ANALYSIS OF MORPHOLOGICAL VARIATION OF <u>SCHIZACHYRIUM</u> <u>SCOPARIUM</u> (LITTLE BLUESTEM) IN OKLAHOMA

By

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Thesis Adviser

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PREFACE

This study elucidates the variation in morphology of *Schizachyrium scoparium* (Little Bluestem) along a northwest-southeast transect across the state of Oklahoma. For a truly adequate description of the variation of the taxon in the state more intense sampling needs to be undertaken in the future involving the southwest and northeast areas.

I would like to express my appreciation to Dr. Don Banks and Dr. Charles Taliaferro, members of my committee, for their advisement and assistance during the course of my study.

Special thanks is given to my advisor, Dr. Ronald J. Tyrl, for his encouragement and assistance during my research program.

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CHAPTER I

INTRODUCTION

Occurring throughout the United States east of the Rocky Mountains is Schizachyrium scoparium (Michx.) Nash, a bunchgrass generally considered to be a dominant member of the Tall-grass prairie. Throughout its range it exhibits considerable variability. Previous workers have discovered significant interpopulational differences in its phenotypic morphology (Nash, 1903; Gould, 1967; McMillan, 1964, 1965), chromosome morphology (Nielson, 1939) and habitat (Gould, 1975). Five varieties have been described to characterize this variability (Nash, 1903; Gould, 1967).

In 1964 Calvin McMillan suggested that the distribution of S. scoparium was characterized as an ecocline of ecotypes across the United States. He estimated that there were morphologic and physiologic trends from south to north and east to west. Flowering time, inflorescence characters, pubescence, stature and edaphic conditions exhibited this clinal variation. Later flowering time, larger spikelets, a high degree of pubescence, sparse glaucousness and increased height predominated in the western Lousiana area decreasing in degree and time in a northwesterly direction. Within the state of Texas alone this ecoclinal trend is evident resulting in the naming of varieties divergens (Hack.) Gould and virile (Shinners) Gould in the east, variety frequens (C. E. Hubb) Gould in central Texas and variety neomexicanum (Nash) Gould in the west.

These previous studies of variation sampled individuals from few populations often at great distances from each other. As a result, our knowledge of the interpopulational and intrapopulational variation is incomplete. The objective of this investigation was to study the extent and direction of intrapopulational variation in S. scoparium in Oklahoma based upon many individuals of populations not as widely separated as those of previous studies. Four large areas were sampled along a transect established from the southeastern portion of the state to the northwest. Twenty-six morphological characters of a quantitative nature were analysed using the Statistical Analysis System and various Fortran programs. Univariate and multivariate analyses were employed along with principle component analysis and cluster analysis as aids in visualizing similarities and differences within and among populations. The large number of characters measured and the attempt to adequately sample populations elucidates intrapopulational variation.

CHAPTER II

ANALYSIS OF MORPHOLOGICAL VARIATION

Materials

Five populations were selected at random in each of four areas along a transect extending from the southeastern to the northwestern corners of Oklahoma (Figure 1). From each population (Appendix A) 15 specimens were collected, dried and pressed. Voucher specimens were deposited in the Oklahoma State University Herbarium (OKLA). Twenty-six morphological characters of each individual were measured (Table I; Figure 2). Characters 18 and 25 (pubescence type of sessile spikelet's first glume and width of rachis at apex, respectively) showed no variation and were eliminated from further statistical consideration. In summary a total of ten vegetative characters, four inflorescence characters and twelve spikelet characters were evaluated. All of the following statistical analyses were performed at the Oklahoma State University Computer Center using an IBM/360 computer system.

Methods and Results

Univariate Analysis

The Statistical Analysis System (SAS) designed by Anthony Barr and James Goodnight (1972) was employed to produce the simple statistics for populations and areas. The character means and standard deviations for

