QUANTITATIVE ANALYSES OF PHENOTYPIC RELATIONSHIPS AMONG SELECTED CULTIVARS OF COTTON, *GOSSYPIUM HIRSUTUM* L.

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CHAPTER I

INTRODUCTION

Genetic variability is essential for the achievement of breeding progress. Breeders and geneticists have long recognized the need for obtaining, maintaining, describing, and utilizing sources of germplasm to provide variability which can be utilized in future breeding efforts.

Collections of germplasm in cotton (Gossypium spp.) are fairly large, but they probably do not include a near complete catalog of the variability in the genus. In the United States, a collection of Gossypium barbadense L. strains, cultivars, and marker stocks is maintained at the Cotton Research Center, Phoenix, Ariz. At Texas A&M University, College Station, Texas, are maintained an Asiatic collection (cultivars and marker stocks of Gossypium herbaceum L. and Gossypium arboreum L.), a wild diploid species collection, and a genetic marker collection of Gossypium hirsutum L. At the Delta Branch Experiment Station, Stoneville, Miss., a collection of obsolete U.S. cultivars of G. hirsutum is maintained. In the above collections, there does not exist an organized mechanism for U.S. cotton breeders to take advantage of the germplasms recently developed by cotton breeders in other parts of the world. This study was undertaken to at least partially remedy that deficiency. Since the most efficient system of developing improved cultivars involves the utilization of proven germplasms, the use of new genes or genetic recombinants from currently grown foreign

cultivars might shorten considerably the time required to produce new cultivars more highly adapted to U.S. environmental conditions.

The practical objective of the research reported herein was to characterize a selected group of currently grown foreign cultivars of cotton (G. hirsutum) and to thereby allow estimates for the potential of each as a germplasm source for future breeding efforts in the U.S. A more theoretical objective of the study was to determine relative phenotypic responses among the foreign and selected, currently grown U.S. cultivars and to make such inferences as seem warranted in regard to phylogenetic relationships and to the breeding programs in the countries involved. For the latter objective, a statistical procedure for quantitative classification designated as "numerical taxonomy" was adopted using the dendrograph approach.

CHAPTER II

LITERATURE REVIEW

Numerical Taxonomy

Classification is the process of ordering similar organisms into an unknown number of distinct categories or groups on the basis of their relationships, with the organisms in each category being more similar to each other than to the organisms in all other categories (70, 74, 77). The classification technique designated as numerical taxonomy is defined as the numerical evaluation of the affinity or similarity between taxonomic units and the ordering of those units into taxa on the basis of their affinities, where taxa is an abbreviation for taxonomic groups of any desired nature or rank (70, 74). In this study, taxonomic units are defined as currently grown cultivars of cotton (Gossypium hirsutum L.).

Sokal (71) reported that one of the first attempts to apply numerical methods to problems in classification was made in 1898 by Heincke, who used a measure of phenetic distance to distinguish among races of herring (Fam. Clupeidae). Yet, even though the basic concepts and methods of numerical taxonomy are not new, its widespread application was dependent upon the development and refinement of computers.

The method is based on the fact that if a group of organisms originated from a common ancestor, the more closely related will in general

have the greater number of characters in common (50, 72, 73). The procedure consists of any of a variety of multivariate techniques with the primary aims being repeatability and objectivity. Emphasis is placed on the measurement of the maximum number of characters possible to provide an adequate sample of the genetic composition of the organisms under study.

Numerical taxonomy is based primarily on the assumptions that quantitative evaluation of phenotypic similarity over all characters between taxonomic units is an estimate of their genetic similarity, that overall similarity must be determined from as many characters as possible all of which are assigned equal weights, and that all characters of an organism are considered potentially of equal value and importance in creating phenotypic classifications (70, 74).

Numerical taxonomic techniques currently used in organismal classification were developed and promoted principally by Sneath (68, 69), Michener and Sokal (50), Sokal (71), Sokal and Sneath (74), and Rohlf and Sokal (67). Since its development, the majority of studies utilizing numerical analyses have involved organisms other than the higher plants.

Applications Other Than in Higher Plants

In zoology, numerical taxonomy has been applied to many different organisms with especially extensive work being done with bees (50, 67, 73). Studies among 97 species of the Hoplitis complex indicated that the similarities among species and their diagram of relationship were in good agreement with the previous, more orthodox taxonomy of the group. In addition, however, interesting new information was obtained

on the finer structure of the taxonomic hierarchy.

Rohlf (66) studied 48 species of the mosquito genus Aedes, developing a classification resembling those established by traditional studies of the group. Ehrlich (31) investigated butterflies (Euphydras spp.) examining the relationships between similarities based on characters from different parts of the body and between phenetic and geographic location.

Numerical methods have been used satisfactorily for a wide range of bacteria. The concept was introduced into bacteriology in 1957 by Sneath (68, 69), who performed a detailed study of the genus Chromobacterium. He found very good correspondence with the previous grouping of species and with serological data. However, in nearly all of the 35 bacterial genera studied to date, some clarification or improvement of the original classification has been achieved (77). The species of phytopathogenic bacteria of the genera Pseudomonas and Xanthomonas have been especially intensively studied using numerical classification (23, 24, 80). Quantitative relationships in viruses, yeasts, and fungi have also been ascertained (70, 77).

The principles of numerical taxonomy have also been applied in other fields than those related strictly with living organisms, i.e., archeology, anthropology, sociology, psychology, geology, and paleontology (5, 56, 74, 87, 91). Sneath and Sokal (70) have published a recent review of the research in those fields.

Applications in Higher Plants

The number of studies in which plants were investigated using numerical taxonomic treatments is limited. A review of the plant work

will be presented here, with emphasis given to the classification of cultivars following shortly thereafter. Applications in plants have been primarily among species to develop taxonomic systems without the subjectivity of classical taxonomy, to identify hybrid plants in segregating populations, and to determine the structure of introgressive populations. The technique has also been applied on a more limited basis to classify cultivars.

The classification of species using numerical techniques has been directed toward the overall improvement of previously defined taxonomy. Morishima and Oka (52) devised a quantified classification of the genus Oryza following the lines of work devised by Michener and Sokal (50). Results obtained were largely comparable with those empirically reached previously, but they did display a more detailed structure of interspecific relationships. Soria and Heiser (75) studied certain tropical species of the Solanum nigrum complex. The relationships derived also showed close agreement with those expected based on ordinary taxonomic procedures.

Carpena (21) wanted to correct possible misclassifications in the genus Cynodon using numerical classification. Her diagram of relationships among the 37 accessions studied utilizing the clustering procedure exhibited on the average good agreement with the presently accepted classification of the genus. In sorghum (Sorghum spp.), Liang and Casady (46) studied 21 species to derive their pattern of interspecific variation. The taxonomic diagram indicated that those 21 species should be divided into three groups consisting of 14, 6, and 1 species, respectively.

De Wet and Huckabay (27) followed the procedure outlined by Sokal

and Michener (73) in studying the origin of Sorghum bicolor using morphological data. In their study, the 52 taxa previously recognized by Snowden were characterized. The three large complexes into which the Snowdenian species clustered coincided exactly with the previous classification derived by De Wet. The data indicated that the non-rhizomatous weeds were closely allied as a whole to the cultivated complex.

Katz and Torres (45) compared the relationships as indicated by three separate numerical techniques with the relationships derived by morphological and cyto-chemotaxonomic methods when applied to nine species of Zinnia subg. Diplothrix. The numerical technique developed by Rogers and Tanimoto (65) most closely agreed with the results obtained by traditional methods. Rhodes et al. (62) applied several techniques of numerical taxonomy to the genus Cucurbita and compared the results with known phylogenetic relationships among 21 species. Three similarity coefficients were used to compute phenetic similarities, and cross-compatibility ratings were used to compare statistical procedures. The distance and divergence coefficients were more highly correlated with the cross-compatibility ratings than was the Q-correlation coefficient; however, the Q-correlation coefficients were in closer agreement with biological and geographical information. Species which were highly compatible and normal in size clustered together regardless of technique.

Nine diploid taxa of the genus Haplopappus section Blepharodon were compared by Ramon (59) to determine their relationships and to study the effectiveness of selected taxonomic approaches as a basis for classification. The study compared numerical results with hybridization

and cytological observations among the nine taxa. The results obtained by the different procedures agreed loosely with presently accepted taxonomy. He points out that combining results obtained from cytological, hybridization, and numerical studies should provide a more accurate classification than is presently available. Orloci (55) described a simple model suitable for the classification of individual plants. The collection he analyzed represented 94 specimens within the genus Phyllodoce. Considering the hierarchical relationships within the taxa and comparison of mean vectors, he reported a much more complex taxonomic structure in the examined materials than was suggested for the genus in the published literature.

The use of numerical taxonomy to determine the relationships between interspecific hybrids and their parent species has been reported in several species. Heiser, Soria, and Burton (40) utilized materials of known relationship within the section Morella of Solanum (which included species, artificial hybrids, and polyploids) to perform a numerical study based on 58 characters. The results exhibited several discrepancies with the taxonomic interpretations previously held by the authors for certain species. Homoploid hybrids and alloploids were usually fairly closely linked to one of their parent species; and the autoploids, as expected, closely resembled their diploid progenitors.

The use of numerical chemotaxonomy was reported by Dass and Nybom (26) who examined the relationships among six Brassica species, three primary diploids, and their amphidiploid hybrids utilizing chromatographic studies. Taxonomic distance, renamed by them as biochemical distance, was employed to determine similarities. On the whole, related types were separated by smaller biochemical distances than were

unrelated ones; but there were some notable exceptions. The results demonstrated that chemotaxonomy may be taken to verify in general the accepted evolutionary sequences within the group. A close analysis of the data showed that even if they had not known which diploid species were the parents of each amphidiploid, the biochemical data would have revealed that information.

Vaughan, Denford, and Gordon (84) investigated the seed proteins of three synthesized Brassica napus crosses with their parents and two established cultivars. Similarities between the albumin patterns of the taxa were computed, and a three-dimensional model was constructed. The model reflected the expected evolutionary process; the well-established hybrids were further apart from the parents than were the newly synthesized forms. Bemis et al. (10) studied 53 taxonomic units representing Cucurbita species, F_1 hybrids, and unclassified accessions. Q-correlation coefficients were computed, and cluster analysis by the unweighted pair-group method using simple averages was employed to derive the diagram of relationship. The F_1 interspecific hybrids tended to cluster with one of the parent species or species group when the parents are widely divergent. F_1 interspecific hybrids between wild and domesticated species clustered toward the wild parent. The phenetic similarities resulting in the grouping of species were in close agreement with known genetic compatibility relationships.

Applications in the Classification of Cultivars

Many useful statistical devices have been developed to solve problems of classification among populations; but multiple character analysis, based on numerical data as criteria, has seldom been used for

separating cultivars and indicating their relationships. Classification of cultivars, particularly those with worldwide distributions, has seldom been performed. Baum and Lefkovitch (7) state that among the few early attempts were those of Koernicke and Werner on cereals in 1885.

One of the earliest efforts to apply the techniques of numerical taxonomy to the classification of cultivars was made by Rogers and Tanimoto (65), who reported a study of 300 herbarium specimens of yucca (Manihot esculenta) collected in Jamaica and Costa Rica. Most specimens represented cultivars. They described a particular coefficient of similarity which used the presence-absence technique to code characters. Because most cultivars occur in South America, particularly Brazil, no final conclusions on the overall classification of this variable species was possible. However, they stressed the fact that use of qualitative and quantitative information helps eliminate subjective bias introduced by the traditional method of classification. They defined the procedure as taxonometrics.

Murty and Pavate (54) studied by multivariate analysis a selected set of 13 flue-cured Virginia tobacco (Nicotiana tabacum L.) cultivars for genetic diversity and prediction of genetic advance in crosses among them. Classification was made using Mahalanobis generalized distance, followed by a selection procedure based on four leaf quality characters. The cultivars, based on degree of divergence, were clustered in four groups of one, two, three, and seven cultivars, respectively.

Rhodes and Carmer (60) grouped 46 sweet-corn (Zea mays L.) inbreds by their overall phenetic similarities to determine if numerical

taxonomy could be applied to such material and to check the efficiency of the method. A subjective classification served as a partial check. Overall similarity between inbreds was measured by standardized correlation coefficients based on 93 plant characters. Phenetic relationships were summarized in a dendrogram by the unweighted pair-group method using arithmetic averages. The correlation coefficients appeared to be good measures of overall similarity, and they generally agreed with the pedigrees. Inbreds closely related by pedigree had high positive correlation coefficient values and exhibited close relationships in the dendrogram where four large groups were formed. Intraspecific material, such as corn inbreds, appeared to offer certain advantages over species in measuring the relative efficiencies of numerical methods.

Edwards (29) applied cluster analysis to race classification in maize. Data for 80 cultivars measured for 34 morphological characteristics were analyzed by four numerical methods. Data from 391 open-pollinated maize cultivars, collected and measured in Yugoslavia for 20 morphological characters, were also numerically classified for the determination of race groups. Both sets of data were compared to subjective classifications. The degree of consistency between the groupings indicated that numerical clustering methods of classification were suitable for race classification in maize, and that unweighted averages were in best agreement with the subjective classification. Comparisons between groups formed using numerical analyses in each of two years indicated that environmental variation had little effect on the results obtained.

Goodman (35, 36) reported the utility of multivariate analyses of

variance in the derivation of a classification system based on phenotypic similarities among races of maize. Quantitative relationships were determined among 15 races from Southeastern South America, and 16 characters commonly used in taxonomic studies were employed. The racial means and the residual covariance matrix from the multivariate analysis of variance were used to calculate generalized distances between races. Sokal and Sneath's (74) unweighted average method of cluster analysis was used to construct the diagram of relationships. All methods used showed approximately the same results, and they generally agreed with conclusions reached on the basis of more conventional taxonomic methods. However, one race seemed to be positioned incorrectly by all the numerical methods used in the study.

Overall similarity among strains of Oryza perennis M. were estimated by Morishima (51). Sixty-five strains each collected from natural habitats and representing several geographic groups were studied for 24 characters. Two techniques were used to analyze the data, i.e., cluster and pattern analyses. For cluster analysis, both correlation coefficients and taxonomic distances were computed. For the formation of groups, the unweighted pair-group method with arithmetic averages was employed. The two methods gave consistent results in spite of the differences in procedure. It was demonstrated by both methods that the four geographical groups (i.e., Asian, African, American, and Oceanian) formed separate clusters. She concluded that phenetic pattern in O. perennis can be largely represented by differentiation of strains into geographical groups and then into perennial versus annual types.

