THE INFLUENCE OF SOURCE OF SEED AND LENGTH OF DAY ON THE GROWTH OF CERTAIN NATIVE GRASSES

by

GLENN CHARLES KLINGMAN

B. S., University of Nebraska, 1939

A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1941

TABLE OF CONTENTS

INTRODUCTION

Interest in grassland has been increasing in the past several decades. Until recently, land under cultivation usually had been considered more productive than when left in grass. This may be attributed to the fact that the poorest land on a farm was left for the pasture and little or no care given to it. Not until a major portion of the great grassland had been destroyed did the general public begin to realize its importance in helping to stabilize American agriculture.

A number of factors have helped to draw the attention of the American people to the conservation and restoration of the native prairies. The most phenomenal was the great dust storms that have occurred particularly since 1934 as a result of continued destruction of these grasslands by drought, overuse and by the plow. The reduced carrying capacity of most pastures, drought, financial losses from cash crop farming, and the realization that fairly consistent good farm incomes may be secured from a properly managed grassland unit, have all helped to emphasize the importance of our native prairies.

In the virgin prairies the bluestems were the dominant vegetation of the eastern third of Kansas. Big bluestem (Andropogon furcatus Muhl.) was the dominant native perennial grass of the fertile uplands and well aerated bottomlands. Little bluestem (Andropogon scoparius Michx.) was the dominant grass on the less fertile uplands and drier slopes in eastern Kansas, and was found on the slopes and lower ground to the west. Weaver and Albertson (1936) after examining prairie vegetation of north central Kansas

stated that, "a large part is clothed with the Andropogon scoparius type with little bluestem furnishing 65 to 80 per cent or more of the plant cover. A. furcatus is present everywhere, varying in importance from 5 to 20 per cent except on banks and ravines and in shallow draws where it usually takes complete possession."

Little bluestem and big bluestem were listed by Aldous (1938) as the dominant species of the Flint Hills, with side-oats grama (Bouteloua curtipendula Michx.) and switch grass (Panicum virgatum L.) as two of the grasses assuming secondary importance.

Since the above grasses are so well adapted to Kansas conditions, it is not likely that better grasses can be found; however, through careful plant breeding methods these native species may be improved. A gradually increasing desire among farmers to return at least a part of their land to grass has raised questions of seeding methods, kinds of seed to be used, as well as the problem of obtaining adapted strains. Plant breeding stations are producing superior strains of the various grasses, but in all probability, they will not be available for some time in sufficient quantities to meet the demand that will follow the development of more efficient methods of obtaining stands. For this reason seed harvested from the native prairies, in the beginning at least, will be cheaper and as a result will be used.

Plants of the same species but from different geographical sources respond differently when brought to the same locality. One of the factors of environment that is thought to be quite important is the change in length of day at different latitudes.

A greenhouse experiment was conducted to study the response of plants from different sources to varying lengths of day. From this study it was hoped that a better understanding of the plant's behavior in the field would result.

Plants grown from seed of various sources should be studied to determine their suitability to any given location. Difficult as it is to get satisfactory stands of the native grasses, it would be discouraging for a farmer to find that he had started a grassland consisting of poorly adapted plants. With this problem in mind an experiment was conducted at the Kansas Agricultural Experiment Station, Manhattan, Kansas to determine the behavior of the four important native grass species mentioned above. Plants were grown from seed obtained from several of the prairie states and observed during the growing seasons of 1939 and 1940.

The seed for this experiment was furnished by Donald R. Cornelius of the Soil Conservation Service, Manhattan, Kansas. It was planted in the greenhouse on March 7, 1939 and the seedlings were spaced in flats on April 3. On June 1 the small plants were set out in the Kansas Experiment Station Grass Nursery. For the various seed sources of the four species studied, a row of 20 plants each spaced 30 inches apart were transplanted to the nursery.

In this study the method of obtaining the data is given just preceding its presentation and discussion. Thus, accompanying each subdivision of the "Data and Discussion" the materials and methods used specifically in that part of the experiment will be given.

DESCRIPTION OF SPECIES AND ECOTYPES

Big bluestem (Andropogon furcatus Muhl.), little bluestem (Andropogon scoparius Michx.), switch grass (Panicum virgatum L.), and side-oats grama (Bouteloua curtipendula (Michx.) Torr.) were the grass species included in this study. For purposes of clarity the species in this paper, except where scientific names are used in direct quotations, are referred to by the common names listed above.

Hitchcock (1935) described the various species as quoted below:

> Big bluestem: Plants often glaucous; culms robust, often in large tufts, sometimes with short rhizomes, 1 to 2 m tall, usually sparingly branching toward the summit; lower sheaths and blades sometimes villous, occasionally densely so, the blades flat, elongate, mostly 5 to 10 mm wide, the margins very scabrous; racemes on the long-exserted terminal peduncle mostly 3 to 6, fewer on the branches, 5 to 10 cm long, usually purplish, sometimes yellowish; rachis straight, the joints and pedicels stiffly ciliate on one or both margins, the joints hispid at base; sessile spikelet 7 to 10 mm long, the first glume slightly sulcate, usually scabrous, the awn geniculate and tightly twisted below, 1 to 2 cm long; pedicellate spikelet not reduced, awnless, staminate.
>
> Little bluestem: Plants green or glaucous, often purplish; culms tufted, from slender to robust, compressed, 50 to 150 cm tall, erect, the upper half freely branching; sheaths and blades commonly glabrous or nearly so, frequently sparsely pilose at their junction, rarely pubescent to villous throughout, the blades 3 to 6 mm wide, flat; raceme 3 to 6 cm long, mostly curved, the filiform peduncles mostly wholly or partly included in the sheaths, commonly spreading, the rachis slender, flexuous, pilose, sometimes copiously so; sessile spikelet 6 to 8 mm long, scabrous, the awn 8 to 15 mm long; pedicellate spikelet reduced, short-awned, spreading, the pedicel pilose.
>
> Switch grass: Plants usually in large bunches, green or glaucous, with numerous scaly creeping rhizomes; culms erect, tough and hard, 1 to 2 m tall; sheaths glabrous; blades 10 to 60 cm long, 3 to 15 mm wide, flat, glabrous,

or sometimes pilose above near the base, rarely pilose all over; panicle 15 to 50 cm long, open, sometimes diffuse; spikelets 3.5 to 5 mm long, acuminate; first glume clasping; two thirds to three fourths as long as the spikelet, acuminate or cuspidate.

Side-oats grama: Perennial, with scaly rhizomes; culms erect, tufted, 50 to 80 cm tall; blades flat or subinvolute, 3 to 4 mm wide, scabrous; spikes 35 to 50, 1 to 2 cm long, purplish, spreading or pendulous and mostly twisted to one side of the slender axis, this 15 to 25 cm long; spikelets 5 to 8, appressed or ascending, 6 to 10 mm long; fertile lemma acute, mucronate; rudiment with 3 awns and subacute intermediate lobes, often reduced and inconspicuous.

The United States Soil Conservation Service furnished seed of the above species as received from various sources. Complete data as to origin were not available at the time the seed was obtained and later verification by Donald R. Cornelius of the Soil Conservation Service showed that a few of the samples should not have been used in this study. A complete botanical description of each type is not feasible in this paper. The name of the town or county, the state where each originated and the Soil Conservation Service accession number are given in Table 1.

Table 1. Sources of seed and the Soil Conservation Service accession numbers.

	Soil Conservation Service accession number	Source of seed
Plants studied in the field		
Big bluestem	KG581	Mandan, North Dakota
	KG662	Columbus, Nebraska
	G112	Anderson County, Kansas
	KG752	Stillwater, Oklahoma
	-----	Texas. Seed failed to grow.
	KG636	Received at Tucson Nursery from O'Neil, Nebraska. Exact origin unknown.

continued --

Table 1 cont.

	Soil Conservation Service accession number	Source of seed
Little bluestem	KG570	Towner, North Dakota
	G1	Holt County, Nebraska
	KG473	Eldorado, Kansas
	KG1085	Woodward, Oklahoma
	KG531	Vernon, Texas
	KG725	Received by Tucson, Arizona nursery from San Antonio, Texas in 1936.
Switch grass	KG568	Received at Mandan, North Dakota from Holt County, Nebraska in 1935.
	KG1131	Holt County, Nebraska
	KG493	Anderson County, Kansas
	KG767	Yukon, Oklahoma
	KG515	Vernon, Texas
	KG719	Received at Tucson, Arizona from San Antonio, Texas in 1936.
Side-oats grama	KG1052	Cannonball, North Dakota
	KG731	Columbus, Nebraska
	KG482	Received at Manhattan, Kansas from ElReno, Oklahoma in 1934.
	KG754	Nowata, Oklahoma
	KG758	Temple, Texas
	G60	Tucson, Arizona
Plants studied in the greenhouse		
Little bluestem	KG743	Towner, North Dakota
	KG473	Eldorado, Kansas
	KG750	Gatesville, Texas
Side-oats grama	KG1052	Cannonball, North Dakota
	KG462	Gibson, Kansas
	KG751	Austin, Texas

The North Dakota, Texas and Arizona selections of big bluestem were omitted from this study. But one North Dakota plant survived the first summer, the Texas seed was not viable and the Arizona selection was found to have been received from Nebraska

but the exact origin was not known. As shown above, little bluestem, KG725; switch grass, KG568 and KG719; and side-oats grama, KG482 were ecotypes grown from seed collected off plants that were one generation removed from the area in which they originally grew. The plants in this experiment were considered typical for the area in which the seed used was collected, thus the later locality was used as its source.

REVIEW OF LITERATURE

This review of literature is divided into two fields of study. The first concerns the range of adaptation and importance of big bluestem, little bluestem, side-oats grama and switch grass in the tall grass prairie. The second includes material relative to the length of day and its influence on plants.

There are but few references in the literature concerning the adaptation to a given locality of the native grasses found in the Great Plains. However, several recent Masters' theses prepared at Kansas State College have mentioned the different habitat forms observed in plants grown from seed of various sources.

Cornelius (1938) observed that plants of big bluestem (Andropogon furcatus Muhl.) grown from seed collected in Kansas and Oklahoma were more leafy, matured later and were taller than plants grown from seed collected in Nebraska, North Dakota or Michigan. Anderson and Aldous (1938) grew strains of little bluestem (Andropogon scoparius Michx.) from seed collected in

North Dakota, Nebraska, Kansas, Oklahoma and Texas. According to their observations northern types were earlier, smaller, and less leafy than those from the south, while those from Kansas were intermediate in all three respects. In 1937 plants from northern Nebraska headed, on an average, seventeen days earlier than those from Manhattan, Kansas, while the southern Oklahoma plants headed ten days later. Law (1940) and Cornelius (1938) working independently on big bluestem, observed that plants of various seed sources growing in the Manhattan nursery exhibited definite habitat types corresponding to the ecotypes of Turesson (1922b) and the habitat types of Gregor and Sansome (1927). The same phenomena were found to be true for little bluestem by Anderson and Aldous (1938).

Turesson (1922a) in comparing the flora of the much exposed west coast of Sweden with that of the more sheltered eastern coast, found that very few erect plant forms existed on the west coast, whereas the more prostrate forms were predominate; the reverse being true on the east coast. In discussing the reasons for the variations observed he stated that "... prostrate forms of the species are favoured on the west coast while erect ones tend to be eliminated ...". He further concluded that habitat types represent the genotypical response of the species-population to a definite habitat and are not the result of sporadic variations preserved by chance isolations. In a later article, Turesson (1923) cited several examples of species that were found as constants yet they were known to be extremely variable and he concluded that "... it is just the ability of these species to

respond genotypically to a wide range of ecological factors that enables them to establish associations in regions climatically dissimilar."

Gregor and Sansome (1927) agreed with Turesson when they showed that there were definite hereditary habitat types within a grass species. They later stated that the habitat type represented the genotypical response of the species population to a definite habitat, and have not necessarily arisen through chance isolation of variations or by the gradual change from one type to another type without selection of individuals. They believed that the types not suited to the prevailing environmental conditions of their habitat were gradually eliminated. Those surviving were phenotypically similar; with genetic uniformity being extremely rare in wild populations.