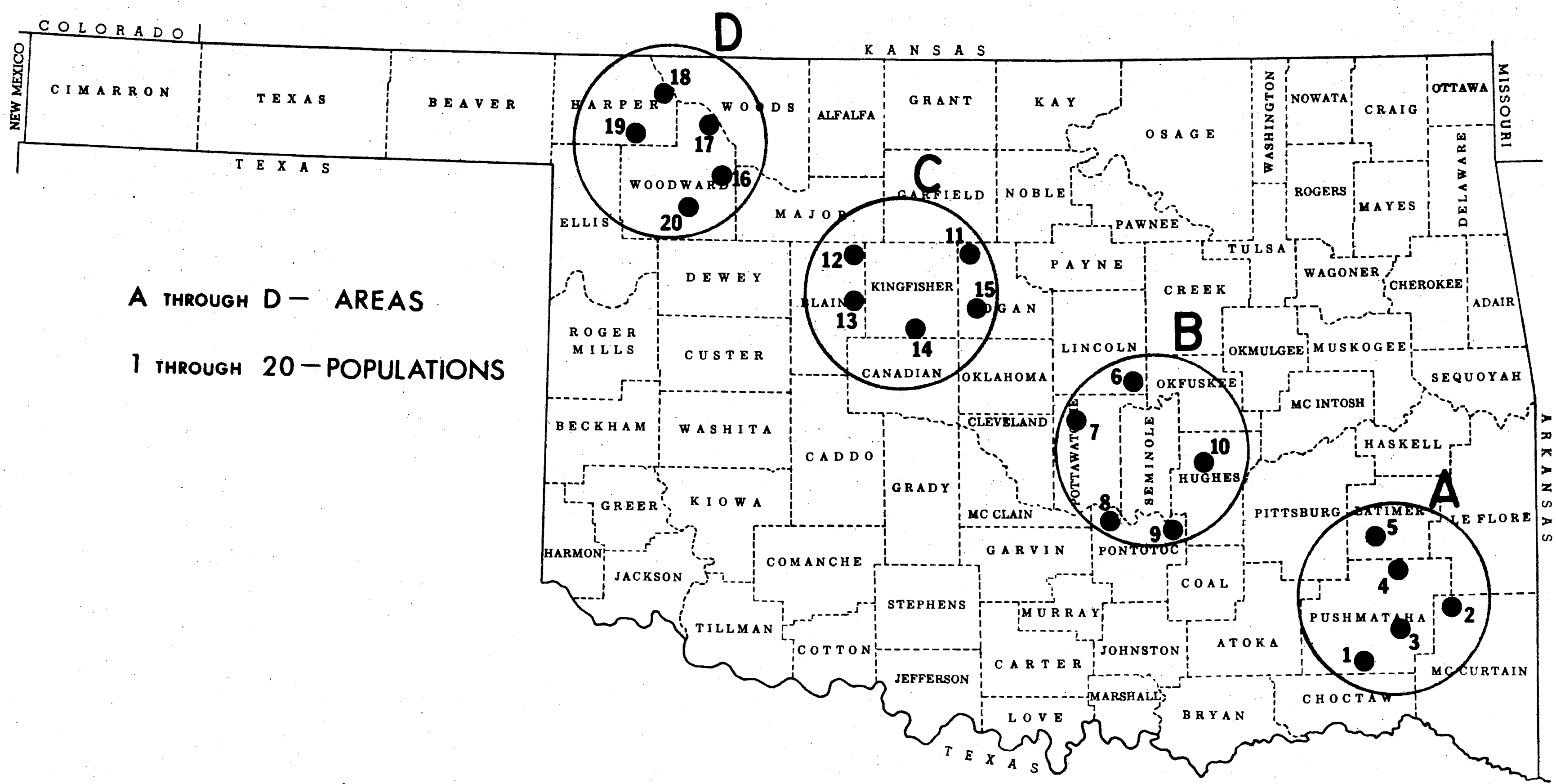

Figure 1. Illustration of Range of Collections

TABLE I

LIST OF MORPHOLOGICAL CHARACTERS EVALUATED WITH CODE NUMBERS AND UNITS OF MEASUREMENT

Code Number	Character	Unit of Measurement
1	Culm Height	cm
2	Leaf Blade Length	cm
3	Leaf Blade Width	mm
4	Leaf Sheath Pubescence Density	$\#/2mm^2$
5	Leaf Blade Pubescence	+ or -
6	Leaf Sheath Length	cm
7	Leaf Sheath Pubescence Length	mm
8	Leaf Number	-
9	Length of 5th Internode	cm
10	Diameter of 4th Node	mm
11	Raceme Length	cm
12	Number of Spikelets Per Raceme	-
13	Rachis Length	mm
14	Length of Longest Rachis Pubescence	mm
15	Sessile Spikelet Length	mm
16	Lemma Awn Length	mm
17	Length of Sessile Spikelet's 1st Glume	mm
18	Pubescence Type of Sessile Spikelet's 1st Glume	-
19	Length of Sessile Spikelet's 2nd Glume	mm
20	Length of Spikelet Pedicel	mm
21	Length of Pedicel Pubescence	mm
22	Length of Pedicelled Spikelet	mm
23	Length of Pedicelled Spikelet's Awn	mm
24	Callus Pubescence Length	mm
25	Width of Rachis at Apex	mm
26	Length of Lemma	mm

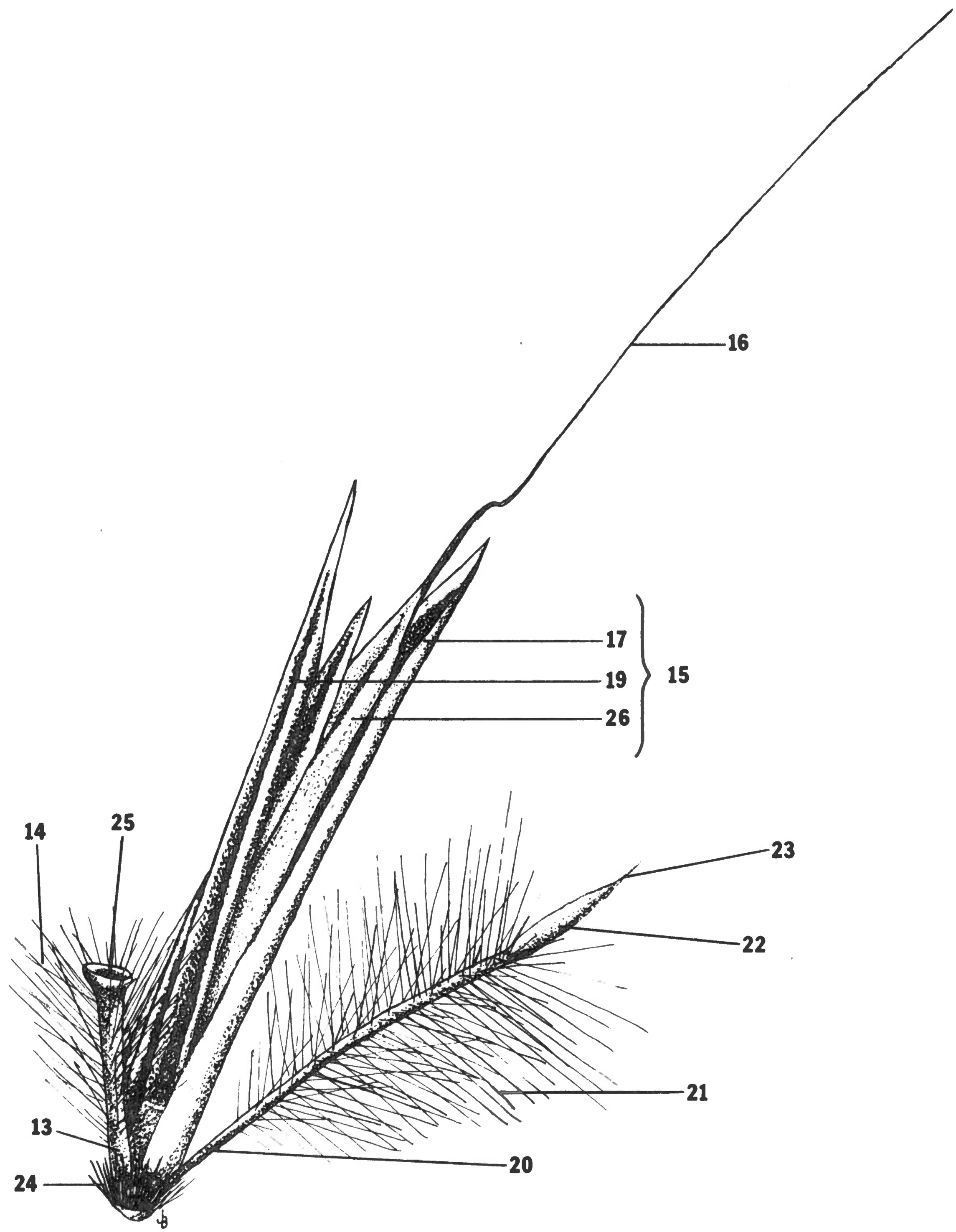

Figure 2. Illustration of Rame Characters

the plants of each population are provided in Table II, Appendix B. Analysis of variance for each character across the sample range was calculated and those characters which did not differ significantly at the 0.05 level in F-tests (1, 2, 6, 9, 11, 13, 16, 20, 21, 22, 23, 26) were excluded from further analyses. The twelve remaining characters (3, 4, 5, 7, 8, 10, 12, 14, 15, 17, 19, 24) were compared from area to area to area using LSD tests (Table III, Appendix B). The data revealed that the density of sheath pubescence decreases from the southeast to the northwest dropping abruptly to zero after Area B (Figure 3). The length of this pubescence did not differ when it was present. Blade pubescence was more frequent in the populations of the southeast decreasing towards the northwest. Leaf width was equally large in Areas A and D with areas in between having narrower blades (Figure 3). The last vegetative character, leaf number, decreased from the southeast to the northwest. Spikelet number decreased from the southeast to the northwest while sessile spikelet size increased in the same direction. Both rachis and callus pubescence lengths increased from Area A to Area B.

Inspection of character variances by populations (Table IV, Appendix B) indicates that the populations in the southeast have the highest interpopulational and intrapopulational variation.

Multivariate Analysis of Variance (MANOVA)

The SAS-Manova program was used to generate correlation matrices (Table V, Appendix B). Most correlations were quite logical. As height increased, so did leaf size, pubescence of the sheath and blade, leaf number, internode length and node diameter. The number of spikelets per raceme also increased with the height. Components of the rame