Bhatt (12) used multivariate analysis to select parents for hybridization aiming at yield improvement in self-pollinated crops. He

quantitatively measured genetic divergence using data on yield and five yield components as measured on 40 genotypes of wheat (Triticum aestivum L.) having their origins in different geographic regions of Australia. His results demonstrated that the squared generalized distance technique is a sensitive tool for measuring divergence among genotypes. He observed no direct relationship between geographic distribution and genetic divergence. Of the 12 groups into which the cultivars clustered, genotypes from different origins grouped together in seven cases.

Baum (6) and Baum and Lefkovitch (7, 8, 9) studied the problem of classifying cultivars with special emphasis on oats (Avena spp.). Baum (6) stated that existing methods of classification were inadequate for worldwide application and stipulated that such classification of cultivars be based on as many attributes as possible. Later, they described the establishment and validation of 14 groupings of cultivars in the hexaploid cultivated oats (7). The study was based on 5,000 samples of cultivars and strains obtained from the Oat World Collection. Twenty-one characters were measured for each entry. Gower's (37) similarity coefficient and a divisive chain algorithm, developed especially for the large number of entries, were used to obtain primary groupings. The 107 secondary reference individuals formed were processed by a single linkage cluster analysis. The second part of the study (8) included analyses of the 14 groupings and the definition of new groups of cultivars in terms of probabilities to formulate an identification scheme and to establish a method for identifying cultivars. Using analyses of variance, four characters were chosen to discriminate among the 14 groupings. The 14 sets of 36 multinomial probabilities obtained

therefrom, together with the estimated probability of occurrence of each group, were used to construct a Bayesian identification procedure. Computer simulation suggested that 50 plants from an oat field would be sufficient for the purpose of classifying a cultivar within one of the 14 groupings. Next, they looked into the concordance between phenetics and phylogenetics of 16 selected cultivars of oats having some genealogical kinship (9). The 36 characters measured were divided into agronomic and nonagronomic. Gower's coefficient (37) was computed; and subsequently, different methods of clustering were applied to these similarities. Phylogenetic relationships among the cultivars were described by cladograms and coefficients of common parentage. The best fit with traditional taxonomy was shown by the single linkage clustering of the similarities computed from the nonagronomic characters. In general, phenetic relationships among cultivars disagreed with those defined by cladograms even though some agreement existed with selected sets of characters. Genetic relationships, as measured by coefficients of common parentage, were very similar to ones derived by clustering methods from the phenetic similarities over all characters. Based on their results, they concluded that reconstruction of a true phylogeny from phenetic relationships is impossible.

Rhodes, Carmer, and Courter (61) compared classifications derived by two methods using horseradish (Armoracia rusticana Gaertn., Mey., and Scherb.) cultivars as a model to select diverse genotypes representative of the genetic variability within the group. Twenty cultivars were measured and classified. One classification was based on two highly diagnostic characters that showed the limits of the germplasms in the form of scatter diagrams. The other classification was based on

40 characters, and methods of numerical taxonomy were employed. Two coefficients of similarity, Q-correlation and Sokal's distance (71), were employed. The phenograms were based on the unweighted pair-group method of clustering using simple averages. The two classifications appeared equal in defining the extreme limits of the genetic variability. The main area of disagreement was among the relative positions of intermediate genotypes.

Numerical analyses among wild and cultivated chili peppers, Capsicum baccatum, were performed by Eshbaugh (33). Nineteen collections of wild and 17 of cultivated baccatum were selected at random from the stocks available for the two taxa. Twenty quantitative and 16 qualitative characters were considered in the study. The relationship between the two taxa was expressed as a correlation coefficient, 0.169, which indicated a low degree of similarity.

Rhodes et al. (63) measured and classified the variability among 40 cultivars of mango (Mangifera indica L.) using numerical taxonomy. As a group, the 40 represented much of the genetic variability among mangos currently grown in Florida. Distance coefficients based on 73 characters and the weighted pair-group method of cluster analysis was used. Most of the cultivars clustered into one of four major groups formed by polyembryonic cultivars common to Southeast Asia, monoembryonic cultivars common to India, cultivars from India and the West Indies, and several hybrids developed in Florida and Hawaii, respectively. A few cultivars did not show sufficient affinity to be placed into any of the above groups.

In Australia, numerical methods were used by Edye, Williams, and Pritchard (30) to separate cultivar types among 51 introductions of the

perennial creeping or twining legume (Glycine wightii) native to tropical Africa, Asia, and South America. Thirty-one morphological and agronomic characters were used. Preliminary assessment resulted in four homogeneous and two nonconformist groups. The 11 introductions in the latter groups were individually studied and in some cases reallocated. Finally, six cultivar groups were obtained. It was concluded that numerical methods of cultivar classification appear valuable for integrating morphological and agronomic data to evaluate large numbers of polymorphic species.

Brunken (19) studied cytological and morphological variation in switchgrass (Panicum virgatum L.). Three populations of switchgrass in Central and Southern Oklahoma were sampled for chromosomal variation. Two were typical examples of upland and lowland races. The third site contained members of both races. Based on chromosomal variation, 11 populations were constructed, and each individual in each population was classified for 21 morphological characteristics. A squared Euclidean distance coefficient was calculated, and the clustering was executed by the centroid method and multivariate factor analysis. Both techniques demonstrated that differences in chromosomal variation between the upland and lowland races are reflected in their morphological characteristics. The two races clustered at a very high level of dissimilarity. The results indicated that cytological and morphological differences between the races were maintained in the mixed population.

Applications in Cotton

Probably the earliest attempt to classify cotton cultivars was performed in Alabama about 1894 by Mell (49), who instituted 14

categories of cultivars which he later reduced to seven. The bases for his classifications were general morphologic differences. The next such effort was made by Tracy (82) in 1896; he constructed arbitrary groups based on lint percent, fiber length, and earliness and ranked all cultivars in all categories, studying later which were the best over groups. He mentioned that the Arkansas Agr. Exp. Sta. classified cultivars according to growth habit placing them in two groups, long versus short limbed.

In 1899 Duggar (28) initiated in Alabama a classification of cotton cultivars according to their natural relationships and based on various characteristics, rather than single traits. He was aware of the variation present in cotton and suggested the use of averages for characters measured from a number of typical plants within a cultivar. He grouped cultivars into eight classes: Cluster, Semi-cluster, Rio Grande, King-like, Big Boll, Long Limb, Intermediate, and Long Staple. Tyler (83) in 1910 classified cotton cultivars into eight divisions which followed fairly closely the earlier grouping by Duggar (28).

Brown (16) around 1925 developed a new classification, based primarily on boll size and staple length, which included seven types: King, Dixie, Cook, Triumph, Delfos, Webber, and Mixed. Brown and Ware (18) in 1958 listed 16 groups into which the then currently grown cultivars were classified; the groups were based on the breeding development of the cultivars.

As far as is known to the author, no one has actually used the techniques of numerical taxonomy to classify cotton cultivars. However, the technique has been used in cotton to classify environments and to compare diploid species.

Abou-El-Fittouh, Rawlings, and Miller (1) conducted a quantitative study of environmental similarity as measured by genotype by environment interactions in cotton. The interaction effects were measured on lint yield/hectare for different cultivars in each region. The distance coefficient was used as a measure of similarity among environments; the unweighted average linkage was used for clustering. Their results suggested some modification in the then recognized zoning of the Cotton Belt. The suggested rezoning should reduce variance component estimates for genotype by environment interaction within regions.

Johnson and Thein (44) evaluated evolutionary affinities among 25 diploid species of Gossypium using seed protein patterns. Correlation coefficients for comparing species were calculated from 120 pairs of optical density values. Evolutionary affinities were evaluated from those coefficients and from the diagram of relationships computed by the weighted variable-group method using Spearman's (76) sums of variables procedure for recalculating correlation matrices. The relationship revealed by the protein spectra is remarkably consistent with the classification indicated in the most recent taxonomic revision of the genus. The largest modification suggested by the data was in the division of the New World diploids into two subgroups. The clustering pattern showed three complexes separated by low correlation coefficients. Two of these consisted of the A- and D_B-genomic groups. The third included the genomic groups D_E, B, C, E, and F. Close mutual affinity among species of the last complex suggests their derivation from a common primordial population possibly occupying Central Africa and contiguous lands prior to continental drift. The diagram also suggests that the D_E subgroup maintained close contact with the Old

World species.

Fryxell (34) studied the relationships among 30 diploid species of Gossypium for 25 characters. The Wagner divergence index was used to evaluate phylogenetic patterns; construction of a relationship diagram was based on the principle of evolutionary parsimony as elaborated by Camin and Sokal (20). The information contained in the diagram conformed in broad outline to previously proposed phylogenetic schemes derived from cytogenetic studies. In addition, it graphically drew attention to differences in evolutionary advancement and provided new insights into species relationships.

CHAPTER III

MATERIALS AND METHODS

Cultivars Investigated

All cultivars in this study are classified taxonomically within the species Gossypium hirsutum L. Thirty-two entries representing 11 foreign countries (Greece, Bulgaria, USSR, India, Pakistan, Thailand, Chad, Mali, Cameroon, Uganda, and Zambia) and three continents (Europe, Asia, and Africa) and eight cultivars representing the United States were included in these investigations. The cultivars, their P.I. and C.B. numbers, and their countries of origin are listed in Table I. The US cultivars used as checks herein represented the Eastern Region ('Coker 310'), the Delta Region ('Stoneville 7A' and 'Deltapine 16'), the Plains Region ('Lankart LX 571', 'Lockett 4789-A', 'Paymaster 202', and 'Westburn 70'), and the Western Region ('Acala 1517-70'). Based on currently available information, all 40 cultivars are being grown commercially at the present time in their respective countries of origin. They do not represent a random sample of all G. hirsutum cultivars (nor all countries in which hirsutum is grown). Therefore, inferences derived from the data apply only to the cultivars (and countries) studied. The extent to which they apply to G. hirsutum (or the cotton-growing regions of the world) as a whole is unknown.

TABLE I

CULTIVARS, IDENTIFICATION NUMBERS, AND COUNTRIES OF ORIGIN

Code No.	Cultivar	P.I. No.	C.B. No.	Country of Origin	
1	10E	361150	3987	Greece	(GR)§
2	4S 180	361151	3988	Greece	(GR)
3	HG 9	362157	3995	Chad	(CH)
4	BJA 592	362158	3996	Chad	(CH)
5	Laxmi	367241	4038	India	(IN)
6	Lasani 11	365529	4021	Pakistan	(PK)
7	Pak 51	365532	4024	Pakistan	(PK)
8	AC 134	365527	4019	Pakistan	(PK)
9	LSS	365530	4022	Pakistan	(PK)
10	M4 (N.T. Sind)	365531	4023	Pakistan	(PK)
11	SK 14	365544	4036	Thailand	(TH)
12	SK 32	365545	4037	Thailand	(TH)
13	Allen 333-61	365535	4027	Mali	(ML)
14	HL 1	365534	4026	Cameroon	(CM)
15	137-F	274465	3424	USSR	(RS)
16	138-F	274466	3425	USSR	(RS)
17	108-F	324468	3833	USSR	(RS)
18	152-F	324469	3834	USSR	(RS)
19	CX 349	324467	3832	USSR	(RS)
20	C-1211	324466	3831	USSR	(RS)
21	73	362154	3992	Bulgaria	(BG)
22	4521	362155	3993	Bulgaria	(BG)
23	3996	365543	4035	Bulgaria	(BG)
24	3279	365542	4034	Bulgaria	(BG)
25	6111	362156	3994	Bulgaria	(BG)
26	AH(67)M	365536	4028	Uganda	(UG)
27	BP 52/NC 63	365537	4029	Uganda	(UG)
28	BPA 68	365538	4030	Uganda	(UG)
29	CA(68)36	365539	4031	Uganda	(UG)
30	CA(68)41	365540	4032	Uganda	(UG)
31	SATU 65	365541	4033	Uganda	(UG)
32	Albar 627	‡	‡	Zambia	(ZM)
33	Coker 310*	--	--	USA	(US)
34	Stoneville 7A	--	--	USA	(US)
35	Deltapine 16*	--	--	USA	(US)
36	Lankart LX 571†	--	--	USA	(US)
37	Lockett 4789-A*	--	--	USA	(US)
38	Paymaster 202†	--	--	USA	(US)
39	Westburn 70†	--	--	USA	(US)
40	Acala 1517-70*	--	--	USA	(US)

*National standard cultivar in 1972 and 1973.
†Plains region standard cultivar in 1972 and 1973.
‡Number unavailable.
§Country identification symbol used in figures and in Table IV.

Experimental Procedures

For the measurement of the more economically important traits (e.g., yield), irrigated and dryland experiments were conducted in 1972 and 1973 at the South Central Research Station, Chickasha, Okla., and at the Southwest Agronomy Research Station, Tipton, Okla., on Reinach and Tipton silt loam soils, respectively. Randomized complete-block designs with three replications were used in these experiments. Plots were single rows 7.6 m long with 1.0 m between rows. Planting, cultivation, and other cultural procedures were performed by personnel at those experiment stations following the recommended procedures for that part of the state.

For the measurement of fiber properties, 15-25 boll samples were harvested from each plot in each year, ginned on an eight-saw laboratory-type gin, and the lint forwarded to the Cotton Fiber Laboratory at Oklahoma State University, Stillwater. In 1972, a 75-100 boll sample was also taken from each of two replications; and the lint samples therefrom were sent to the US Cotton Quality Laboratory at Knoxville, Tenn., for fiber and spinning tests.

