants of the central group showed the smallest base diameter, ranging from .60 mm. to .45 mm., their tip cross-section ranging from .25 mm. to .20 mm.

The increase in the number of crown roots of the plants in the various plots showed little variation (Fig. 6-7-8} until July 18, when it was observed that the northern group had the greatest number of roots per plant and the plants of the central sections the least (Table IV).

On October 28, however, the crown root increase coincided with the tiller increase, Arizona of the southern group having an average per plant of 709 crown roots followed by New Mexico and Texas with 492 and 474 respectively.

The plants of the northern sections of the Great Plains were found to have produced an average of more roots per plant than those of the central sections, during the 1938 growing season. The variation (Table IV) between the north and the central plants, however, was small.

Table V. Variations in plots with regard to phases of root growth at close of growing season, October 28, 1938.

	Diameter crown roots base mm.	Diameter crown roots tip mm.	Diameter secondary roots mm.	Diameter tertiary roots mm.	Secondary roots per cm. primary root	Tertiary roots per cm. secondary root	Working depth of roots cm.	Greatest depth of roots cm.
Ariz.	.67	.50	.20	.07	20	16	30	156
N. Mex.	.63	.30	.10	.05	18	16	35	240
Tex.	.70	.30	.16	.05	20	14	33	165
Kansas	.5	.25	.10	.05	12	14	30	78
Neb.	.6	.25	.07	.05	10	14	25	130
Colo.	.45	.20	.13	.05	16	10	32	110
Wyo.	.60	.23	.10	.05	12	14	21	65
N. Dak.	.60	.20	.10	.05	24	16	26	80
Mont.	.60	.20	.10	.05	20	22	33	155

The roots of the southern plants penetrated to the greatest depth, Arizona plants reaching a length of 156 cm., New Mexico 240 cm., and Texas 165 cm. The average root depth of the plants of the central group was, with the exception of Montana, greater than that of the northern plants (Table V).

In summary, the southern group of plants produced roots which exceeded those of the central and northern plants in numbers, coarseness, and depth of penetration. Only slight variation was evident between the central and northern plants in root growth.

Table VI. Variations of blue grama plants in plots in period of anthesis and seed production.

	Date of coming into flower		Av. No. of spikes per plant	Av. No. spikes per peduncle	Per cent of tillers bearing flower stalks	Av. length of spikes in cm.
Ariz.	July	30	92	2	13	3.5
N. Mex.	"	23	44.9	1.3	9	3.15
Tex.	"	23	68	1.8	14	3.20
Kansas	August	5	41.6	1.5	17	3.2
Neb.	July	23	77.9	1.6	30	3
Colo.	"	2	83.2	1.3	30	2.7
Wyo.	"	2	74	1.5	26	2.75
N. Dak.	"	2	60.3	1.25	19	2.25
Montana	June	25	39	1.25	15	2.8

Variations in period of anthesis

The northern group of plants were the first to blossom (2) (10), erecting flower stalks in seven weeks after planting the seed (Table VI). The Montana plot had two plants to begin flowering on June 25, while Wyoming and North Dakota plants began to blossom on July 1 (Fig. 9-10-11). Colorado plants, of the central group, began to show spikes on June 28, the early anthesis being due, presumably, to the altitude and short growing season to which the ancestors of these grass plants were accustomed. The plants of the Nebraska plot started blooming on July 23, as did the southern plants of New Mexico and Texas. The first spikes in the Arizona plot were observed July 24, while the plants in the Kansas plot did not begin to bloom until August 4. These observations show a considerable variation within the central group as to period of anthesis.

Variations in seed production

The plants in the Arizona plot produced an average of 92 spikes per plant, while the plants of Texas had 68 and New Mexico 44.9. Many of the spikes of the southern plants were immature and were killed by the frost before their seed had ripened. Of the central group the Colorado plants had 83.2 spikes per plant, Nebraska 77.9 and

