A STUDY OF THE VARIABILITY IN NATIVE FORAGE GRASSES AND ITS RELATIONSHIP TO SOURCES OF COLLECTION

by

MARVIN CARL ANDREW LUNDQUIST

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INTRODUCTION

Native forage plants are widely variable in many characteristics. Study of this variability and its possible relation to the conditions under which the plants occur in their natural habitat is of importance in the discovery of new and superior materials and in the future planning of further exploration and collection.

The importance of improved strains of plants in the agriculture of the nation is generally recognized, but far less attention has been given to the grasses than to the cultivated crops. Especially is this true of the native forage species. The current need for grass strains for reseeding depleted lands and for soil improvement, for erosion control, and for increasing forage production on farms and ranches in general has lent emphasis to the relatively new field of grass improvement.

Collection and the study of variability in true prairie species have been extremely limited. The plant breeder has, therefore, been limited by the available range of variability within which to select for improved strains. This study has been an attempt to bring together materials from areas not heretofore sampled, to select strains or individuals of potential value in strain improvement, and to examine the relationships between the behavior of the materials collected and the habitats from which they have been obtained.

REVIEW OF LITERATURE

Permanent grassland constitutes approximately 40% of the land area of Kansas. It is evident that grass is an important factor of the Kansas economy. Aamodt (1) stated that of the home produced feeds, pasture contributes the greatest amount of nutrients. In spite of the large acreages, overgrazing has depleted much pasture land to the extent that it can be restored to maximum carrying capacity only by reseeding. Improved strains of grasses are needed for this. Cardon (5) pointed out that because the soil erosion problem was so accute the Soil Conservation Service workers had expressed a hope that plant breeders could develop improved strains of pasture species possessing soil binding properties. Increased emphasis is now being placed on native range grasses for soil conservation.

Increase in forage yields through the use of superior strains and recommended grass mixtures is recognized. Cornelius (6) found that mixtures of improved strains of Andropogon gerardi, Bouteloua curtipendula, and Panicum virgatum, together with some Sporobolus asper, produced twice as much forage as average stands of native grass in pastures. According to Newell (19), Andropogon gerardi appeared in tests to have the greatest potential yield of any of the species tested in a three year evaluation study. Strains with greater leafiness, greater number of culms, later maturity, improved disease resistance, and increased seed and forage yields have been developed (3, 7, 10, 14, 17, 18, 19, 24, 27, 29).

Variations have long been observed in grasses and have been used in strain improvement (32). As emphasized by Turesson (31) and Vavilov (32), the widest range of variability in a species is encountered in the heart of its native habitat. Sampling the forage species in the grasslands where they occur naturally affords opportunity to study this wide range of variability. Anderson and Aldous (3) stated that knowledge of variability is essential to strain improvement. Evans (7) has pointed out that in 1889 Hays selected plants and observed wide variations in Phleum pratense, and that more than a century ago Sinclair recorded attempts to improve Lolium perenne through selection. Variations are common within lines as well as between lines. Harlan (9) stated that the difference between strains is sometimes extraordinary, particularly in warm season grasses. Hopkins (12) and Kish (14) both emphasized variation as a factor which in nature produces plants of increased survival value. Working with Panicum virgatum, Nielsen (21) indicated that of the lines selected in this species, one-half differed significantly from one another. Pickett (22) found that in Bromus inermis yield differences among plants were significant in more than half of the families analyzed. He found that differences in yield of individual plants within certain families were as great as the differences among unrelated families. However, Warmke (33) showed that even before being transplanted to the field, seedlings of Panicum species showed

remarkable uniformity within progeny and some striking differences among groups which continued throughout the period of field growth. Anderson and Aldous (3) stated that in Andropogon scoparius variation between types was greater than that within types, but they also noted that when habitat types or strains from a particular area were studies more closely they were found to be quite variable within themselves. Evans (7) also pointed this out in Phleum pratense.

Many theories have been proposed to explain the source of variation. Many had considered it to be a reaction to environment. One phase of a study by Reigel (24) was made to determine whether variations in Bouteloua gracilis were hereditary or the products of environment. These variations have puzzled field men in making range reconnaissance surveys and have led to the belief that several species of Bouteloua had been encountered. Investigation, however, proved these to be variations within the one species, modified by difference in climatic conditions. Ecotypic variations have been shown in such cases as in Reigel's work. It is only through careful study of individual plants and progeny groups that questions such as these can be answered.

Law and Anderson (18) showed that ecotypes of Andropogon gerardi from the north were smaller, less leafy, and earlier than native Kansas materials. Southern strains on the other hand, were leafier and considerably later in heading than the Kansas strains. Anderson and Aldous (3) demonstrated that Andropogon scoparius behaved in the same manner. Other workers

have reported similar findings (7, 9, 11, 19, 28).

It has been shown by Turesson (31) that habitat groups tend to differ from one another. These habitat groups he termed ecotypes. The differences were considered to be hereditary, having been established by natural selection, as shown by Hopkins (12) and Kirk (14). Fults (8) noting variation in Bouteloua, agreed that plants grown from different seed sources produced distinctive types. He stated that this fact indicated a high degree of adaptation to particular habitats and was a factor that should be carefully considered in the domestication of such species as the Bouteloua curtipendula and B. gracilis.

Extreme, localized variations have been found in some species. Turesson (31) termed such local variates, ecophenes, which, he stated, are habitat modifications of ecotypes. Similar local differences have been reported by Harlan (9) in Bouteloua gracilis. He noted that in the Capitan Mountains of New Mexico collections obtained as little as a half mile apart often showed striking differences, although the B. gracilis stand was nearly pure and continuous between the sources. Similar occurrences have been observed in other grasses. Rice (23) found that Andropogon scoparius differed on adjacent areas such as slopes and hill tops in the same region. Webb (36), working with Buchloe dactyloides near Hays, Kansas, noted considerable variation in growth forms and habits.

Research has indicated that these variations are hereditary. Bird (4) stated that perhaps variability in disease resistance

was due to genotypic differences. Harlan (10) stated that Bouteloua curtipendula, for the most part, was cross-pollinated and highly variable. Because of variability in chromosome number, the likelihood of producing viable seed was reduced. Law and Anderson (18) stated that even though the plants did look much alike the diversity of the genetic makeup was great. They termed the variation as genotypic and also due to chromosome number differences because of cross-pollination, hexaploidy, and tetraploidy. In Andropogon gerardi, Law and Anderson explained that the variability was due to the polyploid nature of the species and to its hybrid origin. They stated that statistical analysis indicated the variability in leaf area to be due, in large part, to genetic differences in the plant. Fults (8) stated that since plants grown from seed from different localities were distinctive and were able to maintain their characters for as long as five years when grown in one environment, their chromosomes undoubtedly had structural differences. Kreitlow and Myers (16) found Festuca elatior var. arundinacea with 42 chromosomes to be resistant to crown rust, while Festuca elatior, with a chromosome number of 14, was susceptible. Nielsen (21) stated that widespread occurrence of polyploidy in grass is known and that tetraploid and octoploid races of Panicum virgatum have been found in Kansas and Oklahoma. He showed Panicum virgatum to have diploid, hexaploid, decaploid and 12-ploid segregates. Each of these segregates gave rise to different strains. He noted that isolates having higher chromosome

numbers tended to have smaller basal areas than those of isolates with lower chromosome numbers. He stated, however, that reference to the sources of the material from which these isolates were obtained gave no indication of regional segregation of type on the basis of chromosome number. In analyzing the variability in Bouteloua gracilis, Riegel (24) concluded that apparently the variations exemplified by the different groups of plants were hereditary. Warmke (33) noted that in the Panicum species inheritance was the major factor in variability. He concluded that the autohexaploid form had greater chromosomal abnormalities and more nondisjunction than the tetraploid.