From this set of experiments, the following quantitative characters were measured:

1. Lint Yield - Weight of snapped cotton per plot in pounds converted into pounds of lint per acre (Yield of lint in pounds per acre was also multiplied by 1.12 transforming the data into kilograms per hectare.),
2. Picked Lint Percent - Ratio of lint to seed cotton expressed as a percentage,

3. Pulled Lint Percent - Ratio of lint to snapped cotton expressed as a percentage,
4. Earliness - Ratio of lint yield from the first harvest to total lint yield expressed as a percentage,
5. Fiber Length (2.5% Span Length) - Length in inches at which 2.5% of the fibers are of that length or longer as measured on the digital fibrograph,
6. Fiber Length (50% Span Length)- Length in inches at which 50% of the fibers are of that length or longer as measured on the digital fibrograph,
7. Fiber Length Uniformity Index - Ratio of 50% to 2.5% span length expressed as a percentage,
8. Fiber Fineness - Fineness as measured on the micronaire and expressed in µg per inch,
9. Fiber Strength (T_1) - Strength of a bundle of fibers as measured on the stelometer with the two jaws holding the bundle separated by a one-eighth inch spacer and expressed in grams per grex,
10. Fiber Strength (T_0) - Strength of a bundle of fibers as measured on the stelometer with the two jaws holding the bundle not separated by a spacer and expressed in grams per grex, and
11. Plant Height - Mean height in cm of five randomly selected plants per plot measured at the end of the season from ground level to the apex of the main stem.

Earliness could be measured in only the irrigated test at Chickasha in 1972 and in both experiments (irrigated and dryland) at Tipton in

1973, as those were the only experiments with more than one harvest. Fiber samples from each harvest in those three experiments were analyzed separately, and then weighted averages for the fiber characteristics and lint percents were calculated for each plot based on the percentage of total lint yield per harvest. Those weighted averages were used in all later calculations involving those traits in those experiments.

From the analyses performed at the US Cotton Quality Laboratory in Knoxville, only the traits not measured in the Cotton Fiber Laboratory in Stillwater were used. Means of the irrigated locations were utilized for these traits because several cultivars in the dryland experiments did not produce sufficient fiber for measurement in the Knoxville Laboratory. The additional characteristics determined from these analyses were:

1. Fiber Reflectance - Percentage of reflectance as measured using the Nickerson-Hunter colorimeter,
2. Fiber Yellowness - Also measured using the Nickerson-Hunter colorimeter,
3. Fiber Tex - Linear density of fibers expressed as the weight in grams of 1,000 m of fiber,
4. Yarn Tenacity - Strength of 27 tex yarn expressed in grams per tex, and
5. Yarn Strength - Strength of 22's (actually 27 tex) as determined from a small-scale, 50-gram test.

Five disease reactions were determined during the 1972 and 1973 seasons at the following locations:

1. Sandy Land Research Station at Mangum, Okla., and a private farm at

Hollis, Okla., for reactions to the fusarium wilt [Fusarium oxysporum Schlecht. f. vasinfectum (Atk.) Snyder and Hansen] and root-knot nematode [Meloidogyne incognita (Kofoid and White) Chitwood (M. incognita acrita)] complex,

2-4. Agronomy Research Station at Perkins, Okla., and the Plant Pathology Research Station at Stillwater for reactions to bacterial blight [Xanthomonas malvacearum (E. F. Sm.) Dows.] race 1, race 2, and a mixture of virulent races of the bacterium, and

5. Plant Pathology Research Station at Stillwater for reactions to verticillium wilt (Verticillium dahliae Kleb.).

At each location in each year, a single row plot 9.0 m long and 1.0 m apart was grown for each cultivar.

To determine reactions to the fusarium wilt-nematode complex, the cultivars were grown in naturally infested soil (Meno loamy fine sand at Mangum and Hardeman fine sandy loam at Hollis) under dryland conditions; plants were graded in late summer on the basis of external and internal symptoms with the scale ranging from one, no symptoms, to four, dead plant (14).

Bacterial blight reactions were determined by artificially inoculating plants with 4 to 6 true leaves grown under irrigation on a Teller loam at Perkins and Norge loam at Stillwater. The inoculums from race 1, race 2, and the virulent mixture were applied suspended in water with single-nozzle guns from a power sprayer operated at about 400 psi (15). Disease symptoms 12 to 14 days after inoculation were graded on a scale of one, immune, to four, fully susceptible (13).

Verticillium wilt reactions were determined in late fall after the cultivars had been grown on naturally infested soil under irrigation;

the plants were graded on the basis of external and internal symptoms on a scale ranging from one, no symptoms, to six, dead plant, as a variation of the scale used by Verhalen et al. (86).

Twenty-three discrete characters were determined for each cultivar at the Agronomy Research Station at Perkins during the same two-year period. For this purpose, single-row plots 15.0 m long and 1.0 m apart were planted on a Teller loam soil under irrigation. Selection of characters to be measured was based on previous descriptions of cotton cultivars and their classifications (2, 3, 32, 38, 39, 64, 81). Only those characters which varied among cultivars were included herein. A number of characters such as glanded plants and seed, extrafloral nectaries, and lack of petal spots were constant over all the cultivars studied and were not included in these analyses. An attempt was also made to avoid redundant, i.e., highly correlated, characters. For example, the trait "lint yield, lbs/A" was omitted because it was obviously highly correlated with "lint yield, kgs/ha" which was included in these analyses. Subjective ratings were used to score the traits with sufficient units being included to accommodate each distinct type or character-state for that trait. Character-states were coded in a logical order taking into consideration the characteristics of the check cultivars which were scored (insofar as possible) with the lowest number in the arithmetic code used. The discrete characters, their character-states, and corresponding arithmetic codes are listed in Table II.

A number of continuous characters were also measured at this location during both growing seasons. They included:

1. Number of Bract Teeth - Mean number of teeth per bract from a

TABLE II

DISCRETE CHARACTERS, THEIR CHARACTER-STATES, AND CORRESPONDING ARITHMETIC CODES

No.	Character	Character-State*	Arithmetic Code
1	Stem Pubescence	Normal (Like US Cultivars)	1
		Hairy	2
		Densely Hairy	3
2	Apex Pubescence	Normal (Like US Cultivars)	1
		Hairy	2
		Densely Hairy	3
3	Stem Erectness	Erect	1
		Intermediate	2
		Lax	3
4	Branching Habit	Bunch	1
		Semi-cluster	2
		Cluster	3
5	Plant Foliage	Dense	1
		Intermediate	2
		Sparse	3
6	Leaf Lobation	Leaf Incision Less Than 1/3	1
		Leaf Incision From 1/3 to 2/3	2
		Leaf Incision Over 2/3	3
7	Leaf Size	Large	1
		Medium	2
		Small	3
8	Leaf Color	Dark Green	1
		Light Green	2
		Grayish Green	3
9	Leaf Pubescence	Normal (Like US Cultivars)	1
		Hairy	2
		Densely Hairy	3
10	Leaf Margin	Normal	1
		Crinkled	2
11	Corolla Color	Cream	1
		Yellow	2
12	Pollen Color	Cream	1
		Mixed (Cream and Yellow)	2
		Yellow	3
13	Pedicel Length	Short	1
		Long	2

TABLE II (Continued)

No.	Character	Character-State*	Arithmetic Code
14	Bract Size	Large	1
		Medium	2
		Small	3
15	Bract Shape	Length Smaller Than Width	1
		Length Equal to Width	2
		Length Larger Than Width	3
16	Bract Teeth Shape	Coarse	1
		Fine	2
17	Boll Shape	Round Pointed	1
		Conical	2
		Oval	3
		Oval Pointed	4
		Mixed 1 (Round Pointed and Conical)	5
		Mixed 2 (Oval and Oval Pointed)	6
		Mixed 3 (More Than Two Classes)	7
18	Boll Pittedness	None	1
		Fine	2
		Coarse	3
19	Boll Waxiness	Dull	1
		Shiny	2
20	Bract Versus Boll Size	Bract Covers 1/3 of Boll	1
		Bract Covers 2/3 of Boll	2
		Bract Covers Boll	3
21	Seed Fuzziness	Heavy	1
		Moderate	2
		Sparse	3
		Naked	4
		Mixed (All Classes)	5
22	Seed Fuzz Color	Gray	1
		White	2
		Mixed (Gray and White)	3
		Green	4
23	Seed Shape	Pyriform	1
		Mixed (Pyriform and Dumpy)	2
		Dumpy	3

*Character-states were determined by observing all plants in a row or by taking random samples of the pertinent plant parts. In Table IV (see Appendix) are reported the number and type of observations taken per cultivar for each of these characters.

15-bract sample,

2. Stormproofness - Force in grams required to remove a lock of seed cotton from the bur of a fully open (i.e., mature) boll as measured by a 500-g force gauge (92),
3. Boll Size - The weight of seed cotton in grams per boll,
4. Bur Size - The weight of the empty bur in grams per boll,
5. Number of Locks per Boll - Mean of 25 mature bolls taken at random,
6. Number of Seed per Lock - Mean number from single locks taken at random from 25 randomly selected bolls,
7. Weight of Lint per Boll - Mean weight of lint per boll in grams from a 25-boll sample,
8. Lint Index - The weight of lint in grams per 100 seed [calculated as (picked lint percent x seed index)/seed percent], and
9. Seed Index - The weight of 100 seed in grams.

In summary, a total of 53 characters (30 continuous and 23 discrete) were measured for each cultivar in these experiments. Observations per character ranged from one (on a total row or sample basis) to 120 (see Table IV).

Cultivar number 30, 'CA(68)41' from Uganda, was omitted from these analyses because of poor stands in all experiments in 1973.

Statistical Procedures

Combined analyses of variance for the 39 cultivars over the two years and four experiments per year were performed for the following characters: lint yield in kgs/ha, picked and pulled lint percents, earliness, 2.5% span length, 50% span length, uniformity index,

fineness, T_1 and T_0 strengths, and plant height. The form of the analyses followed that described by Comstock and Moll (25). The F-tests for each source of variation were performed using the appropriate error term assuming a random model (79). Procedures described by Cochran (22) were used to perform the F-tests for the cultivars source of variation when one or more of the first-order interactions were significant.

Phenotypic relationships among the cultivars were studied as a function of all 53 observed characteristics and by considering only the 16 more economically important characters (eleven replicated traits listed above plus the five disease reactions). A raw data matrix was constructed with rows representing cultivars and columns representing characters; in each row-column slot appeared the mean over all observations in the case of continuous characters or the coded character-state for discrete characters.

Sokal (71) and Rohlf and Sokal (67) recommended the standardization of characters when measurements among traits were in different units and when coding of character-states was arbitrary. Since those were the circumstances herein, the raw data matrix values were transformed to standardized values by character before proceeding with the computation of similarity coefficients.

From the standardized data matrix, generalized Euclidean distances (70, 74) were computed as a measure of pairwise similarity between all combinations of 39 cultivars taken two at a time in an n-dimensional space where the n coordinates were the 53 (or 16) characters. The generalized Euclidean distance (d_{ij}) between cultivars i and j over n-standardized characters is defined here as:

$$d_{ij} = [\sum_{k=1}^{n} (X_{ik} - X_{jk})^2]^{\frac{1}{2}}$$

where:

X_{ik} is the standardized value of the k^{th} character for the $\underline{i}^{th}$ cultivar, and

X_{jk} is the standardized value of the k^{th} character for the $\underline{j}^{th}$ cultivar.

Two 39 x 39 distance matrices were constructed which contained the computed distances among cultivars; one was based on 53 characters and the other on the 16 more economically important traits. The distance matrices were then used to group the 39 cultivars; the clustering method employed was the unweighted pair-group method using arithmetic averages (70, 74) in combination with the dendrograph program (47, 48) which depicts in a hierarchical manner the relationships among cultivars in two dimensions.

To study within-group relationships, geographically distinct groups of cultivars were also clustered separately. Diagrams of phenotypic relationships among selected groups of cultivars were also constructed using the distance values for the cultivars of interest from the computed distance matrices.

The statistical analyses, the standardization by character of the raw data, the computation of the distance values, and the dendrograph program were performed at Oklahoma State University's Computer Center on an IBM 360 Model 65 digital computer; and the diagrams of relationship were produced using a 1627 Calcomp plotter adapted to the computer.

CHAPTER IV

RESULTS AND DISCUSSION

Cultivar Relationships Based on 53 Characters

The characterization by traits of the cultivars in this study is presented in the Appendix, Table IV. Numerical descriptions are reported for each cultivar as overall means for the respective characters. Also included in the table are the number of observations per cultivar mean, means over cultivars, and standard deviations over cultivar means.

Results of analyses of variance performed over years, locations, and cultivars are reported in Table III. Mean squares are shown for each of the 10 characters measured in both years at the four locations, as well as earliness, which was measured in only three experiments. F-tests indicate that differences among cultivars were highly significant for all 11 traits. This suggests the presence of measurable phenotypic (and thus genotypic) variation in those characters among the cultivars studied. In general, the differential effect of environment on each of the characters analyzed, as implied by the statistical significance of the first- and second-order interactions, indicates that relative performance among cultivars was influenced by environment for all 11 traits.

Distance coefficients (computed from the standardized numerical descriptions of the 39 cultivars based on 53 characters) are shown in

TABLE III

ANALYSES OF VARIANCE FOR 11 TRAITS AND 39 CULTIVARS OVER YEARS AND LOCATIONS

Source of Variation	df[†]		Mean Squares: Lint Yield, kgs/ha	Picked Lint Percent	Pulled Lint Percent	Earliness	2.5% Span Length	50% Span Length	Uniformity Index	Fiber Fineness	Fiber Strength, T_1	Fiber Strength, T_0	Plant Height, cm
Cultivar (C)	38	(38)	290359**	125.38**	97.88**	1906.3**	.0842**	.01110**	30.57**	1.431**	.4549**	1.380**	3417.4**
C x Year (Y)	38		37072**	15.39**	9.57	--	.0114**	.00230**	4.62	0.471**	.0893**	0.149**	100.4
C x Location (L)	114	(76)	25010**	6.80	6.99	399.3**	.0018	.00086	3.28	0.275**	.0298**	0.054*	112.5
C x Y x L	114		15451**	6.60**	7.51**	--	.0018**	.00066*	3.25**	0.165**	.0193	0.041	87.2**
Error	608	(228)	8802	2.94	2.37	54.2	.0012	.00049	1.84	0.075	.0183	0.040	51.3

*, **Significant mean squares at the 0.05 and 0.01 levels of probability, respectively.

[†]Numbers in parentheses denote the degrees of freedom for earliness over three experiments.

the Appendix, Table V. The interpretation of the distance values between any given pair of cultivars is that the lower the value, the closer the relationship, while the higher values indicate lesser resemblance between entries. The coefficients observed ranged from 0.32 between entries 24 and 25 to 5.71 for the cultivar combinations 3, 35; 3, 40; and 4, 40. The coefficient between 4 and 35 was 5.70. These results imply that the cultivars '3279' and '6111' from Bulgaria exhibit the greatest phenotypic resemblance over all 53 traits, while 'HG 9' and 'BJA 592' from Chad exhibit the least with Deltapine 16 and Acala 1517-70 from the US.

