VARIABILITY AND INHERITANCE IN *ANDROPOGON* *FURCATUS* (MUHL.), BIG BLUESTEM

by

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TABLE OF CONTENTS

INTRODUCTION

Recent years of drouth, soil blowing, and overproduction of some grain crops have made the people of the United States "grass conscious." Drouths have greatly reduced the stand of grass in pastures and meadows throughout the middle west during 1934 and 1935 and in some sections during 1936 and 1937. Soil blowing has brought to attention the mistake of breaking out much of the poorer land in western Kansas, the panhandle of Oklahoma and Texas, and eastern Colorado for the growing of wheat.

A survey conducted by the United States Department of Agriculture reveals the seriousness of soil erosion on sloping crop land. The Soil Conservation Service classifies 100 million acres as no longer suitable for crop production, 125 million acres have lost all or most all top soil, and 100 million acres are beginning to lose top soil.

Expressing the erosion losses from a 14-year experiment at Missouri (32) in terms of years required to remove the surface seven inches or the so-called "plow-soil," only about 24 years would be necessary for the cultivated fallow land, 50 years for continuous corn, 100 years for continuous wheat, 368 years for a crop rotation, and a little over 3,000 years for continuous bluegrass. Experiments conducted by Duley and Miller (14) at Missouri show that sod and clover land absorbed much more water than cultivated land. The slope of the land averaged 3.68 feet per hundred. Sod land lost only .68 per cent as much soil as the uncropped soil spaded four inches deep.

Gray (21) reports that approximately 9,500,000 acres of unproductive land is being acquired by the United States Department of Agriculture Resettlement Administration. The land will be converted into such uses as grazing, forestry, recreation, and wild life conservation.

One of the important problems connected with turning land back to grass is a source of adapted viable seed that can be planted with reasonable assurance of producing a stand of forage that is of satisfactory quality and yield. Much of the land being turned back to grazing purposes comes under the region of low rainfall and summer drouth. The species of grass commonly used in revegetation work in the eastern section of the United States are not adapted to the regions of lower rainfall in the middle west. The practical solution to this problem appears to be the collection and study of the grasses native to this region where revegetation is needed. From these native grass species we should select and propagate desirable types that will be adapted and suitable for grazing, erosion control, and will possess other qualities desired.

Andropogon furcatus is a native grass, occurring throughout the tall grass prairie section of the United States and extends through the mixed prairie into the fringes of the short grass area. This species of grass has been used in Nebraska, Kansas, Oklahoma, and Texas. It is vigorous, palatable, nutritious, drouth resistant, insect and disease resistant, and high yielding. The sod is of sufficient density to control erosion. Forage of high quality is produced throughout the summer and this species withstands considerable grazing. The selection and improvement of *Andropogon furcatus* appears to be more feasible and practical than to attempt to find an introduced species.

REVIEW OF LITERATURE AND GENERAL COMMENTS

Distribution of *Andropogon furcatus*

Andropogon furcatus Muhl. (big bluestem) has been reported from 43 of the 48 states and has been found on dry soil, prairies, and open woods from Quebec and Maine to Saskatchewan and Montana, south to Florida, Wyoming, Utah, Arizona, and Mexico. Hitchcock (25) also states that it is an important forage grass in the prairie states of the

Mississippi Valley, making up the most important constituent of the wild hay of the prairie states. This species sometimes appears in literature as _Andropogon provincialis_ Lam. (33) (13) and the common name is sometimes given as blue joint turkeyfoot (25). _Andropogon furcatus_ Muhl., or big bluestem, will be used in this paper since that is the most common usage in the prairie states.

Big bluestem is the dominant grass in the Bluestem Region of Kansas, covering a strip through eastern Kansas approximately 65 miles wide and 140 miles long. This area comprises one of the most important and high yielding native grass pasture sections of the United States. Bluestem grass is also important throughout the Osage country of eastern Oklahoma.

Harvey (24) mentions the prominence of _Andropogon furcatus_ and _A. scoparius_ in the prairies of southeastern South Dakota where they assume the bunch habit upon higher crests and ridges. He says in these situations the _Andropogons_ assume facial rank, _A. furcatus_ being the taller and on account of its invariable bunch habit far the more conspicuous.

On the distribution of _Andropogon furcatus_ (big bluestem) Elias (15) says, "it is very characteristic of the grass flora of the prairie region of the Great Plains but its distribution is much wider than this. It is particularly abundant in the edges of bottom lands in the Dakotas and Montana, but farther south and east, where the rainfall is more abundant, it inhabits the open prairies and uplands."

Sarvis (34) reports the occurrence of Andropogon furcatus at Mandan, North Dakota where the species is greatly relished by livestock but occurs in such limited areas that it is unimportant in the total amount of forage annually produced.

Weaver and Fitzpatrick (43) rank Andropogon furcatus (big bluestem) as one of the two most important dominants of the prairie. They state, "Together with A. scoparius of uplands it constitutes fully 70 per cent of the entire grassland cover. Seedlings develop rapidly when conditions are favorable to growth. The primary roots develop rapidly. Two months after germination these range from 14 to 40 inches in depth. Depths of 5-7 feet are usually attained. The mature roots are coarse (.5-3 mm. in diameter). The tillering habit is pronounced. Rhizomes are also pronounced and the area occupied by both shoots and roots is thus greatly increased."

In reporting on the vegetation of Oklahoma, Bruner (7) says, "Andropogon furcatus is the most characteristic dominant in the eastern half of the state but is also important in the vast climax prairies. It is conspicuous because of its size, abundance, and general distribution.

Its great vegetative growth makes it one of the most important grasses for grazing and for hay."

Clements and Chaney (11) describe significant movements within the grassland climax proper among the grasses themselves following the glacier that covered much of the northern portion of what is now the true prairie. The tall-grasses, notably *Andropogon*, evidently were pushed far to the northeast in the late Pliocene. They also state, "Concomitantly, the mid-grasses replaced the tall-grasses during dry phases and shrank back before them during moist ones, while short-grasses bore the same relation to the mid-grasses. Finally, the *Andropogons* came to maintain the position they occupied at the time of settlement along the edge of the forests, the mid-grasses dominated the true prairie, were mixed with short-grass in the Great Plains, and the *Bouteloua*s and *Aristidas* held sway over the desert plains. This is the condition that prevails today, but it is much confused and obscured by the disturbances wrought by man through cultivation and grazing."

Valuable Characteristics of *Andropogon furcatus*

Bluestem grasses grown on the Flint Hill pastures of Kansas are considered by cattlemen to be especially valuable for grazing. Approximately 190 thousand head of cattle are shipped from the short grass ranges of Texas, New Mexico, Oklahoma, Arizona, and Colorado each year to be fattened for market on the nutritious grass of the Bluestem section of Kansas. Although the palatability and nutritive value becomes lower late in the season it is exceptionally good during May, June, and July. The palatability rating of big bluestem as given by the Forest Service, United States Department of Agriculture, is about 70 per cent for the eastern one-half of Kansas.

Aldous (4) makes the following statements regarding forage production, "bluestem grasses are valuable pasture plants because they make a major portion of their growth during June and July, and if moisture is available, a substantial amount of forage will be produced during August. In contrast with this most of the 'tame' perennial grasses are semi-dormant after their normal period for maturing seed or from July until late summer or early fall."

Stapledon (36) says, "the nutritive value of a grass at any particular time depends more on its growth stage and its stem to leaf ratio than on the inherent chemical properties of its various parts; thus real differences that may exist between species and species, and strain and strain are exceedingly difficult and perhaps quite impossible to estimate with any absolute degree of accuracy." He also states, "The economic value of a grass depends in the last resort not only upon its palatability and nutritive value but equally upon its ability to maintain itself and withstand the conditions of management superimposed upon it."

Characteristics other than nutritive value and palatability of *Andropogon furcatus* which enhance its economic value are as follows: resistance to drouth, vigor and ability to withstand grazing, and disease and insect resistance.

Data obtained by Aldous (4) in a grazing experiment conducted near Manhattan found that *Andropogon furcatus* survived the drouth better than *A. scoparius*. One advantage which *A. furcatus* has in drouth resistance can be attributed to its deep root system with a working depth of 5-8 feet. It can thereby obtain moisture from a lower depth during periods of extreme drouth.

High temperatures, which usually accompany a lack of moisture during summer drouth, also cause considerable injury to plants. With a deep root system *A. furcatus* can survive longer than shallow rooted grasses. Another advantage of *A. furcatus* over *A. scoparius* in drouth resistance might be the sod type as contrasted with the bunch habit of growth. The bunch type of growth appears to be more susceptible to injury from excess temperatures.

When once established, bluestem grass plants are vigorous and long lived. Aldous states (3), "big bluestem is very vigorous, standing close grazing, and it will recover from improper grazing in two or three years if protected at least during the first part of the season."