Hilgendorf (1928), Jenkins (1936), Evans (1931, 1939), Evans, Allard and McConkey (1935) and others are in agreement with the general conclusions drawn by Turesson and by Gregor and Sansome.

Cornelius (1938) reported that, "Commercial sources of bromegrass, timothy, orchard grass, Kentucky bluegrass and perennial ryegrass have been grown by numerous investigators as individual plants and in all cases exhibit considerable variation between plants." In New Zealand, Hilgendorf (1928) found that when selections of ryegrass (Lolium perenne) and orchard grass (Dactylis glomerata) from two environments were grown together, distinct ecotypes were apparent. Bromegrass (Bromus inermis) was shown by Waldron (1921b) to exhibit considerable difference

in the behavior of plants from varying sources, with a lesser variation between plants from the same source. He reported (1921a) that clones of bromegrass were quite uniform but found considerable variation between them. Keyser (1913) recognized wide variations in types of bromegrass, and he discussed the need for different grass types for varying localities and conditions. Jenkins (1936), working on Lolium and Festuca, concluded that plants derived from the same habitat differed from one another but this variation usually was not great. Plants from different habitat types conformed to different general plant types.

Evans, Allard and McConkey (1935) divided timothy into early, medium and late groups based on the time of heading and flowering. A consistent relationship was found to exist between these characters and the latitude in which they were grown.

Thus variation is the general rule in all widely distributed species, and an intensive study of each is necessary to a thorough understanding of the various types.

There are many references concerning the distribution, ecological adaptation and economic importance of big bluestem, little bluestem, side-oats grama and switch grass. A clear understanding of these salient points is necessary to an explanation of the differences observed in the species grown from seed of various sources. Hitchcock (1935) gave the regions of adaptation of the various grasses as follows:

> Big bluestem: ... dry soil, prairies and open woods, Quebec and Maine to Saskatchewan and Montana, south to Florida, Wyoming, Utah and Arizona; Mexico.

Little bluestem: ... prairies, open woods, dry hills, and fields, Quebec and Maine to Alberta and Idaho, south to Florida and Arizona.

Side-oats grama: ... plains, prairies, and rocky hills, Maine and Ontario to Montana, south to Maryland, Alabama, Texas, Arizona and southern California; South Carolina.

Switch grass: ... prairies and open ground, open woods, and brackish marshed, Quebec and Maine to Montana, south to Florida, Nevada, and Arizona; Mexico and Central America.

Featherly (1938) gave similar regions of the United States in which each of the above grasses were found.

Weaver and Fitzpatrick (1932) studied the prairies of the eastern third of Nebraska, western third of Iowa, northward to a small portion of Minnesota and south in Kansas to the Kansas River. They noted that big bluestem was one of the most important dominants. In well watered areas on the sufficiently aerated soils, it often furnished 80 to 90 per cent of the cover. Together with little bluestem it composed fully 70 per cent of the total grassland vegetation. Little bluestem constituted the most extensive upland type and easily exceeded in importance all other upland species combined. Weaver and Fitzpatrick (1932) stated that side-oats grama was scattered widely throughout the prairies in all types of situations but rarely occurred in great abundance, usually being found in small isolated clumps scattered among the other species, especially in the big bluestem type of prairie. Switch grass was described as a "tall, coarse, rank, sod forming grass" and was an important dominant of the low moist areas. It was found far up ravines and draws and also occurred in disturbed uplands. In the different areas studied switch grass was most

important in the southern and eastern section, which included a part of eastern Kansas.

Schaffner (1913) described the typical prairie of the Great Plains as being composed of big bluestem, little bluestem, Indian grass (Sorghastrum nutans L.) and switch grass; arranged in the order of their importance. Sarvis (1920) reported the occurrence of big bluestem in limited areas at Mandan, North Dakota and stated that it was palatable, being greatly relished by livestock. Little bluestem was listed as being of primary importance along the west side of the Missouri river. Side-oats grama was ranked as being of secondary importance.

In a study of the structure of the prairie vegetation of east central Nebraska, and comparing species of grasses and sedges, Stieger (1930) arranged them as to rank in habitat and as to the per cent of the total vegetation composed of each species as shown in Table 2.

Table 2. Rank in habitat and per cent of total vegetation of big bluestem, little bluestem, side-oats grama and switch grass of the prairie of east central Nebraska.

	Rank in habitat		Per cent of total vegetation	
	Lowland	Upland	Lowland	Upland
Big bluestem	1	5	34.9	8.8
Little bluestem	3	1	25.6	26.4
Side-oats grama	4	6	4.2	8.0
Switch grass	14	-	trace	-

According to Frolik and Keim (1938) big bluestem grows commonly over the eastern third of Nebraska and flourishes on well drained bottomland and thrives reasonably well on much of the

uplands. Little bluestem was listed as growing generally over the state and important in the upland native grass pastures of eastern Nebraska, often constituting 50 to 75 per cent of the vegetation. Side-oats grama was reported as growing throughout the state but was more common in eastern Nebraska. It was noted to be reasonably well adapted to dry soils, and also able to compete quite successfully under the more favorable conditions in which the bluestems were found. Switch grass occurred commonly "... over the state where moisture conditions are favorable but seldom to any great extent in local areas". It was most important in the areas between the big bluestem and slough grass (Spartina pectinata L.) plant communities, but also thrived where the bluestems were found growing.

Newell (1938) stated that the bluestems were desirable forage species for eastern Nebraska. Frolik and Shepherd (1940) found in a typical sandhill area of north central Nebraska that switch grass ranked fourth in total vegetative cover, little bluestem fifth and big bluestem ninth. It was observed that these species, particularly little bluestem, were severely injured by the recent drought and as a result their relative importance was much reduced.

According to Aldous (1938) the vegetation of eastern Kansas originally consisted of big and little bluestem as the dominant species. Other grasses of secondary importance were side-oats grama, switch grass, Indian grass and prairie June grass (Koeleria cristata L.). After studying the prairies of north central Kansas, Weaver and Fitzpatrick (1934) stated that big

and little bluestem constituted fully 80 per cent of the grassland. The big bluestem consociation occurred on the moist slopes and aerated lowlands, whereas the little bluestem consociation was the most extensive upland type. Side-oats grama was scattered throughout the prairie and a rather heavy sprinkling of dwarfed switch grass was found, especially in the low poorly aerated soils.

Little bluestem was noted by Aldous (1936) to be lower in palatability in western Kansas than in the eastern part of the state. However, for the Flint Hills area Aldous (1934) ranked little bluestem with big bluestem as leading the list of grasses in both palatability and nutritive value. The low palatability of little bluestem in western Kansas corresponds to that noted by Sarvis (1920) in North Dakota, and by Frolik and Shepherd (1940) in the Sand Hills of Nebraska. Nevertheless, it remains as an important species in the three areas.

The subclimax prairie of eastern Oklahoma was found by Bruner (1931) to be composed of big bluestem in the depressions and on moist slopes. Slightly drier slopes and more exposed areas were occupied by little bluestem, usually accompanied by side-oats grama. Where the soil was still more moist than that occupied by big bluestem, switch grass was usually dominant.

Many workers have observed variations within plant species as found growing in different latitudes. These differences were also apparent when these types were brought together and grown side by side.

According to older biological writings temperature was considered the most important determinant affecting distribution of plants and animals. Several important investigators should be mentioned in this connection, although the original articles were not available to the writer of this paper. These investigators were, however, reported on by other authors. According to Evans (1939), Shelford in 1932 wrote that temperature was the most important factor in determining the distribution of plants and animals. Reaumur in 1735 calculated the time of appearance for certain plants and animals by summing the accumulated degrees of temperature above freezing. Merriam in 1894 and 1899 mapped life zones in North America and in determining the boundaries of these zones he used 43° F. as the effective temperature. (Evans, 1939).

According to Hopkins' (1918) summary of his Bioclimatic Law "... there is a country wide average rate of variation in the time of occurrence of regular periodical events in plants and animals between different geographical positions as defined by latitude, longitude and altitude. This rate is 4 days for each one degree of latitude, 5 degrees of longitude and 400 feet of altitude."

Evans (1939) noted that timothy grown at various latitudes evidenced variations which led him to believe that some other factor than temperature, and one that was not recognized in the Bioclimatic Law, had an important influence upon the time of blooming.

Allbright (1933) stated that rapid midsummer growth of plants growing in high latitudes has often been noticed. In

June, 1932, wheat and oats reached a height of 18 to 20 inches at 58°22' N. latitude. A week later 220 miles south the same varieties, seeded on almost the same date, were only a foot tall. He further found that over an 8 year period, wheat matured in 16 days less time at the northern station than in similar experiments conducted in the south.

Two years after the publication of Hopkins' Bioclimatic Law, Garner and Allard (1920) published the results of an experiment which they conducted on the effect of different lengths of day on various plants. They found that some plants produced inflorescences only when exposed to light for a long period each day, while others required short daily light periods. Still another group was indifferent to the length of day. From this study Garner coined the word "photoperiodism" to designate the response of the plant to the length of day. For convenience in describing the behavior of different plants they were divided into short day, long day, and everblooming plants.

In the 20 years which have passed since the appearance of Garner's and Allard's first paper on photoperiodism, considerable interest has been aroused in the subject, and as a result there has been a rapid accumulation of literature dealing with various phases of the work. Time and space as well as the importance of the subject to this paper will permit reference to but a limited number of these articles.

Adams (1923) found that the plants he studied were heavier, taller and earlier of maturity when exposed to a long daily light

period than when darkened a number of hours each day. It was suggested that for plants to attain their best development there was a certain optimum relation between the daily amounts of light and darkness.

Evans (1931) stated that timothy plants, taken to the greenhouse when the season's growth was about completed and artificially illuminated for several hours each evening, developed elongated culms and formed inflorescences within a comparatively short time. However, other timothy plants taken to the greenhouse and not given artificial light remained in the vegetative state throughout the winter.

Changing the length of day by units as small as 30 minutes per day gave considerable variation for some plants, as shown by Evans and Allard (1934). They also reported, as have many other investigators, that varieties of the same species may have reactions extremely different from each other even when grown under identical greenhouse conditions.

Adams (1924) found that wheat and rye reacted differently under varying light treatments. Increased time of illumination caused wheat to head 27 days earlier and rye 45 days earlier than plants subjected to the normal length of day.

It is not intended that light should be considered the sole cause of the diverse growth forms observed. Kellerman (1926) lists environmental factors such as temperature, moisture and character of food supply as important, but stated that they may be changed through a "... rather wide range before the existence of the individual plant is jeoporidized or its behavior or type

of growth ..." is markedly affected. Miller (1938), referring to other investigators, showed that the optimum temperature for plant growth may vary with differences in length of exposure to light. Steinberg and Garner (1936), making rather extensive observations of soybean plants, found that temperature differences altered the critical light periods to a limited degree, but there were no marked contrasts. McKinney and Sando (1935), in expressing the relationship of light and temperature, concluded that winter wheats are not typical long day plants but are what may be termed "short day ⟶ long day plants and low temperature ⟶ high temperature plants." This method of expression indicated that the temperature and the length of the photoperiod must increase with the development of the plant in order to induce early sexual reproduction.

Garner and Allard (1925), Garner (1937), and Zimmerman and Hitchcock (1936) reporting on the localization of the plant parts that were responsive to light treatments agreed that the growing stem tips were the organs affected. The latter reference stated that the regulators were probably chemical agents of a hormone-like nature, manufactured in the stem tips and sent to other parts of the plant where they exert a controlling influence. Redington (1929) found a change of the carbon-nitrogen ratio in plants under different lengths of light exposure, and Garner, Bacon and Allard (1924) were convinced of a change in the acidity of the stem tips under different photoperiods. These reports have been verified by many other investigators.