The ranges of coefficients for each of the countries represented by three or more cultivars were as follows: In the US group, the minimum distance value was 0.58 between Coker 310 and Stoneville 7A with a maximum distance of 2.19 between Paymaster 202 and Acala 1517-70; in Pakistan, from 0.86 between 'AC 134' and 'LSS' to 2.63 for LSS and 'M4'; in Russia, with 0.41 between '137-F' and '138-F' to 1.28 between '152-F' and 'C-1211'; in Bulgaria, from 0.32 for 3279 and 6111 to 0.77 between '73' and 3279; and in Uganda, with 0.75 between 'BP 52/NC 63' and 'CA(68)36' to 2.73 for 'AH(67)M' and BP 52/NC 63. For Greece, Chad, and Thailand, each of which was represented by only two cultivars, the distance coefficients were 0.60, 0.66, and 1.56, respectively. India, Mali, Cameroon, and Zambia could not be included in these comparisons because each was represented by only a single cultivar. Of the eight countries which could be compared, the Bulgarian cultivars as a group were phenotypically more alike than those from the other countries studied (the mean distance value among Bulgarian cultivars was 0.54); Bulgaria was followed by Greece (0.60), Chad (0.66),

the USSR (0.89), the US (1.24), Thailand (1.56), Uganda (1.65), and Pakistan (1.69).

The structure of the distance coefficient matrix (for the 39 cultivars based on 53 characters), as defined by the dendrograph procedure, is presented in Figure 1. The distance values at which the stems of the graph join may be read along the ordinate axis. To study the groups formed, a distance value of 1.0 was subjectively chosen as the point of group determination. Cultivars joined below that number were considered as members of the same cluster. Analysis of the resulting dendrograph revealed 12 major groups which could be distinguished. Group A is formed by nine cultivars which include the two from Greece, three from the USSR, and four from the US. The first cultivars to join were 137-F and 138-F from the USSR. Entries '10E' and '4S 180' from Greece and Lankart LX 571 and Lockett 4789-A from the US also paired together before becoming members of the group at large. Paymaster 202 from the US was the only cultivar in Group B. AC 134 from Pakistan is the last cultivar to join Group C as constituted by an early grouping of C-1211 and '108-F' from the USSR, followed by 'CX 349' from the same country, and 'Albar 627' from Zambia. Three US cultivars were included in Group D; Deltapine 16 and Acala 1517-70 bore more resemblance to each other than to Westburn 70, which joined at a higher distance value.

Groups E, F, and G were formed by the cultivars M4 from Pakistan, 'HL 1' from Cameroon, and AH(67)M from Uganda, respectively. Two entries from Uganda, 'SATU 65' and 'BPA 68', comprised the next group, H. The five cultivars from Bulgaria were included together in Cluster I; 3279 and 6111 joined first with '3996', '4521' and 73 becoming members progressively later followed by 'Pak 51' and LSS from Pakistan, and

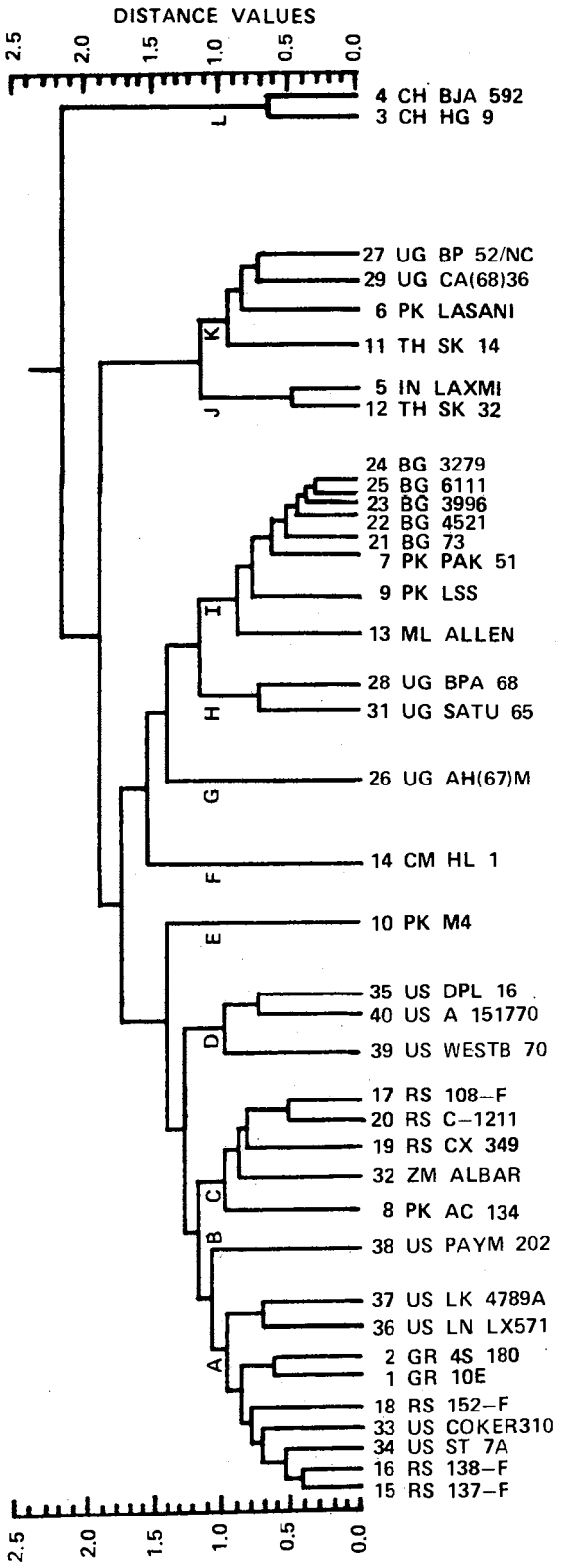

Figure 1. Dendrograph Depicting the Phenotypic Relationships Among 39 Cultivars Based on the Distance Coefficients Computed on 53 Characters

'Allen 333-61' from Mali. Two cultivars formed Cluster J; one came from India, 'Laxmi', and the other from Thailand, 'SK 32'. The next group, K, consisted of two Uganda cultivars, BP 52/NC 63 and CA(68)36, which joined each other followed by 'Lasani 11' and 'SK 14' from Pakistan and Thailand, respectively, which joined them in turn. The last group, L, is composed of the two cultivars from Chad, HG 9 and BJA 592.

The overall diagram of relationships clearly showed that the cultivars from Greece, Chad, and Bulgaria clustered first among themselves by country before joining, or being joined by, any other cultivars. This is indicative of the high degree of relationship among the cultivars examined within those countries. Of these entries, the two from Chad as a group are very different from the rest, as they joined the other cultivars in the dendrograph at the highest distance observed. The diagram also showed that in general the cultivars from Greece, the USSR, and the US exhibited considerable similarities. Groups A through D included all of the cultivars from those three countries.

The representative from India, Laxmi, tended to cluster with the cultivars from Thailand (especially SK 32) which from the geographical standpoint at least would seem reasonable. Even though Uganda's cultivars did not exhibit a close overall, within-country relationship, the manner in which BP 52/NC 63 and CA(68)36 and in which BPA 68 and SATU 65 clustered is in good agreement with their reported pedigrees (4, 42, 43, 89). The cultivars from Pakistan showed a variable pattern of relationship. In most cases, those entries clustered with different groups, including the closely related AC 134 and LSS (based on the distance coefficients matrix). Consistency of within-group relationships as indicated by the computed distance values and by the

dendrograph was shown between the cultivars from the US, Coker 310 and Stoneville 7A; from the USSR 137-F and 138-F; and from Uganda, BP 52/NC 63 and CA(68)36. Some of the apparent within-group distortions between the relationships indicated by the distance coefficients matrix versus the dendrograph are probably due to the high distance values at which some of the cultivars within a group joined, coupled with the mechanics of the clustering procedure used.

To determine if phenotypic relationships among the US cultivars, as generated by the numerical technique, would indicate some consistency with known phylogenetic relationships based on pedigrees, a dendrograph was derived using the distance values for those cultivars from the distance matrix previously computed (Figure 2). This diagram clearly shows the clustering of the eight cultivars into two major groups; however, if the determination point is placed at a distance value of about 0.9, four clusters are apparent. Group A is formed by Coker 310, Stoneville 7A, Deltapine 16, and Westburn 70; Group B by Acala 1517-70; Group C by Paymaster 202; and Group D by Lockett 4789-A and Lankart LX 571. This breakdown of the US cultivars agrees fairly closely with expected resemblances based on their reported genealogies (17, 18, 57, 58, 78, 85, 88, 90). This agreement may be interpreted as an indication that a rather large portion of the genetic variability present in these populations has been sampled, which in turn helped define reasonably well their true phylogenetic relationships. The slightly different patterns for these cultivars observed when comparing Figure 1 with Figure 2 are undoubtedly due to the mechanisms of the clustering procedure. For the US cultivars, Figure 2 presents the clearer picture of their relative positions.

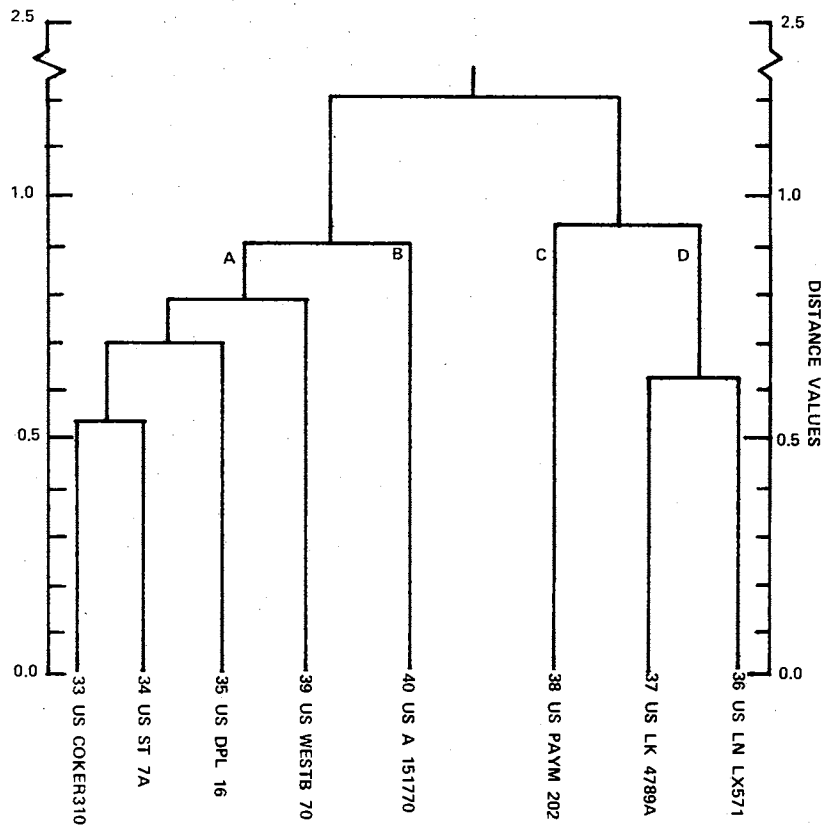

Figure 2. Dendrograph Depicting the Phenotypic Relationships Among the Cultivars from the United States Based on the Distance Coefficients Computed on 53 Characters

Cultivar Relationships Based on 16 Characters

Of the 53 characteristics observed, several were not replicated over locations, years, or both. Also, a number of traits could be considered of negligible importance from the economic standpoint. Therefore, the decision was made to use only those characters which were obviously of economic importance and which were more accurately measured to define phenotypic relationships among the 39 cultivars. For this purpose, 16 of the more economically important characters obtained from replicated observations over locations, years, or both were chosen.

Distance coefficients, computed from the standardized numerical descriptions of the 39 cultivars and based on the 16 characters, are shown in the Appendix, Table VI. The values ranged from 0.13 between 3279 and 6111 from Bulgaria to 3.93 for HG 9 and Acala 1517-70 from Chad and the US, respectively. BJA 592 from Chad and Acala 1517-70 had a distance value of 3.92. The two Chad cultivars were again considerably different from the US cultivar Deltapine 16 (values of 3.84 and 3.83, respectively).

A survey of the mean distance values for the eight countries with two or more entries indicated that Greece and Chad cultivars exhibited the greatest similarity (0.32) within their respective countries followed by Bulgaria (0.33), Thailand (0.53), the USSR (0.57), the US (0.68), Pakistan (0.94), and Uganda (1.02).