Some studies have indicated that a certain amount of the variation in growth form may be due in some part to competition. Ahlgren and Aamodt (2) stated that differences due to species interactions could not be accounted for on the basis of differential response to light and other factors. Weaver and Darland (34) recognized this in their study of vigor in range grasses. They reported differences due to overstocking.

Relation of Evaluation and Improvement Programs

Selection. Smith (25) emphasized that the testing of new grass strains is influenced greatly by the ultimate use to which they are put. He also pointed out that at present the major concern is isolating better plants and combining these into superior strains. The selection of superior individuals is the most important method of accomplishing this.

Evans (7) employed the method termed "selection with open-pollination" in which a selection for desirable characteristics is made. The seed of these selections is planted. The progeny are propagated by clones and again selected. Wright (37) noted, however, that although there must be careful selection, a process which is too severe may destroy the field of variability. Kirk (15) noted that to obtain strains which will persist under varied conditions it is necessary to bring together as wide a range of selected genotypes as possible. Newell and Tysdal (20) stated that in the selection of individual plants the broadest range of gene population should be secured. Stapledon (26) outlined a grass breeding program with emphasis on finding and standardizing highly desirable regional strains.

Strain Building. The term strain building was used by Kirk (15) in 1933 to include any system of mating by which a strain is built up from carefully selected plants by crossing. As outlined by Stevenson (27), this method involved the composite crossing of a number of parent plants which had been carefully selected on the basis of type and breeding behavior. He further pointed out that evaluation of the original selections was an important feature of strain building. He concluded that strain building should be considered a continuous process whereby better parent material was being uncovered from time to time and the new strain constantly being reconstructed with the best parental materials available. These considerations have influenced the evaluation of native prairie species in this study.

Strain Fixation. Along with strain building and in the same category, more recent work has advanced the term "strain fixation" (Harlan 10). He succeeded by means of selection, in fixing growth form, late flowering, and broad and narrow leaf in Bouteloua curtipendula. Progeny were reselected without regard to chromosome number. Correlation between the growth form of the individuals in a progeny group and that of the parental type was demonstrated.

Mass Selection. This type of selection is similar to individual selection but it has been dealt with separately in the literature. In discussing mass selection, Kirk (15) stated that ecotypes tended to be phenotypically uniform but genetically more or less heterogeneous, depending on the stability of the habitat. He further pointed out that by mass selection one can take advantage of natural selection. Stevenson (27) noted that mass selection as a method of improving cross-fertilized species is probably of greatest value in taking advantage of ecotypes which have, as a result of natural selection, become relatively homozygous with respect to certain characteristics. Kirk (15) stated that to obtain strains that will survive under varied conditions it will be necessary to bring together as wide a range of selected genotypes as possible. Law and Anderson (18) noted that strain building included careful selection, inbreeding, and recombination. Newell and Tysdal (20) stated that in preliminary testing of grasses representing ecotype selections or strains from farmers' fields, differences sufficient to warrant

the increase and use of these naturally occurring strains have been found.

Individual Characteristics

Each character must be studies separately to evaluate the over-all desirability of any plant or progeny group. This has been demonstrated by many workers (3, 4, 7, 10, 18, 22, 30, 33). Certain characteristics appear to be associated in linkage groups. This will add to the difficulty of improvement if strong linkage between desirable and undesirable genes occurs. However, linkage groups association may be desirable if the strong linkage is between desirable genes.

Leafiness. Leafiness is an important factor in quality. Anderson and Aldous (3) showed that by means of selection it was possible to decrease variability in leaf area. Law and Anderson (18) stated that leaf area of Andropogon gerardi was increased twelve-fold by means of selection and that greater uniformity was achieved. Harlan (10) stated that broad and narrow leaf characters were readily stabilized in Bouteloua curtipendula. Due probably to linkage, coarse leaved plants usually were later in flowering and more susceptible to rust than were fine-leaved individuals. Practically all late flowering progeny had broad leaves and the broad leaved ones usually had a blue-green color. The fine leaved ones were yellow-green in color. However, he emphasized that fixation of abundant leaf was more difficult. Pickett (22) showed by statistical analysis that

yield and leafiness were positively correlated. Rice (23) and Warmke (33) indicated that a close association existed between floral and leaf development.

Disease. Disease is a problem of great importance. Bird (4) found rust to be a factor in yielding ability of strains, the large majority of improved strains showing marked resistance. He further indicated that some plants were able to withstand a given amount of infection with much less injury than others. Evans (7) noted that rust resistance in Phleum pratense was secured by selection.

Seed Head Production. Seed head production was one of the characteristics noted in this study of materials collected in Kansas. Rice (23) had showed disease reaction to be closely associated with seed production. Increased seed production can be achieved by selection for improved vigor and increased number of seed stalks and by selections for maturity dates favorable to blossoming and seed development. Harlan (10) stated that fixation of late flowering was easy in Bouteloua curtipendula. In Andropogon scoparius, Law and Anderson (18) noted that the later strains were more productive of seed because the early ones often were blasted by hot summer winds.

MATERIALS AND METHODS

Objectives and Methods

Native forage grasses are characterized by extreme variability. In order to study the variations in important agronomic

characters of Andropogon gerardi Vitman, A. scoparius Michx., Panicum virgatum L., and Sorghastrum nutans (L.) Nash and to discover, if possible, superior plants or progeny groups, field samples collected in the fall of 1949 from a wide area in southeastern and south central Kansas and adjacent counties in Missouri and Oklahoma were grown in field plots at Manhattan, Kansas.

Variability among plants within progeny groups, among progeny groups from different localities, and among groups from different sites have been studied. It is the purpose of these trials to find, if possible, materials of value in grass improvement and to make these available to plant breeders, but also to study variability due to sources of collection and to sites from which the collections have been obtained. This may aid in planning further field collection of native materials.

The seedlings had been started in vermiculite in greenhouse flats early in 1950, each accession in an individual planting band, and transplanted to flats of soil when they had attained a height of approximately two inches. Transplanting to the field was done in May 1950, the plants by then having attained a height of 3 or 4 inches.

For the purposes of this study, field plantings were of individual plants, 20 to the accession, spaced 36 inches apart each direction. Rapid establishment after transplanting was favored by the rather ample rains which followed. Space limitations prevented the planting of replicated rows of these progeny groups or accessions.

During July and August of 1950, field notes were taken on the following characteristics: aggressiveness, color, freedom from leaf diseases, earliness, erectness, fineness of stem and leaf, height, leafiness, production of seed heads, and vigor. Also included were notations of any special or unusual characteristics. These field notes or scores were based on a scale of 1 through 9 after the manner of Newell and Tysdal (20), the approximate values employed here being as follows: 1-excellent, 3-good, 5-average, 7-fair and 9-poor. Notes for each accession were taken on the row as a whole from an over-all observation of the entire progeny group. In addition, field notes were obtained on selected individuals, the progeny of which were to be grown in 1951.

During the summer of 1951 field notes were again taken as in 1950 but on single plants rather than whole progeny groups. Earlier studies have shown that by their second year of growth, plants will have become well established and will, therefore, be more likely to supply reliable data on which to base selection (17). These individual plant notes furnished records for the plants which might be selected for increase. In addition to the notes on individual plants, plant parts were measured to study quantitatively the range of variability employing a 5% sample of the population consisting of one plant taken at random from each nursery row. The range of measurements for each characteristic was divided into 9 equal segments to permit their conversion to scores 1 to 9, employed in taking the field notes.