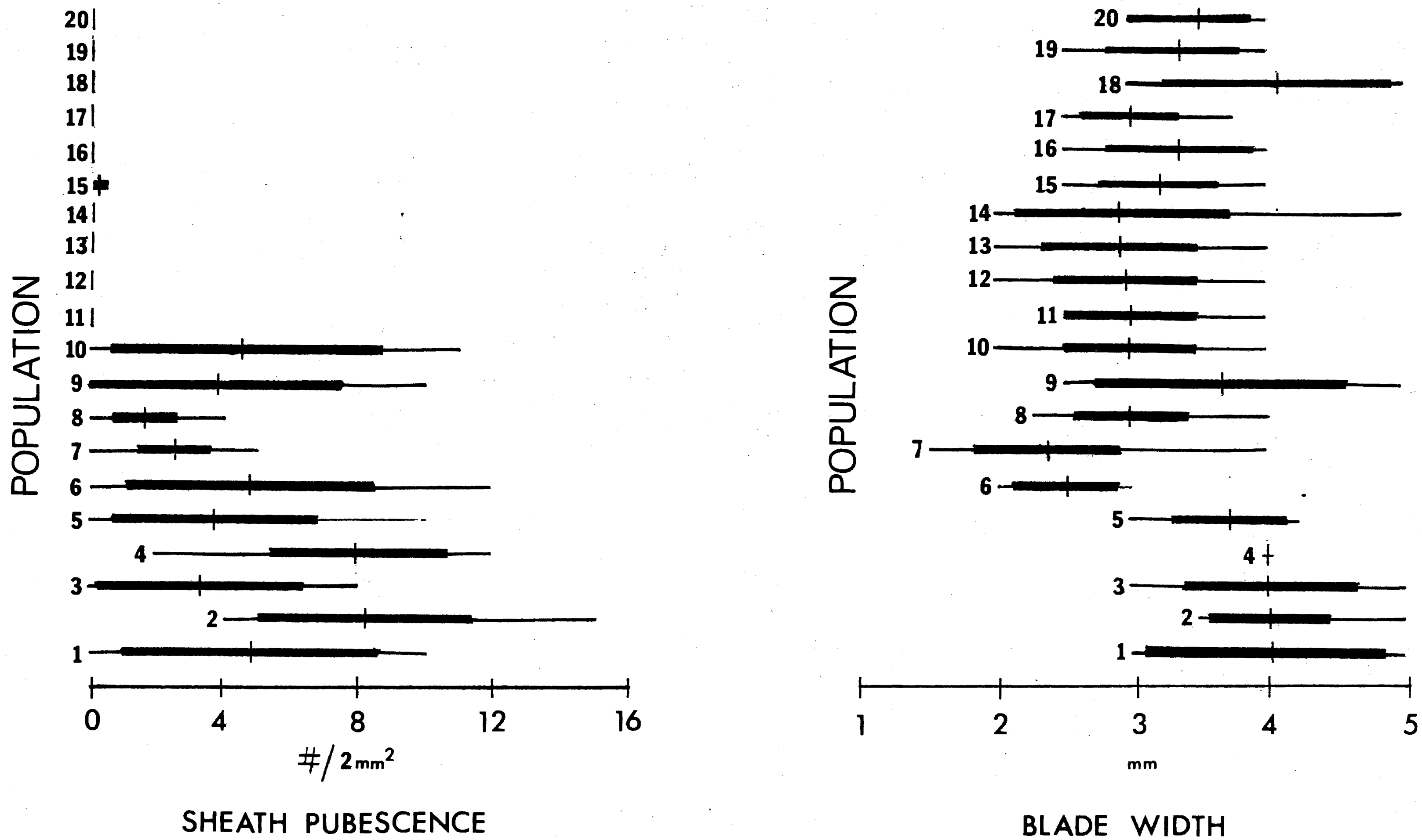

Figure 3. Partial Results of Univariate Analysis

were all correlated[1]. As the sessile spikelet increased in size so did the glumes, rachis, pedicel, pediceled spikelet and lemma. The pubescence of the rachis, pedicel and callus increased in length as the rame increased in size. There was a slight negative correlation of the rame size with height and its correlated characters.

After the correlation matrix was prepared, the SAS was used to compute the appropriate rotated factor matrix (Sokal and Sneath, 1973). The populations which were once represented by 24 variance vectors were then identified by only seven composite vectors. Each vector represents an axis along which a certain amount of variation separates the populations. Of the seven vectors produced only four were used as the variance of the remaining three amounted to only 26%. A relative value of 70% was used to determine the significance of vector components.

By taking three vectors at a time a 3-dimensional diagram was constructed illustrating the relationships of populations. In Figure 4, vector 1 which represents 33% of the variation was composed of five rame characters. Supporting the univariate analysis it indicates that the northwest populations were generally larger in size with respect to the rame than the southeast populations. Vector 2, representing 15% of the variation, is composed of vegetative leaf characters. It indicates that, here, there is a great deal of variation but no discernable trend. Vector 3 accounts for 14% of the variation and identifies vegetative pubescence. This vector clearly separates the two major groups, A-B and

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[1]The rame as defined by various workers applies to the entire inflorescence (a modified raceme) of the Andropogoneae. Others recognise the rame as the aggregation of components (rachis, sessile spikelet, pedicel and its spikelet) at a single node of the inflorescence. The term is used here in the latter sense.

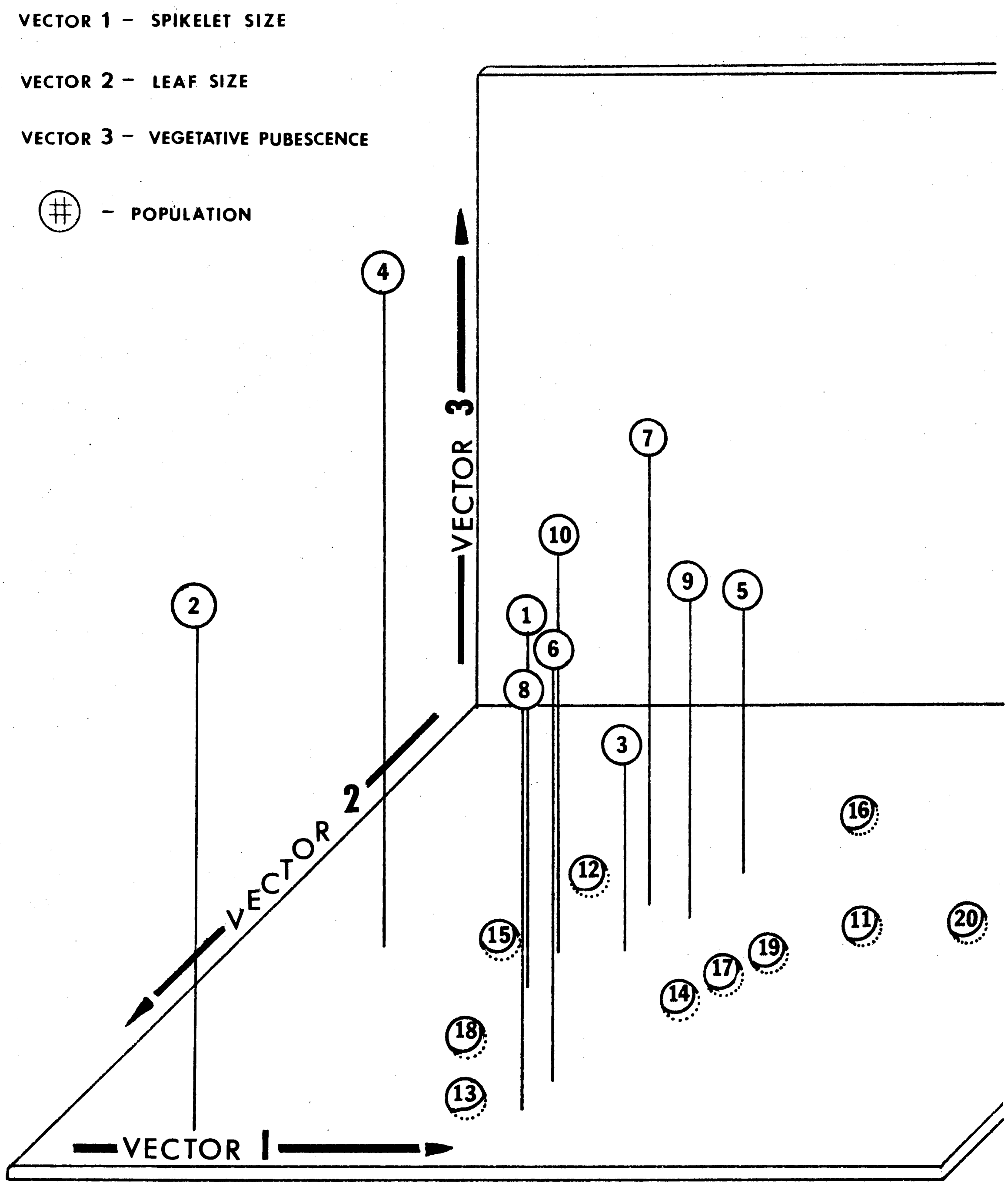

Figure 4. Principle Components Diagram I

C-D, with pubescence decreasing towards the northwest. The sharp differences between Areas B and C probably result from the failure to sample areas in between.