The dendrograph derived from the distance coefficient matrix for 39 cultivars and based on 16 characters is reported in Figure 3. For the definition of groups, a determination point at the distance value

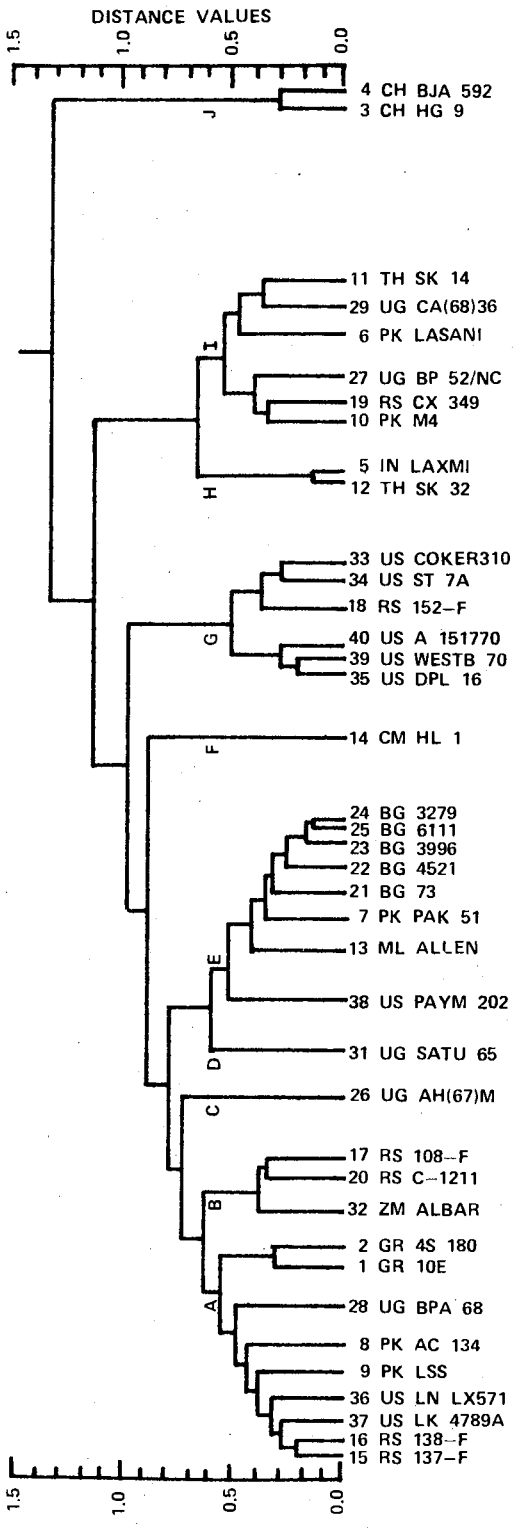

Figure 3. Dendrograph Depicting the Phenotypic Relationships Among 39 Cultivars Based on the Distance Coefficients Computed on 16 Characters

of 0.6 was taken. As a result, 10 clusters could be distinguished. The primary similarities and differences between the clustering of the two dendrographs for 39 cultivars (Figures 1 and 3) were as follows:

Previously described Groups F, G, J, and L in Figure 1 remained the same, and they are represented in Figure 3 as Groups F, C, H, and J, respectively. Members of Groups B and K in Figure 1 join Groups E and I, respectively, of the new diagram. Group A in Figure 3 still contains six of the original cultivars (137-F, 138-F, Lankart LX 571, Lockett 4789-A, 10E, and 4S 180) in Group A from Figure 1. However, LSS and AC 134 from Pakistan and BPA 68 from Uganda have replaced 152-F, Stoneville 7A, and Coker 310 in that group.

Cluster B in Figure 3 is formed by two USSR cultivars, 108-F and C-1211, which are joined by Albar 627 from Zambia. These three cultivars were also related in Figure 1 since they comprised three of the five cultivars in Group C in that figure. The five cultivars from Bulgaria are again included in the same group, this time E, in the same order of relationship; and again, Pak 51 is the cultivar showing the greatest resemblance to the Bulgarian cultivars as a group. Allen 333-61 is also a member of this group in both figures. LSS, in this group in Figure 1, has been replaced by Paymaster 202. SATU 65 forms a group of its own in Figure 3, D, which is distantly related to Group E.

Group G in Figure 3 may be considered as two sets of three cultivars each. One set (Deltapine 16, Westburn 70, and Acala 1517-70) formed Group D in Figure 1; the other set (152-F, Stoneville 7A, and Coker 310) formed a closely related group in Group A of that figure. Group I in Figure 3 is formed by the same cultivars (SK 14, CA(68)36, Lasani 11, and BP 52/NC 63) as were in Group K in Figure 1 plus M4 from

Pakistan and CX 349 from the USSR.

As before, the cultivars with the least resemblance to the others were from Chad. The US cultivars appeared to form a more closely related group than before, with the exceptions of Lankart LX 571 and Lockett 4789-A, which remained in Group A, and of Paymaster 202, which joined Group E at a relatively high distance. The Bulgarian cultivars exhibited the same close relationship and order of relationship as before. The USSR and Pakistani cultivars were widely distributed over the dendrograph as were those from Uganda.

The phenotypic relationships among cultivars as depicted by the dendrograph based on 16 traits resembled to a large extent the diagram based on 53. Probably one of the more important changes observed was the more complete discrimination of the US cultivars from the others. This would suggest that whenever the characters of lesser economic importance are ignored, the US cultivars are more alike genetically than their external appearance would lead one to expect.

Relationships Among Cultivar Subsets as Based on 16 Characters

To determine the relationships among selected groups of cultivars, more detailed analyses were conducted of the dendrograph based on 16 characters. The procedure used in accomplishing this objective was to extract the relevant coefficients from the distance matrix computed for 39 cultivars on 16 characters. Diagrams of phenotypic relationships were then generated using the dendrograph procedure.

The diagram of relationships among the US cultivars was derived first, and their pattern is depicted in Figure 4. The cultivars were

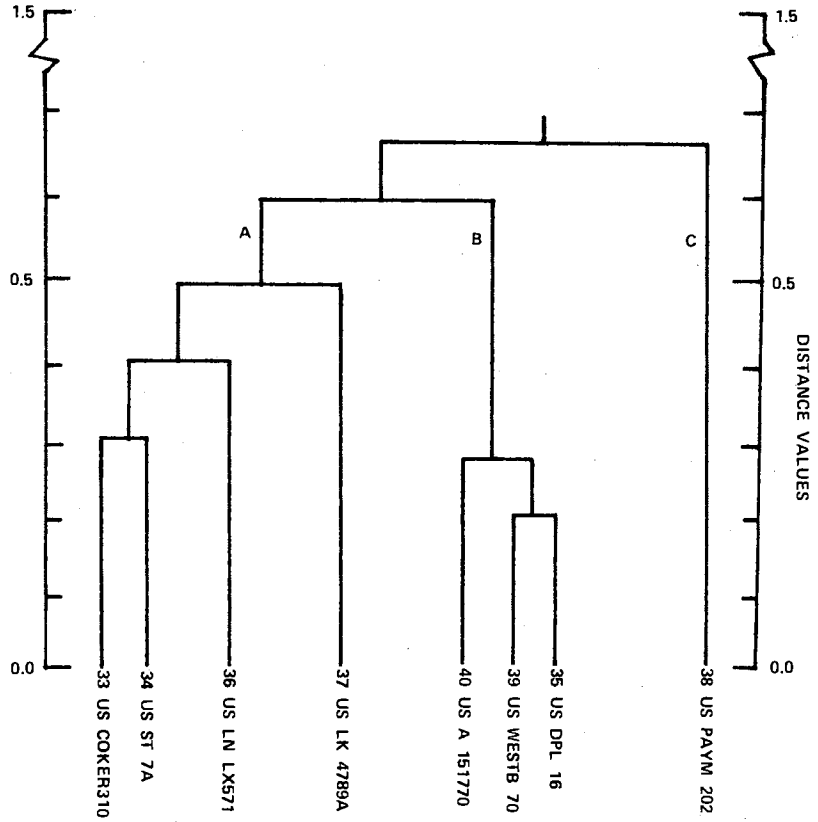

Figure 4. Dendrograph Depicting the Phenotypic Relationships Among the Cultivars from the United States Based on the Distance Coefficients Computed on 16 Characters

discriminated into three well-defined clusters if a distance value of about 0.55 is used to distinguish among groups. Of the Delta cultivars, Stoneville 7A resembled more closely the Eastern cultivar (Coker 310) while Deltapine 16 resembled the Western representative (Acala 1517-70). The relatively close resemblance between Lankart LX 571 and Lockett 4789-A was not surprising. However, the alliance of Westburn 70 (a Plains cultivar) with the Acala-Deltapine group was. As in previous figures, Paymaster 202 was quite different from the other US cultivars studied.

When the eight US cultivars were omitted from the group of 39, the entries remaining exhibited several changes in their relationships (Figure 5). Considering the discrimination point to be at the distance value of 0.7, seven groups are recognizable. The major differences observed, when compared with the diagram for the 39 cultivars (Figure 3), are within the first three clusters. The other four groups (D, E, F, and G) maintained the same structure as before (F, H, I, and J in Figure 3, respectively). In this figure, Group A was formed by Group E (Figure 3) less the US cultivar, Paymaster 202, plus the cultivars from Greece. Cluster B was composed of Group B from Figure 3 plus four cultivars from Group A in that figure (137-F, 138-F, LSS, and AC 134) plus the USSR cultivar (152-F) most closely allied with the US cultivars in Group G, Figure 3. Group C formed a new grouping of cultivars not seen in the previous figure.

With the deletion of the US cultivars, the USSR cultivars tended to cluster more closely than in any of the diagrams studied previously, and the two cultivars from Greece (in the absence of the US group) showed greater resemblance to those from Bulgaria.

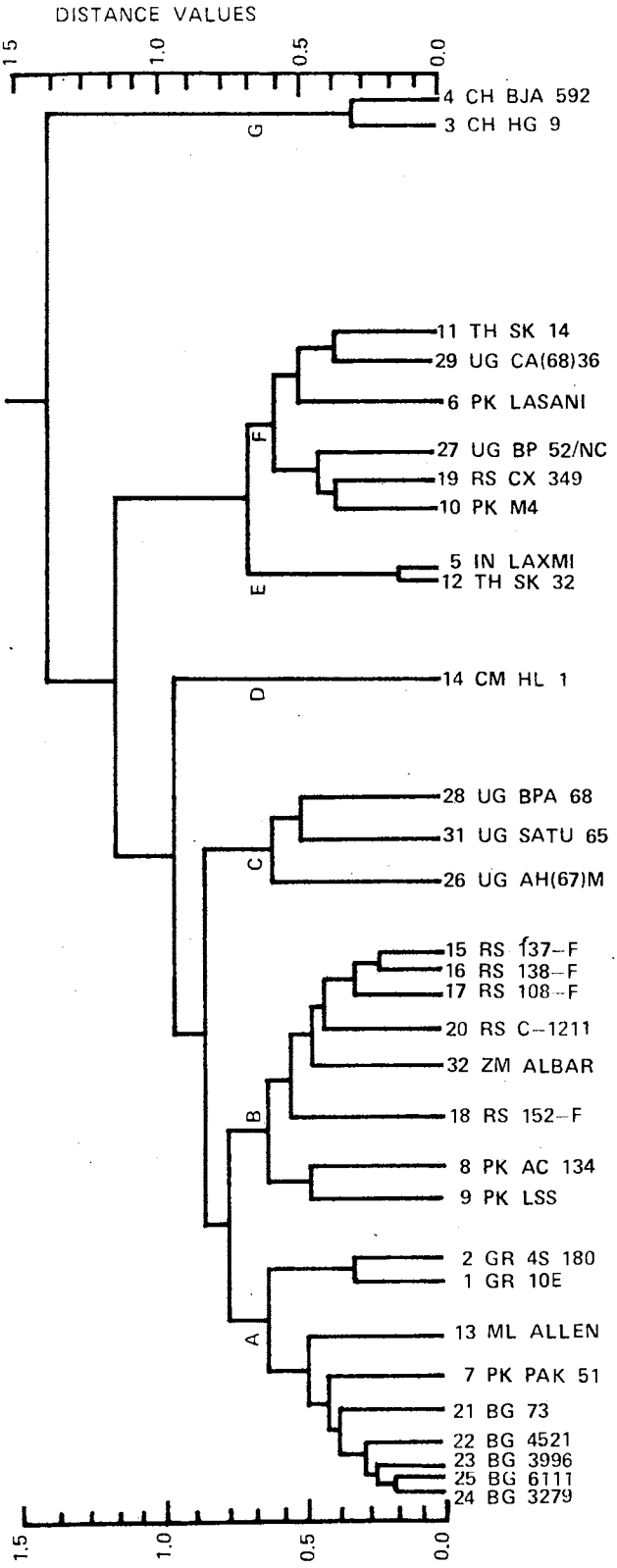

Figure 5. Dendrograph Depicting the Phenotypic Relationships Among 31 Foreign Cultivars Based on the Distance Coefficients Computed on 16 Characters

The 31 foreign cultivars were then classified as European, Asian, and African and studied separately. The dendrographs for those groups are presented in Figures 6, 7, and 8, respectively.

The European cluster, formed by the entries from Greece, the USSR, and Bulgaria, clearly indicates that the cultivars of the countries involved were more alike within than between each country (Figure 6). The Bulgarian and Greek groups displayed a closer likeness to each other than to the USSR group. However, the USSR cultivars displayed more variability than did the other two.

The Asian representatives (India, Pakistan, and Thailand) formed three well-defined clusters when a discrimination point of 0.7 was employed (Figure 7). However, those clusters did not correspond to countries of origin as they did in the previous figure. The first cluster consisted of a mixed group of cultivars from all three countries; the relationship exhibited by Laxmi and SK 32 in that cluster has been consistent throughout this study. Group B contained two cultivars, one from Pakistan and the other from Thailand. The last cluster was formed by the three remaining Pakistani cultivars.