The ability of Andropogon furcatus to resist disease makes it well worth considering this species for revegetation plantings. While there are several species of smut and some rust which affect A. furcatus, the amount of damage which might be attributed to these diseases is practically negligible.

During the season of 1935 several different kinds of smut were observed on species of Andropogon, principally A. furcatus. Collections of smut of the several different kinds and from various parts of the state were made. These collections were given to Mr. E. D. Hansing of the Botany Department, Kansas State College. Mr. Hansing, Dr. C. L. Lefebvre, and Mr. C. O. Johnston added to the collection. Mr. Hansing (23) identified the smuts as follows:

1. Sorosporium everhartii Ellis & Gall

on A. furcatus	Cornelius	4 collections
	Lefebvre	2 "
	Hansing	2 "
on A. scoparius	Cornelius	1 collection

2. Sorosporium provinciale Clinton

on A. furcatus	Cornelius	3 collections

3. Sphacelotheca andropogonis

on A. furcatus	Cornelius	2 collections
on A. scoparius	Cornelius	1 collection

4. _Sphacelotheca holci_

on _Sorghum halepense_	Cornelius	1 collection

5. _Sphacelotheca occidentalis_

on _A. furcatus_	Cornelius	3 collections
on _A. hallii_	Cornelius	1 collection

The fact that several different smuts were found on _A. furcatus_ should not be construed to mean that the amount of damage was appreciable. In the fields where the collections were made there were a very small percentage of the florets affected, usually less than one per cent and never more than five per cent. However, this susceptibility should be kept in mind in the selection and breeding of the species to propagate strains more resistant to the smut and to prevent the smut from increasing as cultivation of the grass becomes more extensive.

Leaf rust, _Puccinia graminis_, has been observed on the leaves of _A. furcatus_. In the nursery some plants were rusted more than others. The damage was not great but in selection work the plants resistant to the rust should be chosen for propagation and strain building.

Diseases found upon _A. furcatus_ have not appeared to damage the plants or seed production to the extent that ergot or rust affects various species of _Agropyrons_, foot rot damages _Agropyron cristatum_, or rust affects _Panicum virgatum_ from the northern states grown in the nursery at Manhattan, Kansas.

The resistance of *A. furcatus* to grasshopper injury was clearly shown during the summer of 1936. There were many grasshoppers in the nursery at the agronomy farm. *A. furcatus* was only slightly eaten while considerable damage was done to near-by rows of the following species: *Bromus inermis*, *Agropyron semicostatum*, *Poa pratensis*, *Dactylis glomerata*, and *Festuca elatior*.

Chinch bugs were observed on *A. furcatus* plants in June 1936 in a meadow in Allen County, Kansas. This species made up approximately 90 per cent of the vegetation but apparently the chinch bugs were not causing injury to the plants. Scattering plants of *Tripsacum dactyloides* and *Spartina pectinata* found in the meadow were suffering considerable damage from the chinch bugs. Leaves of each of these species were starting to roll and several of the *Tripsacum dactyloides* inflorescences failed to produce good seed because of the chinch bug injury.

Breeding and Selection

No work has been published on the improvement of *Andropogon furcatus* to the writer's knowledge. Considerable grass breeding and improvement has been accomplished with several species of cultivated grass at Aberystwyth, Wales and Svalof, Sweden. There have been a few strains of timothy developed in this country and studies have been made on the variation to be found in several of the more important cultivated grasses.

Church (8) says, "Andropogon furcatus is a decaploid with 35 bivalents. The 2n chromosome number is 70. Diakinesis displays a striking ring formation of the synoptic mates. Barring a sluggishness of chromosome action in early stages of both metaphase and anaphase, the heterotypic division is quite regular."

Hubbard (27) has noted several varieties of A. scoparius. Church (8) comments upon this as follows: "A. scoparius has been noted in several varieties in this region and the presence of univalent chromosomes, polycarpy, and sterile pollen makes the evidence overwhelming for its hybrid origin. A. furcatus is equally outstanding in its regularity of reduction divisions and only very small amount of sterile pollen. Its hybrid origin may be more remote than that of A. scoparius, but its decaploidy attests such a lineage. Certainly if polyploidy, even of itself, is a criterion of hybridity, it is very strikingly instanced in the octaploid A. scoparius and the decaploid A. furcatus."

Huskins (28) reporting that the chromosome number of Spartina townsendii is 126 says, "This is the highest number yet recorded in the gramineae, 70 recorded by Church in Andropogon furcatus and Peto in Agropyron elongatum being the previous maximum."

The Swedish Plant Breeding Institute of Svalof was among the first to begin the improvement of grasses. Witte (46) reported on some variations in timothy which were observed and studied as follows: (1) number and length of internodes, (2) thickness of stem, (3) direction of stem, (4) size and color of leaves, (5) variation of head, (6) variation in flower parts, (7) physiological characters (hardiness, earliness, and withering of leaves at blooming), and (8) disease resistance. Pedigreed plants were selected and vegetatively multiplied in plots for the purpose of attaining the truest possible estimate of different characters desired. The best of these plots were then increased vegetatively into larger plots, situated as solitarily as possible for seed production. After a strain has proven superior in several comparative trial plots, and has shown evidence of practical uniformity, it is distributed. Two strains named Primus and Gloria have been distributed with respectively 12 and 20 per cent higher yield of forage than ordinary Swedish timothy. They are also rust resistant and produce high yields of seed.

Clark (10) published results of selfing timothy. Eleven of the better Cornell sorts and six Minnesota selections were used. He found selection within self-fertilized lines of timothy for 1 to 5 selfed generations give relatively homozygous lines. Many plants proved to be highly self-sterile although a small proportion were relatively fruitful. Yielding ability appeared to be inherited as indicated by correlation coefficients in comparing successive selfed generations. Selection in selfed lines appears to be effective and practical with timothy according to Clark.

Evans (16) working at North Ridgeville, Ohio for the United States Department of Agriculture developed a new variety of timothy known as Huron timothy. It is a selection made from plants growing along a roadside. Tests have shown this variety to be later in maturing and that it remains green longer than ordinary timothy.

Evans and Ely (18) state that a selection of timothy was developed by selecting three years for lateness and a tendency for leaves to remain green as seeds mature. The late selection was in full bloom 5 days later than the plots of ordinary timothy. The leaves appeared 4.8 days later and remained green 7.3 days longer than ordinary timothy. Color reading of hay, protein content, and number of green leaves were generally higher for the late selection.

Jenkins (31) of Aberystwyth discusses strain building as follows: "As used in the present connection the term 'strain' presupposes a certain amount of conscious selection. Its application, however, is still very wide, since on the one hand a single plant may be selected as the basis of a strain, and at the other extreme an entire population from a particular source may be taken. Multiple-plant strains are based on two or more selected plants. The first essential in any case is that the plant should be in some degree self-fertile and that the progeny plants so produced should be (1) self-fertile, (2) interfertile with the mother plant, or (3) interfertile with each other."

Jenkins (30) discovered a plant of Lolium perenne that from repeated self pollination gave red base and non-red seedlings in proportion strongly suggestive of a single factor difference. The progeny from this single plant were known as Line 169. Jenkins (32) says, "To determine self-fertility non-red perennial rye grass plants of Line 169 were scattered amongst a heterogenous population of the same species. Non-red are homozygous recessives for anthocyanin coloration, while the plants of a normal population are of the red-base type, and naturally occurring heterozygous plants are exceedingly rare."

There was considerable loss of vigor in perennial rye grass in the first generation from selfing according to Jenkins (31). One particular strain gave slight recovery in the second generation if selected plants were inter-crossed. Such recovery was, however, extremely small, and is of no practical value since the plants obtained are still extremely poor. Jenkins (34) gives the average loss of vigor from selfing *Lolium perenne* as over 60 per cent.

Stapledon (38) has done considerable work in the improvement of *Dactylis glomerata* known as cocksfoot in England and orchard grass in the United States. He says, "Cocksfoot occurs as more or less well-defined habitat races or ecotypes, and although of course normally cross-pollinated it is more highly self-fertile than perhaps the generality of herbage grasses. Work has been concerned more with type of growth form as such than with the behavior of single plants as such.... The economic plant breeder of herbage plants may hope to achieve valuable results without necessarily becoming a slave to the idea of genetical purity. The herbage plant breeder will have done much if he can produce a strain which will breed true to a 'throw up' of 50 per cent 'ideals', generation after generation, where the ordinary seed of commerce is incapable of a 'throw up' of more than perhaps 15 per cent."

In a concentration of types, Stapledon (38) has adopted a method of mass selection but always aimed at obtaining type plants from one and the same habitat. "Vigorous type plants one is desiring to 'concentrate' are likely to be anything but completely homozygous, while it is perhaps the most vigorous plants that are the most heterozygous," says Stapledon (38). He has developed strain No. 1163 after four generations which gives populations consisting of about 75 per cent of "improved" growth form types and this is coupled with very satisfactory seed production.