Figure 5 represents another combination of three vectors. Vector 4, composed of vegetative size characters, has been added to vectors 1 and 3. It is once again evident that as one proceeds from the southeast to the northwest, vegetative size and pubescence decrease while rame size increases.

In the previous figures populations 1, 3 and 5 consistently appear to represent an intermediate state between the populations of the southeast and northwest.

Cluster Analysis

Standardized Euclidian distance coefficients were calculated for each population and cluster analysis was performed as described by McCammon (1968). The results (Figure 6) suggest the clustering of Areas C and D with each other and Area B as a group. Area A is portrayed as a highly variable group resembling members of the other three areas to a limited degree. The results of this analysis are essentially the same as those of principle component analysis.

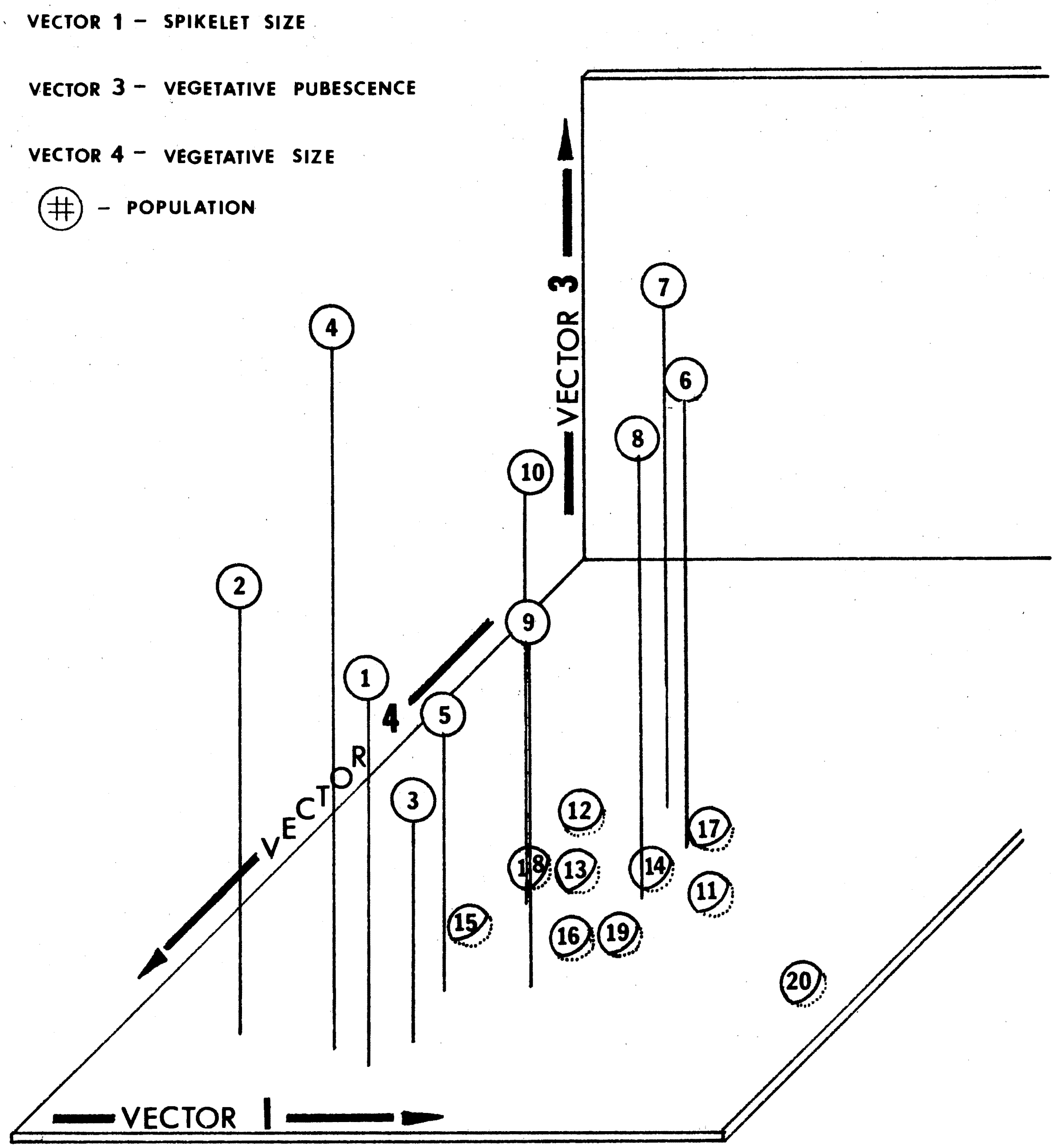

Figure 5. Principle Components Diagram II

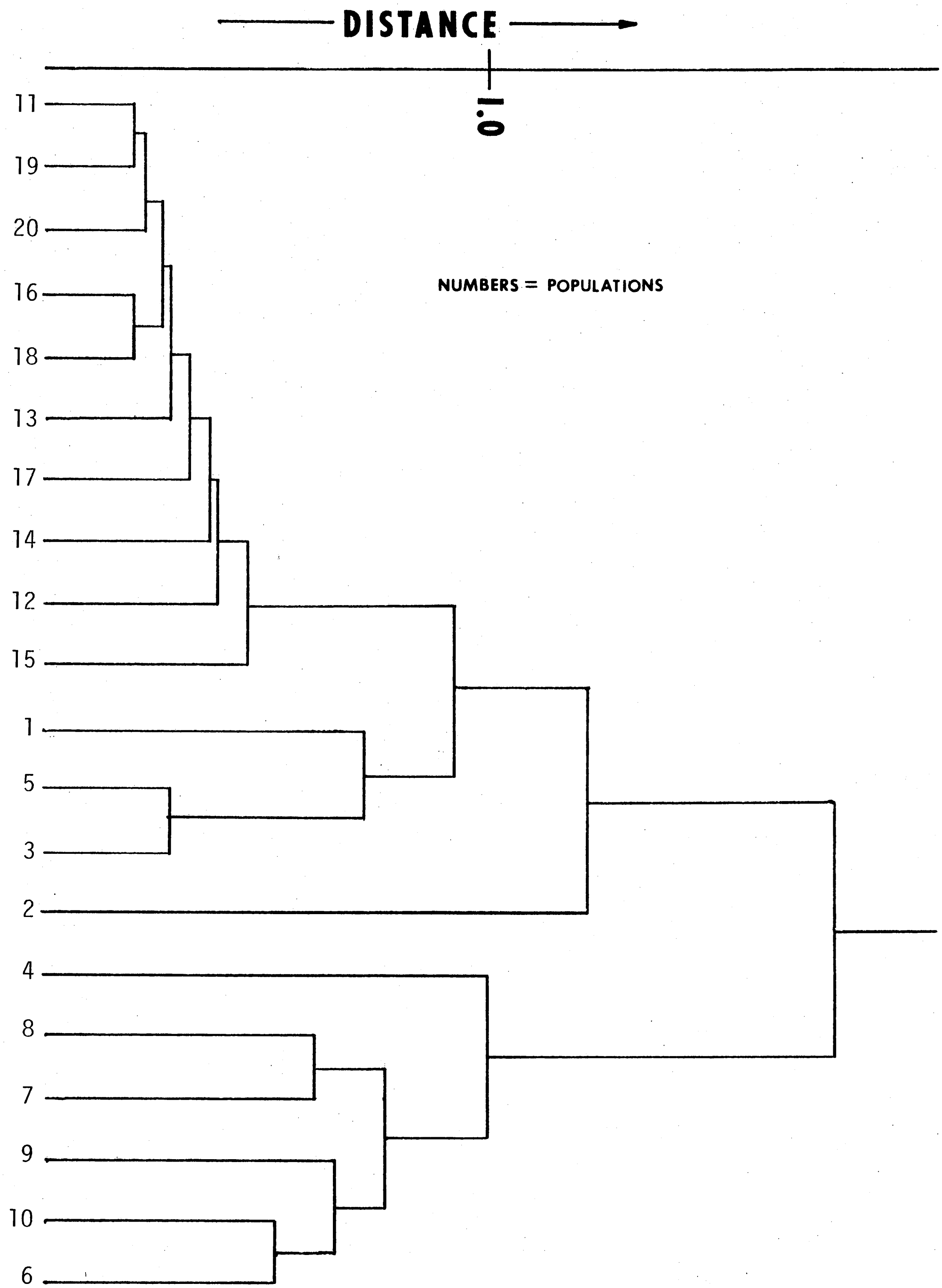

Figure 6. Cluster Analysis Phenogram

CHAPTER III

DISCUSSION

The variation of Schizachyrium scoparium across the United States has been shown previously (McMillan, 1959, 1964, 1965a) to be clinal with respect to maturation time, height and vegetative pubescence. That the clinal variation of these characters is a result of a genetic gradient has been shown by Larsen (1947), Cornelius (1947) and McMillan. This study confirms McMillan's observations that height and pubescence are clinal in Oklahoma and identifies spikelet size and inflorescence pubescence as additional components of the variation which are also clinal in nature. These additional characters correlate with height which suggests that they also arise as a result of a genetic gradient; transplant studies and subsequent morphological examination would confirm this.

As McMillan has pointed out (1959) clinal variation of S. scoparium is related in large part to climatic gradients in the form of photoperiod, growing season, precipitation and temperature. The species also manifests these influences in Oklahoma. Plants of the northwest which are characteristically shorter and earlier flowering are ideally suited to reproduce in a habitat with long-day flowering requirements and a growing season of from 190 to 195 days. In the southeast where short-day influences and a growing season of 200 to 220 days are in effect, plants grow taller and bloom later.

The effect of precipitation and temperature on plants is largely due to the availability of water and the plant's ability to withstand varying degrees of water stress (Salisbury & Ross, 1973). In response to water stress plants often utilize glaucousness and pubescence to reduce water loss. Glaucousness and reduced height are adaptive in the northwest as the area receives only an average 25 inches yearly in combination with high temperatures. In the southeast it is the sporadic occurrence rather than the lack of rainfall in addition to high temperatures which produce plants of greater height and greater vegetative pubescence. Inconsistent rainfall during the growing season favors later flowering and, thus, greater height (Nixon & McMillan, 1964). The increased amount of precipitation must surely contribute in some manner to the greater vegetative growth. The porous, sandy soils and their inability to retain water in addition to the protracted dry periods facilitate the production of pubescence.

The effect of edaphic conditions on plant growth by affecting the water and nutrient availability has been demonstrated often (Russel, 1950, cf. bibliography). High salt content and other factors affecting soil pH greatly influence growth. Nixon and McMillan (1964, p. 138), based on studies in Texas, state that S. scoparium "has become physiologically differentiated concerning iron uptake and or utilization thus allowing plants to occupy acid or calcareous soils." It would not be unreasonable to assume that this species has done the same in Oklahoma. There is a gradient of soil pH in the state from highly acid soils in the southeast to alkaline soils in the northwest.