When the dendrograph for the African cultivars (Figure 8) was separated at a distance value of 0.8, four well-distinguished clusters were apparent. The Uganda cultivars BPA 68, SATU 65, and AH(67)M grouped together (as in Figure 5) and were now joined by Allen 333-61 from Mali. HL 1 from Cameroon again remained by itself. Two Uganda entries, BP 52/NC 63 and CA(68)36, clustered together with Albar 627 from Zambia. The last group in the dendrograph was composed of the consistently segregated cultivars from Chad. The cultivars from Uganda, as noted before, exhibited considerable variability among entries. The

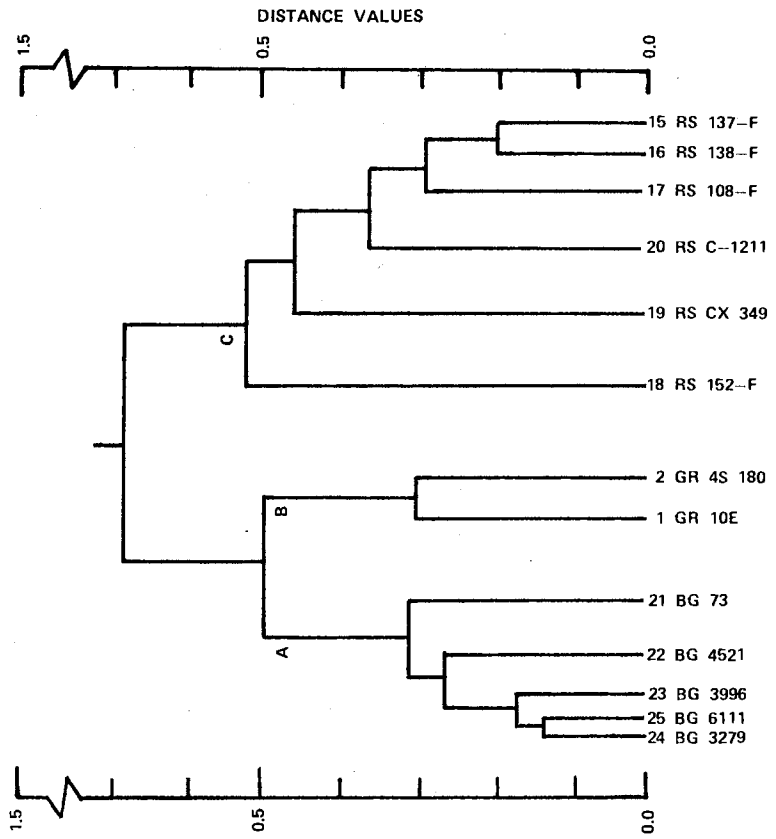

Figure 6. Dendrograph Depicting the Phenotypic Relationships Among Cultivars from Europe

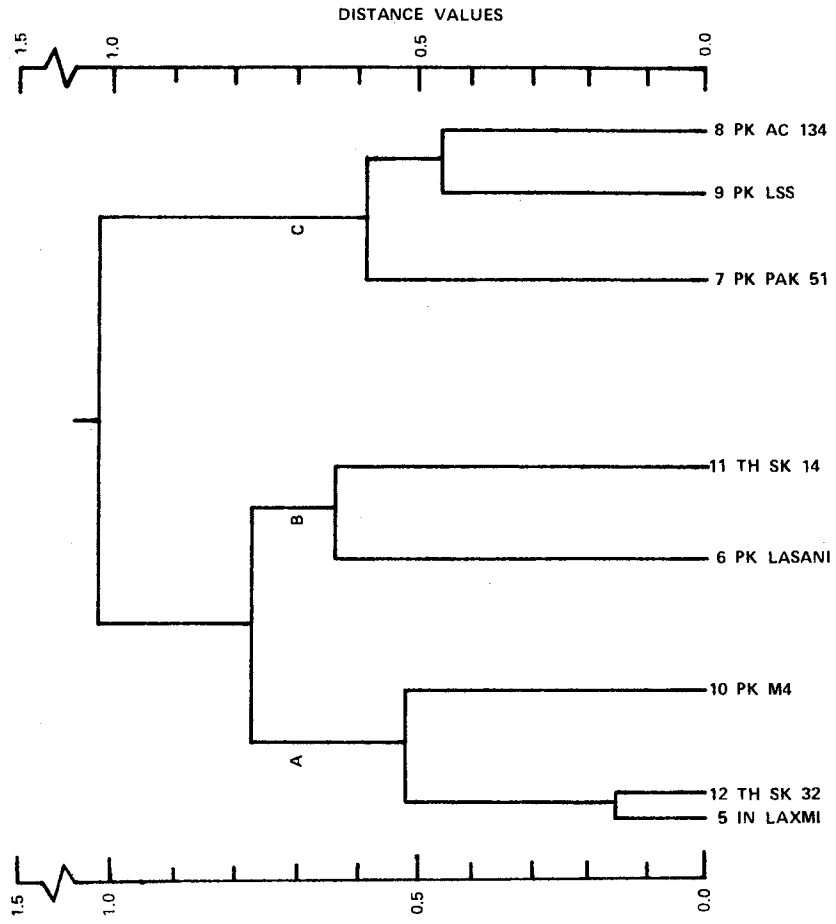

Figure 7. Dendrograph Depicting the Phenotypic Relationships Among Cultivars from Asia

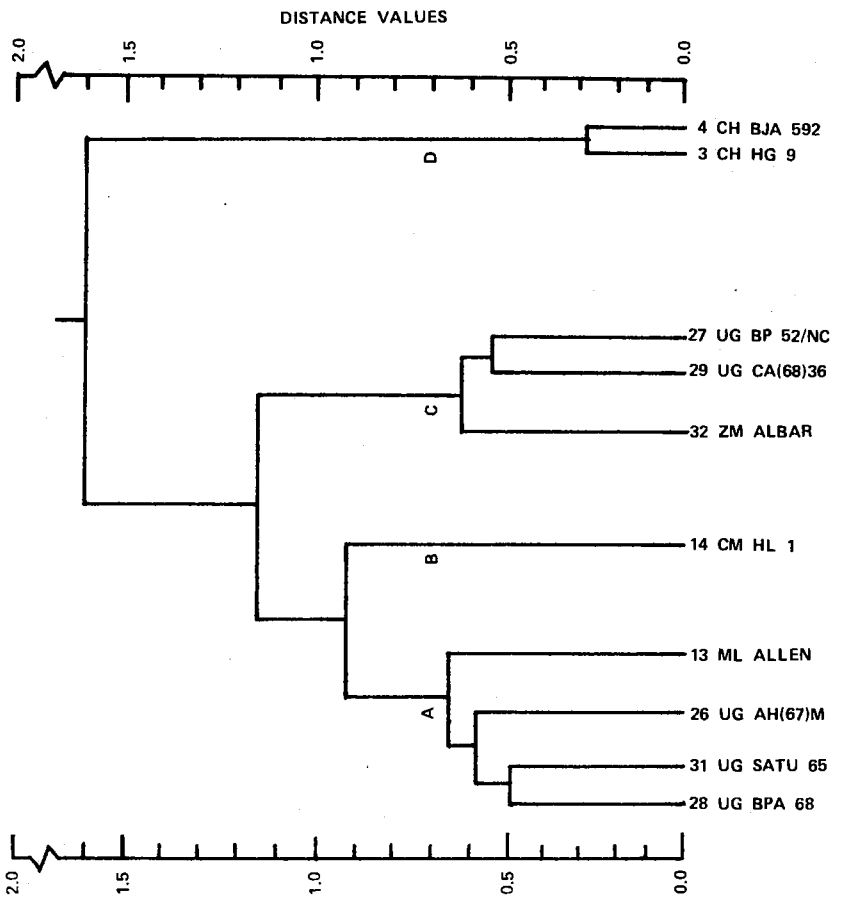

Figure 8. Dendrograph Depicting the Phenotypic Relationships Among Cultivars from Africa

phenotypic relationships among the African cultivars, as defined by the techniques of numerical analysis, agreed quite closely with the pedigrees reported by Arnold, Costelloe, and Church (4), Innes (42), Innes and Jones (43), and Ware (89).

Comparisons Among Cultivar Subsets with the US Cultivars as Based on 16 Characters

To determine more specific relationships between the individual European, Asian, and African cultivar groups and the US cultivars, a combination of each with the North American representatives was studied. Dendrographs depicting the resemblances among the groups thus formed are shown in Figures 9, 10, and 11, respectively.

The resemblances of the European cultivars to the US group (Figure 9) showed that the pattern for the USSR cultivars changed in comparison to the previously defined clustering in Figure 6. The group from Greece and especially the one from Bulgaria maintained their within-group relationships. A group determination point at the distance value of 0.6 defined three clusters which closely resembled the structure of groups A-B, E, and G in Figure 3 when all 39 cultivars were considered. The Bulgarian group appeared to have more resemblance as a group toward the USSR and Greece cultivars than to those from the US. Paymaster 202 was the only US entry very much like the Bulgarian group.

The diagram of the Asian group plus the US entries (Figure 10), with a group determination point at a distance value of 0.7, exhibits four clusters. One cluster includes six of the eight US cultivars, and two of the other three, C and D, exhibited the same structure shown

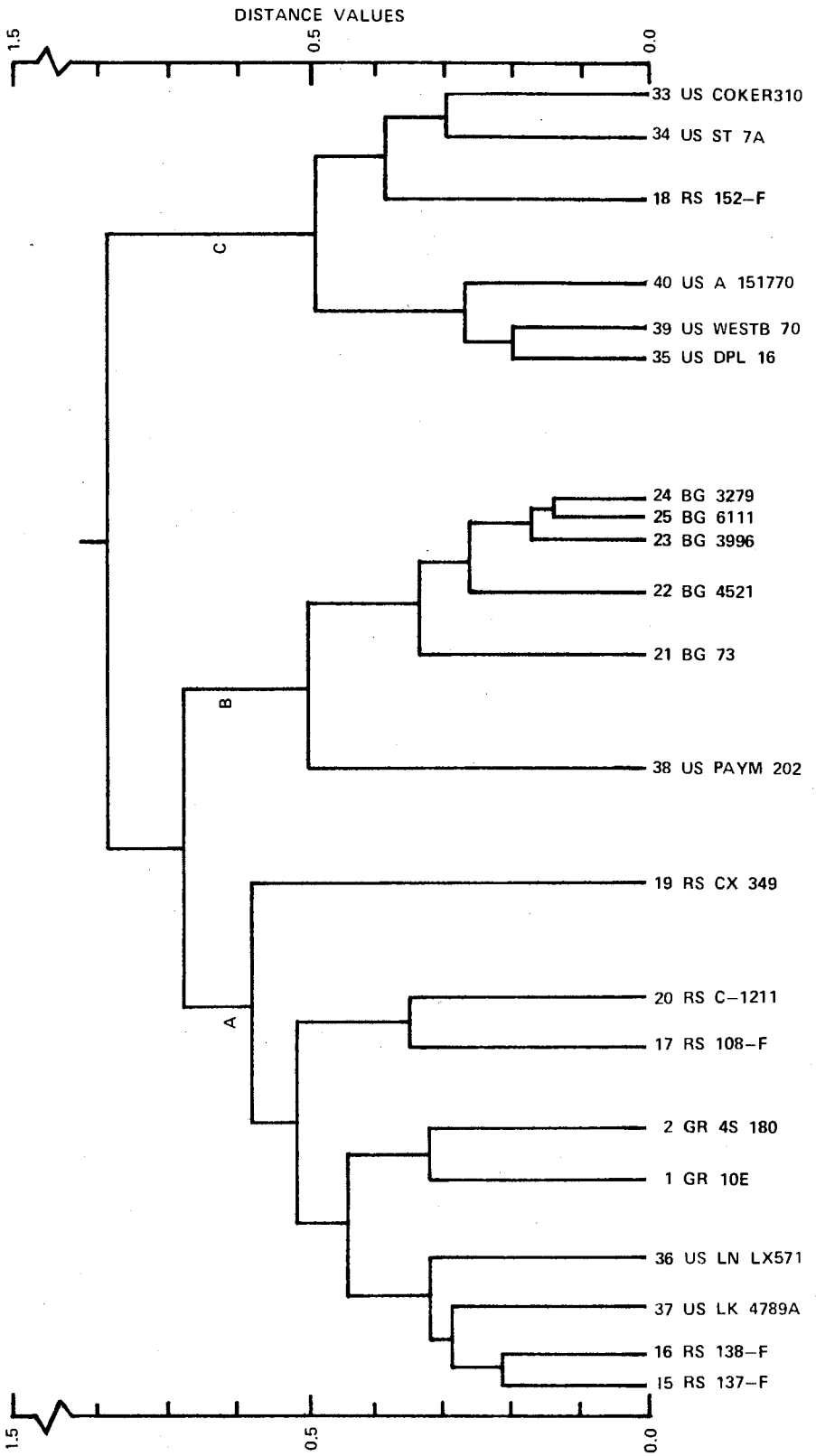

Figure 9. Dendrograph Depicting the Phenotypic Relationships Among Cultivars from the United States with Those from Europe

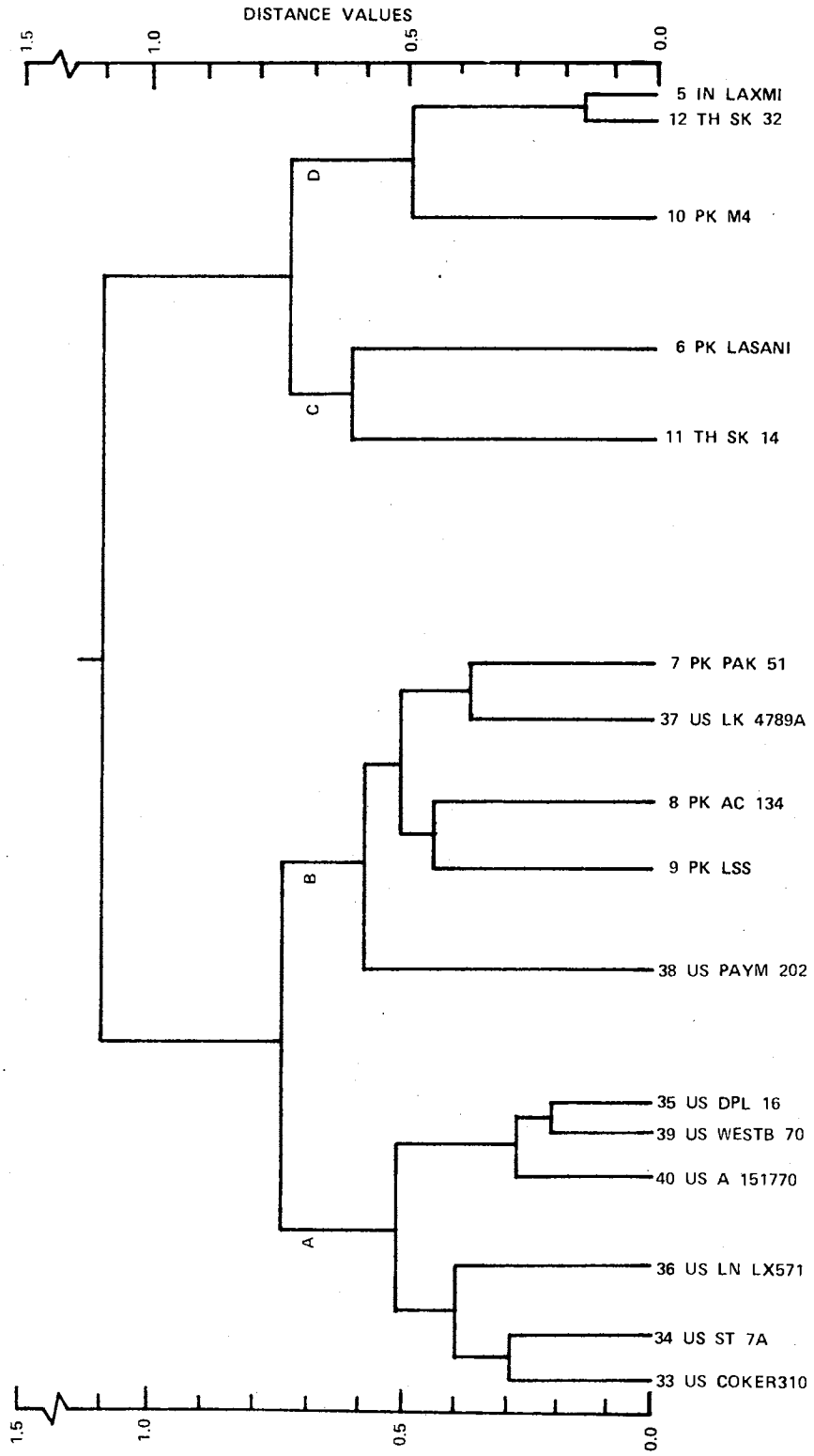

Figure 10. Dendrograph Depicting the Phenotypic Relationships Among Cultivars from the United States with Those from Asia

in Figure 7 for the Asian group alone. Lockett 4789-A showed some relationship to Pak 51, a more distant relationship to AC 134 and LSS, and finally the group as a whole was joined by Paymaster 202. The three Pakistani cultivars (Pak 51, AC 134, and LSS) all resembled the US group more than did the India, Thailand, or other two Pakistani cultivars (M4 and Lasani 11).