Waldron (41) compared the yield of certain clonal lines of *Bromus inermis* with several selfed lines. The clones were derived asexually or vegetatively by breaking up certain parent plants and propagating the lines vegetatively until sufficient plants were produced to make a plot. Sibs or selfed lines were obtained by enclosing a plant in a double wrapping of cheese cloth and cutting all brome grass plants within 50 feet to prevent foreign pollen from getting to the plant. Waldron says, "for 1919 in four out of the five comparisons, the yields were greatest for the sibs, plants from self-fertilized seed. In the one exceptional case the difference was too small to be of significance. The average yield per acre for the clonal plots was 2.62 tons and for the plots carrying sibs the yield was 3.41 tons an increase of 30 per cent. As an average for two years, differences are in favor of the sib groups in three cases out of five which is not significant. The clonal beds were started from plant divisions while the sibs were seedlings, started from seed in 1919, the year when the first yields were secured." Apparently Waldron did not find a reduction in vigor with the first generation of selfing.

Variability

All organisms are variable to a certain extent within the group of which they are a part. As stated by Clark (9), "Variation is the rule rather than the exception in all organisms; therefore a study of living things is not complete without a knowledge of their diversities."

In starting with Andropogon furcatus from the wild or natural condition considerable variation of type and growth was anticipated. Cultivation and selection by mankind had not been given an opportunity to influence the genetic make-up of this species. Turesson (39) (40), Gregor and Sansome (22), and Stapledon (37) have reported upon the effect of habitat and the genotypical response of the plant species. Certain ecotypes develop within species resulting from the influence of different habitats. In addition to the variation resulting from the influence of habitat in developing ecotypes there is variation within the ecotype.

Commercial sources of brome grass, timothy, orchard grass, Kentucky bluegrass, and perennial rye grass have been grown by numerous investigators as individual plants and in all cases exhibit considerable variation between plants. By breaking up the plants and growing them as clones, Waldron (41) has found that brome grass has considerable uniformity within the clones and variation between the clones.

Evans (17) says, "The high variability in commercial timothy has made possible by continuous selection through several generations the development of strains having longer stems, earlier or late maturity, and better retention of green color in the leaves than the plants from which they were derived. The plants of many of these new strains show a high degree of uniformity, even though grown under natural conditions permitting open-pollination.

Most of the variability in Andropogon furcatus reported in this paper is that which exists within the ecotype. The plants studied through three generations came from seed collected near Manhattan, Kansas. A few preliminary comparisons were made with plants grown from seed of various sources, some from more northern habitats and some from Oklahoma.

MATERIALS AND METHODS

The original collection of seed for this study of variability in Andropogon furcatus was made by Aldous in the vicinity of Manhattan, Kansas. Seed was collected from several plants along a railroad cut. This particular habitat was selected because it was a rather drouthy location, therefore, the plants were probably more drouth resistant from natural selection. The seed was planted in plots at the agronomy farm and it was from these plots that seed was harvested in 1934 for use in starting the test during the winter of 1934-35.

In December, 1934, seed was planted in the greenhouse in 4-inch pots. About five weeks after planting the seedlings were transplanted to flats approximately twenty inches square and five inches deep. Each plant was kept separate to permit planting in the nursery row as individual plants. Two hundred of these individual plants were taken to the field in late May, 1935. Rows were thirty inches apart containing twenty plants spaced thirty inches in the row.

The soil was uniform and the plants were all given the same care. The nursery was irrigated during July and August whenever the soil became dry enough to cause the plants to start to wilt. An endeavor was made to give the plants optimum and equal growing conditions at all times, so they could make the most growth and produce the most seed possible.

Early in the study of the plants it was found to be impossible to satisfactorily compare the two hundred plants qualitatively. Considerable variation could be observed for example in the degree of leafiness; some were leafy while others were very sparse and became stemmy late in the season. A few apparently lacked vigor and consequently leafiness. Descriptive terms such as very leafy, leafy, medium, sparse, and very poor did not give sufficient range and could not be analyzed statistically. A ranking of the plants from one to twenty would have been possible but not sufficiently accurate.

The most satisfactory manner to have determined the yield of leaves at any given time would have been to cut the plants and weigh the leaves produced by each. However, the complete life history was desired for each plant to show how it would spread, produce seed stalks, flower, set seed, and continue to produce leaves throughout the summer. Therefore, the plants could not be defoliated during the summer and be expected to make a normal growth and produce the maximum amount of seed.

Early in the summer of 1935 it was determined that the most practical method of obtaining data pertinent to leafiness was to measure leaf area of the plants. This was done by measuring ten leaves at random on each plant. Widths were taken at the widest point in millimeters and the length was measured in centimeters. If the number of leaves was not too great the actual number was counted. If the number of leaves exceeded approximately 125 then the average number of leaves per stem was determined by counting the number for five stems.

The purpose of leaf area determination was to provide a basis for comparison of the different plants, to permit statistical analysis of variance, and to find the correlation of leafiness with certain other characters. Exact leaf area was not necessary for this purpose providing the area, as determined for the different plants, was comparable. Therefore, the leaf area index as used was obtained by multiplying the average width in centimeters by the average length in centimeters which in turn was multiplied by the number of leaves.

By blue-printing several leaves of *A. furcatus* it was found that the actual area of these leaves, as determined by measuring with a planimeter, was .681 of "the length times width at the widest point," thereby making it possible to calculate the actual leaf area of a plant in square centimeters by multiplying the leaf area index times the factor .681.

Since it was desired to study variability through several generations and to observe the effect of selection upon the variability of *Andropogon furcatus*, three generations of plants were grown during the period 1935-37. The area was extended each year to accommodate the new generation of plants. Each nursery was designated by the year in which it was planted. The original two hundred plants were designated as the 1935 nursery, the following year the 1936 nursery was planted, and the third-generation plants were grown in the 1937 nursery.

The 1936 nursery was established by collecting all of the seed produced by each of the individual plants in the 1935 nursery during October, 1935. This seed was planted in the greenhouse early in January of 1936 and seedlings were grown as in 1935, care being taken to keep the seedlings from each parent plant separate. An attempt was made to have 25 seedlings from each parent plant but this was not possible due to poor germination and growth in several cases. The seed was planted about the first of the year when there was but very little sun and the greenhouses were not as warm as later in the year. The germination and growth of the seedlings was better when seed was planted in early March because bluestem grass grows better in a warm seed bed.

The seedlings were transplanted to the nursery in May, 1936. Spacing and other methods employed were the same as used in 1935. Since quantitative data was considered to be of more value on second year plants, measurements were not taken until July, 1937. Only general notes were taken on the plants in 1936.

Measurements of leaf area similar to those taken on the plants in the 1935 nursery were determined in July, 1937 for ten plants from each of 19 rows. The rows originated from and carried the number of single plants in the

1935 nursery. For example row No. 12 comes from the seed collected from plant No. 12 of the 1935 nursery.

Plants comprising the 1937 nursery were grown from seed collected in the 1936 nursery in October, 1936 from individual plants selected because they were leafy, good seed producers, and possessed such other qualities that would enhance their value as good forage plants. The seed was planted in February, 1937 and transplants were made the same as in 1935 and 1936. The rows were numbered to designate the origin of the seed to enable one to quickly check back on the parent plant for comparisons. Rows were numbered 12-11, 12-24, 42-2, etc. The first number is that of the original plant in the 1935 nursery from which row No. 12 was grown in the 1936 nursery. The second number (following the dash) designates the particular plant selected in row 12 of the 1936 nursery. Plants in the 1936 nursery rows were numbered consecutively in each row starting with 1. Therefore, row No. 12-11 in the 1937 nursery indicates that the seed came from selected plant No. 11 in row No. 12 of the 1936 nursery. Fifty-one such ten plant rows were measured.

PRESENTATION OF DATA AND DISCUSSION

Leaf Area

Leaf area measurements were made June 22, 1935 on 197 of the plants in the 1935 nursery. There was a variation in leaf area from a maximum of 4511.4 sq. cm. for plant No. 171 to a minimum 86.1 sq. cm. for plant No. 76. The mean was 1296 sq. cm. The most leafy plant had nearly four times the leaf area of the mean. Table 1 gives the number of plants in each class and the percentage of the total number of plants which are found in each class. If a curve was constructed, there would be positive skewness with 64 per cent of the plants below the mean. This shows the effect of a few superior plants so far above the mean. They will serve as a goal for the development of a leafy strain that will be uniformly high yielding.

Measurements of leaf areas were made June 1-6, 1936 on the identical plants studied in 1935. Each of the 198 plants which survived the season of 1935 were measured. It was anticipated that more reliable data on the ability of the plant as a forage producer could be obtained from second year plants. The effects of transplanting are not important the second season, and since the grass is used in permanent pastures, practically all of the plants are over one year of age. Therefore, data collected the second year affords a more reliable basis upon which to judge the plants.