Materials had been selected from native range in different types of situations, herein termed range sites or merely sites. These were ordinary upland, sandy prairie, and lowland sites. ordinary uplands are sites upon which the true prairie climax has been attained. Lowland sites are favored by abundant moisture and thus support a postclimax prairie vegetation. The sandy prairie sites in this study have somewhat sandy soils of sandstone origin and often support a savanna climax. The sand sites are the sands and sandy soils of south central Kansas where dunes are commonly formed following depletion of the forage. Mid and tall grasses dominate the climax on these sand sites. The sites were further subdivided on the basis of whether or not they had been used for grazing.

Statistical Analysis

Analysis of variance was calculated to detect possible differences among the progeny of materials collected from different sites or between those from grazed and ungrazed portions of sites.

The 1950 data were based on progeny groups. To compare accessions, the field note ratings of the various characteristics of each were added to furnish a single numerical value for purpose of analysis of variance. Since not all the accessions could be included in the analyses, a randomized sample of the progeny groups was taken. In a few cases, insufficient numbers of accessions caused the elimination of whole site groups or

made necessary the combining of the materials from grazed and ungrazed portions of sites for certain analyses. The 1951 data were analyzed on the basis of individual plants chosen at random from the accessions. Four plants were selected at random from each accession. The accessions were selected at random from each species to represent the sites. From 6 to 12 accessions per site were used depending on the total number of accessions from a particular site. Accessions for the grazing studies were selected at random from these. In certain instances, sites had too few accessions to permit their being included in the analysis. Whenever differences statistically significant were observed, calculations of least significant differences (L. S. D.) were made to aid in the comparisons of the groups or individuals in question. On the basis of these L. S. D. determinations, certain groups have been set apart as differing significantly from the population as a whole.

To determine if progeny groups from which plants had been selected as superior individuals actually differed from the population as a whole, the accessions were divided into 3 groups for comparision, (a) those from which more than 2 plants had been selected, (b) those from which 1 or 2 plants had been selected, and (c) those from which none had been selected. Field ratings for freedom from leaf diseases, leafiness, and vigor during the 1951 season were totaled to give a single value for the comparisons. Certain plant part measurements were analyzed to compare plants from the different sites or situations.

Field notes and observations had suggested the occurrence of correlation between certain characteristics. In order to test this, correlation coefficients were calculated. To ensure a representative test, whole progeny groups from accessions selected at random from all sources were used in the study. In addition a study was made in Sorghastrum nutans to determine if the southern strains within the collection area were more more desirable vegetatively than those selected farther north. In addition, strains from eastern and western portions of the collection area were compared.

EXPERIMENTAL RESULTS

Statistical Studies on Andropogon gerardi

1950 Progeny Group Analysis. Analysis of variance based on 1950 progeny group field notes was calculated to study the effect of sites and grazing, as well as interaction.

Table 1. Analysis of variance of the 1950 scores of progeny groups of Andropogon gerardi.

Sources of variation	D/F	SS	MS	F
Sites	3	337.28	112.43	5.72**
Grazed vs. Ungrazed	1	.22	.22	
Site x Grazing	3	25.28	8.42	.43
Accessions or error	32	629.20	19.66	
Total	39	991.98		

**Significant at 1 percent level.

From Table 1 it can be seen that there occurs a highly significant difference among the sites, showing that the variation among these sites is great enough to indicate different populations. Further study of the table shows there is no significant interaction between site and grazing effects nor is the variation between the grazed and ungrazed accessions great enough to be significant.

The scores or rating values used for the analysis indicate that the sand sites had produced plants significantly less desirable on the basis of the characteristics studied while, although the lowland site accessions were observed to be more desirable, they were not significantly different from the sandy prairie or ordinary upland materials.

1951 Progeny Plant Analysis. Field notes were taken in 1951 on individual plants for the characters, disease, earliness, fineness, leafiness, and vigor employing the same rating values used in 1950. These were totaled to give a single composite value for calculation of analysis of variance.

Table 2. Analysis of variance of the 1951 scores of progeny plants of Andropogon gerardi.

Sources of variation	D/F	SS	MS	F
Sites	3	777.02	259.00	20.02**
Grazed vs. Ungrazed	1	2.26	1.13	
Site x Grazing	3	34.02	11.34	
Accessions	32	568.90	17.78	1.37
Plants, same site, accessions, and grazing	120	1554.25	12.95	
Totals	159	2936.45		

Table 2 indicates that there is not enough difference among any of the sources of variation except sites to warrant grouping the plants into different populations. From these 1951 data it could be concluded that there was as much variation among the individuals within accessions as among accessions and between grazed and ungrazed groups.

A comparison of the scores used in evaluating the plants showed that materials from sandy prairie and lowland sites were significantly superior to those from the sand sites. Ordinary upland material is also significantly inferior to sandy prairie or lowland materials.

Selected Progeny Groups. Progeny groups from which varying numbers of superior individuals had been selected were compared by means of analysis of variance. Groups having provided 3 or more selected plants were compared with those having provided 1 or 2 and with those from which none were selected.

Table 3. Analysis of variance of 1951 selected progeny groups of Andropogon gerardi.

Sources of variation	D/F	SS	MS	F
Groups	2	340.82	170.41	8.35**
Accessions, within groups	12	244.80	20.40	2.63**
Plants or error	105	814.75	7.76	
Totals	119	1400.37		

The analysis summarized in Table 3 furnished evidence that the selected progeny groups displayed sufficient variation to

be considered different populations. It could be concluded from this that there was sufficient difference among the three categories to consider them as separate populations. Also it can be noted from this analysis that the accessions themselves are significantly different.

A comparison of the scores on the basis of calculated least significant differences that the groups contributing 3 or more selected plants were significantly more desirable than those in which selections were fewer than 3 per accession group. Also, the groups contributing 1 or 2 plants were significantly superior to those having contributed none.

Correlation Studies. Correlation coefficients between the characters, disease and earliness were calculated. In the field it had appeared that late-maturing plants tended to be relatively freer of disease than early ones. Statistical analysis did not wholly confirm this, because certain accessions did tend to exhibit a significant correlation while others did not. Certain accessions actually showed significant negative correlations.

Correlation between disease and leafiness, disease and vigor, and between vigor and leafiness showed the same type of relationship as those between disease and earliness.

Statistical Studies on Panicum virgatum

1950 Progeny Group Analysis. Analysis of variance based on the 1950 progeny group field notes was calculated in the same manner as for Andropogon gerardi.

Table 4. Analysis of variance of the 1950 scores of progeny groups of Panicum virgatum.

Sources of variation	D/F	SS	MS	F
Sites	3	96.06	32.02	
Grazed vs. Ungrazed	1	45.37	45.37	
Site x Grazing	3	40.53	13.51	
Accessions or error	16	924.00	57.75	
Total	23	1105.96		

From this analysis there is no indication of such differences due to site as were found for A. gerardi. Difference among the sources of variation were not great enough to warrant considering the groups as different populations.

Though significant differences couldn't be established statistically, field observations indicated that sandy prairie and lowland site groups of P. virgatum were somewhat superior to the other materials.

1951 Progeny Plant Analysis. Field notes were taken in 1951 on the characters, color, freedom from leaf diseases, earliness, erectness, fineness of leaf and stem, leafiness, seed head production, and vigor, employing the same rating values as in 1951. These were totaled to give a single composite

value for calculation of analysis of variance.

Table 5. Analysis of variance of the 1951 scores of progeny plants of Panicum virgatum.

Sources of variation	D/F	SS	MS	F
Sites	3	249.12	83.04	
Grazed vs. Ungrazed	1	17.52	17.52	
Site x Grazing	3	229.69	76.56	
Accessions	16	2192.17	137.01	8.60**
Plants, same site accessions, and grazing	72	1146.75	15.93	
Totals	95	3835.25		

This progeny plant analysis indicates the occurrence of highly significant differences among accessions. Not enough variance was found among progeny groups delineated on the basis of sites and grazing to be significant.