The intensity of the light necessary to produce photoperiodism, according to Withrow and Benedict (1936) varies widely for different plants. One third foot candle was as effective as 100 foot candles in inducing early blooming in the Chinese aster. One tenth foot candle, or about twice the intensity of bright moonlight applied from about dusk until midnight was sufficient to influence flowering. It should be noted that the above light intensities were too weak to affect photosynthesis directly.

Considerable variation occurs in the length of day within the boundaries of the United States which extend from the southern boundary of 24°20' to 49° north latitude. According to the U. S. Nautical Almanac Office (1940), on June 19, the length of time between sunrise and sunset was approximately 13.7 hours at 25° N. latitude, while at 49° N. latitude there was 16.2 hours. At Manhattan, Kansas located at 39°12' N. latitude, the time was 14.9 hours. For a more extreme example, at 60° N. latitude on June 19 the sun was above the horizon for a few minutes less than 19 hours.

DATA AND DISCUSSION

For simplicity in discussion and presentation the data were divided into two main divisions with subdivisions for each. The first division and the main objective of this research problem, concerned the suitability and adaptability to Kansas conditions of big bluestem, little bluestem, side-oats grama and switch grass grown from seed of various sources. The investigations included a study of winter injury, date of heading, total leaf

area per culm and total leaf area per plant, maximum height of plants, number of culms per plant and relative vigor ratings of 1939 and 1940.

In addition to the above field study a greenhouse experiment was conducted to study the effect of varying lengths of day on plants grown from seed of various sources.

Field Study of Four Native Grass Species Grown From Seed of Various Origins

Winter Injury. A perennial grass plant normally develops a larger number of culms in the second season of growth than in the first. A failure to make an increase in the number of culms would indicate a lack of adaptation to conditions of the winter season. With this in mind, the number of culms remaining from the previous season's growth and the number of culms from the current year's growth were counted on June 18, 1940. In plants which showed a reduction in the number of culms, the per cent of winter injury was calculated by dividing the difference by the number of culms that developed in the first season's growth.

The native grass species studied exhibited wide variations in the amount of winter injury between the various habitat types. As shown in Table 3, side-oats grama from North Dakota and Nebraska showed no winter injury, Oklahoma, Kansas and Texas selections showed but slight damage, whereas many Arizona plants were killed. However, a few plants that appeared to be dead on June 18, resumed growth later in the season. A similar condition was found in little bluestem, except that winter injury in the

Arizona row was not so severe.

Table 3. The average per cent of winter injury based on the difference in number of culms that developed between the first and second season.

Source	Side-oats grama	Switch grass	Little bluestem	Big bluestem
North Dakota	0.0	0.0	0.0	
Nebraska	0.0	3.9	0.0	0.0
Kansas	0.6	8.8	2.2	0.0
Oklahoma	2.8	23.0	2.6	1.3
Texas	6.1	24.7	10.5	
Arizona	91.8	48.9	71.1	

Winter injury was apparent in each of the switch grass accessions except the one from North Dakota. The relatively high per cent of injury found in the Nebraska, Kansas, Oklahoma, and Texas rows was to be expected since there were a few plants in each row that did not become well established in their first season of growth. As a result they were unable to build sufficient food reserve to resist winter injury. Other switch grass plants that became well established were little damaged by the 1939-1940 winter. Less injury was apparent in the Arizona row of switch grass than in the Arizona selections of little bluestem and side-oats grama.

Big bluestem plants grown from Nebraska and Kansas seed evidenced no signs of winter injury, while the Oklahoma plants showed a slight amount. Plants from North Dakota, Texas and Arizona were not included in this study for reasons previously given.

Plates I and II show the effect of winter injury on side-

oats grama and switch grass grown from seed of Texas and Arizona origin. On close observation winter injury can be noted in plates VI and VIII.

A blanket of snow which covered the ground through the cold part of December, 1939, January and February, 1940, prevented serious winter injury except in those plants of extreme southern origin. In fields near the grass nursery, varieties of oats that seldom survive the winter at Manhattan were apparently uninjured. Had there been no protective covering of snow, winter injury would probably have been more severe in the Oklahoma, Texas and Arizona selections as plants from those areas are adapted to a milder winter climate.

Date of Heading. Time of maturity is an important factor in determining the forage value of the native grasses. In the leafy stages of growth the plants are more palatable and nutritious to livestock than when mature. Most grass plants grow less rapidly following the formation of heads and the maturing of seed; thus, by delaying the time of heading the plants would be maintained in a leafy condition through a longer portion of the growing season. For the maintenance of satisfactory stands and for wide use, plants must be able to develop seed before frost. Thus, the most desirable strains, so far as date of heading is concerned, are those that mature seed late in the season, yet escape injury to the seed by frost. The individual plants were considered as headed when three culms had produced inflorescences.

EXPLANATION OF PLATE I

Side-oats grama

Plant No. 1 grown from seed of Arizona origin

Plant No. 2 grown from seed of Texas origin

Plate I

1 2

EXPLANATION OF PLATE II

Switch grass

Plant No. 1 grown from seed collected in Arizona

Plant No. 2 grown from seed collected in Texas

Plate II

1 2

First year data are not reliable, as shown by Law (1940) for newly established native grass plants. However, general trends may be observed in the first season's growth that are apparent in the second and later seasons.

Large F values, as seen in Table 4, show pronounced variations in heading date in all four species as influenced by the source of seed. The variations found in Table 5 show distinctly that plants grown from northern seed tend to be early, and plants from southern seed tend to head late in the season.

Little bluestem showed a consistent relationship between the date of heading and the latitude from which the plants originated.

Table 4. The effect of source of seed on time of heading in the 1939 and 1940 seasons.

	No. of plants	Mean and standard deviation	Analysis of variance between sources	
			F values[1]	1% level of significance
Side-oats grama	108	49.0±16.9	21.95	3.11
Little bluestem	95	76.3± 7.2	216.60	3.11
Big bluestem	51	29.6± 8.06	27.49	4.82
Switch grass	85	43.5± 9.6	114.36	3.11

In the 1939 season it was apparent that the North Dakota row did not head because the plants had not become sufficiently well established by the time environmental conditions were such as to induce flowering. The Arizona row failed to form heads because climatic conditions favoring the development of heads in these plants did not occur until so late in the season that the heads

[1] Obtained by dividing variance between sources by variance within sources. Snedecor (1938).

EXPLANATION OF PLATE III

Big bluestem

Plant No. 1 grown from seed collected in Kansas

Plant No. 2 grown from seed collected in Nebraska

Plant No. 3 grown from seed collected in Oklahoma

Plate III

1 2 3

EXPLANATION OF PLATE IV

Switch grass on August 7, 1940 growing in the Manhattan Soil Conservation Nursery

Fig. 1. Plants grown from seed collected in North Dakota (Compare with Figs. 2 and 3).

Fig. 2. Plants grown from seed collected in Oklahoma. (Compare with Figs. 1 and 3).

Fig. 1

Fig. 2

EXPLANATION OF PLATE V

Fig. 3. Switch grass on August 7, 1940 growing in the Manhattan Soil Conservation Nursery. The plants were grown from seed obtained from Arizona. (Compare with Figs. 1 and 2).

Plate V

Fig. 3

were frosted before emergence. However, in both years flowering stems developed.

Table 5. Average heading date as influenced by source of seed.

	Side-oats grama	Switch grass	Little bluestem	Big bluestem
		1939		
North Dakota	July 15± 7.3	Aug. 14±13.3	(2)	
Nebraska	" 17± 5.6	" 9±30.8	Aug. 26±9.4	Aug. 27±10.4
Kansas	" 30± 8.7	" 11±11.5	" 31±5.4	Sept. 1± 6.3
Oklahoma	Aug. 15±25.1	" 13±11.0	Sept. 5±5.2	" 7± 6.4
Texas	July 29± 6.4	" 12± 6.1	" 15±7.8	
Arizona	" 11± 6.2	" 22±27.8	(2)	
		1940		
North Dakota	June 16± 6.2	July 8±11.5	June 24± 8.0	
Nebraska	" 22± 6.9	" 31±18.1	July 13±12.0	Aug. 19±7.9
Kansas	" 22±16.1	Aug. 9± 6.2	Aug. 27± 8.6	" 25±8.7
Oklahoma	July 23±25.8	" 16± 9.2	" 28± 8.0	" 31±6.4
Texas	June 24±26.5	" 19± 4.4	Sept.15± 1.1	
Arizona	July 3±18.4	" 19± 4.8	(2)	

2 Plants did not head.

The selections of big bluestem exhibited the same general trends as indicated by the species above (Plate III and Table 5).

Switch grass showed little variation in the date of heading between sources in the season of 1939, whereas, rather wide variations were observed in 1940 corresponding to those found in the above two species (Table 5 and Figs. 1, 2 and 3).

The earliness of heading found in the Texas and Arizona selections of side-oats grama in the season of 1939 may have been due to several factors. It may have been caused by the large amount of vigor exhibited by these plants enabling them to become sufficiently developed in the greenhouse to stimulate

heading. As yet no satisfactory explanation can be presented from the available data to explain the extreme lateness of the Oklahoma selection as evidenced in both years. Possibly the selection is composed of unusually late maturing plants even as grown under Oklahoma conditions.

Variation of time of heading between adjoining states was seldom statistically significant due to the large standard deviations. As the source of seed was more diverse, statistical differences were increased giving significant variability in many cases between alternate states.

Total Leaf Area Per Culm and Total Leaf Area Per Plant. In determining the forage value of a grass the leaves are considered of primary importance. Of the grasses studied the leafy portion is the most palatable and nutritive part of the plant. In order to compare the different ecotypes it was necessary to calculate the total leaf area per culm and the total leaf area per plant. The "total leaf area per culm" was considered as important in determining the actual leafiness of the plant in relation to the stems, whereas "total leaf area per plant" shows the total leafy forage produced by the plant without regard to stems.

In discussing the leafiness of plants the term "total leaf area" was used and not the "actual leaf area". To find the "total leaf area per culm" the length was multiplied by the greatest width times the average number of leaves per culm. To calculate the "total leaf area per plant" the leaf area per culm was multiplied by the number of culms per plant. The above measurements would indicate that the leaf was rectangular rather