The leaf area was approximately ten times greater June 1-6, 1936 than the same plants had June 22, 1935. This was because more stems were produced, leaves appeared earlier, and there had been some spread by rhizomes. To compare the plants the measurements taken June 1-6, 1936 were divided by ten in using the same class intervals as found in Table 1 for the 1935 data. The variation presented by the plants in 1936 was much greater than in 1935. Plant No. 145 was highest with 49,517.2 sq. cm. while plant No. 20 was lowest with 1154.7 sq. cm. The same plant which had the greatest leaf area in 1935 did not have the greatest area in 1936 nor was the same plant lowest each year. However, there was a tendency for the good plants to remain high in leaf area and the poor plants to be low in leaf area.

A curve of the 1936 measurements shows greater distribution within the classes. There were four classes in 1935 with 15 or more plants (Table 1) while in 1936 there were only two.

Table 1. Frequency distribution of leaf areas for 1st generation plants, 1935 nursery.

Sq. Cm.	Data June 22, 1935 Number Plants	Per Cent	Sq. Cm. / 10	Data June 1-6, 1936 Number Plants	Per Cent
0-125	1	.5		1	.5
126-250	5	2.5		3	1.5
251-375	12	6.0		5	2.5
376-500	13	6.5		8	4.0
501-625	15	7.5		16	8.0
626-750	18	9.0		13	6.5
751-875	19	9.5		12	6.0
876-1000	13	6.5		6	3.0
1001-1125	15	7.5		15	7.5
1126-1250	16	8.0		11	5.5
1251-1375	3	1.5		11	5.5
1376-1500	7	3.5		13	6.5
1501-1625	7	3.5		7	3.5
1626-1750	4	2.0		7	3.5
1751-1875	5	2.5		8	4.0
1876-2000	7	3.5		12	6.0
2001-2125	--	---		2	1.0
2126-2250	7	3.5		6	3.0
2251-2375	1	.5		5	2.5
2376-2500	3	1.5		7	3.5
2501-2625	4	2.0		7	3.5
2626-2750	--	---		5	2.5
2751-2875	3	1.5		1	.5
2876-3000	1	.5		3	1.5
3001-3125	3	1.5		3	1.5
3126-3250	2	1.0		2	1.0
3251-3375	2	1.0		1	.5
3376-3500	3	1.5		1	.5
3501-3625	1	.5		--	---
3626-3750	1	.5		1	.5
3751-3875	2	1.0		--	---
3876-4000	--	---		1	.5
4001-4125	1	.5		1	.5
4126-4250	--	---		1	.5
4251-4375	1	.5		--	---

Table 1 continued.

Sq. Cm.	Data June 22, 1935 Number Plants	Per Cent	Sq. Cm. / 10	Data June 1-6, 1936 Number Plants	Per Cent
4376-4500	--	---		1	.5
4501-4625	1	.5		--	---
4626-4750	--	---		--	---
4751-4875	--	---		1	.5
4876-5000	--	---		1	.5

Ave. 1296
Total No. plants 197
Max. 4511.4 Plant No. 171
Min. 86.1 Plant No. 76

Ave. 1436±938
Total No. plants 198
*Max. 49,517.2 Plant No. 145
*Min. 1154.7 Plant No. 20

* Square centimeters

Table 2 gives the leaf area class frequency distribution for the plants in the 1936 nursery measured in 1937. It is important to note that there is considerable variation within the ten plants of the various rows, some of the rows exhibiting more than others, e.g. row No. 115 has 16 class intervals between the plants with lowest and highest leaf areas while row No. 199 has 36 class intervals between the plants with lowest and highest leaf areas. It is significant to note that the rows with the widest intervals as No. 12, No. 85, No. 87, No. 126, No. 183, No. 191, and No. 199 are the rows having certain plants with the greatest leaf areas. The greater leaf area for certain plants in the rows exhibiting the greatest variation might be attributed to heterosis. Andropogon furcatus is thought to be mainly cross pollinated and since the seed

Table 2. Leaf area class frequency distribution for nineteen 10-plant rows in 1936 nursery, 1937 data.

Sq. Cm. / 10	Row Number																			
	12	14	39	45	80	85	87	115	117	126	145	146	151	156	174	183	191	196	199	Total
500-625								1			1			1						3
626-750																				
751-875								1									2			3
876-1000	1							3			1	1								6
1001-1125					1			1	1								1			4
1126-1250										1					1					2
1251-1375									1							2	1	2		6
1376-1500	2		1					1			1			1					1	7
1501-1625									1				1							2
1626-1750			1	1							1									3
1751-1875										1	2		1	1	1	3		1	2	12
1876-2000			2	1	1	1		1	2			1	1				1	2		13
2001-2125		1		1	1	1					1	1								6
2126-2250				1		1	1				2				3				1	9
2251-2375		1	2	1	1		1	1				1	1	1				1		11
2376-2500	1	1			1	1			1			1	2			1		1	2	12
2501-2625		1	1					1	1			2					1			7
2626-2750	1				2				1					2			2			8
2751-2875		1				1						2	1		1	1			1	8
2876-3000		1				3					1		1	1				1		8
3001-3125	1						2			1				1	1		1			7
3126-3250		1	2		1		2					1		1	1					9
3251-3375	1								1	1					1					4
3376-3500		2				1	1							1		1		1		7
3501-3625	2								1											3

Table 2 continued.

Sq. Cm.	Row Number																			
10	12	14	39	45	80	85	87	115	117	126	145	146	151	156	174	183	191	196	199	Total
3626-3750				1															1	2
3751-3875			1	2									1							4
3876-4000					1										1					2
4001-4125					1								1			1				3
4126-4250		1		1														1	1	4
4251-4375																				--
4376-4500	1									1										2
4501-4625				1			1			1										3
4626-4750										1							1			2
4751-4875										1										1
4876-5000																				--
5001-5125																				--
5126-5250										1						1				2
5251-5375										1										1
5376-5500						1	1													2
5501-5625							1													1
5626-5750																				--
5751-5875																				--
5876-6000																			1	1
No. of intervals between highest and lowest	28	17	19	23	24	28	27	16	20	33	19	18	20	23	22	31	31	23	36	190

was produced under open-pollination, foreign pollen might have caused the fertilization of the seed, producing the plants with greater leaf area.

A significant difference was found in leaf area of the rows given in Table 2. Analysis of variance, calculated according to the procedure of Snedecor (43) for the difference in leaf area of the nineteen rows, is as follows:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	189	230,503,416.0	1,219,594.7
Between rows	18	58,747,477.4	3,263,748.7*
Within rows	171	181,755,938.6	1,062,900.2

$F = \frac{3,363,748.7}{1,062,900.2} = 3.0706$ surpasses the 1 per cent point 2.00 for 20 and 150 d. f.

* Highly significant

Since the F value of 3.07 greatly exceeds the 1 per cent value 2.00 there is a highly significant difference between rows. The variation within the rows is not as great as between rows. This lends encouragement to the possibility of obtaining a strain by selection under open-pollination that will be better than the general run of plants found under natural conditions.

Measurements were made July 23 to August 3, 1937 in the 1937 nursery. Since these measurements were made on first year plants they can not be compared directly with measurements on second year plants in the 1936 nursery. There are indications that greater uniformity is present in the 1937 nursery than the 1936 nursery, especially in certain rows.

An inspection of the frequency distribution of leaf area values for the 1937 nursery, as given in Table 3, shows considerable uniformity in some of the rows, e.g. 42-2, 80-10, 89-11, 107-1, 144-2, 147-16, 159-32, 171-11, and 174-5. Again as observed in data for the 1936 nursery the rows having the greatest variation were the rows having the exceptionally good plants with a large leaf area. The analysis of variance is as follows:

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	M	σ
Total	509	59,927,444	117,736	523.7	±343.126
Between means of rows	50	19,312,266	386,245*		621.486
Within rows	459	40,615,178	88,486		297.467

$F = \frac{386,245}{88,486} = 4.365$ surpasses 1 per cent point 1.57 for 50 and 400 degrees of freedom. Coefficient of variability = 65.5

* Highly significant

Table 3. Class frequency distribution of leaf areas (open-pollinated), 1937 nursery. Data collected 7/23 to 8/3, 1937.