Observation of the scores used in the analysis indicated that significantly different accessions were found in all the sites except sandy prairie. Field observations indicated that the greater number of desirable plants occurred in the lowland and sandy prairie materials.

Selected Progeny Groups. Progeny groups and accessions delineated on the basis of the number of selected individuals occurring in each were compared by means of analysis of variance calculated from 1951 individual plant notes or scores.

Table 6. Analysis of variance of 1951 selected progeny groups of Panicum virgatum.

Sources of variation	D/F	SS	MS	F
Groups	2	91.22	45.61	2.39
Accessions, within groups	12	228.90	19.07	2.89**
Plants or error	105	691.75	6.59	
Totals	119	1011.87		

The analysis in Table 6 indicates that in Panicum virgatum there occur significantly different accessions but that there was not enough difference among the selected groups of accessions to be significant. Significant differences among accessions were found in all groups.

Correlation Studies. Correlation coefficients were calculated for the characters disease and earliness. Statistical analysis did not show a consistent correlation. As in the other species, certain accessions tended to exhibit significant positive correlations while others showed no correlation at all, and still others showed significant negative correlations.

Statistical Studies on Andropogon scoparius

1950 Progeny Group Analysis. Analysis of variance based on 1950 progeny group field notes was calculated in the same manner as for the previous species.

Table 7. Analysis of variance of the 1950 scores of progeny groups of Andropogon scoparius.

Sources of variation	D/F	SS	MS	F
Sites	3	135.75	45.25	
Grazed vs. Ungrazed	1	136.33	136.33	1.95
Site x Grazing	3	208.92	69.64	3.34*
Accessions or error	24	501.00	20.87	
Totals	31	982.00		

*Significant at 5 percent level.

In this study there is a significant difference in variance among sites with regard to the effects of grazing, as shown by the site x grazing interaction. There was not enough variation among sites, however, to be significant.

The scores used in the analysis indicate that grazing had had a significant effect in the sand and lowland sites. Field observations indicated the presence of superior plants in the sandy prairie and lowland sites.

1951 Progeny Plant Analysis. Field notes were taken in 1951 on individual plants for the characters disease, earliness, erectness, fineness of stem and leaf, leafiness, seed head production, and vigor.

Table 8. Analysis of variance of the 1951 scores of progeny plants of Andropogon scoparius.

Sources of variation	D/F	SS	MS	F
Sites	3	39.78	13.26	
Accessions	20	758.01	37.90	1.25
Plants, same site, accessions	96	2900.80	30.22	
Totals	119	3698.59		

The grazed vs. ungrazed and site x grazing comparisons had to be omitted from this study because of insufficient numbers of progeny groups. This analysis could be calculated to compare only sites and accessions.

The analysis indicates that none of the sources of variation gave significant F values. The variance among plants within accessions is as great as the variance among accessions and sites.

Observations indicated lowland materials to be superior but not significantly so.

Selected Progeny Groups. Analysis of variance was calculated in the same manner as for Andropogon gerardi.

Table 9. Analysis of variance of 1951 selected progeny groups of Andropogon scoparius.

Sources variation	D/F	SS	MS	F
Groups	2	191.27	95.63	6.54**
Accessions, within groups	12	224.85	18.73	1.28
Plants or error	105	1535.75	14.62	
Totals	119	1951.87		

This study indicates a significant difference among sites but variations of plants among accessions was as great as the variation of plants within accessions.

The scores used indicate that although the groups yielding 3 or more selected plants were not significantly different from the groups that yielded 1 or 2, but they were significantly superior to the groups from which none were obtained.

Statistical Studies on Sorghastrum nutans

1950 Progeny Group Analysis. Analysis of variance based on the progeny group field notes was calculated in the same manner as previously outlined for the 1950 progeny group analysis, except that materials from the lowland sites was omitted because too few accessions were included in this species to represent the grazing source of variation.

Table 10. Analysis of variance of the 1950 scores of progeny groups of Sorghastrum nutans.

Sources of variation	D/F	SS	MS	F
Sites	2	13.07	6.54	
Grazed vs. Ungrazed	1	58.80	58.80	
Site x Grazing	2	375.20	187.60	10.32**
Accessions or error	24	436.40	18.18	
Totals	29	883.47		

From the above table it can be seen that there are no consistent differences among sites or between the ungrazed and

grazed groups. There is a significant difference among sites with regard to the effects of grazing, as shown by the site x grazing interaction.

Observations of the scores used in the analysis indicate that grazing had had a significant effect on the sandy prairie sites.

1951 Progeny Plant Analysis. Field notes were taken in 1951 on individual plants for the characters, disease, earliness, fineness of leaf and stem, leafiness, and vigor. These were totaled in the manner previously outlined.

Table 11. Analysis of variance of the 1951 scores of progeny plants of Sorghastrum nutans.

Sources of variation	D/F	SS	MS	F
Sites	2	50.45	25.23	1.17
Grazed vs. Ungrazed	1	.30	.30	
Site x Grazing	2	62.45	31.23	1.44
Accessions	24	518.80	21.62	2.02**
Plants, same site, accessions, and grazing	90	964.50	10.72	
Totals	119	1596.50		

The analysis indicates that significant differences occur only among accessions. Although not statistically significant, observations indicated that the sand site materials possess a greater number of desirable plants. Significant differences were found among the accessions of all sites.

Selected Progeny Groups. The analysis of variance compared groups of selected progeny and accessions.

Table 12. Analysis of variance of 1951 selected progeny groups of Sorghastrum nutans.

Sources of variation	D/F	SS	MS	F
Groups	2	204.01	102.01	11.09**
Accessions, within groups	12	122.10	11.09	1.21
Plants or error	105	965.88	9.19	
Totals	119	1302.99		

The analysis in this species indicates a highly significant difference among progeny groups. There was as much difference among plants within accessions as among accessions.

The scores compared in the analysis indicate that the progeny groups from which 1 or more superior plants were selected are significantly superior to the groups from which none were selected.

Correlation Studies. Correlation studies on Sorghastrum nutans to compare earliness and disease indicated that this species behaved in the same manner as the other species in this study. Negative correlations were obtained but none were significant.

Area Studies. A study was made in this species to determine whether or not there might be significant differences between the accessions from the north and south parts of the collection area and between those from the east and west parts. The line dividing the area into north and south parts was an east-west extension of the northern boundary of Crawford county. The line separating east and west portions was an extension of

the western boundary of Chautauqua county.

An analysis of variance based on progeny group field notes of 1950 was calculated to compare the areas.

Table 13. Analysis of variance of scores of progeny groups of the directional areas.

Sources of variation	D/F	SS	MS	F
Areas	3	18.16	6.05	
Accessions or error	76	672.29	8.84	
Totals	79	690.45		

This analysis indicates that there was as much variation among the accessions within an area as there was among areas. Although significance could not be established, observations indicate the southern accessions to be more desirable, at least on the basis of first-year data. Another analysis made on the 1951 data from individual plants, employing the characters, disease, vigor, leafiness, and earliness indicated as did Table 13 that there was as much variation among individuals within an area as among the areas. Apparently, the distance between the southern and northern selections was not sufficient to cause significant forage differences.

Measurements of Plant Parts of *Andropogon gerardi*

Measurements of the plant parts of the different species were taken in mid-July. Comparative studies have shown the

variations exhibited by the plants. The measurements taken for A. gerardi were number of seed stalks, the height to which leaves occurred on the culms, basal diameter and spread of tops, length of leaf, coarseness, and length of region of pubescence of the sheath below the collar.