Although S. scoparium is not characterized by distinct ecotypes such as described by Turesson (1922) in Hieracium or Clausen, Keck and Hiesey (1940) in Potentilla, populations which occur on gypsum outcrops may be incipient ecotypes. Characterized by shorter stature and smaller spikelets, population 12 is decidedly different, morphologically, from what would be expected considering its position in the ecocline.

Both interpopulational and intrapopulational variation are greater in the southeastern populations of the state. This seems to support the idea that variability in phenotype is greater in areas of greater habitat diversity. This high degree of variability is responsible for the superficial resemblance of populations of Area A to the central areas of the state in the results of the cluster analysis. Populations of the central areas (B and C) fall within the limits of variability of Area A with respect to all characters excluding sheath pubescence. The high loading effect of non-sheath characters in the analysis results in the slightly distorted phenogram. Pubescence, however, clearly identifies these populations of A as resembling Area B more than any others.

Differences in morphological variation within a species are often due to differences in chromosome number. Analysis of variation in Panicum virgatum (Nielson, 1944; Quinn, 1969; Brunken, 1971) and Cenchrus species (Ramaswami & Menor, 1971) have found this to be the case. Investigations indicate, however, that the variation in S. scoparium is not of polyploid origin. Chromosome counts consistently reveal a diploid number of 40 except for supernumery chromosomes in a few Nebraska clones (Hunter, 1934; Gould, 1956; DeWald, 1971; Hatch, 1975).

While chromosome number does not seem to be related to S. scoparium's variability, chromosome morphology may be. Nielson (1939) reported a correlation of chromosome morphology with phenotype. Plants with pilose, lower sheaths and dense robust foliage had one pair of deep, subterminally to submedially constricted chromosomes. Plants with glabrous sheaths and sparse foliage possessed 'normal' chromosomes with medial centromeres. Examination of the cytological aspect of S. scoparium should be undertaken to see if there is indeed a distributional correlation of chromosome morphology with phenotype.

While the degree of density of sheath pubescence appears to be clinal across the state the rapidity with which it decreases and is eliminated within a relatively small distance (approx. 80 miles) is startling. There is the possibility that sheath pubescence may be correlated with the land resource areas (soils and associated plant communities). Plants with sheath pubescence occur largely on the sandy soils of the postoak-blackjack oak and oak-pine forests (Cross Timbers and Ouachita Highlands respectively) while plants of the dark, clay soils of the Reddish Prairies lack vegetative pubescence. Elucidation of this apparent correlation awaits further work.

The results of this analysis suggest that the value of vegetative pubescence in delimiting varietal taxa in S. scoparium is questionable. Five infraspecific taxa have been described. Variety divergens (Hack.) Gould is described as having densely villous sheaths and large, well developed pedicelled spikelets and occurs in eastern Texas, Arkansas, Lousiana and Mississippi (Figure 7). In contrast, var. frequens which occurs throughout Texas except in eastern sections possesses glabrous to slightly hispid sheaths and small, reduced pedicelled spikelets. A third variety, virile, appears to be an intermediate between var. divergens and var. frequens as it has little vegetative pubescence,