Sq. Cm. / 10	12-1	12-11	12-24	14-3	15-1	15-7	15-36	42-2	52-2	53-18	64-8	80-10	80-24	81-4	84-8	85-11	85-17	86-11
0-125	1		3					1			1			1				
126-250		3	4		1	1	2	3	2	3	3	5	4	3	2	3	1	1
251-375	3	2	3	4	1	3	2	6	4	3	2	2	3	4	4	4	3	1
376-500		5		1	2	3			1	3	2	2	2	2	3	2	2	1
501-625	3			2	1	2	1		2	1	1		1				1	
626-750	2					1	1		1						1		1	1
751-875	1				2		1				1						1	1
876-1000				3	3		1									1		2
1001-1125							2											1
1126-1250												1						
1251-1375																		
1376-1500																	1	1
1501-1625																		
1626-1750																		
1751-1875																		
1876-2000																		
2001-2125																		1
2126-2250																		
2251-2375																		
2376-2500																		

Sq. Cm. / 10	87-19	87-28	87-30	89-5	89-11	89-13	95-7	97-9	98-14	98-23	103-2	107-1	108-10	116-19	117-25	119-12	126-39
0-125	1	1					1										
126-250	1	2	1	1	2	1	1		1			1	4		1		
251-375	2	3	2	2	5	1	3	5	2		1	2	3				3
376-500	3	1	3		2	1	1		3	1	1	3			2	1	
501-625	1		2	1	1	1	1	1	3	3	2	4		2	3	4	1
626-750		3	1			1	1	1		3				1		2	
751-875	1		1	1		3	1			2	2		2	1	1	1	1
876-1000	1			3		1	1	2			1		1	2	2		
1001-1125				1					1	1	1			1			
1126-1250														1		1	2
1251-1375								1			2			2			1
1376-1500															1		
1501-1625																	
1626-1750																	1
1751-1875																	
1876-2000						1											
2001-2125																1	
2126-2250																	
2251-2375																	
2376-2500																	1

Sq. Cm. / 10	132-45	137-12	144-2	146-8	146-23	146-31	147-16	151-16	155-1	156-3	156-12	159-32	170-62	171-11	174-5	174-16	Total
0-125									1								11
126-250	5		1	1	2	1			1	1		4	3	2	3		81
251-375	1	1	5	2	4	3	3	2	1		1	2	3	4	4	3	127
376-500	2		2		1	1	2	4	2	3	1	3		2	1		77
501-625		1	1	1	1		2	1	3	2	3	1	2	1	2	1	67
626-750		2	1	1	2	1	3	1	2	1	2			1		1	39
751-875	1	3		2		3		1		1						2	37
876-1000		1				1		1								2	29
1001-1125		1		1									2				12
1126-1250				1						2	1						9
1251-1375	1	1														1	9
1376-1500											1						4
1501-1625																	--
1626-1750											1						2
1751-1875																	1
1876-2000																	1
2001-2125				1													3
2126-2250																	--
2251-2375																	--
2376-2500																	1

The difference between the rows therefore is highly significant with an F value of 4.365 when the 1 per cent value is only 1.57. Although considerable variability is found within the rows, there is a tendency toward approaching uniformity in many of the rows. General observation of the nursery reveals more of the leafy type of plants and fewer of the plants that are sparsely leafed than in the 1935 or 1936 nursery.

Leaf Length and Width

Leafiness is of primary importance in a forage plant. A study of the factors tending to increase the leaf area is therefore of major importance. Exact measurements were taken of the width of ten leaves from each plant measured in obtaining data on the plants for a statistical analysis of the quantitative differences in leafiness of the different plants and progenies. Considerable difference in width of leaves was found to exist among twenty-one plants selected at random from the first generation plants measured in the 1935 nursery. The average width of the ten leaves measured from each plant is as follows:

Plant No.	Leaf Width mm.	Plant No.	Leaf Width mm.
8	9.95	145	10.80
9	6.60	146	9.10
14	7.40	151	9.60
17	6.60	156	8.70
18	9.40	174	9.25
22	8.55	183	6.50
39	8.00	191	9.60
85	7.70	196	8.80
87	7.10	199	7.10
117	8.55	200	5.30
126	8.15	M	8.23$\pm$2.017

It is observed from the above widths that some plants have much wider leaves than certain other plants. Plant No. 145 with a mean leaf width of 10.8 mm. is over twice the mean leaf width of plant No. 200 with 5.3 mm. The average width for the 210 leaves measured was 8.23$\pm$2.017 mms. The widest leaves were about 13 mm. and the narrowest were 3, 4, and several 5 mm. wide.

There was some variation between the widths of the ten leaves measured on each plant but the difference between plants was significant. The analysis of variance for width of leaves on the 21 plants is as follows:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	σ
Total	209	877.010	4.07	2.017
Between means of plants	20	357.075	17.85*	4.2249
Within plants	189	519.935	2.75	1.658

$$M = 8.23 \pm 2.017$$

$F = \frac{17.85}{2.75} = 6.5$ surpasses 1 per cent point 1.97 for 20 and 200 degrees of freedom

* Highly significant

The comparison of the average width of leaf after two years of selection and one year of selfing measurement will be analyzed for the 1937 nursery of selfed plants. Ten leaves per plant and ten plants per row for 16 rows will be considered. The averages for the ten plant rows are as follows:

Row No.	Ave. Width mm.	Row No.	Ave. Width mm.
KBB 1-3	10.21	94-1	10.24
12-11	9.94	177-25	9.84
12-25	8.94	142-21	10.75
22-7	11.04	146-23	10.12
39-16	11.10	151-12	9.21
45-40	9.56	156-3	9.22
87-19	9.83	156-12	9.58
87-28	10.04	174.2	9.17

$$M = 9.93 \pm 1.2689$$

From the above measurements a comparison of the means shows the 1937 measurements on the 1937 nursery to be 1.7 mm. wider than the mean width of the 1935 measurements. Through selection there has evidently been an increase in leaf width. The standard deviation is lower for the 1937 nursery indicating more uniformity than for the 1935 nursery plants which had not been influenced by the selection for leafiness.

The width of leaf may be of more importance than increasing the leaf area. Stapledon (35) says, "Narrow leaved forms (speaking of cocksfoot) were not as palatable to sheep as broader leafed forms." The affect of this character upon palatability will probably depend upon the species under consideration and the class of livestock to be used in grazing the pasture. Several of the wide leafed plants of Andropogon furcatus appeared to be somewhat coarse in texture.

Another character affecting leaf area which has been found to vary with different plants is that of leaf length. Leaf length measurements were made on the same plants in the 1935 nursery. The mean length of ten leaves per plant in centimeters is as follows:

Plant No.	Mean Length Cm.	Plant No.	Mean Length Cm.
8	261	126	254
9	250	145	253
14	293	146	199
17	257	151	180
18	196	156	246
22	229	174	307
39	269	183	187
85	342	191	232
87	227	196	172
117	162	199	186
		200	140

$M = 230.5 \pm 72.3$

An analysis of variance shows a high F value indicating considerable variation between means of plants.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	209	1,094,088	5,234.9
Between means of plants	20	446,137.5	22,306.9*
Within plants	189	647,950.5	3,428.3

$F = \frac{22,306.9}{3,428.3} = 6.506694$ surpasses 1 per cent point 1.97 for 20 and 200 degrees freedom.

* Highly significant

Number of Culms per Plant

The ability of certain big bluestem grass plants to produce numerous culms was thought to be a valuable character for which to select. Individual plants producing a large number of tillers or culms appeared to be more leafy, finer texture, and better seed producers. Culm counts were made on the plants of the 1935 nursery, October 23, 1935. Culm counts were made in the 1936 and 1937 nurseries for the open-pollinated and selfed plants in 1937. Since the plants in the 1936 nursery on which culm counts were made in 1937 were two years old the number was higher than would be expected the first year.

The 197 plants in the 1935 nursery averaged 27.29

culms per plant. The maximum number was 73 culms for each of two plants, Nos. 171 and 196, while the minimum was 3 culms for plant No. 20. It is of interest to note that plant No. 171 was also highest in leaf area. Plant No. 196 was about twice the average leaf area of the plants measured in 1935. Plant No. 20 was second from the lowest in leaf area.

Culm counts were made on the same plants in the 1936 and 1937 nurseries that were reported under the heading of leaf area determinations. This affords a comparison of number of culms for the rows from different parent plants. The average number of culms for the ten plants from 19 rows are as follows:

Row No.	Ave. No. Culms	Row No.	Ave. No. Culms
12	113.2	126	132.0
14	111.4	145	80.8
39	84.7	146	108.6
45	90.3	151	105.0
80	78.0	156	96.9
85	104.5	174	82.3
87	152.1	183	126.9
115	44.7	191	71.0
117	68.4	196	95.7
		199	128.2

$M = 98.7 \pm 42.6$

The number of culms in general is higher than either the 1935 counts or the 1937 counts on the 1937 nursery because the above plants were in their second year of growth, consequently, the number of culms is greater than it would be for first year plants but the relationship can be studied. The ten plants in row 87 from plant No. 87 of 1935 nursery, averaging 152.1 culms per plant, was highest. It is of interest to note that plant 87 was one of the most leafy plants and considered to be the best type for selection in 1936 of the plants in the 1935 nursery. This leafy type is illustrated by Plate I. Row 115 had the lowest average culm count of 44.7. It was grown from seed of plant No. 115 of the 1935 nursery which, when counted October 23, 1935, had only 9 culms.