The relationship of the African cultivars as a group to the US entries (Figure 11) indicates that the resemblance among the African entries was greater within their own structure than to any of the US cultivars. If a determination point of 0.7 is used, the relationships within the African group remained the same as defined in Figure 8 and are represented here by the last four groups. Cluster A was entirely composed of the US cultivars which maintained their pattern of relationship from Figure 4. These results indicate little phenotypic resemblance between the entries from Africa and those from the US. Of the African cultivars, BP 52/NC 63 and CA(68)36 from Uganda and Albar 627 from Zambia showed the greatest resemblance to the US group.

The relationships among the US cultivars, as defined by numerical analysis and based on the 16 more economically important characters, are in fairly close agreement with their kinship as indicated by known pedigrees. The cluster formed by Deltapine 16, Westburn 70, and Acala 1517-70 is probably the least in agreement since it was not expected that an Acala cultivar would be so closely related to Plains or Delta types. Sneath and Sokal (70) have discussed the possibility of incongruence between phenotypic and phylogenetic relationships, i.e., a cultivar may genetically belong to a given group, but it may phenotypically be considered part of another group because of extensive

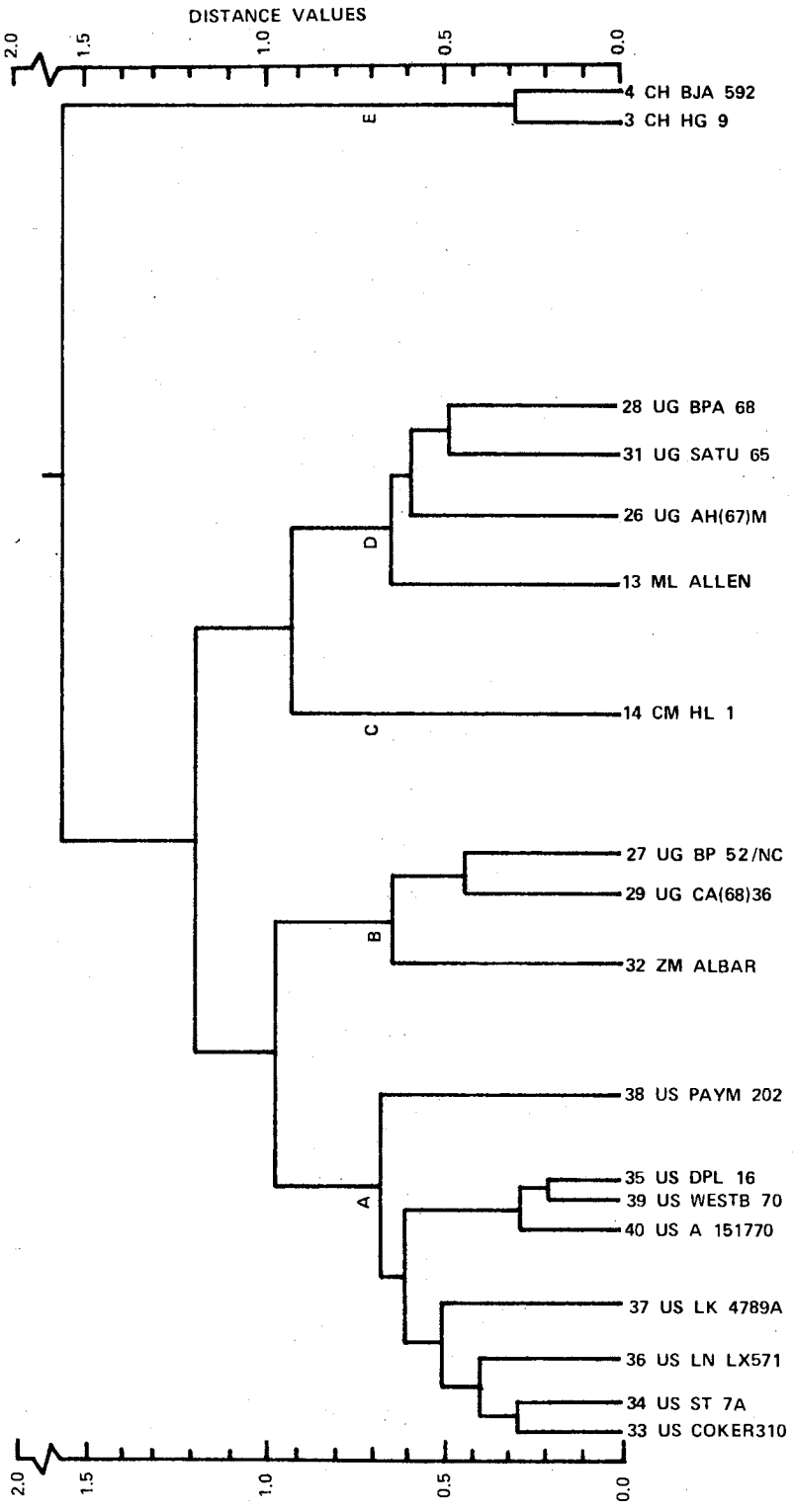

Figure 11. Dendrograph Depicting the Phenotypic Relationships Among Cultivars from the United States with Those from Africa

parallelism. From the standpoint of areas of origin within the Cotton Belt, the US group appears more accurately defined by the dendrograph derived from the 53 characters (Figure 2). In it, the Delta-Eastern and Plains groups are clustered more-or-less separately while Westburn 70 (a Plains entry) joins the Delta-Eastern group at a higher distance value followed at an even higher distance value by the Western cultivar, Acala 1517-70.

Even though the relationships described by the techniques of numerical taxonomy are not necessarily those of a true phylogeny, speculation as to the phylogenetic relationships among the US cultivars and those from other countries can be made. This is possible because the phenotype is the direct or indirect expression of the genotype, the more closely related genotypes would occur on the dendrograph in small, compact clusters; this was particularly true for the cultivar groups from Bulgaria and Chad. The cultivars from Greece, 10E and 4S 180, which are known to be genetically related (11), joined consistently close together throughout this study. The close relationship consistently shown by two cultivars from the USSR (137-F and 138-F) and two from the US (Lankart LX 571 and Lockett 4789-A) may be considered indicative of genetic relationship. Another USSR cultivar, 152-F, seemed to have a consistently close resemblance to Coker 310 and Stoneville 7A.

The groups of cultivars which clustered together by countries (e.g., Bulgaria, Chad, and Greece) clearly indicate the high phenotypic relationships among cultivars within those respective countries. If the cultivars tested are an adequate sample of the cultivars grown in such countries, this uniformity suggests that the genetic variability

present within those countries has been restricted to a rather narrow set of environmental conditions. Also, if some cultivars within those countries are grown on larger acreages than others, the genetic variability within that country for the crop as a whole is even more restricted. With limited genetic variability, genetic vulnerability to unforeseen disease epidemics, etc., in the future is more likely to occur (41). Uganda and Pakistan are the countries with cultivars displaying the greatest variability. The US, USSR, and Thailand are intermediate in cultivar variability. If Mali, Cameroon, Zambia, and India rely for their cotton production on the single cultivars they contributed to this study, they are in even more vulnerable positions than are Bulgaria, Chad, and Greece.

In conclusion, it should be pointed out that the phenotypic relationships among cultivars have been defined herein based on their performance under Oklahoma environmental conditions; how their relationships would be modified under other environmental situations is unknown.

CHAPTER V

SUMMARY AND CONCLUSIONS

The application of numerical taxonomy techniques continues to expand into a wide range of fields (53); however, its use for quantifying phenotypic resemblance among cultivars has been relatively limited to date. The objectives of the research reported herein were to utilize this quantitative method of classification to study the phenotypic and phylogenetic relationships among 39 selected cultivars of cotton (Gossypium hirsutum L.) developed in 12 countries of the world and to make such inferences therefrom as seemed warranted.

For this purpose, replicated experiments were conducted for two years under irrigation and on dryland at two locations in Oklahoma. Disease reactions were measured at four locations and qualitative traits were determined at a single location over both seasons. Analyses of variance for the 11 characters measured in the replicated experiments indicated the presence of highly significant differences among cultivars for those traits.

The overall mean quantitative descriptions of the 39 cultivars were standardized by characters before Euclidean distance values were computed for all 53 characters and for 16 of the more economically important traits. The structures of the distance coefficients matrices were defined by the dendrograph program which depicts relationships among entries in a hierarchical fashion. Phenotypic relationships within

selected groups of cultivars were also studied separately using the distance coefficients matrix based on 16 traits. The US cultivars subset was also studied based on the 53 character matrix.

Both distance coefficients matrices (for 53 and 16 characters) indicated that cultivars 3279 and 6111 from Bulgaria had the smallest distance between them, which suggested that they were the closest related genetically of all the cultivars in this study. On the other hand, the cultivars from Chad, HG 9 and BJA 592, and Deltapine 16 and Acala 1517-70 from the US exhibited the largest distances, thus, the greatest differences.

Cultivars from Bulgaria, Greece, and Chad exhibited close within-country relationships. The group from Chad was consistently segregated at a high distance value from all other entries. Cultivars from Pakistan and Uganda showed the most variability while those from the US, the USSR, and Thailand were intermediate. Mali, Cameroon, Zambia, and India could not be ranked as to within-country cultivar variability, as each only contributed one cultivar to this study. If those entries were their only or major cultivars, then they are likely to be in an even more genetically vulnerable position than are Bulgaria, Greece, or Chad.

Throughout this study the cultivars with the closest relationship to the US group were from the USSR, Greece, and Bulgaria. The USSR cultivars as a whole more nearly resembled those from the US, while those from Greece and Bulgaria bore a closer relationship. The USSR cultivars 137-F and 138-F closely resembled the US cultivars Lockett 4789-A and Lankart LX 571, and 152-F from the USSR bore considerable resemblance to Stoneville 7A and Coker 310 from the US.

Resemblances between the Asiatic and US cultivars were small. Three cultivars from Pakistan (Pak 51, AC 134, and LSS) exhibited some similarities with the US cultivars Lockett 4789-A and Paymaster 202. Poor phenotypic resemblances among the African and US cultivars were observed, especially with the cultivars from Chad. The cultivars BP 52/NC 63 and CA(68)36 from Uganda and Albar 627 from Zambia showed the most relationship to the US group.

The technique of numerical classification proved useful for the quantification of phenotypic and phylogenetic relationships among cultivars of cotton. The basis for this statement is that the defined quantitative resemblances among cultivars within the US and the African groups agreed fairly closely with their known pedigrees.

From the breeding point of view, the numerical characterization conducted by traits for the cultivars paired with the quantitative definition of phenotypic relationships among those cultivars should prove useful for the selection of complementary genotypes to be used in breeding or as sources of specific genes for the transfer of desired characteristics.