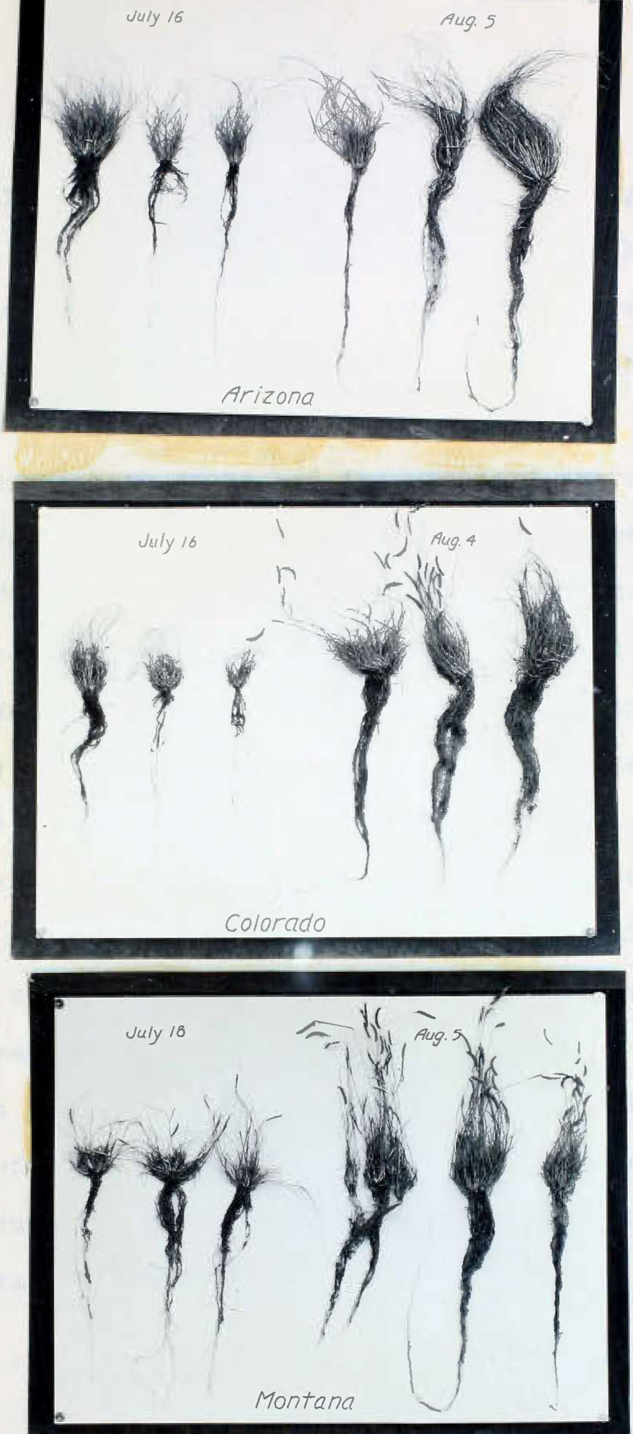

Fig. 9-10-11. Variations in length of root, height of plant, and period of anthesis are apparent in the plants represented in the above figures.

DISCUSSION

The blue grama plants used in this study are divided into three groups: southern, central, and nortern, according to the geographical location in which the seed was produced. They were grown in plots where near optimum conditions of moisture, tilth, and freedom from competition were provided. Plentiful spring rains filled the porous subsoil with a good reserve of moisture and a summer with few days of exceptionally hot, dry weather made a favorable average temperature. Little injury from insect pests was experienced and each plot apparently produced a maximum growth of tops and roots.

Germination of seed

The samples of seed showing the lowest germination per cent in the blotter test produced a poor stand of plants in the plots even though the seeds were sown thicker in the row than were those of greater viability.

Under favorable conditions, seeds, which had the lemma and palea removed from the caryopsis, germinated nearly twice as quickly as seed on which they were retained. It was apparent that the covering over the caryopsis slowed the penetration of moisture through the seed coat. When the husked and unhusked seeds of blue grama were

placed between wet blotters in a warm room; some of the seeds with bared seed coats were observed to germinate in one day, both the coleorhiza and coleoptile having emerged within that time. Thirty-six hours were required by the unhusked seeds to reach the same degree of germination.

When unhusked seeds were planted in pots in the greenhouse, some coleoptiles appeared above ground within four days after planting. Other plants made their appearance four weeks after the date of planting, showing a great variation in rate of germination. Further study would be necessary to determine the cause of this variation in germination. The removal of the sheath-like covering from the caryopsis of blue grama seed, which is to be used for the seeding of pasture land and revegetation areas, may prove to be an aid to the rapid germination necessary to get the plant up and established before the moisture leaves the surface of the soil.

<u>Individual variations</u>

The blue grama grass plant has definite characteristics by which it is recognized and classified, but within the species individual plants show variations not true of the plants in general.

Two variations were observed with regard to hirsute qualities. The average blue grama plant is hairy only on

or near the ligule, the remainder of the plant being glabrous. Several plants were observed to have a hirsute sheath with the blades glabrous, and a few plants were found to be hirsute on both sheaths and blades. The hairs were scattered irregularly over the surface of the plant and were from one to two mm. long. These hirsute plants were observed in the plots of the southern group and of Colorado in the central group. In other characters, they were like the rest of the plants.

The individual plants varied in leafiness and seed production. In observing sixty plants from which seed was collected, it was noted that, generally, the best producers of seed were the lightest producers of foliage, and that heavy producers of foliage were light producers of seed.

Many of the grass plants from the southern states tended to grow very erect, resembling Aristida (10). A few plants in each of the southern plots, however, were spreading in habit, the tillers growing out nearly parallel with the surface of the soil and covering considerable space. The central and northern plants generally produced curly leaves which produced compact bunches of foliage. A few plants in each of these plots were observed to produce a fine textured, short foliage which made very little forage and these plants produced short flower stalks with

very small spikes.

Foliage

The continuous vigorous growth exemplified by the plants of the southern group of plots, until killed by freezing, was due presumably to the longer growing season which they had experienced in their previous habitats. The early maturing qualities of the northern group reflected the short growing season, and limited rainfall, of their native environment. Increase in altitude doubtless is a factor in producing a shorter growing season and earlier maturity in plants.