A significant difference in culm count between rows for the 1936 nursery is shown by analysis of variance as follows:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	189	344,036.0	1,820.3
Between means of rows	18	120,668.5	6,703.8*
Within rows	171	223,368.5	1,306.2

M = 98.7±42.6 F = 6,703.8 = 5.13 surpasses 1 per cent point 2.12 for 16 and 150 degrees freedom.

* Highly significant

A count of culms in late August and early September, 1937 was made for the 1937 nursery. Data has been summarized for 510 plants measured. Each row of ten plants was grown from seed collected from an individual, bearing that number in the 1936 nursery. The average culm count for the different rows is as follows:

Row No.	No. Culms	Row No.	No. Culms	Row No.	No. Culms
12-4	41.1	86-11	29.1	126-39	31.4
12-11	26.5	87-19	24.2	132-45	19.7
12-24	22.4	87-28	23.9	137-12	36.3
14-3	29.2	87-30	25.8	144-2	16.4
15-1	32.4	89-5	32.1	146-8	38.4
15-7	23.5	89-11	16.7	146-23	25.0
15-36	31.1	89-13	30.1	146-31	24.2
42-2	21.8	95-7	24.1	147-16	26.0
52-2	21.1	97-9	28.8	151-16	25.1
53-18	20.4	98-14	25.1	155-1	18.2
64-8	22.7	98-23	30.2	156-3	32.9
80-10	15.7	103-2	36.9	156-12	35.6
80-24	12.7	107-1	23.0	159-32	15.4
81-4	11.0	108-10	19.3	170-62	24.3
84-8	18.2	116-19	36.2	171-11	20.3
85-11	15.5	117-25	26.1	174-5	16.6
85-17	31.2	119-12	24.6	174-16	31.3

$$M = 25.29 \pm 12.29$$

Row 12-4 gave the highest average of 41.1 culms per plant. Row 81-4 was least with 11.0 culms per plant. It is of interest that rows 80-10 and 80-24 have an average of 15.7 and 12.7 culms per plant, respectively. The original plant No. 80 of the 1935 nursery was a coarse plant with but few stems (14 culms October 23, 1935) and very wide leaves. Row No. 80 of the 1936 nursery averaged only 78 culms when the mean for the nursery was 98.7. Progeny from that one parent plant was consistently low in the number of culms per plant.

Analysis of variance which shows a highly significant difference between the number of culms for the different rows in the 1937 nursery is as follows:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	σ
Total	509	77,027	151.33	12.29
Between means of rows	50	13,791	275.82*	16.60
Within rows	459	63,236	137.77	11.73

$M = 25.29 \pm 12.29$ F = 2.002 surpasses 1 per cent point 1.57 for 50 and 400 degrees freedom. n = 510.

* Highly significant

Plants in the 1937 nursery grown from seed produced in the muslin bags used for selfing in 1936 were measured in August, 1937. The average number of culms per plant for 17 rows is as follows:

Row No.	No. Culms	Row No.	No. Culms	Row No.	No. Culms
1-3	30.3	87-19	51.0	151-12	58.2
12-11	28.0	87-28	49.5	156-3	54.3
12-25	31.7	94-1	39.9	156-12	54.8
22-7	31.7	117-25	51.3	174-2	60.6
39-16	36.4	142-21	40.6	187-25	48.7
45-40	35.8	146-23	48.1		

$M = 44.2 \pm 19.5$ n = 170 plants

Number of Rhizomes

Andropogon furcatus has the ability to spread by short underground rhizomes. This character is of considerable value to the species in making a more uniform sod especially when occurring with A. scoparius which is a bunch grass. A. furcatus does not make a dense or compact sod but is of sufficient density to hold the soil against erosion.

It was observed in the 1935 nursery that some plants produced fairly strong rhizomes and a few plants produced many fine rhizomes. Several plants did not produce rhizomes the first year to be noticeable but grew as a clump or bunch.

A count was made June 19-22, 1937 on 19 of the ten plant rows in the 1936 nursery to determine the number of rhizomes per plant. The maximum was found to be 24 rhizomes for plant No. 196-10. Plants No. 156-1 and 115-9 did not have rhizomes. The following plants had but one rhizome each: 80-5, 126-7, 151-1, and 191-1.

The average number of rhizomes per plant per ten plant row for each of the 19 rows is as follows:

Row No.	Ave. No. Rhizomes Per Plant	Row No.	Ave. No. Rhizomes Per Plant
12	7.3	126	7.9
14	9.4	145	7.5
39	8.1	146	9.4
45	8.9	151	7.6
80	9.9	156	8.7
85	13.4	174	9.1
87	7.1	183	8.2
115	4.5	191	5.1
117	7.2	196	11.4
		199	7.2

$M = 8.3 \pm 4.265$ $\quad$ n = 190 plants

Row No. 85 averaged the highest with 13.4 rhizomes per plant and row No. 115 was considerably lower with 4.5 rhizomes per plant.

There was a significant difference between the number of rhizomes for the different rows as shown by the following analysis of variance:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	σ
Total	189	3,439.0	18.195	4.265
Between means of rows	18	726.4	40.356*	6.352
Within rows	171	2,712.6	15.863	3.982

$M = 8.3 \pm 4.265$ F value = 2.544 1% level = 2.28

n = 190 plants 5% level = 1.80

* Highly significant

Size of Bunch

Although *A. furcatus* plants produce several rhizomes the second year the spread is not great, and the plant continues to grow more or less as a clump. Measurements were made on the width of the clumps in the 1936 nursery from June 19 to June 22, 1937. Each plant was measured at the base to determine the width of clump in inches. The clumps ranged from a minimum width of three inches to a maximum of eight inches.

There was a significant difference between rows as shown by the following analysis of variance:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	σ
Total	189	178.54	.94465	.9719
Between means of rows	18	56.36	3.13111*	1.769
Within rows	171	122.18	.71450	.845

M = 5.4 $\pm$ .9719 F = 4.3822 1% level = 2.28

n = 190 plants 5% level = 1.80

* Highly significant

Date of Heading

The time of seed production of A. furcatus is important for three different reasons. First, the production of seed late in the season permits a longer period of vegetative growth and the forage does not become coarse as early during the grazing season as it does when the seed is produced earlier. Second, a higher percentage of the florets contain developed caryopsis if flowering occurs after the hot winds which frequently prevail in Kansas during late July and early August. Third, the seed must be produced early enough to mature by the middle of October or it may be injured by frost.

All of the flowers of a bluestem plant are not produced at one time but average over a period of about 30 days, a few continuing to be produced until frost. In 1935 the number of inflorescences per plant was counted every ten days after each plant started to flower. The average number of inflorescences per plant was found to be as follows:

5 days after starting to flower M	=	26.6 inflorescences
10 " " " " " "	=	73.0 "
15 " " " " " "	=	89.9 "
20 " " " " " "	=	210.3 "

The emergence of inflorescences appears to be fairly regular after flowering begins. Since counting the number of inflorescences at intervals required too much time, it was decided to use the date the fifth inflorescence appeared for each plant as a comparison of earliness. Data was thus obtained for the 1936 nursery in 1937. The first plant recorded developed the fifth inflorescence on July 6, 1937. In analyzing the data the date each plant produced the fifth inflorescence was recorded as so many days after July 6. The last plant recorded was September 6 or 62 days after July 6. A few plants failed to head due to lack of vigor or other reasons but they were rare. Occasionally a plant was missed.

Data was taken on 19 rows, 11 of them being complete with all ten plants recorded. The average number of days after July 6 for each of these rows is as follows:

Row No.	Ave. No. Days After July 6 that 5th Inflorescence Appeared
12	41.0
14	49.7
39	36.8
45	42.5
85	41.8
87	49.7
115	29.4
117	41.8
145	38.9
146	39.2
174	24.7

M for all plants recorded 39.9 ± 10.68 (Ave. date was Aug. 15)

n = 171 plants

An application of analysis of variance revealed a significant difference between rows as follows:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	σ
Total	170	19,418	114.223	10.68
Between means of rows	18	7,293	405.160*	20.13
Within rows	152	12,125	79.770	8.93
$M = 39.9 \pm 10.68$	F = 5.079		1% level = 2.31	
n = 171			5% level = 1.82	

* Highly significant

The F value of 5.079 is highly significant, thereby, indicating that by selecting certain plants as a source of seed the date of flowering may be extended later into the season for the generations that follow.

Height

Measurements of maximum height at maturity were made in the 1935 nursery on October 23, 1935. The tallest plant was found to be No. 6 which was 110 inches in height. Plant No. 28 grew to a height of only 28 inches. The average height was 68.6 inches.

The height of plants at maturity was not considered to be of as much importance in developing a grass of high forage quality and yield as many other characters. Therefore only sufficient measurements were made to give some conception of the variation that might be expected.