While many of the analyses did not show significant differences among progeny groups there are many individuals that differ widely in the characteristics studied, therefore, although there may be a general tendency for the groups to be more or less alike with respect to certain characters there are wide differences within groups and these serve as a basis for selection. The wide variation within groups may be considered to be evidence of the heterozygous nature of these species.

Number of Seed Stalks. To study tillering, seed stalks of a random sample of plants were counted. The average number of culms per plant for the population was 37. The extremes found were 3 to 118 culms per plant. These figures are comparable to those found by Law (17) in a study of selected plants. Nearly 80 percent of the population was found to have between 7 and 52 culms, while only 0.68 percent had as many as 118 stalks. Weaver and Fitzpatrick (35) stated that they found 200 stalks per square decimeter in native stands of A. gerardi. For the plants examined in this study the average number per square decimeter was only 6.97.

Comparing numbers of culms per plant by sites, plant differences due to sites did not approach significance at the .05 level but variability was greater than the limited sample would

indicate. For this reason many of the variations were presumed to represent real differences to serve as a basis for selection. Field observations indicate that accessions from the sand sites tended to have somewhat fewer stalks than those from the other sites. The materials from grazed ordinary upland sites had the largest number of seed stalks with an average of 45. In all the sites the materials from areas not grazed showed the greatest variation in number of seed stalks per plant. Plants from the ungrazed sand sites, with an average of 24 seed stalks, had the smallest number of culms but were exceeded only slightly by those from ordinary upland sites. The difference due to the effect of grazing approached significance at the .05 level.

Height to Which Leaves Occurred on the Culms. The height to which the majority of leaves occurred on the sulms was studied. Plants with leaves carried high on the culms were considered to be more desirable agronomically than those having leaves only at the base. In this study, the height to which the leaves carried ranged from 40 to 124 cm with the population averaging 77 cm.

Plants from the ungrazed lowland sites tended to carry their leaves higher than those from the other sites, with an average of 104 cm, but only slightly higher than plants from the ungrazed sand sites. The plants from ordinary upland sites, with an average of 70 cm, tended to have a lower leaf height. The leaves of plants from ungrazed areas were not carried so high as on those of plants from grazed areas. Analysis of variance was not calculated for these observations.

Height of Culms. Height was considered a criterion of vigor, but mere height does not necessarily imply superiority. Some of the tallest plants lacked leafiness or were susceptible to disease. Height of culms was measured in mid-July and thus must be regarded as a relative measure because it does not represent the mature height. Sixty-six percent of the plants had heights between 128 and 188 cm. The tallest plant found was 235 cm and the shortest, 78 cm with the population average being 149 cm.

With the exception of that from the ungrazed ordinary upland sites, the material from ungrazed sites tended to be taller but were not significantly different than those from grazed sites. None of the plants of one site were significantly taller than those of other sites. These figures were within limits reported by Weaver and Fitzpatrick (35). These notes were taken at a date comparable to Weaver and Fitzpatrick's, which was near the first of July.

Basal Diameter and Spread of Tops. The extremes in basal diameters were 12 and 45 cm, and the spread of the tops varied from 20 to 120 cm. Seventy percent of the plants had basal diameters between 20 and 34 cm, and 60 percent of the top diameters fell within the range of 38 and 62 cm.

Although no significant differences were found, observations indicated that A. gerardi from ungrazed lowland and ordinary upland sites tended to have small diameters, with an average of only 20 cm, as compared to the population average of 26. By observation the spread of tops for the ordinary upland sites

also tended to have smaller diameters. The population average for the spread of tops was 56 cm. However, analysis of variance was not calculated for this character.

Length of Leaf. Along with leafiness, length of leaves may be of interest. Leaf lengths tend to decrease at the upper nodes. Two measurements were taken, one of the leaf extending from the 5th node and the other of the leaves from the 8th node above the base of the plant. The lengths of the 5th node leaves ranged from 30 to 87 cm, while the 8th node leaves fell within the range of 14 to 56 cm. Seventy percent of the plants had 5th node leaves between 34 and 54 cm long, while 65 percent of the plants had 8th node leaves between 18 and 32 cm long.

With an average of 52 and 30 cm for leaves of the 5th and 8th nodes, respectively, the plants of the grazed sand sites tended to have longer than the average leaves which were 48 cm and 27 cm, respectively. Leaves of the ordinary upland sites, both grazed and ungrazed, tended to be shorter but more variable. The analysis of variance did not indicate plants from one site to be significantly different from those of another.

Coarseness of Leaf and Stem. Leaf width and culm diameters were recorded as a factor of coarseness. Leaf widths ranged from 6 to 15 mm with the average being 9.5 mm. However, 82 percent of the plants had leaf widths within a range of 7 to 11 mm. The culm diameters ranged from 4 to 10 mm with the population average of 5.5 mm. No culm diameter in the sample studies was greater than 8 mm, however. Fifty seven percent

of the plants had culm diameters with a range of 5 to 6 mm.

The culm diameter did not seem to differ among plants from grazed and ungrazed areas within a site but there was some difference among plants of different sites, although the analysis of variance did not indicate significant differences among plants of different sites. Plants from sandy prairie and lowland sites tended to be more coarse, while those from ordinary upland and sand sites tended to have finer culms than those of the other sites. In leaf width, the plants of the ordinary upland sites showed a rather uniform distribution from one extreme of the range to the other, while those from the other sites were quite variable. Plants of the ordinary upland sites tended to have the finest leaves. There was nearly a significant difference among sites for the fineness of leaf character.

Measurement of Plant Parts of Other Species

Similar studies were made on Panicum virgatum, Sorghastrum nutans, and Andropogon scoparius. The details of study for these species are similar to those outlined for A. gerardi.

Panicum virgatum. Analysis of variance calculated for each individual character studies indicated no significant differences among sites. However, field observations will be reported.

Comparing basal diameters, plants from sandy prairie sites with an average of 28 cm tended to be somewhat larger than the plants from grazed ordinary upland sites and ungrazed sand sites,

both of which averaged 22 cm. The basal diameters ranged from 10 to 42 cm with an average of 19 cm. The spread of tops varied widely within the sand and ordinary upland sites, ranging from 30 to 230 cm with 66 percent of the population falling between 42 and 142 cm. The average for the population was 140 cm.

The ordinary upland sites exhibited the greatest variation in height of culms, with the most variation found in materials from ungrazed areas. The ungrazed lowland plants tended to be taller than average with an average of 140 cm. Sixty six percent of the plants were found to be between 110 and 136 cm in height. The range for this measurement was from 96 to 168 cm with the average for the population being 136. The height to which the leaves were carried on the culms was found to be greatest in the ungrazed lowland materials, with an average of 100 cm as compared to the population average of 90 cm. The leaves occurred as high as 130 cm and as low as 50 cm in the population.

Leaf length of the materials from the sandy prairie sites tended to be greater, with an average of 49 cm, than the population average of 44 cm. The plants from the ordinary upland material exhibited considerable variation. The length of leaves of the third node for the population ranged between 25 and 62 cm with 68 percent of the population having leaves less than 51 cm in length.

The coarseness characteristics indicated considerable range also. Culm diameters were from 2 to 8 mm and leaf width was from 9 to 18 mm. The average culm diameter was 4.5 and the average leaf width was 11.5 mm. None of the plants regarding

these characteristics were found to be more superior for one site than another.

Plants that have their inflorescences carried well above the leaves are desired for convenience in seed harvest. That portion of the plant protruding from the upper most leaf sheath was measured and the length of the panicle was subtracted from this measurement to determine how high the inflorescence was carried above the leaves. Some of the inflorescences were carried as high as 14 cm on the plants of the random sample taken for the analysis. These measurements were used in an analysis of variance which indicated no significant difference's among sites.

Sorghastrum nutans. Analysis of variance calculated for the characteristics studied in this species showed significant variations only for leaf width.