It is apparent that the optimum moisture conditions and freedom from competition induced all the plants to produce greater growth than would have been possible under pasture conditions. Albertson (unpublished) observed on August 8, 1938, that blue grama seedlings in the short grass habitat near Hays, Kansas were 3.5 inches in height and had 10 tillers as an average per plant, while the seedlings in the Kansas plot of this study averaged 19 inches in height and had 80 tillers on August 4 of the same year.

Roots

The secondary and tertiary roots are responsible for the great root surface of the blue grama plant as they increase in number until the upper foot of soil is meshed in a network of these fine roots. The relatively great depth to which the roots in some plots penetrated was due possibly to plentiful subsoil moisture and the type of soil in which they grew. Previous watering and cultivation caused the carbonate layer to be much lower and less concentrated where the plots were planted than in the surrounding areas of uncultivated land. Albertson (1) found the roots of blue grama in the short grass habitat near Hays, Kansas, to reach a depth of only a little over 5 feet. The roots of the plants of some of the plots equaled or exceeded that depth in the first season of growth.

SUMMARY AND CONCLUSION

This study is concerned with the variations in the root and top growth of blue grama grass when grown from seed which was produced in various sections of the Great Plains Region. The three phases of this problem which were investigated are: the number and extent of variations, whether or not these variations are inherited, and will these grow and establish themselves in sections to

which they are not native.

Nine plots of blue grama grass were planted May 10, 1938, which included representatives of the southern, central, and northern sections of the Great Plains Region.

Variation of greater or lesser extent occurred in several phases of the growth of the plants. Little variation in growth in plots was observed during the first month. The northern plants slightly outgrew those of the central and southern sections during the first two months, but were overtaken and exceeded in growth by the plants of the other sections throughout August, September, and October. The southern group of plants produced the greatest growth in height for the season and the northern plants the least. The plants in all the plots remained green until they were frozen. The southern plants grew continuously throughout the season, but those from the central section ceased growth about October 1 and the northern plants grew no more after the first of September.

The southern group of plants produced the most and the coarsest textured foliage while those plants of the northern section produced the least and the finest textured foliage. The plants of the southern plots showed the greatest increase in number of tillers and crown roots during the season of growth and the central group the least. Crown roots on all plants were produced on an

average of about one root to each tiller.

The roots of the southern group of plants penetrated to the greatest depth, while those of the northern plots, with the exception of Montana, were the shallowest. The depth of root penetration varied from 68 cm. for Wyoming grass to 240 cm. for that of New Mexico.

The period of anthesis for the Northern group of plants began June 25 to July 1. The southern group came into flower July 23 and 24. The plants of the central group showed a wide variation in anthesis. The Colorado plot began to bloom June 28, Nebraska July 23, and Kansas August 4. The earliness of the period of anthesis usually corresponds with the length of the growing season where the seed from which the plants grew, was produced. The shorter the growing season in the former habitat, the earlier the plants bloomed.

The Arizona plants produced the greatest number of spikes per plant, but the largest per cent of tillers which produced flower stalks was found in the plants of the central section of the Great Plains Region and least in those of the Southern section. The most spikes per flower stalks were produced by the southern plants, the least being present on the plants from the northern section. The plots of southern plants bore the largest spikes on the tallest flower stalks, while the smallest

spikes were produced on plants from the northern section, their flower stalks being the shortest of the 3 groups. Many of the florets of the southern group of plants did not mature due to freezing.

Apparently the variations exemplified by the different groups of plants are hereditary; at least, the first generation would justify such a statement.

The plants of all the plots grew well and produced some seed, seemingly making definite progress in establishing themselves during the first season of growth. However, a check to determine how the plants survived the winter was taken in the spring of 1939, and revealed that several plants in the Arizona plot were dead and an average of only 10 per cent as many tillers to each plant had started growth in the plot as had been present when the plants ceased growth in the fall. The plants of the other plots had 30 to 60 per cent as many tillers at the beginning of spring growth as they had had in the fall and very few of them failed to survive the winter. The results thus far would infer that all the plots investigated, excepting Arizona, can survive our winter. No information is at hand, however, to indicate the drought resistance of the various groups of plants.

APPLICATION

The results of the study of the variations in the growth of blue grama grass as it occurs in various sections of the Great Plains Region may be of some assistance to the inexperienced taxonomist in identifying this grass where ever it may be found throughout the Great Plains area by making him acquainted with the variations he may expect to find.

The individual and sectional variations observed in this grass make it obvious that much improvement and uniformity may be obtained by selection of individual specimens and allowing them to grow and produce seed with which their kind may be reproduced.

Insufficient information is available to make a conclusive statement regarding the effect of the variations in the blue grama in reseeding of pasture lands. Apparently seed harvested in the locality where the pasture is to be reseeded will be more satisfactory than seed from farther north as the northern plants are inferior as forage producers. The southern grasses would exceed in forage production if they are able to withstand the environmental conditions farther north (10). This presents another problem, which is not included in this paper.

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