Height of plants in the 1937 (selfed) nursery was determined August 5 to 18, 1937 at the time of leaf area measurement. This was before maturity and the plants had not attained their maximum height. The plants ranged from 9 inches to 34 inches with a mean of 23.2 ± 4.2. A significant difference was found to exist between the means of the 21 rows analyzed. The analysis of variance is as follows:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	σ
Total	209	3624.4	17.3416	4.164
Between means of rows	20	626.0	31.300*	5.5946
Within rows	189	2998.4	15.8645	3.9825
F = 1.9735			1% level = 1.88	
M = 23.2±4.164			5% level = 1.57	

* Significant

Pubescence

Considerable variation was observed in the amount of pubescence on different plants. Some were smooth and glaucous while others were very pubescent with all degrees of intergrading between the extremes. Notes were taken for three years but no definite conclusions could be obtained from the data. The data obtained was qualitative as to whether the plants were smooth, medium, or pubescent. In some instances, rows would agree with the parent plant from which they originated but in most cases there was considerable irregularity.

There appeared to be a tendency for the plants to become more pubescent the second and third years of their existence. Data obtained from the 1935 nursery for the three years is as follows:

	1935 Data	1936 Data	1937 Data
1935 nursery			
No. pubescent	50	127	13
No. medium	67	5	4
No. smooth	81	66	2
Total No. plants observed	198	198	19

It was observed in the vicinity of Iola, Kansas, June, 1936 that there was a striking tendency for the upland *Andropogon furcatus* to be more pubescent than the lowland. Dense stands of *A. furcatus* on the lowland were relatively smooth whereas that on the upland was very pubescent. The reason for this difference is not known. Shading in the dense lowland stands might have had some influence but other factors could have been the reason for the condition described.

Seed Production

Variation in the seed production of different individual plants was determined for the 1935 nursery in 1935. The number of caryopses per plant was determined by removing the glumes with a rubber mat hand-operated thresher. Five hundred caryopses from each plant were counted and weighed. The number of caryopses per plant was calculated by dividing the total weight of caryopses produced per plant by (the weight of 500) times 500.

The average number of caryopses per plant was found to be 3226. A minimum of 23 caryopses per plant was produced by plant No. 102. Plant No. 174 produced the maximum number of caryopses with 11,386.

The 1935 nursery produced an average of 6.73 grams of caryopses per plant. This ranged from some plants producing none to 23.57 grams for plant No. 174. The weight of five hundred caryopses averaged .895 but ranged from .455 to 1.41 grams for different plants. Plant No. 174 which produced the greatest weight and number of caryopses had an average weight of 1.035 grams per 500 caryopses.

Correlations

A statistical analysis of data obtained involving correlations conveniently divides itself into two groups. The first group of correlations is concerned with the tendency of plants which are high in certain qualitative characters to continue high the following year and those plants which are low to remain low. Table 4 gives a correlation for maximum height of plants at maturity using 1935 and 1936 data. The number of culms per plant at maturity for 1935 is also correlated with the number of culms which the same

Table 4. Correlations.

Correlating	Date Data was Obtained	Nur-sery	Mean for Character	S. D. for Character	No. of Plants	Corre-lation	Deviation of Correlation	Levels of Significance* 5% Level	1% Level	Conclusion
Group I										
1. Max. ht. of plant inches	Oct., 1935	1935	73	±12.8	95	.4954	±.077	.205	.267	Highly significant
with	Maturity									
Max. ht. of plant inches	Oct., 1936 Maturity	1935	60	±12.44	95					
2. No. culms per plant	Oct., 1935	1935	28.3	±16.56	197	.3449	±.045	.138	.181	Highly significant
with										
No. culms per plant	Oct., 1936	1935	57.8	±29.25	197					
3. Date fifth head appeared	1936	1935	35 days (Aug.10)	±12.57	193	.6571	±.041	.138	.181	Highly significant
with										
Date fifth head appeared	1937	1935	31 days (Aug. 16)	±9.99	193					
Group II										
1. Sq. cm. leaf area	June, 1936	1935	14,360	±93.80	94	.814	±068	.205	.267	Highly significant
with										
Oven dry wt. of leaves (gms)	Oct., 1936 Mature	1935	250.2	±95.60	94					
2. Sq. cm. leaf area	June22, 1935	1935	1296	±932	197	.288	±.0655	.138	.181	Highly significant
with										
Max. ht. of plant (in.)	Oct.23, 1935	1935	70.3	±11.4	197					
3. Sq. cm. leaf area	7-23-37 8-3-37	1937	5820	±3420	290	.405	±.049	.113	.148	Highly significant
with										
Max. ht. of plants (in.)	7-23-37 8-3-37	1937	25	±5.7	290					
4. Sq. cm. leaf area	7-23-37 8-3-37	1937	5820	±3420	300	.2193	±.055	.113	.148	Highly significant
with										
Ave. ht. of plant (in.)	7-23-37 8-3-37	1937	9.5	±3.27	300					
5. Width of leaf mm.	6-22-35	1935	8.5	±1.3	197	.184	±.069	.138	.181	Highly significant
with										
Sq. cm. leaf area	6-22-35	1935	1296	±932	197					
6. Oven dry wt. leaves (gms)	Oct., 1936	1935	249.2	±98.4	96	.2814	±.094	.205	.267	Highly significant
with										
Max. ht. of plant (in.)	Oct., 1936	1935	64.0	±12.3	96					
7. Max. ht. of plant (in.)	10-23-35	1935	68.3	±17.22	194	.4965	±.054	.138	.181	Highly significant
with										
No. culms per plant	10-23-35	1935	28.3	±16.11	194					
8. Max. ht. of plant	10-22-36	1935	64	±12.3	95	.8505	±.028	.205	.267	Highly significant
with										
Ave. lt. of internode	10-22-36	1935	12.67	±4.23	95					
9. Leaf area in sq. cm.	1936	1935	1680	±950	195	.1462	±.07	.138	.181	Significant
with										
No. days after July 1 that fifth head appeared	1936	1935	42 days (Aug. 11)	±12.69	195					
10. Leaf area sq. cm.	7-23-37 8-3-37	1936	27,325	±10,875	167	.3043	.0057	.159	.208	Highly significant
with										
No. days after July 6 that fifth head appeared	1937	1936	41.7 (Aug. 17)	±11.55	167					
11. Wt. of leaves	10-23-36	1935	252.20	±98.0	95	.3938	±.087	.205	.267	Highly significant
with										
Wt. of inflorescences	10-23-36	1935	33.80	±16.25	95					
12. Leaf area sq. cm.	6-22-35	1935	1296		197	.585		.138	.181	Highly significant
with										
No. caryopses per plant	Oct., 1935	1935	3226		197					

* From Table 7 12, Statistical Methods by Snedecor (43).

plants produced in 1936. A third correlation, involving two different years, measures the earliness of heading or the date the fifth head appears on identical plants in 1936 and 1937. All of these correlations are significant. Each individual plant of <u>Andropogon furcatus</u> tends to have about the same habit of growth each year in regard to height, ability to produce culms, and earliness.

The second group of correlations is concerned with the interaction of characters or the tendency for certain characters to be associated together. The first correlation of this group, and one of the highest, correlates leaf area with the weight of leaves. This correlation is highly significant and lends much encouragement to the use of the leaf measurement method for determining leafiness.

Leaf area in June and maximum height of plant at maturity gives a correlation of .288. This is rather low and might be attributed more to the effect of a difference of vigor in the different plants than an association of the characters. However, the correlation is significant. The third correlation under Group II is somewhat higher than the second correlation. This difference can be attributed to the time measurements were taken. In the first instance height was measured at the maturity of the plant and leaves did not extend to the top of the plant. In the case of the higher correlation (.405) of No. 3, measurement of height was made in late July to early August. The first year plants were in the most leafy stage at this time and in most cases leaves extended to the top of the plant.

To obtain data for the fourth correlation, measurements were taken of the average height to which the bulk of the leaves extended. The difficulty of getting measurements uniform and comparable because the plants are of different types makes this method less satisfactory than to measure maximum height at the most leafy stage of the average plants. This method gave the highest correlation (No. 3) and when there is not sufficient time to make leaf measurements it will give some indication of the relative merits of the plants regarding leafiness but more the difference in vigor.

The correlation of width of leaf and leaf area (No. 5) is rather low ($r = .184$) because width is only one of the factors influencing area. Length of leaf and number of leaves is probably more important. Correlation No. 6 of leaf weight to maximum height of plant at maturity corresponds to correlation No. 2, the difference being in weight measurement instead of leaf area. The value of r is practically the same and probably results from a difference in plant vigor.

Maximum height of plant correlated with average length of internode (No. 8) is highly significant ($r = .8505$). Since there is one leaf for each node the number of nodes per culm influences leafiness, while the length of the internodes affects the height of culm.