Leaf width varied among the plants of all the sites but sandy prairie materials had leaf widths significantly wider than the plants from the other sites (Table 14). Of the leaves observed for the 4 species, the widest leaves were found in this species, with the range falling between 7 and 23 mm. The population average was 18 mm.

Table 14. Analysis of variance of scores of leaf widths of individual plants of Sorghastrum nutans.

Sources of variation	D/F	SS	MS	F
Sites	2	20.62	10.31	4.79*
Grazing vs. ungrazing	1	.03	.03	
Site x grazing	2	3.76	1.88	
Plants or error	36	77.43	2.15	
Totals	41	101.84		

Culm diameters ranged between 4 to 8 mm with the population average being 5.5 mm. Seventy four percent of the population exhibited culm diameters between 4.5 and 6.5 mm. These measurements, however, did not vary enough among material from the different sites to indicate significant F values in the analysis of variance.

Plants of this species exhibited a range in leaf length at the forth node between 24 and 72 cm. The length of leaf was not significantly different among the plants of different sites though they did vary within each site group. Sixty six percent of the population had leaf lengths between 45 and 63 cm. Although the analysis of variance did not indicate significant differences among group of different sites, the plants from ordinary upland sites tended to have taller culms with an average of 158 cm. The average height for plants of the population was 144 cm. The range was between 60 and 172 cm.

Observations indicated that the basal diameters of the plants from the lowland sites, averaging 22.5 cm, and the plants from the sandy prairie sites, averaging only 16 cm, tended to be smaller than the population average of 26 cm. The range of basal diameters for the entire population was between 12 and 40 cm. Sixty nine percent of the population fell between 21 and 31 cm, however. The spread of tops tended to be slightly greater in the materials from grazed areas, and particularly in those from grazed ordinary upland sites. The tops of the plants were found to spread as much as 277 cm and as little as 29 cm. The average spread of tops for the population was 92 cm. Eighty

percent of the population had spread of tops between 44 and 137 cm.

Andropogon scoparius. The characters, basal diameter and culm diameters, were found to vary significantly among plants of the different sites. Basal diameters of the plants from the ordinary upland were significantly smaller, with an average of 13 cm, than those of plants from other sites (Table 15).

Table 15. Analysis of variance of basal diameter scores of individual plants of Andropogon scoparius.

Sources of variation	D/F	MS	SS	F
Sites	3	28.75	9.58	3.07*
Accessions	28	87.25	3.12	
Totals	31	116.00		

Materials from the sand sites, with an average of 20 cm tended to be somewhat larger than the general population average of 17 cm. There did not appear to be consistent differences between materials from grazed or ungrazed sites, although this was not tested in the analysis. The range for this measurement was between 7 and 30 cm, with 80 percent of the population between 12 and 22 cm. The analysis of variation indicated no significant differences among plants from different sites for the character spread of tops. The average spread of tops for the population was 43 cm. The range for this measurement was 20 to 90 cm, 76 percent of the population falling within

the range of 30 and 60 cm.

Culm heights of the plants from the ordinary upland sites, with an average of 39 cm, were significantly less than those of the plants from the sand and sandy prairie sites, the latter averaging 45 cm in height (Table 16).

Table 16. Analysis of variance of height of culms scores of individual plants of Andropogon scoparius.

Sources of variation	D/F	SS	MS	F
Sites	3	38.47	12.82	9.09**
Accessions	28	53.50	1.41	
Totals	31	91.97		

The height of culms of Andropogon scoparius ranged from 19 to 80 cm. The plants from the sandy prairie sites tended to be taller, with an average of 46 cm., than the population average of 44 cm. Seventy eight percent of the population fell between 30 and 54 cm.

Although the F value was not significant to indicate differences among groups of different sites, the plants from the sandy prairie tended to have longer leaves with an average of 35 cm. The range for the population was 18 to 42 cm. The plants from the sand sites tended to have shorter leaves averaging 26 cm, as compared to the population average of 32 cm for the average leaf length of the plant.

Plant Characteristics of Andropogon gerardi

Variations among such characteristics as disease, color, earliness, vigor, and leafiness were scored on the basis previously described. Figures 1 through 7 illustrate the range of growth characteristics that may be observed at different stages of growth.

Characteristics studied in A. gerardi were color, freedom from leaf diseases, earliness, leafiness, and vigor.

Color. The color most representative of the population was a light green to yellowish green, but many individuals were dark to light green and others were of the bluish grey shade characteristic of A. hallii. It was observed that more plants from sand sites tended to be blue or grey green than light to dark green. Plants from sandy prairie sites tended to be rather dark green in color.

Freedom from Leaf Diseases. The disease most common in this population, and which was observed to some extent on nearly every plant, was rust, Puccinia andropogonis Schow. Because rust has been particularly prevalent on A. gerardi, plants showing resistance to this disease have been selected. A few plants had seed smut, Sphacelotheca occidentalis (Seym.). Many had ergot, Claviceps purpurea F. (Tul.). There also was found some Phyllosticta sp., characterized by small tan spots with purple margins. This organism may occur as a secondary infection, invading heavily rusted areas. The field notes taken were not specific for any particular disease but indicated, instead,

Fig. 1. Variation in seedling vigor among progeny groups of *Andropogon gerardi*

Fig. 2. Lack of vigor in Andropogon gerardi during first season of growth. Compare with Fig. 3. (Field note book--8" x 4.5")

Fig. 3. Vigor in Andropogon gerardi. Compare with Fig. 2.

Fig. 4. Variation in leafiness in Andropogon gerardi.

Fig. 5. Variation in culm height in Andropogon gerardi.

Fig. 6. Semi-decumbent habit of growth in Andropogon gerardi.

Fig. 7. Variation in leaf width in Andropogon gerardi.

general freedom from diseases.

The disease score most frequently recorded in this sample population was 7, indicating a fairly high susceptibility to leaf diseases. Although the analysis of variance showed no significant F value, plants from the grazed lowland sites appeared to be the most resistant, while the materials from sand and ordinary upland sites tended to be most susceptible. No consistent differences could be observed between the materials from the grazed and ungrazed sites.

Earliness. Though no statistically significant correlation was found between earliness and disease, observations tended to indicate such a tendency. The field notes on earliness were arranged so the value, 9, represented earliest and, 1, the latest in maturity. It was found that the latest plants were still flowering at the time of the first frost. In this case, even if the plants were vigorous and free of leaf diseases, as those receiving this rating value usually were, the likelihood of producing seed would be very slight.

Although no analysis was calculated for this characteristic, it appeared from field observations that the plants from the lowland sites were somewhat later than those from the other sites, while the plants from the ordinary upland sites tended to be earlier than those from the other sites.

Leafiness. There tends to be a wide variation in leaf area among plants of A. gerardi. No attempt was made to measure the actual leaf area in this study, but the leafiness of the plants was compared on the basis of field notes, assigning

rating or scoring values of 1, excellent to 9, the least desirable. Although the analysis of variance did not indicate significance, the plants from the sand and the ordinary upland sites tended to be somewhat less leafy than the sandy prairie and lowland site material. No consistent differences could be noted between the plants of the grazed and ungrazed areas.

Vigor. Vigor is an overall expression of several characteristics, number of culms, leafiness, aggressiveness, and general robustness. The field notes on vigor were arranged so that the value, 1, represented the most vigorous plants and 9 the least vigorous plants.

In this study the plants from the ungrazed areas tended to exhibit greater vigor than those from grazed areas. Among sites, although no significant F value was found, plants with somewhat lower than average vigor were found in the materials from ordinary upland and sand sites.