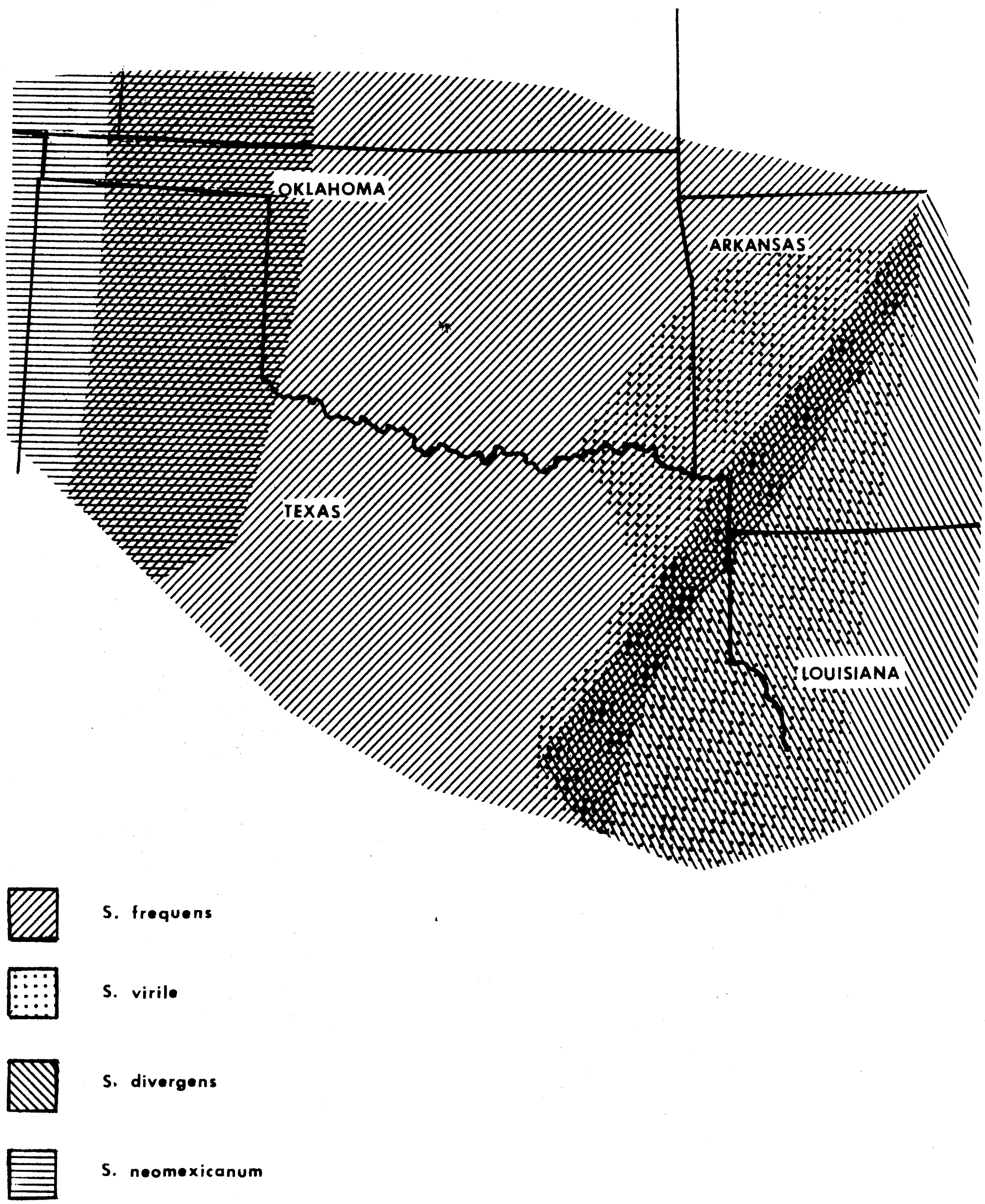

Figure 7. Distribution of Schizachyrium scoparium Varieties (Adapted from Gould, 1975)

larger and well developed pedicelled spikelets and a range which coincides with the areas where the ranges of the two previously mentioned varieties overlap. Gould (1975) reports that plants identifiable as all three varieties are found growing in the same population. In this study plants which would be classified as var. frequens on the basis of inflorescence characters approach a condition of dense pubescence similar to var. divergens. The clinal variation exhibited makes consistent varietal recognition impractical or at best tenuous.

A similar situation exists in northwest Oklahoma regarding var. frequens and var. neomexicanum. These two varieties differ only in the degree of inflorescence pubescence density. Var. neomexicanum has a more densely pubescent inflorescence. In the opinion of this author var. frequens does not warrant varietal recognition and should be considered to be an aspect of the variation of var. neomexicanum.

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APPENDIX A

LOCALITY AND ACCESSION NUMBERS OF POPULATIONS SAMPLED

APPENDIX A

LOCALITY AND ACCESSION NUMBERS (AC)

OF POPULATIONS SAMPLED

AC 1. Pushmataha Co: R18E, T4S, Sect. 22; 0.5 mi. E of Rattan on State Hwy. 7, N roadside field, 21 Aug 1975.

AC 2. McCurtain Co: R23E, T1S, Sect. 31; 2.5 mi. N of Battiest on logging road, rocky clearing, 21 Aug 1975.

AC 3. Pushmataha Co: R20E, T1S, Sect. 8; 1 mi. W of Nashoba on State Hwy. 2, roadside field, 21 Aug 1975.

AC 4. Pushmataha Co: R20E, T2N, Sect. 20; 1.5 mi. W of Kiamichi on State Hwy. 271, roadside field, 22 Aug 1975.

AC 5. Latimer Co: R20 E, T3N, Sect. 13; 6.5 mi. E of Laura on State Hwy. 63, northfacing inclined field, 22 Aug 1975.

AC 6. Pottawatomie Co: R6E, T12N, Sect. 5; 4 mi. N of Prague on State Hwy. 99 and 1.5 mi. W on county road, abandoned field, 9 Sept 1975.

AC 7. Pottawatomie Co: R3E, T13N, Sect. 5; 0.5 mi. N of State Hwy. 270 on State Hwy. 177, ungrazed roadside field, 9 Sept 1975.

AC 8. Pontotoc Co: R4E, T5N, Sect. 6; 1.5 mi. S of the intersection of State Hwys. 177 and 13 on 13, forest clearing, 9 Sept 1975.

AC 9. Pontotoc Co: R7E, T4N, Sect. 31; 3.5 mi. E of Ada on State Hwy. 12, forest margin field, 9 Sept 1975.

AC 10. Hughes Co: R9E, T5N, Sect. 4; 3.5 mi. NE of Allen on State Hwy. 12, roadside field, 9 Sept 1975.

AC 11. Logan Co: R4W, T19N, Sect. 16; 2.5 mi. W of the intersection of State Hwys. 74 and 51 on 51, roadside field, 20 Sept 1975.

AC 12. Blaine Co: R10W, T19N, Sect. 14; 2 mi. W of Okeene on State Hwy. 51, roadside field on gypsum, 20 Sept 1975.

AC 13. Blaine,Co: R10W, T17N, Sect. 27; 2.5 mi. S of Hitchcock on State Hwy. 8, field between railroad and highway, 21 Sept 1975.

AC 14. Kingfisher Co: R8W, T16N, Sect. 13; 10 mi. W of Kingfisher on State Hwy. 33, south roadside field, 21 Sept 1975.

AC 15. Logan Co: R4W, T6N, Sect. 13; 0.5 mi. E of the intersection of State Hwys. 74 and 33 on 33, south roadside field, 21 Sept 1975.

AC 16. Woodward Co: R18W, T23N, Sect. 28; 3.5 mi. E of Mooreland on State Hwy. 15, open, sandy field E of road, 20 Sept 1975.

AC 17. Woodward Co: R18W, T26N, Sect. 14; 1 mi. SW of the State Hwy. 50 Cimarron River Bridge on Highway 50, field E of road, 20 Sept 1975.

AC 18. Harper Co: R19W, T27N, Sect. 5; 1.5 mi. E of the intersection of State Hwys. 34 and 64 on 64, dry field N of road, 20 Sept 1975.

AC 19. Harper Co: R25W, T25N, Sect. 13; 13 mi. S of the intersection of State Hwys. 64 and 34 on 34, W roadside field, 20 Sept 1975.