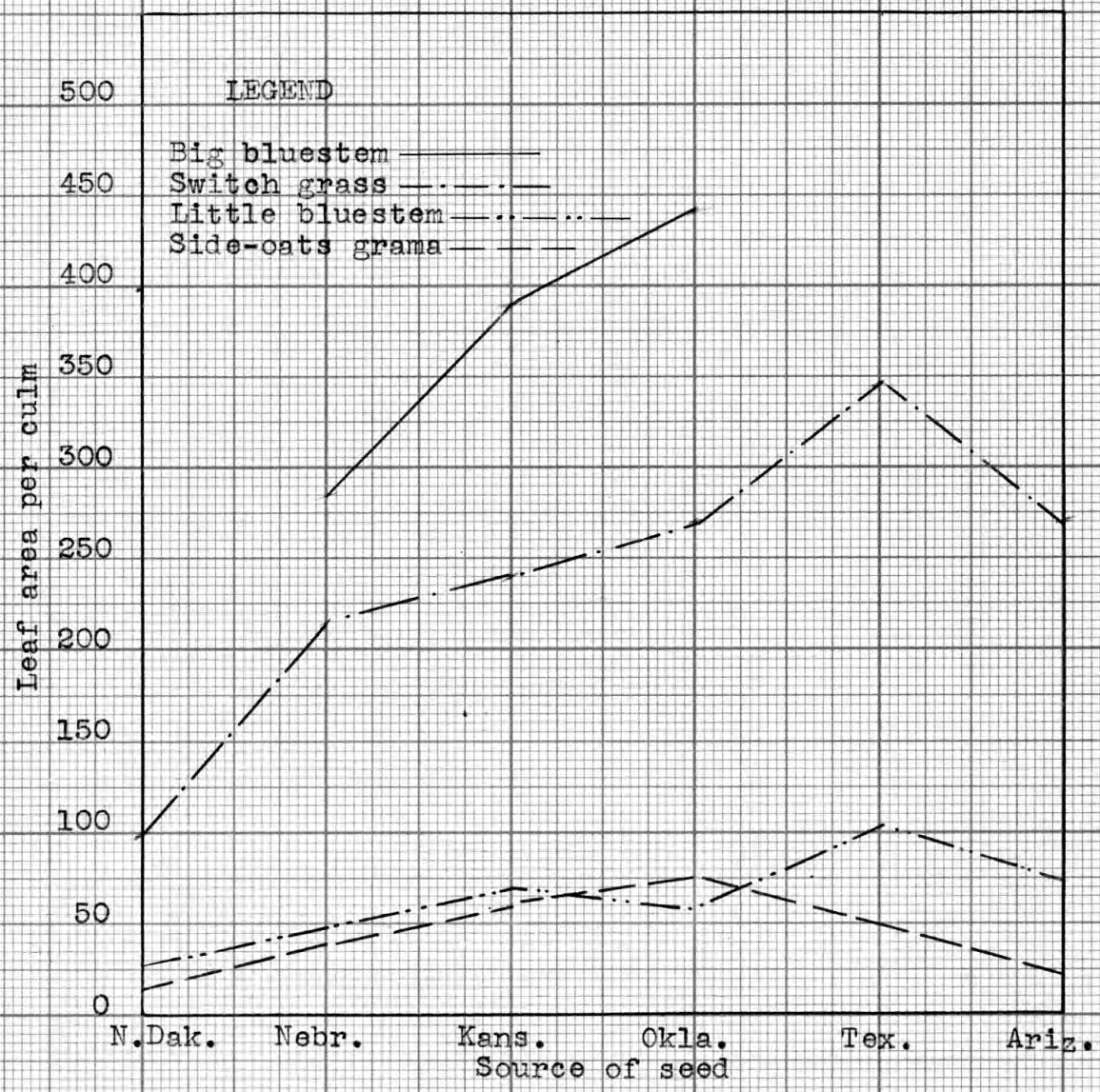

Fig. 4. Total leaf area per culm expressed as $\frac{\text{sq. centimeters}}{100}$

than lanceolate. The "total leaf area" was used, however, and was considered accurate when used comparatively. To find the "actual leaf area" for big bluestem it would be necessary to multiply the "total leaf area" by the factor 0.6811±.058 (Law, 1940) and for little bluestem by the factor 0.8118±.0587 (Anderson, 1938). Factors for determining the actual leaf area of side-oats grama and switch grass were not available. The above measurements were made on July 31, August 1 and 2, 1940.

Total leaf area per culm, as shown by Table 6 and Fig. 4, was least in each case in the northern selection. The maximum leafiness per culm for the species studied was found in the Kansas, Oklahoma or Texas selections.

Table 6. Total leaf area per culm expressed in sq. centimeters. 100

	Side-oats grama	Switch grass	Little bluestem	Big bluestem
North Dakota	16.0± 4.5	96.1± 32.4	28.7±12.9	
Nebraska	40.9±10.3	214.2± 75.8	46.7±29.1	284.5± 78.8
Kansas	61.7±22.1	240.7± 48.4	68.1±27.7	392.4±147.8
Oklahoma	73.5±13.5	269.9± 78.7	60.9±13.4	441.9±115.5
Texas	48.0±14.2	347.8± 85.0	104.8±15.5	
Arizona	23.1± 7.1	268.0±121.4	77.1±23.9	

In the three species of Arizona plants that were studied there was a decrease in leafiness from that found in the Oklahoma plants. Severe winter injury which reduced the vigor of the plants plus other lack of adaptation to Kansas conditions may have resulted in a lower leafiness than would be expected in their original environment.

Total leaf area per plant as shown by Table 7 and Fig. 5, exhibits the same general trends as found above. The apparent exceptions were the Kansas and Oklahoma selections of switch grass. Observation of these plants in the field and culm counts indicated that the plants had grown fewer but larger and coarser culms than either the Nebraska or Texas selections. Leafiness per culm was not reduced as shown above. The small total leaf area per plant may be accounted for by the reduced number of culms and large amount of plant material stored as stems.

Table 7. Total leaf area per plant expressed as sq. centimeters/100.

	Side-oats grama	Switch grass	Little bluestem	Big bluestem
North Dakota	29.3±10.6	84.3± 60.6	62.0±27.8	
Nebraska	36.4±24.3	265.9±121.7	136.5±60.1	187.7± 59.7
Kansas	155.5±59.3	179.7± 45.4	160.9±46.7	271.8±109.1
Oklahoma	192.2±71.7	172.8±112.8	145.8±31.2	283.2±146.8
Texas	89.4±36.5	314.4±138.6	187.2±41.9	
Arizona	25.4±15.7	185.4± 39.1	107.4±61.2	

Levels of significance have been established through statistical analysis for species of crop plants exhibiting much less variability than is found in unselected native grass plants. When the subject studied is of such a variable nature a larger number of plants should be grown to make statistical analysis more applicable. Tables 6 and 7 show that because of the large standard deviation there is in most cases, no significant difference between habitat types from adjacent states. However, when types from alternate states, or from areas correspondingly far apart, are compared the number of cases having a significant difference is

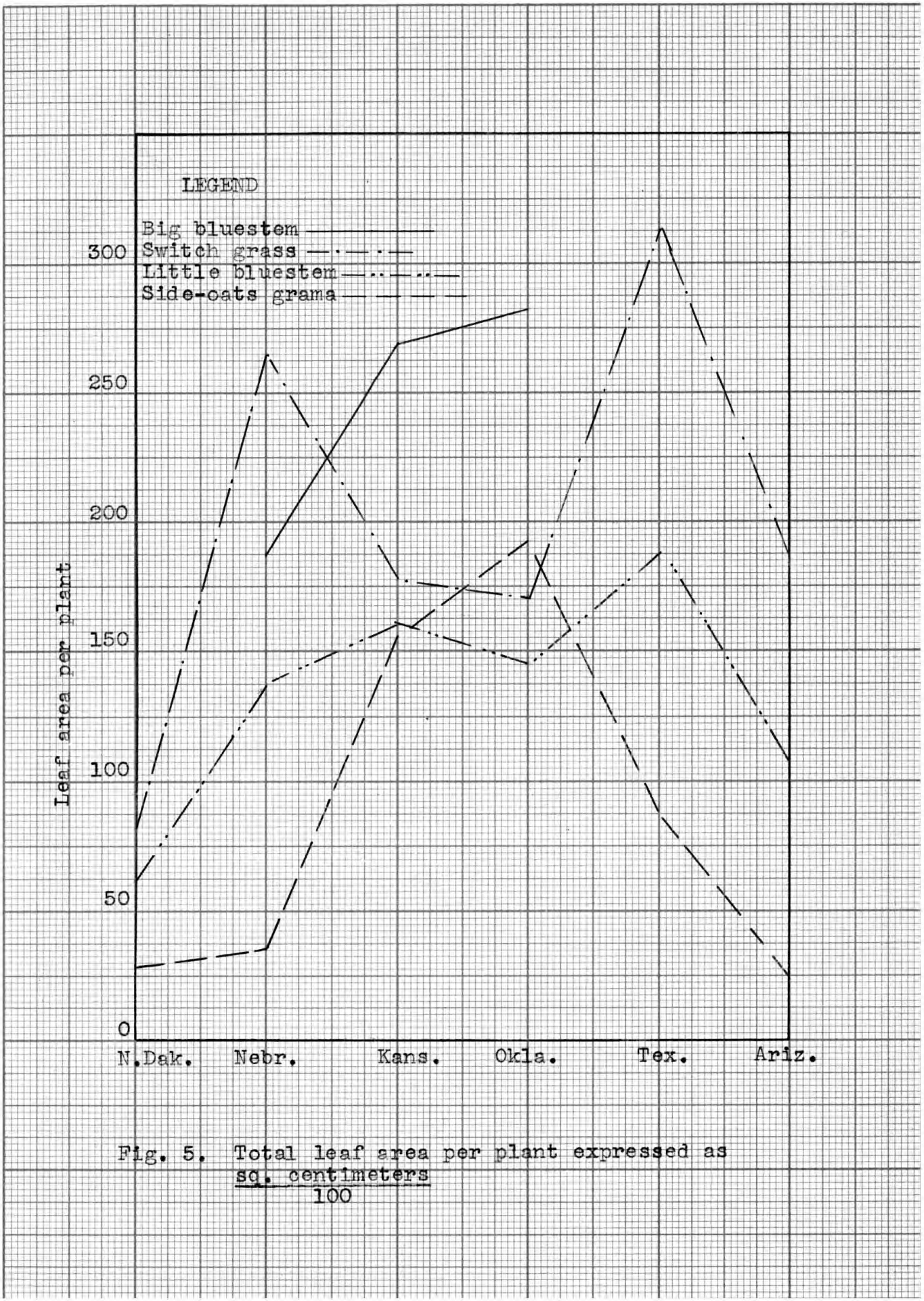

Fig. 5. Total leaf area per plant expressed as $\frac{\text{sq. centimeters}}{100}$

increased. Thus plants from adjacent states may exhibit visible variability of leafiness as in Plates III, IV, V, VII and VIII but statistical analysis of small numbers such as used in this experiment may exhibit no significant difference.

Maximum Height of Plants. The maximum height was determined by holding the plant upright and measuring from the ground to its tallest point. It was taken as a comparative measure to be used in describing the various ecotypes or habitat types. However, as shown by Law (1940) plant height was not highly correlated to the total forage yield. Other characters such as the number of culms and basal diameter of the plant were shown to have greater significance to the total yield of forage than did plant height.

In general, the southern selections of switch grass (Table 8, Figs. 1, 2, 3 and 6) were taller than those originating in the north. The Arizona plants grown at the Agronomy farm were somewhat reduced in size as a result of the severe winter injury and apparent lack of adaptation to other Kansas conditions. The Arizona selection of switch grass (Figs. 1, 2, 3) grown in the Soil Conservation nursery was injured less by the winter, showing no loss of vigor, than that grown at the Agronomy farm. The Arizona plants were taller than those of the Kansas accession, both groups being taller than the North Dakota plants.

The variation of plants from different states became more apparent with the progress of the season as shown by Fig. 6 and Table 8. The northern types reached maturity early in the season after which there was a reduced rate of growth. The southern

Table 8. Mean maximum plant height expressed in inches.