Erectness and Other Characteristics. No consistent differences could be observed among sites with regard to erectness of growth. Fineness of leaf and stem was observed to vary widely among the materials from ungrazed lowland sites, but the differences were not great enough to make any group superior to another in this respect. No consistent differences in seed head production could be observed among materials from the various sites. However, analysis of variance was not calculated for these three characters.

Plant Characteristics of Other Species

Plant characteristics of Panicum virgatum, Sorghastrum nutans and Andropogon scoparius were also studied. These were scored in the same manner as A. gerardi. Figures 8 through 19 show growth characteristics that may be observed for these species.

Panicum virgatum. The color of P. virgatum is characteristically bluish green on the upper leaf surface and yellowish to light green on the lower. However, some plants from all sites varied to lighter or darker shades of green. Plants from ordinary upland and sand sites were well represented by dark green plants, although the range of color was great among these materials.

The disease found to be most abundant on P. virgatum was rust, Uromyces graminicola Burr. This disease was very abundant during 1950 and 1951. No significant differences were observed among plants from any of the sites.

Earliness or time of maturity varied considerably within all sites. No consistent differences could be observed among sites as regards to erectness. No consistent differences in seed head production could be observed among materials from the various sites. However, analysis of variance was not calculated for these three notes.

The fineness of leaf and stem note was observed to vary quite widely among the materials from ungrazed lowland sites but differences were not great enough to make any group superior

Fig. 8. Variation in vigor, leafiness, and width of leaf in Panicum virgatum.

Fig. 9. Variation in leafiness in Panicum virgatum. Plant at left severly infected by rust.

Fig. 10. Leafiness and vigor in *Panicum virgatum*. Compare with Fig. 11.

Fig. 11. Variation in vigor and leafiness in Panicum virgatum within progeny group.

Fig. 12. Variation in seedling vigor among progeny groups of Sorghastrum nutans.

Fig. 13. Variation among progeny groups of Sorghastrum nutans at the end of oneseason of growth.

Fig. 14. Variation of width of leaf and diameter of culm in Sorghastrum nutans.

Fig. 15. Variation of leafiness and width of leaf in Sorghastrum nutans.

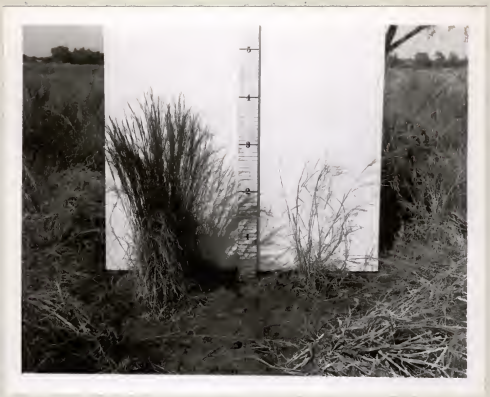

Fig. 16. Variation in vigor and leafiness in Andropogon scoparius.

Fig. 17. Variation in erectness in Andropogon scoparius.

Fig. 18. Extreme height of culms in Andropogon scoparius. Compare with Figs. 16 and 19.

Fig. 19. Variation in seed head production and vigor in Andropogon scoparius.

to another in this respect, as no significant differences were found.

Plants from ungrazed areas tended to have more vigor than those from grazed areas, those from the lowland being particularly vigorous. This was not indicated, however, by the analysis of variance as the F value indicated no significant differences among the sites.

Sorghastrum nutans. Color varied in this species from greyish green to yellow-green. Plants from the ordinary upland sites varied more widely in this characteristic than did those from the other sites. Lowland and sandy prairie sites yielded plants with the lowest variability, the color shades ranging mostly in the dark, light, or yellow greens. Plants from the sand sites tended to be of the grey and bluish greens.

Leaf smut, Tolyposporella chrysopogonis Atkl., was abundant. Some seed smut, Sphacelotheca occidentalis (Seym.) Clint., was also evident. During 1950 a heavy epidemic of rust, Puccinia virgata E. and E., was observed. Although the entire range of resistance was observed, differences among plants from the various sites were not significant according to the analysis of variance. Similarly, a wide range with no consistent differences due to site was also observed for the character, earliness, although this was not tested by analysis of variance.

Materials from the sand and lowland sites exhibited finer leaves and stems than those from the other two sites. The entire range of variability was found in plants from ordinary upland sites. Leafiness tended to vary widely within site groups,

but no group was significantly different. Vigor also varied by approximately the same degree within all site groups. Although analysis of variance tests did not indicate significance, plants from lowland sites tended to exhibit somewhat less variation than those of the other site groups.

Andropogon scoparius. The most common disease found in A. scoparius was leaf rust, Puccinia andropogonis Schw. Freedom from disease varied widely in all site groups, with plants from the ordinary upland sites showing significant resistance over the other sites (Table 17). Earliness also varied widely with no site group being earlier than any other group, although no statistical analysis was calculated.

Table 17. Analysis of variance of freedom from leaf diseases scores on individual plants of Andropogon scoparius.

Sources of variation	D/F	SS	MS	F
Sites	3	24.13	8.04	3.1*
Plants or error	20	45.50	2.27	
Totals	23	69.63		

The erectness of the plants did not vary as widely as did other characteristics. Fineness of stem and leaf tended also to exhibit a narrow range of variability, although it did tend to vary somewhat more in accessions from sandy prairie and ordinary upland sites than in those from the other sites. Erectness and fineness of stem were not tested statistically, however. Leafiness tended to vary more in plants from ordinary

upland sites than from the other sites, but aside from this, no consistent variations could be observed. Seed head production varied greatly in all site groups. Vigor varied within all site groups but no group could be rated as superior to any other according to the analysis of variance.

DISCUSSION

This investigation has been an examination of the nursery grown, space-planted progeny of native forage grasses collected in their natural habitat in an attempt to evaluate the relationships between the behavior and variability of the materials collected and the environment in which they have originated. The ultimate purpose is the search for strains or lines superior in one or more of the characteristics required of grazing plants, but in addition, it is desired to learn whether or not a knowledge of the behavior of accessions in relation to the environment under which they originated could be employed in planning further exploration for and collection of better pasture grasses.

Progeny groups were examined in 1950, their first year of growth, on the basis of whole progeny groups. In 1951 the examinations were on the basis of individual plants to obtain a more comprehensive evaluation for each character studied. In addition to field notes for the evaluation of each individual plant, measurement data were obtained from a sample of the population taken at random by rows.

The 1950 data indicated differences among accessions but analysis of variance could not be calculated on the basis of

progeny group evaluations. However, when these data were compared to observations, made on the basis of individuals the following year, close agreement was apparent. This suggests that some selection could be done the first year, although second year data are more likely to give an accurate evaluation of the characteristics under observations and more likely to result in improvement by selection.

In this study, although field notes were taken plant by plant on all plants, the analysis of variance was calculated on a randomized sample drawn from each progeny group studied. For collections that included a large number of progeny groups, a randomized sample of these was drawn for study in order to reduce the size of the sample analyzed. This method has provided information concerning progeny-plant relationship within species. Analysis of variance for selected groups of Andropogon scoparius indicated variation among lines to be significantly different than with in lines. This is in agreement with the findings of Anderson and Aldous (3). Lines of Panicum virgatum were found by Nielsen (21) to differ significantly. Similarly, the lines observed in this study showed significant differences. To reduce the time and cost of sampling and analyzing, a randomized sample may be drawn from the population or from the various groups. This may provide sufficient evidence of differences among groups, but in the search for superior plants it is necessary to examine each individual. Individuals selected in this manner have been harvested and made available to plant breeders.

Correlation coefficients were calculated for certain characteristics. The degree of correlation between characteristics varied within species. For instance, the correlations between earliness and freedom from leaf diseases was significantly negative in some groups, and significantly positive in others, while in still others, no correlation could be shown. This behavior was noted in all of the correlations determined in the four species under study. Knowledge of the fact that these significant correlations do occur must be taken into account in breeding and selection programs. Further study is needed to determine the significance of this behavior.