AC 20. Woodward Co: R17W, T20N, Sect. 4; 17 mi. SE of Woodward on State Hwy. 270, W sloping field on E side of road, 21 Sept 1975.

APPENDIX B

STATISTICAL TABLES

TABLE II

MEANS AND STANDARD DEVIATIONS OF CHARACTER MEASUREMENTS BY POPULATIONS

	Population									
	1		2		3		4		5	
Character Code Number	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1.	89.73	19.93	81.40	17.71	96.53	9.92	103.20	11.79	86.26	15.79
2.	19.07	7.55	29.09	13.24	19.46	6.49	71.94	3.73	13.23	4.31
3.	4.06	0.79	4.16	0.40	4.00	0.62	4.00	0.00	3.73	0.45
4.	4.80	3.68	8.33	3.17	3.23	3.17	8.00	2.67	3.80	3.00
5.	0.40	0.50	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
6.	6.98	1.70	9.29	2.49	7.72	1.95	7.26	1.26	6.12	1.22
7.	2.30	1.22	3.73	0.67	1.66	1.44	2.93	0.25	2.20	1.37
8.	10.60	1.68	11.80	1.74	11.75	1.72	12.20	1.42	10.60	1.45
9.	11.70	3.13	13.10	3.03	12.26	2.57	12.84	2.19	12.24	2.43
10.	1.70	0.49	2.40	0.50	2.43	0.56	1.70	0.31	1.53	0.22
11.	3.97	0.69	3.20	0.71	3.81	0.50	3.19	0.53	3.97	0.95
12.	8.80	2.11	8.26	2.71	10.06	1.57	9.00	2.20	10.26	1.66
13.	4.36	0.54	3.88	0.62	3.93	0.75	3.66	0.67	4.56	0.72
14.	2.23	0.49	2.76	0.49	2.50	0.50	2.40	0.50	2.53	0.51
15.	6.53	0.63	5.96	0.71	6.93	0.59	6.03	1.02	6.96	0.91
16.	10.86	1.93	10.38	1.90	10.16	1.68	10.40	2.02	10.46	2.26
17.	6.50	0.65	5.90	0.66	6.93	0.59	6.10	0.98	6.96	0.91
19.	6.5	0.65	5.90	0.66	6.90	0.63	6.10	0.98	6.96	0.91
20.	4.26	0.45	4.50	0.59	4.56	0.59	4.50	1.00	4.80	0.45
21.	2.03	0.12	2.20	0.41	2.26	0.45	2.06	0.25	2.33	0.48
22.	2.90	1.15	2.43	0.53	2.16	0.40	2.03	0.39	2.86	0.58
23.	1.10	0.38	1.96	0.71	1.10	0.60	1.00	0.37	1.03	0.29
24.	0.93	0.17	0.60	0.28	0.96	0.12	1.00	0.18	0.96	0.12
26.	5.30	0.56	4.73	0.62	5.66	0.52	4.90	0.87	5.56	0.94

TABLE II (Continued)

	Population									
	6		7		8		9		10	
Character Code Number	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev	Mean	Std. Dev.	Mean	Std. Dev.
1.	97.13	13.80	70.86	9.86	107.53	16.57	93.06	12.52	71.93	8.25
2.	26.16	3.75	18.22	5.32	29.36	8.32	16.18	5.08	18.87	5.36
3.	2.53	0.44	2.36	0.61	3.06	0.41	3.73	0.88	3.10	0.57
4.	4.73	3.82	2.46	1.06	1.53	1.12	3.73	3.82	4.46	4.12
5.	0.80	0.41	1.00	0.00	0.86	0.35	0.66	0.48	0.93	0.25
6.	8.98	2.35	6.49	1.26	10.80	4.16	6.84	1.33	7.14	1.53
7.	2.76	1.14	2.83	0.81	2.40	1.32	2.06	1.76	2.33	1.47
8.	11.53	0.91	9.80	1.61	13.13	2.29	11.60	1.91	11.46	1.12
9.	15.07	1.48	14.44	3.41	12.55	3.50	12.92	2.99	10.78	2.14
10.	1.76	0.41	1.63	0.22	2.46	0.71	2.26	0.56	1.83	0.48
11.	3.79	0.42	3.72	0.53	4.17	0.76	3.84	0.37	3.53	0.41
12.	8.66	0.89	9.06	1.57	10.73	1.48	9.46	0.74	9.40	1.35
13.	4.16	0.64	4.00	0.75	3.93	0.67	4.00	0.42	3.63	0.58
14.	2.93	0.17	3.03	0.58	3.20	0.42	2.93	0.17	3.13	0.35
15.	7.20	0.62	6.93	0.65	7.16	1.73	7.10	0.38	6.76	0.37
16.	11.10	1.79	11.10	2.53	10.63	1.73	11.70	2.00	9.93	2.21
17.	7.20	0.62	6.93	0.65	7.16	0.55	7.10	0.33	6.76	0.37
19.	7.13	0.58	6.93	0.65	7.16	0.55	7.10	0.33	6.76	0.37
20.	5.23	0.31	4.86	0.58	5.23	0.56	4.83	0.36	4.60	0.54
21.	2.36	0.44	2.30	0.36	2.16	0.36	2.26	0.37	2.50	0.56
22.	2.86	0.44	3.13	0.58	2.86	0.54	2.73	0.49	2.40	0.43
23.	0.80	0.31	1.06	0.62	1.23	0.41	0.96	0.35	0.80	0.81
24.	1.23	0.25	1.26	0.25	1.46	0.35	1.26	0.25	1.53	0.35
26.	5.63	0.63	5.46	0.48	5.66	0.61	5.80	0.31	5.40	0.43

TABLE II (Continued)

	Population									
	11		12		13		14		15	
Character Code Number	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1.	74.80	6.73	46.23	7.52	84.26	10.69	100.80	13.43	78.86	9.59
2.	16.70	4.71	14.48	7.52	27.26	4.20	20.92	4.01	19.60	6.26
3.	3.00	0.50	2.40	0.47	2.90	0.73	2.96	0.78	3.26	0.56
4.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.61
5.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.45
6.	6.84	1.16	6.12	1.38	9.13	1.12	8.22	2.88	8.06	1.38
7.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	1.26
8.	10.06	1.16	9.73	1.27	11.80	1.20	10.93	1.33	11.13	1.24
9.	12.03	1.57	7.37	0.99	13.06	1.78	16.54	2.06	10.68	2.04
10.	1.73	0.37	1.66	0.44	1.90	0.43	1.76	0.37	2.36	0.44
11.	3.87	0.62	3.32	0.59	3.93	0.50	4.10	0.48	3.68	0.46
12.	8.13	1.35	9.00	1.19	8.73	0.88	9.33	0.97	8.73	1.09
13.	4.46	0.51	3.36	0.48	4.50	0.73	4.33	0.48	4.20	0.41
14.	3.20	0.45	2.83	0.74	3.26	0.45	3.16	0.55	3.20	0.49
15.	7.70	0.59	6.56	0.62	6.90	0.38	7.36	0.35	6.66	0.52
16.	12.06	1.94	8.10	2.23	10.60	1.38	12.06	1.74	11.70	1.68
17.	7.70	0.59	6.63	0.48	6.90	0.38	7.40	0.33	6.66	0.52
19.	7.70	0.59	6.63	0.42	6.90	0.38	7.36	0.35	6.66	0.52
20.	5.36	0.44	4.43	0.31	4.56	0.41	5.10	0.38	4.80	0.36
21.	2.56	0.49	2.16	0.64	2.60	0.57	2.43	0.59	2.70	0.36
22.	3.10	0.54	2.60	0.47	2.83	0.30	2.93	0.31	2.86	0.48
23.	1.00	0.26	1.00	0.42	0.86	0.29	1.06	0.31	0.90	0.28
24.	1.36	0.44	1.13	0.22	1.03	0.35	1.40	0.20	1.40	0.33
26.	5.73	0.53	5.30	0.31	5.06	0.25	5.46	0.35	5.03	0.35