No. plants	N.Dakota 13	Nebraska 12	Kansas 16	Oklahoma 9	Texas 18	Arizona 16
			Switch grass			
June 1	10.2±4.0	14.3± 5.7	14.6±4.7	19.9± 8.8	24.4± 3.2	14.3±6.9
July 1	21.4±2.9	27.5±11.0	31.6±8.9	40.2± 8.7	45.4± 4.5	31.8±9.2
Aug. 1	27.5±3.7	30.6± 3.2	34.1±7.5	46.2±11.5	51.7±13.9	37.1±7.7
Sept. 1	29.6±9.9	34.3±11.5	37.3±4.7	51.3±10.9	56.8± 5.4	42.3±7.3
			Little bluestem			
No. plants	8	16	18	20	20	13
June 1	4.8±2.0	9.9± 1.7	14.2±5.4	11.6± 1.7	13.3± 2.5	9.8±2.9
July 1	9.6±3.1	16.7± 2.3	20.5±2.1	21.0± 6.2	23.7± 6.6	18.4±6.2
Aug. 1	14.7±4.2	23.9± 3.2	24.6±5.6	27.4± 5.7	27.0± 6.2	21.6±4.5
Sept. 1	18.6±3.8	23.3± 3.4	28.1±6.0	34.7± 4.8	35.6± 4.5	25.2±3.5
			Big bluestem			
No. plants		19	20	12		
June 1		15.5± 2.7	15.2±3.0	13.7± 3.2		
July 1		29.3± 2.7	29.6±4.7	25.3± 4.5		
Aug. 1		38.5± 8.5	40.0±6.9	38.7± 8.5		
Sept. 1		45.9± 6.8	53.9±6.4	57.3± 5.2		

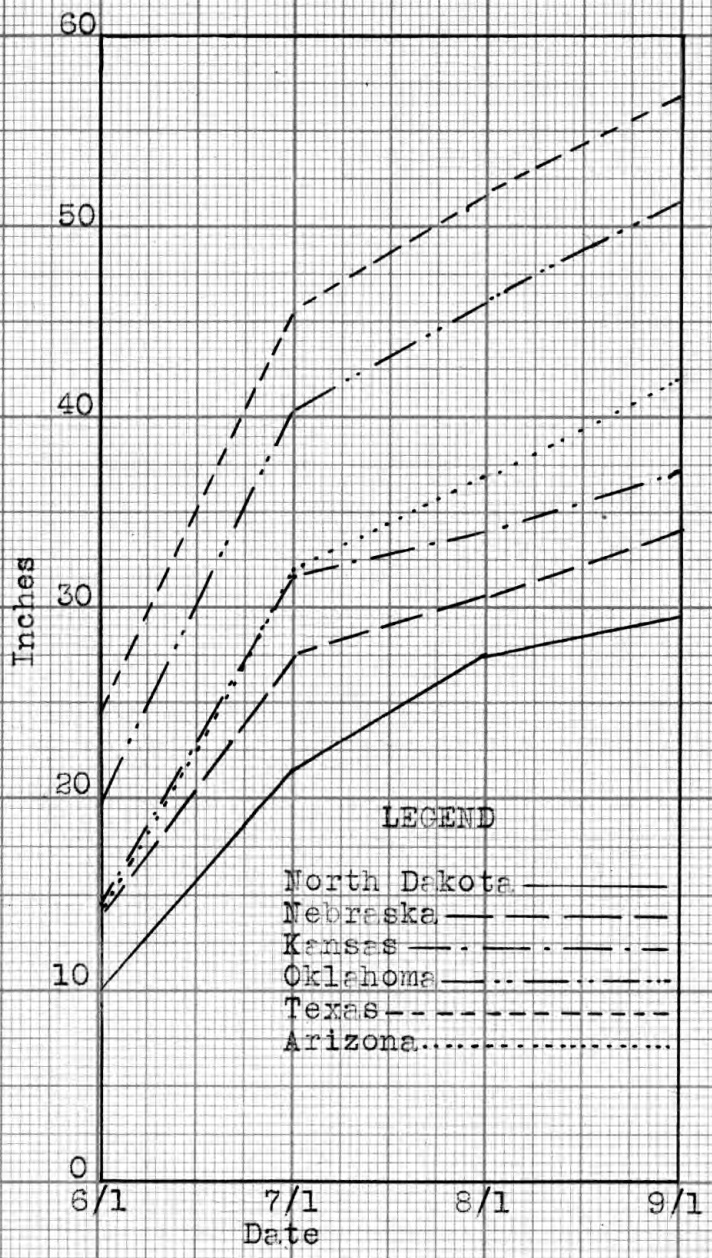

Fig. 6. Average maximum plant height of switch grass on various dates.

types matured late and continued to grow rapidly after the northern strains had matured.

In general the observations made on the height of switch grass apply to little bluestem and big bluestem as shown in Plates VI and VII, Table 8 and Figs. 7 and 8.

Side-oats grama (Plate VIII) showed slight measurable differences of plant height with no apparent correlation as to source of seed.

As shown previously statistical analysis did not show significant differences between lines from adjoining states, but as lines from more diverse sources were studied an increase of significance was observed.

Number of Culms Per Plant. The total number of culms produced by the plant is directly related to its vigor and yielding capacity as shown by Law (1940). In general it has been observed that plants having a large number of culms are also more leafy, have a finer texture, and produce more seed than plants having but few culms. The number of culms per plant was counted on the first day of the months June, July, August and September.

A consistent relationship between the number of culms and source of seed of the various species was not apparent. The extreme southern and northern ecotypes, with but few exceptions, had the smallest number of culms as shown by Table 9 and Figs. 9, 10, 11 and 12. The southern types, severely winter injured, developed but few culms per plant early in the season, but there was a rapid increase in the number of culms as the season progressed. The northern types were shorter in height than were the southern

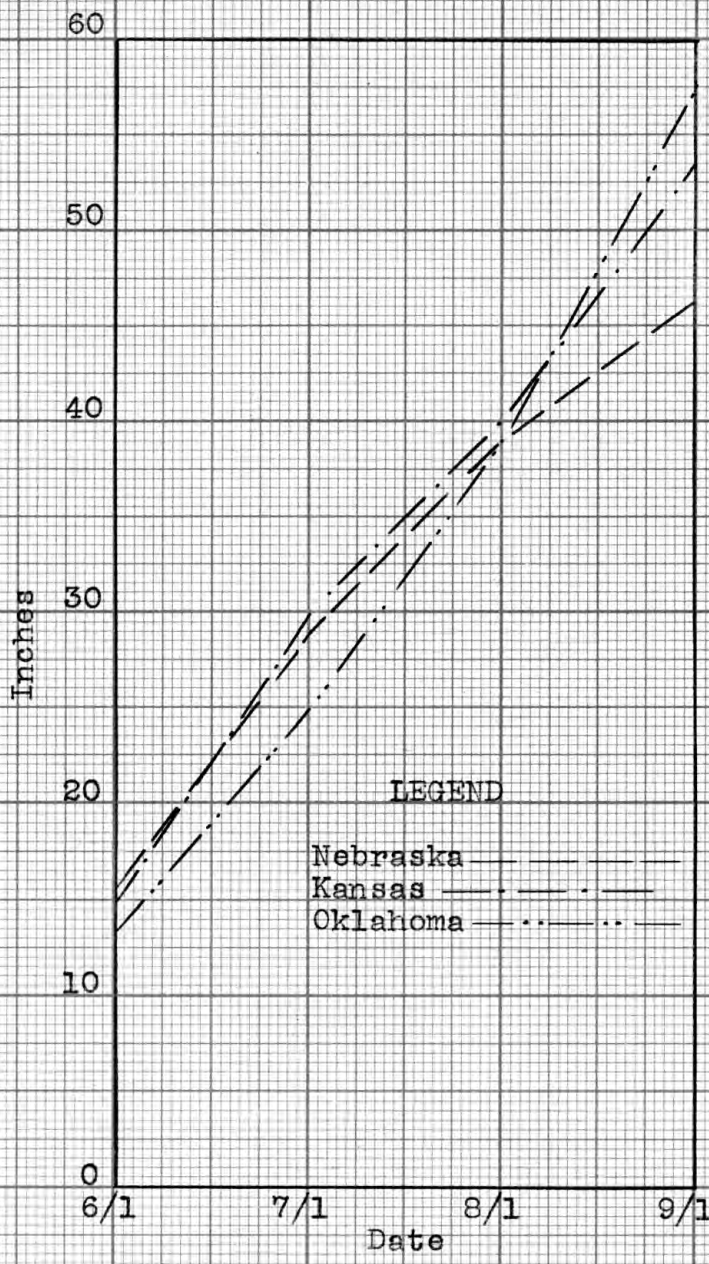

Fig. 7. Average maximum plant height of big bluestem on various dates.

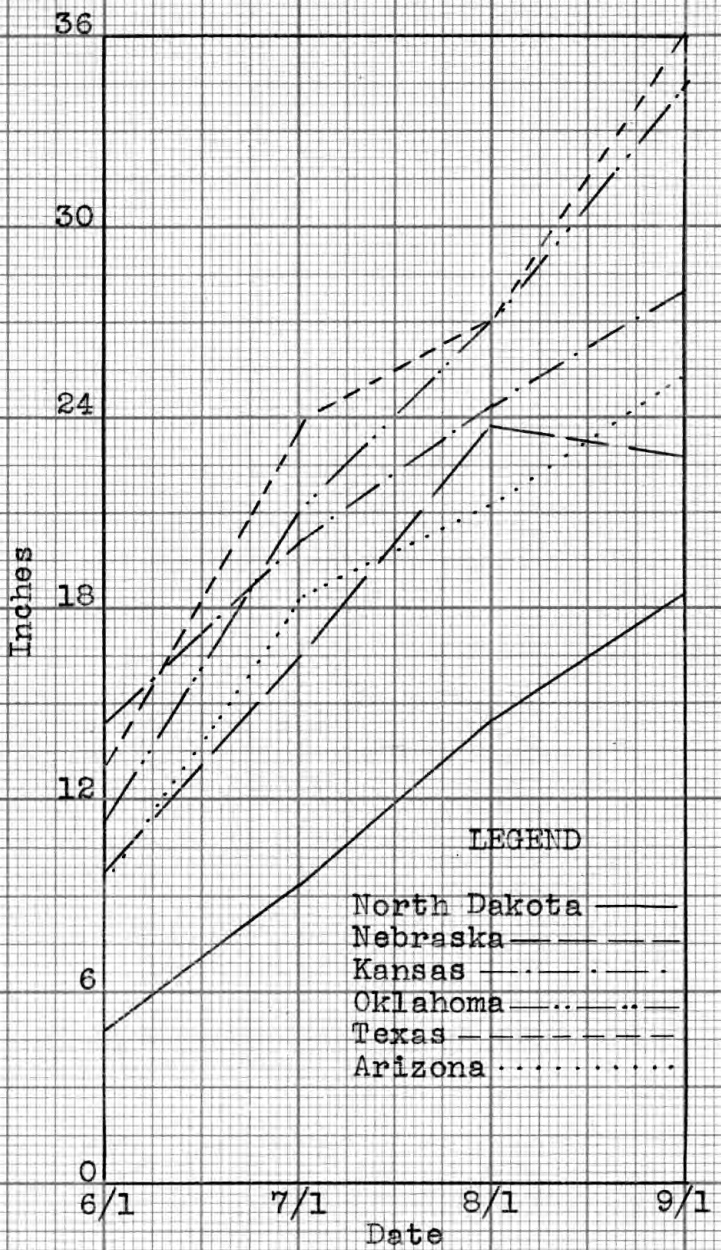

Fig. 8. Average maximum plant height of little bluestem on various dates.

EXPLANATION OF PLATE VI

Little bluestem showing the effect of source of seed on growth habit on June 24, 1940.

Row No. 1. Arizona
Row No. 2. Texas
Row No. 3. Oklahoma
Row No. 4. Kansas
Row No. 5. Nebraska
Row No. 6. North Dakota

Plate VI

1 2 3 4 5 6

EXPLANATION OF PLATE VII

Little bluestem showing the effect of source of seed on growth habit on August 7, 1940.

Row No. 1. North Dakota
Row No. 2. Nebraska
Row No. 3. Kansas
Row No. 4. Oklahoma
Row No. 5. Texas
Row No. 6. Arizona

Plate VII

1 2 3 4 5 6

EXPLANATION OF PLATE VIII

Side-oats grama showing effect of source of seed on growth habit on June 24, 1940.

Row No. 1. Arizona
Row No. 2. Texas
Row No. 3. Oklahoma
Row No. 4. Kansas
Row No. 5. Nebraska
Row No. 6. North Dakota

Plate VIII

1 2 3 4 5 6

Table 9. Mean number of culms per plant and standard deviation on various dates.