The desirability of obtaining a strain of _Andropogon furcatus_ which remains leafy later in the season and produces seed later in August has been mentioned. Correlations No. 9 and 10 where r = .1462 and .3043 respectively show some relationship between leafiness expressed as leaf area and date the fifth inflorescence appears denoting lateness. There is a significant correlation (r = .3938) between the weight of leaves and the weight of inflorescences. Also correlation No. 12 (r = .585) involving leaf area and the number of caryopses per plant is significant. These two correlations indicate the possibility of obtaining plants which are high in leafiness and seed production. This combination is sometimes difficult to obtain in certain forage grasses but appears to be possible with _Andropogon furcatus_.

Source of Seed Studies

Seed was obtained from several sources to determine the variability that might be attributed to different habitats from the northern part of the Great Plains to the southern Great Plains. Seedlings were planted in the 1936 nursery in the spring of 1936 from three sources, viz., Holt County, Nebraska; Anderson County, Kansas; and Guthrie Oklahoma.

Measurement of leaf area in 1937 for twenty-four plants from each source is as follows:

Holt County, Nebraska 1398±1044 sq. cm.

Anderson County, Kansas 1969±544 sq. cm.

Guthrie, Oklahoma 1604.5±836 sq. cm.

The plants of Oklahoma origin grew near plants of <u>Andropogon hallii</u> and the competition probably prevented the plants from attaining their maximum leaf area. Later observations revealed the fact that plants of southern origin in general are more leafy than plants of northern origin. The Nebraska plants had the smallest leaf area but the greatest variation as shown by a large standard deviation.

The analysis of variance for leaf area data in 1937 from source of seed study in 1936 nursery is as follows:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	71	60,641,728	
Between means of rows	2	10,491,735	5,245,868*
Within rows	69	50,149,993	725,362

$F = \frac{5,245,868}{725,362} = 7.23$ surpasses the 1 per cent point 4.92 for 2 and 70d. f.

* Highly significant

Considerable difference in the relative earliness of seed production was found for plants from the three different sources. The average number of days after June 22, 1937 that the fifth head appeared for the different sources is as follows:

Holt County, Nebraska (16 plants) M = 20.7±10.5 (about July 13)

Anderson County, Kansas (11 plants) M = 42±8.15 (about August 3)

Guthrie, Oklahoma (20 plants) M = 58.2±14.5 (about September 19)

The plants of northern origin are significantly earlier than those of southern origin.

Analysis of variance for date* first five heads appeared for southeast Kansas, Nebraska, and Oklahoma accessions, 1936 nursery, 1937 data is as follows:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	46	18,297	
Between means of groups	2	12,510	6255.0**
Within groups	44	5,787	131.5

F = 6255/131.5 = 47.5 which surpasses 1 per cent level of 5.12 for 2 and 44 degrees of freedom.

* Number of days after June 22, 1937 that fifth head appeared.
** Highly significant

The height of individual plants grown from seed of different sources and transplanted to the Soil Conservation

Grass Nursery, Manhattan, Kansas is given in Table 5. Average height for the plants of the northern sources in North Dakota, Michigan, and Nebraska is less than the average height of plants from Kansas and Oklahoma. The average for ten foot rows is from three measurements made on rows with a stand sufficient to test the plants under competition. There is a significant difference in height of the plants from different sources. Height tends to be increased as seed is collected farther south in the plains section.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	92	12,298	
Between sources	11	3,343	303.9*
Within states	81	8,955	110.56

F = 303.9/110.56 = 2.75 surpasses the 1 per cent point 2.48 for 11 and 81 degrees of freedom.

* Highly significant

SUMMARY AND CONCLUSIONS

<u>Andropogon furcatus</u>, big bluestem, has been one of the most valuable native grasses for pasture and hay in the tall grass or prairie region of the United States. It deserves attention in removing land from crop production and establishing a satisfactory cover of grass. Considerable

Table 5. Height frequencies of big bluestem plants grown from seed of different sources in Soil Conservation Nursery, Manhattan, Kansas. October 20, 1937.

Class Range Inches	G14 North Dakota	G11 Detroit Michigan	G13 Lincoln Nebraska	G19 Kingman Kansas	G18 Hutchin- son, Ks.	G15 Manhattan Kansas	G111 Manhattan Kansas	G112 Anderson Co., Ks.	G10 Nowata Okla.	G12 Guthrie Okla.
32-35	1	1				1		2		
36-39				1				1		
40-43	1	4	1				1	3	1	
44-47		4					1	6		1
48-51		3		1		1		3	1	1
52-55	1	1		2	1	2		3		2
56-59				2		2		5	1	2
60-63					1	1	1	4		1
64-67					2		2	2		1
68-71						1		2	1	
72-75							1	1	1	1
76-79										
80-83										1
84-87										
88-91										
92-95										
Ave. for individu- al plants	43	45	42	50½	52 4/5	54 3/4	51 3/7	53 3/4	57 4/5	59½
Number plants	3	13	1	6	4	8	6	32	5	10
Ave. for 10 rows	34	40	38	--	--	--	44	51	60	56

improvement can be accomplished by selection and breeding to produce strains of Andropogon furcatus which will be more valuable than the extremely heterozygous forms which occur in nature.

Studies in the variation of certain characters such as leafiness, height, seed production, number and length of rhizomes, and earliness carried through three generations indicate a very heterozygous condition of plants obtained from a natural habitat. The range was wide for all of the characters and no lines were homozygous.

Leafiness which is of primary importance in a good forage plant can be determined accurately by measuring the width and length of ten leaves, counting the number of leaves per plant and determining the leaf area in square centimeters. The best measurement of earliness in seed production is the date the fifth inflorescence emerges. Both of these methods give data which can be analyzed statistically.

Individual plants were selected for certain characters and the seed produced under open-pollination was planted in a manner to produce ten individual plants from each parent. Statistical analysis of these ten plant rows revealed a highly significant difference between the rows in regard to leaf area, number of culms, height, earliness, and number of rhizomes. This indicates the possibility of obtaining superior strains by selection under open-pollination.

An ideal plant of Andropogon furcatus should be leafy (10,000 square centimeters of leaf area in July of the second year); fairly late in producing seed (fifth inflorescence appearing about August 25); spreading by rhizomes (clump size of 6 to 8 inches the second year); of fine texture; resistant to grasshoppers, chinch bugs, leaf rust, and smut; and high in seed production (500 to 700 racemes, 60-70% of florets containing mature caryopses, and germination of 60-70%). These represent the maximums and such a strain can probably be attained only by ten or twelve years of selection and strain building.

Analysis of variance gave a highly significant difference between rows of individual plants originating from seed of different sources. Plants of Kansas and Oklahoma origin were more leafy, later, and taller than plants grown from seed collected in Nebraska, North Dakota, or Michigan. This difference in response to growing conditions in the nursery can be attributed to the effect of natural selection in the habitat from which the seed originated. The more northern habitats have a shorter growing season, therefore the plants are earlier and make less vegetative growth when moved southward. Plants of the Oklahoma-Kansas type are more leafy and later in producing seed. They are more desirable for forage production. None were observed to have winter killed.

Correlation of characters indicate that plants with a large leaf area tend to be taller. This can probably be attributed to greater vigor. An exceptionally high correlation of leaf area to oven dry weight of leaves lends encouragement to the use of leaf area as a measure of leafiness and yield. A significantly high correlation of leaf area to a later heading date indicates the possibility of obtaining a strain which is leafy and late in heading, thus permitting a longer grazing season with seed production occurring after the hot winds of July and August. A highly significant correlation was found between leaf area and the number of caryopses per plant. Leafy plants tend to produce more caryopses per plant.

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Plate I

Variation shown in bluestem parent plants. KBB74, small, erect bunch; very wide, medium to coarse blades, fairly short; culms, thick, sheaths densely pubescent, rhizomes few (1 and short), leaves sparse (medium to very slightly grayish green).

KBB87, very large, dense bunch, leaves overhanging; blades long, medium width and very fine texture, bright green; culms, fine and thin, sheath medium pubescent. One of leafiest big bluestem plants in nursery. Rhizomes several, medium to short length. A desirable plant. (Photograph No. C6265, taken 6-12-36)

Plate I

Plate II

Growth types of big bluestem plants. KBB1, very coarse, wide leaves; culms coarse and thick, rhizomes vigorous and numerous. Undesirable as forage plant because of coarseness. Desirable for spreading ability.

KBB40, fine texture and leafy. Desirable as a forage plant. Rhizomes few and but little spread. (Photograph No. C6261, taken 6-12-36)

Plate II

Plate III

Showing differences in time of maturity of big bluestem plants grown from seed collected in Kansas, Nebraska, and Oklahoma. (Photograph No. A8197, taken 9-24-36)

Kansas plant - leafy and late
Nebraska plant - early and sparsely leafed
Oklahoma plant - very late and leafy

Plate III

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