Measurement of plant parts has furnished information on range of variability. The range of measurements found in this study for the various plant parts are in agreement with those found by Weaver and Fitzpatrick (35), suggesting that certain plant responses under nursery and pasture conditions are similar. Measurement data were obtained from a 5 percent sample of the population, randomized within groups, to make possible a study of quantitative characteristics that existed in the population. For a quantitative comparision of accessions, several plants of each should be measured. In this study measurement of one plant per accession made possible comparisons by site sources. Although there may be a general tendency for the groups to be more or less alike with respect to certain characters, there were wide differences within groups. Actually the variability was greater than the limited sample would indicate. Therefore, many of the variations were presumed to be real differences and will serve as a basis for selection.

Another objective of this study was to investigate the relationships of progeny groups to their original habitat. Field notes on progeny groups in their first year of growth (Table 1) indicated that Andropogon gerardi plants differ significantly among sites. Grazing of the sites from which collections of Sorghastrum nutans and A. scoparius had been made appeared to have had a significant influence on progeny behavior, whereas difference due to sites were not significant. Reference to Tables 6 and 10 show that the site and grazing interaction in these species is significant while variation due to sites is not.

Individual plant evaluation scores analyzed in 1951 indicate that each species in this study has a characteristic behavior pattern. Andropogon gerardi strains appeared, on the basis of accessions selected at random, to differ only among sites. This may be observed in Table 2. However, in Table 3 it is seen that significant differences occurred among the accessions selected for superiority with regard to such agronomic characters as leafiness and vigor. Panicum virgatum strains tended to show significant differences both in the random population sample and in the accessions selected as agronomically superior. Sorghastrum nutans behaved in a similar manner, (Tables 5, 6, 11 and 12). On the other hand, A. scoparius strains taken at random did not differ significantly among sites or among accessions. However, significant differences were found among groups of the selected accessions.

Andropogon scoparius was the only species that did not show significant differences among accessions or sites. In all species, however, accessions differing significantly could be selected.

Andropogon gerardi was the only species in this study in which significant differences among sites were found. Plants from the sandy prairie and lowland sites were significantly superior agronomically to those from the other sites. Further study will be required to determine why plants from these sites were not significantly superior for the other species as well, although the other species did tend to behave in a similar manner.

Selecting plants somewhat south of where they are to be grown will improve the desirable agronomic characteristics of the progeny. This was tested in a study with Sorghastrum nutans. Although the plants of one site did not differ significantly from plants of other sites as is shown in Table 13, the scores used for this analysis indicate that the southernmost strains of the population did tend to be more desirable in these characteristics than those found farther north.

SUMMARY

An investigation was made to find superior plants and their range of variability for plants breeders and to find relationships among progeny groups and the situations under which they were found. Differences among accessions were also studied. Plants were found having highly variable characteristics and from these superior plants were selected. The progeny plant-site relationships was found to exist only in Andropogon gerardi Vitman. species while significant accessions differences were found in Panicum virgatum L. and Sorghastrum nutans (L.) Nash.

Progeny group notes were taken during the summer of 1950 on all accessions to note differences among accessions after one season of growth and to study variability due to the sites from which they had come. Analyses indicated site differences for Andropogon gerardi and an interaction of site and grazing for A. scoparius Michx. and Sorghastrum nutans.

Field notes were taken on individual plants in the summer of 1951. These were used to select superior plants for preservation and propagation and to compare variation among accessions and sites, as well as differences that may have resulted from grazing. Accessions were found to be significantly different in Panicum virgatum and Sorghastrum nutans. Significant site differences were found for Andropogon gerardi and no significance was found among the sources of variances for Andropogon scoparius.

Measurements of plant parts were also made of randomly selected plants during the summer of 1951, this study furnishing data that showed a wide quantitative variation within each species. However, variability was greater than the limited sample would indicate, the wide variation within groups furnishing evidence of great heterozygosity. Analysis showed certain characteristics to be significantly different among sites.

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A STUDY OF THE VARIABILITY IN NATIVE FORAGE GRASSES AND ITS RELATIONSHIP TO SOURCES OF COLLECTION

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MARVIN CARL ANDREW LUNDQUIST

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A wide range of variability exists in native forage grasses and finding lines or strains among these that possess superior qualities is prerequisite to improvement of the species. Study of the wide variability found in forage grasses and its possible relationship to their natural habitat will be helpful in planning future collections.

This study has been an evaluation of lines of Andropogon gerardi Vitman., A. scoparius Michx., Sorghastrum nutans (L.) Nash., and Panicum virgatum L. collected from native grasslands in southeastern and south central Kansas and adjacent counties in Missouri and Oklahoma. It has been the purpose of these evaluations to isolate lines superior in such characters as leafiness, vigor, and disease resistance, and to relate variability to the conditions existing in the site or habitat. Seedlings of this material, started in greenhouse flats, were transplanted as seedlings to the field nursery in May, 1950.

Field notes of whole progeny groups were taken in 1950 for the evaluation of vigor, freedom from leaf diseases, leafiness, erectness, aggressiveness, earliness, and fineness. In addition, a similar evaluation was made for certain individual plants selected as superior in one or more characteristics. These were later harvested for increase and further selection. During 1951 similar field notes were taken on each individual plant for evaluation to serve as a basis for the selection of superior plants. In order to provide a more careful evaluation

of the population, measurements of such plant parts as height, length and width of leaves, and basal diameters were taken on a 5 percent sample of the population. This sample consisted of 1 plant selected at random from each row.

Analyses of variance were calculated for a composite value representing all field notes both in 1950 and 1951. The plants were divided into 4 groups according to site of origin, the sites being sand, sandy prairie, ordinary upland, and lowland. These were further subdivided according to whether or not the sites had been grazed. Other analyses in 1951 were based on a composite rating value for disease, leafiness, and vigor to determine whether certain accessions from which superior plants had been obtained were actually superior to those which had not yielded superior selections. Some correlation studies were made to determine whether or not relationships existed between certain pairs of characters. Accessions of Sorghastrum nutans from southern and northern collections were compared to study their relative response to conditions north from their points of origin.

1950 progeny group analysis gave some indication of different behavior patterns for each species. Andropogon gerardi accessions differed significantly among sites, while those of Panicum virgatum did not. An interaction of the influence of grazing on effects of site was found in Andropogon scoparius and Sorghastrum nutans, indicating that grazing did not always have the same influence on the natural selection induced by the environmental factors of the site.

During 1951 individual plant notes were taken to provide more reliable evaluation of lines and to make further studies of behavior patterns of the species. Accessions of Andropogon gerardi, A. scoparius and Sorghastrum nutans from different groups differed significantly in respect to the number of superior plants that were obtained, while Panicum virgatum accessions were significantly different regardless of group.

Sorghastrum nutans and Panicum virgatum differed significantly among accessions regardless of site. Andropogon gerardi differed significantly among sites while A. scoparius did not differ significantly among either sites or accessions. Further study will be required to explain these differences. When compared on the basis of least significant differences, accessions originating from sandy prairie and lowland sites appeared to contribute a greater number of desirable plants than those from the other sites. Southernmost accessions tended to be more vigorous and leafy than those farther north within the collection area. The study of relationships between such pairs of characters as disease and earliness, and disease and leafiness, revealed there were significant correlation coefficients varying from positive to negative for each comparison in each of the species. It is inferred from this that the populations within species were not homogeneous. Knowledge of the fact that these significant correlations do occur must be taken into account in breeding and selection programs.

Studies of the plant measurements revealed that wide variations occurred both within and among progeny groups. The variability was, in most instances, as great within groups as among groups.