	N.Dakota	Nebraska	Kansas	Oklahoma	Texas	Arizona
No. plants	17	17	19	20	20	15
Side-oats grama						
June 1	52.9±18.3	121.8±57.2	156.6±104.0	96.9±40.4	120.3±63.2	17.5± 21.4
July 1	117.1±31.7	197.2±37.8	221.8± 96.5	178.7±67.9	187.6±69.3	67.5± 81.5
Aug. 1	192.1±47.7	192.3±44.8	275.7± 88.8	205.2±60.5	219.1±75.4	130.0±115.8
Sept. 1	183.5±54.4	189.7±51.1	279.6± 81.3	216.4±70.8	229.9±95.4	164.4± 93.2
Switch grass						
No. plants	13	12	16	9	18	16
June 1	25.2±16.6	32.1±14.5	34.7± 18.0	25.2±15.4	35.3±16.6	21.3± 12.8
July 1	46.4±35.9	66.7±41.6	57.4± 31.6	49.3±20.1	72.3±20.4	45.6± 31.0
Aug. 1	78.2±44.5	101.8±50.0	68.1± 34.3	61.6±20.3	80.0±31.1	59.3± 33.9
Sept. 1	65.1±44.5	92.0±39.9	66.9± 33.1	69.7±26.6	80.9±30.2	60.8± 31.6
Little bluestem						
No. plants	8	16	18	20	20	13
June 1	29.6±17.1	131.6±46.8	126.2± 62.2	152.7±62.5	75.9±29.9	41.8±23.0
July 1	123.9±52.2	277.6±78.5	201.2± 68.5	231.9±86.6	184.3±49.9	101.6±70.4
Aug. 1	218.6±64.7	310.4±71.1	199.1± 86.7	222.5±69.7	187.6±56.2	129.3±63.0
Sept. 1	211.6±68.4	315.9±98.0	201.2± 64.0	234.9±62.2	199.0±56.9	151.3±73.7
Big bluestem						
No. plants		19	20	12		
June 1		45.1±28.2	54.4± 31.6	42.4±22.6		
July 1		69.1±39.6	74.2± 32.0	61.3±27.3		
Aug. 1		64.8±36.5	76.6± 28.2	69.2±36.7		
Sept. 1		69.1±40.0	73.9± 37.0	62.5±31.3		

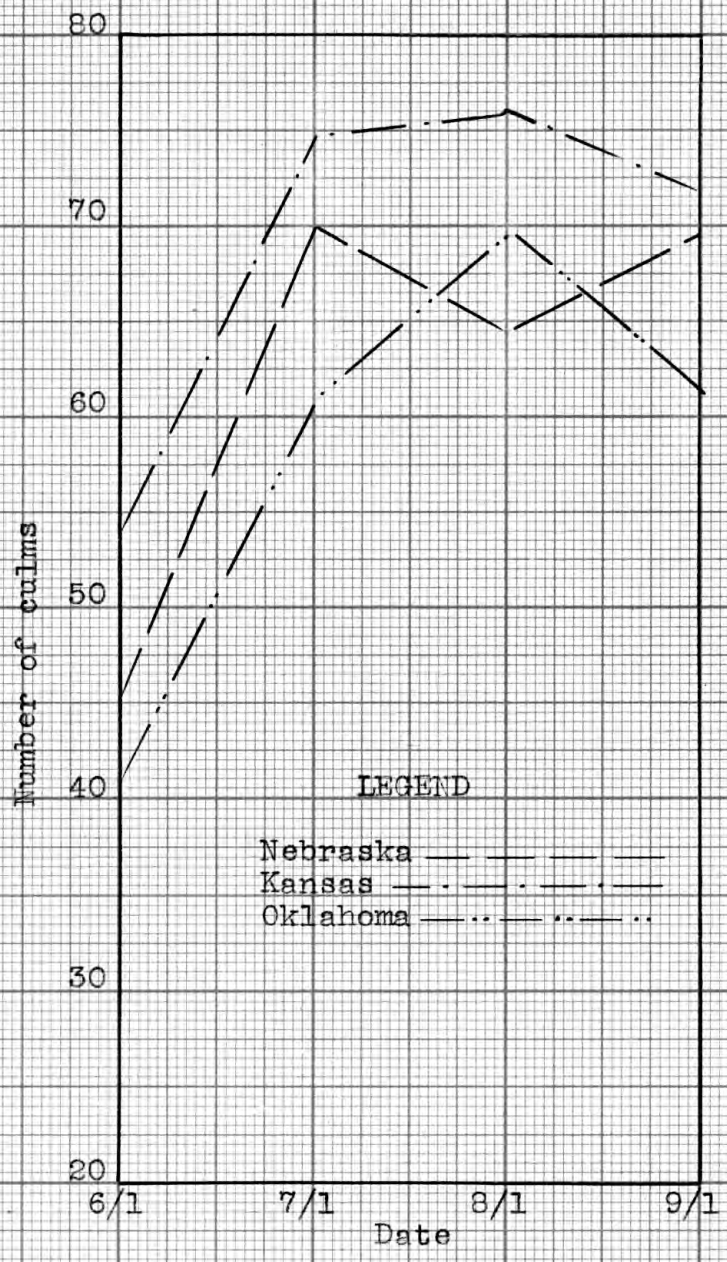

Fig. 9. Average number of culms of big bluestem on various dates.

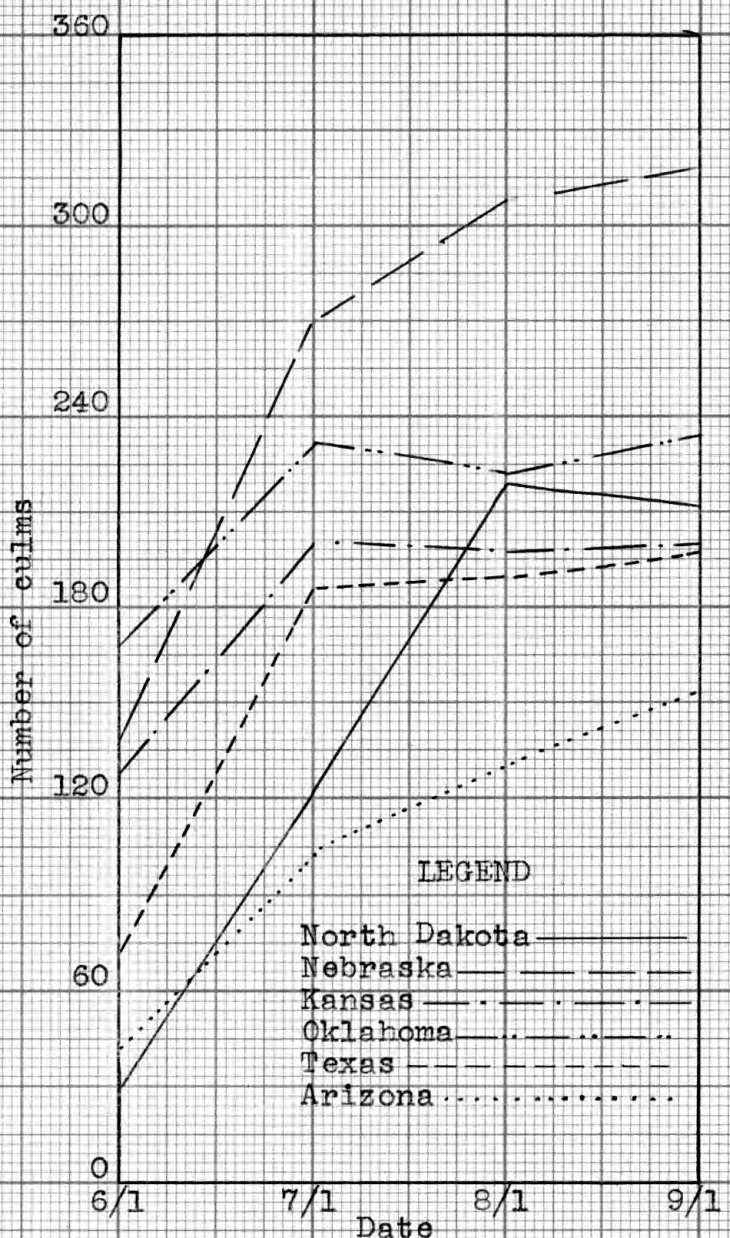

Fig. 10. Average number of culms of little bluestem on various dates.

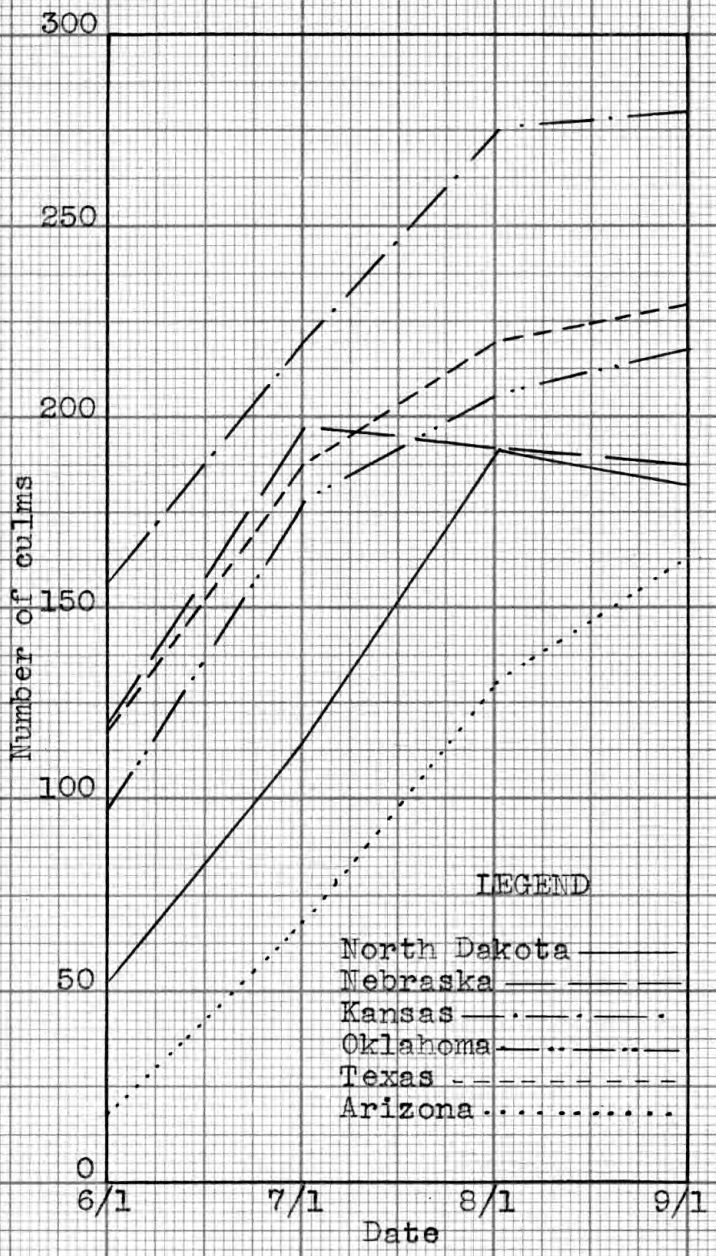

Fig. 11. Average number of culms of side-oats grama on varying dates.

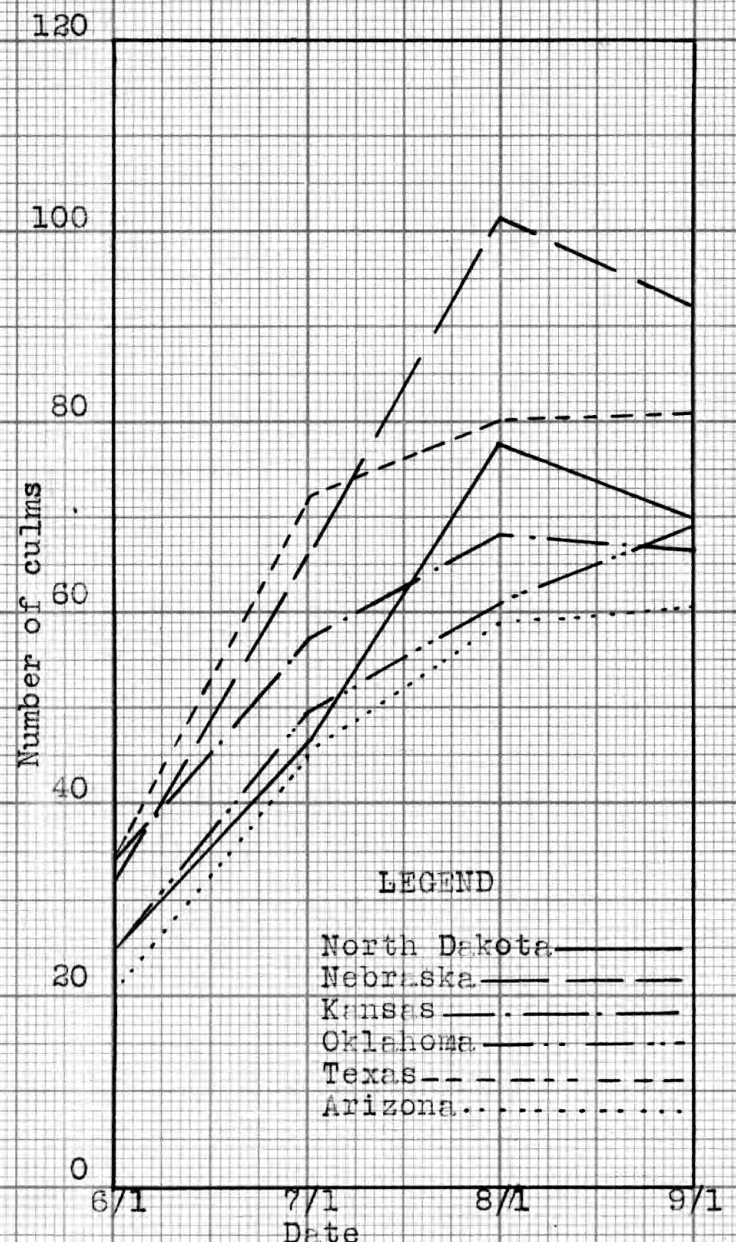

Fig. 12. Average number of culms of switch grass on various dates.

selections. With more light near the ground an increased number of culms was to be expected, but counts revealed that the northern types failed to produce a large number of culms per plant.