TABLE II (Continued)

	Population									
	16		17		18		19		20	
Character Code Number	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1.	69.53	10.42	66.66	9.14	72.33	7.72	73.06	10.14	78.73	13.38
2.	10.82	2.58	21.23	4.48	23.20	4.91	19.93	4.21	17.14	4.53
3.	3.43	0.59	2.96	0.35	4.16	0.85	3.36	0.44	3.80	0.31
4.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.	4.78	0.77	6.42	0.86	9.28	2.04	7.99	1.58	6.50	1.16
7.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.	9.93	1.27	10.00	1.19	10.40	0.98	9.26	1.43	9.86	1.18
9.	10.06	1.87	10.92	2.02	10.67	2.92	13.38	1.83	12.70	1.92
10.	1.90	0.50	1.73	0.31	2.30	0.62	2.36	0.48	2.03	0.39
11.	3.44	0.53	4.74	1.61	3.34	0.56	4.23	0.54	3.94	0.72
12.	8.53	1.30	7.33	1.49	8.60	1.24	8.46	0.99	7.73	1.43
13.	3.80	0.67	4.86	0.54	3.50	0.56	5.16	0.83	4.96	0.95
14.	3.30	0.31	2.70	0.70	2.93	0.49	2.80	0.49	3.40	0.39
15.	7.46	0.83	7.36	0.66	6.86	0.74	7.33	0.64	8.56	0.92
16.	11.70	1.67	10.36	1.44	8.93	1.85	9.53	2.12	12.42	3.06
17.	7.46	0.83	7.30	0.64	6.86	0.74	7.33	0.64	8.56	0.92
19.	7.26	0.79	7.06	0.72	6.86	0.74	7.26	0.62	8.50	0.94
20.	4.53	0.58	4.96	0.58	4.63	0.66	5.33	0.55	5.26	0.67
21.	3.06	0.37	2.50	0.50	2.13	0.35	2.20	0.41	3.06	0.17
22.	3.00	0.42	3.10	0.80	2.46	0.48	3.00	0.46	3.43	0.72
23.	1.10	0.33	1.20	0.75	0.96	0.35	0.80	0.25	1.10	0.33
24.	1.03	0.35	0.76	0.25	1.13	0.22	1.16	0.30	1.26	0.25
26.	5.70	0.59	5.43	0.84	5.30	0.49	5.60	0.63	6.36	0.93

TABLE III

MEANS AND LSD VALUES OF SIGNIFICANT
CHARACTERS BY AREAS

Area	Character Code Numbers									
	3	4	5	7	8	9	12	14	15, 17,19	24
A	3.99	5.63	0.28	2.56	11.34	12.43	9.28	2.48	6.48	0.87
B	2.96	3.38	0.85	2.48	11.50	13.15	9.46	3.04	7.03	1.35
C	2.90	0.06	0.05	0.14	10.73	11.94	8.78	3.13	7.04	1.26
D	3.54	0.00	0.00	0.00	9.89	11.54	8.13	3.02	7.50	1.07
LSD	0.52	1.84	0.31	0.61	1.11	2.71	0.91	0.28	0.28	0.22

TABLE IV

VARIANCES OF SIGNIFICANT CHARACTERS BY POPULATIONS AND BY AREAS

		Character Code Number									
Area	Population	3	4	5	7	8	9	12	14	15, 17,19	24
A	1.	0.63	13.60	0.25	1.49	2.82	9.80	4.45	0.24	0.40	0.03
	2.	0.16	10.00	0.00	0.45	3.02	9.23	7.35	0.24	0.51	0.07
	3.	0.39	10.00	0.00	2.09	2.98	6.62	2.49	0.25	0.35	0.01
	4.	0.00	7.10	0.00	0.06	2.02	4.80	4.85	0.25	1.05	0.03
	5.	0.20	9.00	0.00	1.88	2.11	5.92	2.78	0.26	0.83	0.01
B	6.	0.19	14.60	0.17	1.31	0.82	2.19	0,80	0.03	0.38	0.06
	7.	0.37	1.10	0.00	0.66	2.60	11.64	2.49	0.33	0.42	0.06
	8.	0.17	1.20	0.12	1.75	5.26	12.25	2.20	1.18	0.30	0.12
	9.	0.78	14.63	0.23	3.10	3.68	8.97	0.55	0.02	0.11	0.06
	10.	0.32	16.90	0.06	2.16	1.26	4.58	1.82	0.12	0.13	0.12
C	11.	0.25	0.00	0.00	0.00	1.35	2.49	1.83	0.20	0.35	0.19
	12.	0.22	0.00	0.00	0.00	1.63	0.99	1.42	0.55	0.38	0.05
	13.	0.54	0.00	0.00	0.00	1.45	3.18	0.78	0.23	0.15	0.12
	14.	0.62	0.00	0.00	0.00	1.78	4.28	0.95	0.31	0.12	0.04
	15.	0.31	0.38	0.20	1.60	1.55	4.18	1.20	0.24	0.27	0.11
D	16.	0.35	0.00	0.00	0.00	1.63	3.51	1.69	0.10	0.69	0.12
	17.	0.12	0.00	0.00	0.00	1.42	4.09	2.23	0.49	0.44	0.06
	18.	0.73	0.00	0.00	0.00	0.97	8.55	1.54	0.24	0.55	0.05
	19.	0.19	0.00	0.00	0.00	2.06	3.38	0.98	0.24	0.41	0.09
	20.	0.10	0.00	0.00	0.00	1.40	3.70	2.06	0.15	0.85	0.06

TABLE V

CORRELATION MATRIX OF SIGNIFICANT CHARACTERS

Character Code Number	3	4	5	7	8	10	12	14	15	17	19	24
3	1.00	0.23	-0.06	0.18	0.18	0.39	0.00	-0.18	-0.13	-0.14	-0.13	-0.20
4	0.23	1.00	0.08	0.40	0.10	0.03	0.11	-0.14	-0.07	-0.08	-0.08	-0.08
5	-0.06	0.08	1.00	0.59	0.27	0.10	0.11	-0.00	-0.18	-0.18	-0.16	-0.25
7	0.18	0.40	0.59	1.00	0.30	0.04	0.15	-0.18	-0.27	-0.28	-0.26	-0.05
8	0.18	0.10	0.27	0.30	1.00	0.38	0.23	-0.00	-0.15	-0.14	-0.13	0.08
10	0.39	0.03	-0.01	0.04	0.38	1.00	0.08	0.02	-0.03	-0.03	-0.01	0.03
12	-0.00	0.11	0.11	0.15	0.23	0.08	1.00	0.00	-0.04	-0.03	-0.01	0.12
14	-0.18	-0.14	-0.00	-0.18	-0.05	0.02	0.00	1.00	0.31	0.30	0.31	0.31
15	-0.13	-0.07	-0.18	-0.27	-0.15	-0.03	-0.04	0.31	1.00	0.99	0.97	0.23
17	-0.14	-0.08	-0.18	-0.28	-0.14	-0.03	-0.03	0.30	0.99	1.00	0.98	0.24
19	-0.13	-0.08	-0.16	-0.26	-0.13	-0.02	-0.01	0.31	0.97	0.98	1.00	0.26
24	-0.20	-0.08	0.25	0.05	0.08	-0.03	0.12	0.31	0.23	0.24	0.26	1.00

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