Relative Vigor Ratings of 1939 and 1940. Vigor ratings taken in both 1939 and 1940 are important in comparing the growth vigor of different ecotypes in the two seasons. A rating of 1 to 10 inclusive was given each plant on the relative amount of vigor shown by each plant on August 21 of both years. A score of 10 indicated that the plant had made considerable growth and appeared healthy in every respect, and a rating of 1 that it was small and exhibited little growth vigor.

The northern types remained small in the 1939 season with a relative increase the second year, as shown by Table 10. In most cases there was significant variation in vigor ratings between the North Dakota and Nebraska selections with somewhat less variation between selections from other states. The more nearly adapted plants showed no significant variability between sources of seed.

It should be noticed that in the North Dakota, Nebraska, Kansas, Oklahoma and Texas selections, in all but one instance, there was an increase in the vigor rating between the seasons of 1939 and 1940.

In contrast to the above the Arizona types of the various species studied showed little insignificant increase in the vigor ratings of little bluestem and a marked decrease in vigor rating of the side-oats grama. Had winter injury been more severe the

Table 10. Relative plant vigor ratings in 1939 and 1940.

	N.Dakota	Nebraska	Kansas	Oklahoma	Texas	Arizona
No. plants	17	17	19	20	20	16
			Side-oats grama			
1939	1.65±0.5	4.18±0.65	4.89±1.15	4.35±0.75	3.90±0.91	5.13±1.5
1940	2.82±0.6	4.35±0.50	6.53±0.97	6.00±1.1	6.65±1.1	3.25±1.8
			Switch grass			
No. plants	13	12	16	10	18	16
1939	1.69±0.6	2.50±1.1	3.19±0.3	3.80±2.05	5.22±1.1	4.13±1.1
1940	3.46±1.4	4.25±1.1	4.69±1.3	4.80±2.70	6.11±2.7	4.06±1.1
			Little bluestem			
No. plants	8	16	18	20	20	13
1939	1.00±0.0	3.25±1.6	4.83±0.7	4.10± .32	5.10±0.9	4.85±0.57
1940	3.25±2.2	6.13±0.9	6.61±1.2	6.70± .89	6.50±1.3	5.00±1.8
			Big bluestem			
No. plants		19	20	12		
1939		5.00±2.1	5.20±1.1	4.50±0.7		
1940		4.63±1.05	6.05±1.2	6.00±0.7		

Arizona types would likely have shown a greater decrease in vigor, with a relative decrease in the Texas and Oklahoma selections.

Effect of Length of Day on Little Bluestem and Side-Oats Grama Grown from Seed of Various Sources

A length of day experiment was conducted in the laboratory with the hope of discovering facts that would help to explain the response of plants grown under field conditions; and also more fully to understand the problem so that a more complete experiment could be developed in the future. Seed of little bluestem and side-oats grama from North Dakota, Kansas and Texas was planted in the greenhouse on March 23, 1940. The seedlings were transplanted to individual pots on April 6 and placed under the different photoperiods on April 13. Three pots of each species from each source were placed under daily light exposures of 8, 10, 12, 14 and 16 hours. Frames covered with heavy building paper were used to protect the plants from light when the normal days were too long. When light was needed to lengthen the photoperiod a 200 watt bulb with reflector, placed $3\frac{1}{2}$ feet above the plants, was lighted. It is doubtful that a light so intense would have been necessary according to work mentioned in the review of literature.

A limited number of the plants developed inflorescences making it possible to gain but little knowledge concerning the heading of grasses derived from various sources and grown under different photoperiods. From the few inflorescences that were formed the northern types tended to respond more readily to the

EXPLANATION OF PLATE IX

Effect of length of day on side-oats grama grown from seed collected in North Dakota, Kansas and Texas.

Plant No. 1. North Dakota plant under a 16 hour day.
Plant No. 2. Kansas plant under a 16 hour day.
Plant No. 3. Texas plant under a 16 hour day.
Plant No. 4. North Dakota plant under a 14 hour day.
Plant No. 5. Kansas plant under a 14 hour day.
Plant No. 6. Texas plant under a 14 hour day.
Plant No. 7. North Dakota plant under a 10 hour day.
Plant No. 8. Kansas plant under a 10 hour day.
Plant No. 9. Texas plant under a 10 hour day.

Plate IX

EXPLANATION OF PLATE X

Effect of length of day on little bluestem grown from seed collected in North Dakota, Kansas and Texas.

Plant No. 1. North Dakota plant under a 16 hour day.
Plant No. 2. Kansas plant under a 16 hour day.
Plant No. 3. Texas plant under a 16 hour day.
Plant No. 4. North Dakota plant under a 12 hour day.
Plant No. 5. Kansas plant under a 12 hour day.
Plant No. 6. Texas plant under a 12 hour day.
Plant No. 7. North Dakota plant under an 8 hour day.
Plant No. 8. Kansas plant under an 8 hour day.
Plant No. 9. Texas plant under an 8 hour day.

Plate X

16 hour day than did those of southern origin. Under the 12 and 14 hour day the southern selections usually formed heads before those that originated in the north.

In the growing season, North Dakota (49° N.) has a maximum length of day of 16 hours and 12 minutes while in Texas (29° N.) the greatest length of day is 14 hours. Thus the plants from the north would be expected to respond more readily to the longer light period and those from the south to the shorter photoperiod.

Average Maximum Height of Plants Under Various Lengths of Day. The maximum height of the plants was measured as a partial indication of growth vigor. It was determined by measuring from the ground to the tip of the green or living part of the leaf while being held upright.

Little bluestem originating in North Dakota exhibited less seedling growth vigor than plants of Kansas and Texas origin. All of the little bluestem plants studied were stimulated by an increase in length of day, but the northern types appeared to be stimulated most by the long photoperiod. The greatest total plant height was attained by the Texas, Kansas and North Dakota plants in the order given, with but little difference in the three types under the long day as shown in Plate X and Table 11.

The side-oats grama was apparently more sensitive to variations in the length of day than was the little bluestem, and did not seem capable of growing when exposed to only 8 hours of light. Of the total number of plants started under the 8 hour day, only one plant was living at the end of the experiment. The Texas and Kansas selections became larger under the 14 hour day than under

Table 11. Average maximum height of little bluestem plants under varying lengths of day.

Length of photo-period	North Dakota				Kansas				Texas			
	June 8	July 8	Aug. 8	Sept. 8	June 8	July 8	Aug. 8	Sept. 8	June 8	July 8	Aug. 8	Sept. 8
16 hour	4.7	10.7	17.7	20.3	10.7	16.7	22.3	24.7	8.3	13.3	25.3	27.3
14 hour	5.0	8.7	11.0	10.0	9.7	14.0	17.7	16.3	9.3	13.7	23.7	21.7
12 hour	3.3	4.0	9.3	8.7	10.0	13.0	13.3	13.0	10.7	15.0	18.7	18.7
10 hour	2.3	3.0	7.0	5.7	9.3	13.0	14.7	12.7	8.7	13.3	16.7	16.0
8 hour	3.7	5.0	7.3	7.7	6.7	9.0	12.3	11.7	8.3	10.3	14.3	13.0

Table 12. Average maximum height of side-oats grama plants under varying lengths of day.

Length of photo-period	North Dakota				Kansas				Texas			
	June 8	July 8	Aug. 8	Sept. 8	June 8	July 8	Aug. 8	Sept. 8	June 8	July 8	Aug. 8	Sept. 8
16 hour	14.0	19.7	18.7	18.0	13.0	13.3	14.0	12.5	12.0[4]	15.0[4]	17.0[4]	17.0[4]
14 hour	9.7	12.0	10.3	9.3	12.7	14.0	14.3	13.3	19.0	19.7	22.7	18.7
12 hour	2.0	4.3	9.7	8.3	2.7	6.3	11.3	11.0	10.0[5]	14.5[5]	20.5[5]	18.5[5]
10 hour	1.7	2.0	4.3	6.0	2.7	4.7	10.3	8.0	8.1[5]	14.0[5]	17.5[5]	17.5[5]
8 hour	3.0	3.3[5]	5.0[5]	9.0[4]	4.3	3.7	0.0[3]	0.0[3]	5.5[5]	4.5[5]	0.0[3]	0.0[3]

[3] Plants dead or missing.
[4] Data from one plant.
[5] Data from two plants.

the 16 hour day, while the North Dakota group was stimulated by the longer light period to the extent that it became taller than the southern type as shown in Plate IX and Table 12.

Average Number of Culms Per Plant Under Various Lengths of Day. The number of culms per plant as discussed earlier, showed a close relationship both to the desirability and to the total forage yield of the native grass plants. The culms were counted at monthly intervals from June to September.

Under the 12, 14 and 16-hour day the North Dakota little bluestem plants generally had the greatest number of culms, the Texas selections usually the least, while under the 8 hour day there was little difference or a tendency to reverse the above. The Kansas and Texas selections appeared to be relatively better adapted to the 10 and 12 hour day and the North Dakota plants were favored by the long photoperiod. It should be observed that the greatest number of culms was not obtained with the longest nor the shortest day, but usually at a medium length of light exposure.

It should again be emphasized that conclusions are impossible with so few plants or with but one season's data, but probable trends can be observed. In general as shown by Plates IX and X and Tables 11, 12, 13 and 14, the southern types were more capable of utilizing the shorter length of day and usually exhibited the greater seedling and growth vigor, while plants of northern origin showed a favorable response to the long day.

Table 13. Average number of culms of little bluestem under varying lengths of day.

Length of photo-period	North Dakota				Kansas				Texas			
	June 8	July 8	Aug. 8	Sept. 8	June 8	July 8	Aug. 8	Sept. 8	June 8	July 8	Aug. 8	Sept. 8
16 hour	11.3	20.3	22.7	42.3	6.7	13.0	15.7	26.6	5.7	15.0	15.0	19.3
14 hour	15.0	21.0	31.0	45.7	9.0	19.0	20.3	32.0	7.0	12.0	16.7	28.0
12 hour	9.0	32.1	44.7	54.7	16.7	26.0	34.0	52.7	7.0	16.7	20.0	47.7
10 hour	15.3	24.7	25.7	51.7	18.0	25.7	35.0	56.7	10.7	19.0	28.7	42.0
8 hour	12.0	21.7	20.7	38.7	14.0	30.7	31.7	43.3	9.7	17.7	25.0	40.3

Table 14. Average number of culms of side-oats grama under various lengths of day.

Length of photo-period	North Dakota				Kansas				Texas			
	June 8	July 8	Aug. 8	Sept. 8	June 8	July 8	Aug. 8	Sept. 8	June 8	July 8	Aug. 8	Sept. 8
16 hour	6.6	22.3	25.3	32.0	6.3	12.3	15.0	13.0	4.0(4)	14.0(4)	14.0(4)	17.0(4)
14 hour	12.6	30.0	33.3	54.3	7.3	21.3	36.6	57.2	12.6	21.6	33.0	50.7
12 hour	10.3	15.0	24.3	28.7	6.6	15.3	22.6	32.2	16.0(5)	30.0(5)	46.0(5)	74.5(5)
10 hour	7.6	9.0	13.6	27.0	8.6	13.3	15.3	15.7	12.0(5)	22.0(5)	33.5(5)	48.0(5)
8 hour	6.0	16.5(5)	16.0(5)	24.0(4)	7.3	10.6	0.0(3)	0.0(3)	3.0(5)	3.5(5)	0.0(3)	0.0(3)

3 Plants dead or missing.
4 Data from one plant.
5 Data from two plants.

SUMMARY AND CONCLUSIONS

Big bluestem, little bluestem, side-oats grama and switch grass are four important native grasses found in the tall grass prairies of the United States. Big bluestem and little bluestem, together originally constituted between 70 and 80 per cent of the total vegetation of the well aerated soils and sufficiently watered areas. The growing interest in the reestablishment of the native grasses has pointed out many problems. One that is quite important is the obtaining of seed adapted to a given area. Thus, as a matter of seed selection it becomes necessary to study plants grown from seed of various sources to determine their adaptation to Kansas conditions. With that purpose in mind this investigation was conducted and some of the salient points observed are listed briefly below.

1. The plants grown from northern seed exhibited little or no winter injury but there was an increase in amount of injury as the source of seed progressed southward. Winter injury would have been even more severe had there been no protective covering of snow during the cold weather of December, 1939, and January and February, 1940.

2. There was a consistent relationship between the date of heading and the latitude from which the plants originated. The northern types tended to head early, the southern selections late, those originating centrally being intermediate.

3. The southern types of the four species studied tended to have greater leaf area per culm than the northern selections.

The Arizona selections and one Texas selection had a lower leaf area per culm than that calculated for plants originating farther north. Severe winter injury was probably responsible for the above reduction, although other factors may have had some influence.

4. The total leaf area per plant showed the same general trends as discussed above. The Kansas and Oklahoma selections of switch grass were the outstanding exceptions. These plants developed tall coarse stems, probably because the plant utilized its food for stem production rather than leafy material.

5. In general, except for side-oats grama, the southern selections were taller than those originating in the north. In each case, however, the Arizona selections were shorter than the Texas plants. The rate of growth was nearly the same in both northern and southern selections in the early part of the growing season, but the northern types headed and matured early with a resultant slower rate of growth late in the summer. The southern types matured late and continued to grow rapidly throughout the season.

Side-oats grama showed slight measurable differences of plant height with no apparent correlation as to source of seed.

6. A consistent relationship between the number of culms and source of seed of the various species was not apparent. The extreme southern and northern types, with but few exceptions, had the lowest number of culms. In each species studied either the Kansas or the Nebraska selection had the greatest mean number of culms per plant.

7. In the length of day study but few plants headed, but there was a tendency for the northern types to head first under the 16 hour day while the southern types headed first under the 12 and 14 hour day.

8. Each increase in length of day in this experiment was usually accompanied by an increase in the height of the little bluestem. The longer days stimulated the northern types most. Side-oats grama was more sensitive than little bluestem to variations in length of day. The North Dakota selection of side-oats grama was stimulated by the 16 hour day, whereas the Kansas and Texas selections were favored by the 14 hour day.

9. The southern types appeared to be more capable of utilizing a shorter day and usually exhibited a greater seedling and growth vigor, while plants of northern origin showed a favorable response to the long day.

10. It is probable that adaptation to the length of day is an important factor in determining the adaptation of the native grasses to a given locality. The northern types are adapted to a long day and the southern types to a relatively short day.

11. Grass species consist of many ecotypes. The grass species may be widely adapted but each ecotype may be confined to a narrow range of environmental conditions. Removal of the ecotype from that type of environment may result in a lack of adaptation comparable to that found in the cultivated crops.

12. Only grass seed that is known to be adapted should be planted. From this study it appears that, if good local seed is not available, seed obtained a short distance to the south would

be preferred to northern seed. For good results in seeding and establishment it is just as important to plant adapted ecotypes of the grasses as it is to sow adapted varieties of alfalfa, wheat, oats or corn.

ACKNOWLEDGMENTS

Indebtedness is acknowledged to Professor Kling Anderson for guidance throughout this study; to Mr. Alvin Law, as Research Assistant in Agronomy, for valuable assistance; to Mr. Kenneth Patterson for aid in maintaining a part of the study; and to Dr. H. H. Laude, Professor C. D. Davis and Professor Louis P. Reitz for suggestions on the preparation of the thesis.

LITERATURE CITED

Adams, J.
The effect on certain plants of altering the daily period of light. Ann. Bot. 37:72-94. 1923.

Does light determine the date of heading out in winter wheat and winter rye? Amer. Jour. Bot. 11:525-539. 1924.

Aldous, A. E.
Kansas pasture grasses. Beef cattle in Kansas. Kans. State Bd. Agr. Quart. Rpt. 53(211B):155-170. 1934.

Economic value of native Kansas grasses. Grasses in Kansas. Kans. State Bd. Agr. Quart. Rpt. 55(220A):13-23. 1936.

Management of Kansas bluestem pastures. Jour. Amer. Soc. Agron. 30:244-253. 1938.

Allbright, W. D.
Crop growth in high latitudes. Geog. Rev. 23:608-620. 1933.

Anderson, Kling L.
The improvement of Andropogon scoparius Michx. by breeding and selection. Unpublished thesis. Kans. State Col. Agr. and Appl. Sci. 77 p. 1938.

Anderson, Kling L. and Aldous, A. E.
Improvement of Andropogon scoparius Michx. by breeding and selection. Jour. Amer. Soc. Agron. 30(10):862-869. 1938.

Bruner, W. E.
The vegetation of Oklahoma. Ecol. Monog. 1:99-188. 1931.

Cornelius, Donald R.
Variability and inheritance in Andropogon furcatus Muhl., big bluestem. Unpublished thesis. Kans. State Col. Agr. and Appl. Sci. 77 p. 1938.

Evans, M. W.
Relation of latitude to time of blooming of timothy. Ecol. 12:182-187. 1931.

Relation of latitude to certain phases of the growth of timothy. Amer. Jour. Bot. 26:212-218. 1939.

Evans, M. W. and Allard, H. A.
Relation of length of day to growth of timothy. Jour. Agr. Res. 48:571-586. 1934.

Evans, M. W., Allard, H. A. and McConkey, O.
Time of heading and flowering of early, medium and late timothy. Sci. Agr. 15:573-579. 1935.

Featherly, H. I.
Grasses of Oklahoma. Okla. Agr. Expt. Sta. Tech. Bul. 3. 131 p. 1938.

Frolik, A. L. and Keim, F. D.
Common native grasses of Nebraska. Nebr. Agr. Expt. Sta. Circ. 59. 52 p. 1938.

Frolik, A. L. and Shepherd, W. O.
Vegetative composition and grazing capacity of a typical area of the Nebraska Sandhill range land. Nebr. Agr. Expt. Sta. Res. Bul. 117. 39 p. 1940.

Garner, W. W.
Recent work on photoperiodism. Bot. Rev. 3:259-275. 1937.

Garner, W. W. and Allard, H. A.
Flowering and fruiting of plants as controlled by the length of day. U.S. Dept. Agr. Yearbook, 1920:377-400. 1920.

Localization of the response in plants to relative length of day and night. Jour. Agr. Res. 31:555-567. 1925.

Garner, W. W., Bacon, C. W. and Allard, H. A.
Photoperiodism in relation to hydrogen-ion concentration of cell sap and the carbohydrate content of the plant. Jour. Agr. Res. 27:119-156. 1924.

Gregor, J. W. and Sansome, F. W.
Experiments on the genetics of wild populations. I. Grasses. Jour. Genet. 17:349-364. 1927.

Hilgendorf, F. W.
Plant breeding at Canterbury Agricultural College. Work on cereals, grasses, and red clover. New Zeal. Jour. Agr. 36:156-171. 1928.

Hitchcock, A. S.
Manual of grasses of the United States. U.S. Dept. Agr. Misc. Pub. 200. 1040 p. 1935.

Hopkins, A. D.
The bioclimatic law. U.S. Weather Bur. Monthly Weather Rev. Sup. 9:1-42. 1918.

Jenkins, T. J.
Natural selection in relation to the grasses. Roy. Soc. (London) Proc. Ser. B. 121:52-56. 1936.

Kellerman, K. F.
A review of the discovery of photoperiodism; the influence of the length of daily light periods upon the growth of plants. Quart. Rev. Biol. 1:87-94. 1926.

Keyser, Alvin.
Variation studies in brome grass. Colo. Agr. Expt. Sta. Bul. 190. 20 p. 1913.

Law, Alvin G.
The effect of selection and inbreeding on growth of Andropogon furcatus Muhl. (Big bluestem). Unpublished thesis. Kans. State Col. Agr. and Appl. Sci. 154 p. 1940.

McKinnery, H. H. and Sando, W. J.
Earliness of sexual reproduction in wheat as influenced by temperature and light in relation to growth phases. Jour. Agr. Res. 51:621-641. 1935.

Miller, E. C.
Plant physiology. New York. McGraw Hill Book Co. 1201 p. 1938.

Newell, L. C.
New grasses for Nebraska. Nebr. State Bd. Agr. Ann. Rpt. 729 p. 1938.

Redington, G.
The effect of the duration of light upon the growth and development of the plant. Cambridge Phil. Soc. Biol. Rev. 4:180-208. 1929.

Sarvis, J. T.
Composition and density of the native vegetation in the vicinity of the Northern Great Plains Field Station. Jour. Agr. Res. 19:63-72. 1920.

Schaffner, John H.
The characteristic plants of a typical prairie. Ohio Nat. 13:65-69. 1913.

Snedecor, G. W.
Statistical methods applied to experiments in agriculture and biology. Ames, Iowa. Collegiate Press, Inc. 388 p. 1938.

Steinberg, R. A. and Garner, W. W.
Response of certain plants to length of day and temperature under controlled conditions. Jour. Agr. Res. 52:943-960. 1936.

Stieger, T. L.
Structure of prairie vegetation. Ecol. 11:170-217. 1930.

Turesson, Gote.
The species and the variety as ecological units. Hereditas, 3:100-112. 1922a.

The genotypical response of the plant species to the habitat. Hereditas, 3:211-350. 1922b.

The scope and importance of genecology. Hereditas, 4:171-176. 1923.

U.S. Nautical Almanac Office. The American ephemeris and nautical almanac. 880 p. 1940.

Waldron, L. R.
Some physical and chemical studies of certain clones and sibs of brome grass. N. Dak. Agr. Expt. Sta. Bul. 152. 28 p. 1921a.

Physical characters and some of their correlations in Bromus inermis. N. Dak. Agr. Expt. Sta. Res. Bul. 153. 32 p. 1921b.

Weaver, J. E. and Albertson, F. W.
Effects of the great drought on the prairie of Iowa, Nebraska and Kansas. Ecol. 17:567-639. 1936.

Weaver, J. E. and Fitzpatrick, T. J.
Ecology and relative importance of the dominant tall grass prairie. Bot. Gaz. 93(2):113-150. 1932.

The prairie. Ecol. Monog. 4:109-295. 1934.

Withrow, R. B. and Benedict, H. M.
Photoperiodic responses of certain greenhouse annuals as influenced by intensity and wave length of artificial light used to lengthen the daily period. Plant Physiol. 11:225-249. 1936.

Zimmerman, P. W. and Hitchcock, A. E.
The localization of the mechanism which regulates tuberization in plants. Amer. Jour. Bot. 23:690. 1936.