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APPENDIX

TABLE IV

RAW DATA MATRIX OF 39 CULTIVARS BY 53 CHARACTERS

Code No.	Country ID	Cultivar	Traits in Replicated Tests Over Locations and Years: Lint Yield, lbs/A	Lint Yield, kgs/ha	Picked Lint %	Pulled Lint %	Earliness	2.5% Span Length	50% Span Length	Uniformity Index	Fiber Fineness	Fiber Str., T_1	Fiber Str., T_0	Plant Ht., cm	Disease Reactions (Mean Grades): Bacterial Blight Race 1	Bacterial Blight Race 2	Bacterial Blight Mixture	Fus. Wilt	Vert. Wilt
1	GR	10E	395	442	34.2	24.6	74.6	1.018	.449	44.1	3.8	1.87	3.95	82	3.96	3.98	3.99	2.27	3.71
2	GR	4S 180	369	413	35.2	24.6	55.3	1.126	.493	43.9	3.8	2.13	4.30	81	3.98	4.00	4.00	1.87	3.30
3	CH	HG 9	84	94	30.7	19.5	49.7	1.116	.474	42.5	3.8	2.01	4.29	103	1.17	1.22	1.38	2.72	4.10
4	CH	BJA 592	93	104	31.4	21.0	55.5	1.116	.489	44.1	4.4	1.99	4.37	103	1.16	1.13	1.13	2.42	4.03
5	IN	Laxmi	79	89	28.8	19.1	30.8	1.079	.473	43.9	3.7	2.06	4.30	100	3.08	3.60	3.55	1.04	2.42
6	PK	Lasani 11	129	144	32.1	22.2	53.0	0.991	.461	46.7	3.8	2.20	4.58	108	3.29	3.58	3.36	1.83	3.85
7	PK	Pak 5i	271	304	32.6	22.9	83.3	1.045	.486	46.4	4.3	2.11	4.51	99	3.54	3.60	3.60	2.21	3.48
8	PK	AC 134	256	286	30.5	21.9	72.2	1.011	.476	47.1	4.3	2.11	4.62	107	2.91	3.65	3.49	1.34	3.19
9	PK	LSS	297	333	33.3	23.4	82.1	0.999	.468	46.9	4.1	2.04	4.49	94	3.06	3.51	3.53	1.44	3.80
10	PK	M4(N.T. Sind)	158	178	31.4	21.2	47.8	1.020	.459	45.2	4.2	1.98	4.34	102	3.46	3.82	3.60	1.13	3.00
11	TH	SK 14	167	187	31.5	21.6	66.0	1.011	.460	45.5	4.5	1.98	4.45	101	3.14	3.68	3.65	1.12	3.67
12	TH	SK 32	71	79	30.0	19.4	30.7	1.008	.443	44.2	4.2	1.90	4.23	104	3.22	3.77	3.60	1.05	2.63
13	ML	Allen 333-61	220	246	32.8	22.8	68.4	1.104	.489	44.4	4.3	2.01	4.20	94	2.43	3.01	3.02	2.10	3.42
14	CM	HL 1	225	252	34.0	24.1	61.6	1.109	.488	44.2	4.5	2.01	4.09	96	1.42	2.18	1.90	2.30	3.79
15	RS	137-F	301	337	34.7	24.2	87.1	1.030	.465	45.2	4.0	1.97	3.94	87	4.00	4.00	4.00	1.73	3.77
16	RS	138-F	319	357	35.1	24.5	75.7	1.068	.469	44.0	3.8	1.98	4.06	81	3.91	4.00	3.95	1.49	3.83
17	RS	108-F	272	305	34.0	22.8	78.4	1.003	.462	46.1	4.5	2.00	3.97	84	4.00	3.98	4.00	1.75	3.29
18	RS	152-F	298	334	34.7	24.6	80.8	1.064	.476	44.7	3.8	2.06	4.28	93	3.98	3.98	3.99	1.25	2.62
19	RS	CX 349	214	240	34.0	22.9	51.3	1.122	.490	43.8	4.1	2.08	4.25	92	4.00	4.00	3.91	1.17	3.38
20	RS	C-1211	249	278	36.3	25.3	76.6	1.053	.474	45.0	4.0	1.98	4.17	93	3.93	3.99	3.94	2.18	3.52
21	BG	73	316	354	32.0	22.0	89.6	1.008	.467	46.4	4.4	2.01	4.18	75	3.81	3.99	3.90	2.73	3.54
22	BG	4521	344	385	32.6	23.0	89.5	0.972	.455	46.8	4.4	1.98	4.22	77	3.50	4.00	3.83	2.83	3.95
23	BG	3996	287	321	30.9	21.3	86.3	1.019	.473	46.5	4.2	2.07	4.15	72	3.57	3.99	3.83	2.71	4.19
24	BG	3279	319	357	30.5	21.3	89.5	1.002	.460	45.9	4.3	2.02	4.29	74	3.68	3.98	3.93	3.04	4.46
25	BG	6111	311	348	32.8	22.2	89.4	0.991	.463	46.7	4.3	2.00	4.24	73	3.66	3.90	3.84	2.75	4.30
26	UG	AH(67)M	175	195	30.6	20.4	44.3	1.151	.521	45.2	4.1	2.33	4.71	106	1.61	2.45	1.78	1.13	2.44
27	UG	BP 52/NC 63	137	153	28.7	18.7	61.2	1.134	.497	43.9	3.8	2.27	4.53	98	3.64	3.69	3.59	1.25	3.39
28	UG	BPA 68	233	260	28.5	19.9	61.4	1.168	.527	45.2	4.1	2.33	4.51	90	2.43	3.23	2.64	1.41	3.36
29	UG	CA(68)36	124	139	28.2	18.1	73.8	1.142	.510	44.7	3.9	2.43	4.64	98	2.87	3.57	3.29	1.31	3.26
31*	UG	SATU 65	198	222	28.7	19.3	68.9	1.142	.518	45.4	4.2	2.22	4.66	100	2.31	2.74	2.40	1.38	3.55
32	ZM	Albar 627	203	228	30.8	21.3	62.4	1.063	.485	45.8	4.3	2.27	4.64	100	3.43	3.56	3.22	1.37	2.91
33	US	Coker 310	335	375	36.3	25.3	56.5	1.165	.512	44.1	4.4	2.10	4.22	83	4.00	4.00	3.95	1.04	3.05
34	US	Stoneville 7A	337	378	34.8	24.1	70.2	1.115	.487	43.8	4.2	1.97	4.34	75	3.97	4.00	3.97	1.42	3.34
35	US	Deltapine 16	400	448	35.0	24.6	61.5	1.123	.499	44.5	4.4	2.04	4.04	78	4.00	4.00	4.00	1.05	2.84
36	US	Lankart LX 571	356	399	35.4	24.2	79.8	1.049	.473	45.1	4.2	1.89	4.07	68	4.00	4.00	3.94	1.45	4.02
37	US	Lockett 4789-A	328	367	33.0	23.2	83.6	1.074	.480	44.8	3.9	2.05	4.29	79	3.94	4.00	3.99	2.08	4.12
38	US	Paymaster 202	348	389	33.6	23.7	80.1	0.968	.449	46.4	4.3	1.97	4.29	78	2.92	3.21	3.33	1.65	3.75
39	US	Westburn 70	414	464	34.3	25.1	77.4	1.055	.460	43.6	3.7	1.89	4.02	71	3.95	4.00	3.99	1.07	3.13
40	US	Acala 1517-70	392	439	34.3	23.3	71.7	1.141	.520	45.6	4.1	2.35	5.04	84	3.63	3.79	3.69	1.12	2.40
Number of Observations			24	24	24	24	24	24	24	24	24	24	24	120	2	2	4	3	3
Mean			257	288	32.5	22.4	68.7	1.066	.479	45.1	4.1	2.07	4.32	89	3.30	3.56	3.45	1.72	3.46
Standard Deviation			98	110	2.3	2.0	15.7	0.059	.021	1.1	0.2	0.14	0.24	12	0.83	0.72	0.76	0.61	0.53

TABLE IV (Continued)

Code No.	Country ID	Cultivar	Discrete Characters																							
			Stem Pubescence	Apex Pubescence	Stem Erectness	Branching Habit	Plant Foliage	Leaf Lobation	Leaf Size	Leaf Color	Leaf Pubescence	Leaf Margin	Corolla Color	Pollen Color	Pedicel Lgth.	Bract Size	Bract Shape	Bract Teeth Shape	Boll Shape	Boll Pittedness	Boll Waxiness	Bract vs. Boll Size	Seed Fuzziness	Seed Fuzz Color	Seed Shape
1	GR	10E	1	1	2	1	2	1	3	1	1	1	1	1	1	3	2	2	1	1	1	1	2	1	1
2	GR	4S 180	1	1	2	1	2	1	3	1	1	1	1	1	1	3	2	2	2	1	1	1	5	1	1
3	CH	HG 9	2	2	1	1	1	2	2	2	2	1	1	1	1	2	2	1	2	3	1	2	2	1	1
4	CH	BJA 592	2	2	1	1	1	1	1	2	2	1	1	1	2	1	2	2	5	2	1	1	2	1	1
5	IN	Laxmi	2	2	1	1	1	2	2	2	2	1	2	3	2	3	2	2	6	3	1	2	2	2	3
6	PK	Lasani 11	3	3	1	1	1	2	2	2	2	1	1	1	2	3	1	2	4	1	1	1	5	1	1
7	PK	Pak 51	3	3	1	1	1	2	2	3	2	1	1	1	2	3	1	2	4	1	1	1	5	3	1
8	PK	AC 134	2	2	1	1	1	2	2	3	2	1	1	1	2	2	1	2	1	1	1	1	5	4	1
9	PK	LSS	2	2	1	1	1	2	1	2	3	1	1	1	2	3	2	2	7	1	1	1	4	2	1
10	PK	M4(N.T. Sind)	3	3	1	1	1	2	2	3	3	1	1	1	2	3	1	1	2	1	2	1	2	1	1
11	TH	SK 14	3	3	1	1	1	2	1	3	3	1	1	1	2	2	1	2	1	1	1	1	1	2	1
12	TH	SK 32	3	3	1	1	1	2	1	3	3	1	1	1	2	2	2	2	4	3	2	1	2	2	1
13	ML	Allen 333-61	2	2	1	1	1	1	2	2	2	1	1	2	1	2	2	2	1	1	1	3	2	1	1
14	CM	HL 1	2	2	2	1	1	1	2	2	2	1	1	2	1	2	1	2	1	1	1	2	2	1	1
15	RS	137-F	2	2	1	1	2	2	1	1	2	1	1	1	1	2	1	2	1	2	2	1	2	1	1
16	RS	138-F	1	1	2	2	2	2	2	1	1	1	1	1	1	2	2	1	2	2	1	2	1	2	1
17	RS	108-F	1	1	1	3	2	2	2	1	1	1	1	1	1	1	1	1	5	2	1	2	2	1	1
18	RS	152-F	2	2	1	1	2	2	2	1	2	1	1	1	1	1	1	1	1	1	1	2	1	2	1
19	RS	CX 349	1	1	1	1	1	3	2	1	1	1	1	2	1	1	2	1	2	2	1	2	1	2	1
20	RS	C-1211	1	1	1	3	2	3	1	1	1	1	1	1	1	2	2	1	2	2	1	2	2	1	1
21	BG	73	2	1	2	1	3	2	3	2	2	1	1	1	1	3	1	2	5	2	1	1	2	1	1
22	BG	4521	2	1	2	1	2	1	3	2	2	1	1	1	1	1	2	2	1	1	1	2	2	1	1
23	BG	3996	2	1	3	1	2	2	3	2	1	1	1	1	1	1	2	2	1	1	1	2	2	1	1
24	BG	3279	2	1	2	1	3	1	3	2	1	1	1	1	1	3	2	2	7	1	1	2	2	1	1
25	BG	6111	2	1	2	1	2	2	3	2	2	1	1	1	1	2	3	2	1	1	1	2	2	3	1
26	UG	AH(67)M	2	2	1	1	1	2	3	3	2	2	1	3	2	2	2	2	4	2	1	2	3	1	1
27	UG	BP 52/NC 63	2	2	1	1	1	2	2	2	2	1	1	2	2	2	3	2	4	3	1	2	2	1	1
28	UG	BPA 68	2	2	1	1	1	2	2	2	3	1	1	3	2	2	1	2	4	2	1	2	2	1	1
29	UG	CA(68)36	2	2	1	3	1	2	2	2	2	1	1	3	2	2	2	2	4	2	2	2	1	2	2
31*	UG	SATU 65	2	2	1	1	1	1	1	2	2	1	1	3	2	2	2	2	3	2	1	3	4	2	1
32	ZM	Albar 627	2	2	1	1	1	2	1	2	2	1	1	1	2	1	3	2	4	1	1	2	2	1	1
33	US	Coker 310	1	1	1	1	2	2	2	1	1	1	1	1	1	2	2	1	2	2	1	2	2	2	1
34	US	Stoneville 7A	1	1	2	1	1	2	2	1	1	1	1	1	1	2	1	2	5	1	1	1	2	2	1
35	US	Deltapine 16	1	1	1	1	2	2	2	1	1	1	1	1	1	2	2	1	5	1	1	2	2	1	1
36	US	Lankart LX 571	1	1	1	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2	1	2	2	1	1
37	US	Lockett 4789-A	1	1	1	2	2	2	2	1	1	1	1	1	1	2	1	1	1	2	1	1	2	1	1
38	US	Paymaster 202	1	1	2	1	2	2	2	1	1	1	1	1	1	2	1	1	2	1	1	2	2	1	1
39	US	Westburn 70	1	1	2	1	2	2	3	1	1	1	1	2	1	2	1	2	1	2	1	2	2	1	1
40	US	Acala 1517-70	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1	1	2	2	1	2	2	2	1
Number of Observations			10	10	1†	1†	1†	10	1†	1†	10	1†	1†	1†	20	15	10	10	10	10	10	10	1‡	1‡	1‡
Mean			1.8	1.6	1.3	1.2	1.5	1.8	2.0	1.7	1.7	1.0	1.0	1.4	1.4	2.0	1.6	1.7	2.9	1.6	1.1	1.7	2.3	1.5	1.1
Standard Deviation			0.7	0.7	0.5	0.6	0.6	0.5	0.7	0.7	0.7	0.2	0.2	0.7	0.5	0.7	0.6	0.5	1.8	0.7	0.3	0.6	1.1	0.7	0.4

TABLE IV (Continued)

Code No.	Country ID	Cultivar	Continuous Traits Replicated Over Years									Spinning Traits				
			No. Bract Teeth	Storm proof-ness	Boll Size	Bur Size	No. Locks/ Boll	No. Seed/ Lock	Wt. Lint/ Boll	Lint Index	Seed Index	Fiber Reflec-tance	Fiber Yellow-ness	Fiber Tex	Yarn Ten-acity	Yarn Strength
1	GR	10E	15.7	144	6.0	1.7	4.3	7.8	2.1	6.1	11.7	73	8.5	27.6	10.8	105
2	GR	4S 180	13.5	122	5.9	1.8	4.3	7.6	2.1	6.6	11.7	74	8.1	27.4	13.0	127
3	CH	HG 9	14.4	98	6.6	2.2	4.5	8.1	2.1	5.7	12.0	70	9.1	27.2	11.6	113
4	CH	BJA 592	14.2	124	6.2	2.1	4.4	8.1	2.1	6.1	11.9	69	6.9	27.9	11.9	116
5	IN	Laxmi	14.7	101	4.2	2.0	3.9	7.5	1.1	3.9	11.0	67	6.7	27.4	12.7	123
6	PK	Lasani 11	10.9	140	4.9	1.8	4.4	7.4	1.6	5.1	10.7	72	7.3	28.1	13.2	128
7	PK	Pak 51	11.6	130	5.5	1.8	4.8	7.2	1.9	5.5	11.1	72	7.5	28.2	12.6	122
8	PK	AC 134	13.3	133	5.4	1.6	4.8	7.4	1.7	5.0	11.1	70	7.3	27.9	12.8	124
9	PK	LSS	12.6	90	5.3	1.7	5.0	7.6	1.8	4.9	9.9	73	7.4	27.5	12.4	121
10	PK	M4(N.T. Sind)	14.1	290	6.0	2.2	4.7	8.1	1.9	5.3	11.5	72	8.9	27.8	12.4	121
11	TH	SK 14	15.3	119	5.8	2.0	4.7	7.7	1.8	5.1	11.5	70	7.4	28.2	8.8	86
12	TH	SK 32	13.4	121	6.2	2.3	4.7	7.5	1.9	5.3	12.4	71	6.7	27.8	11.7	113
13	ML	Allen 333-61	15.4	100	5.2	1.4	4.3	7.6	1.8	5.7	10.8	67	8.9	27.7	11.3	110
14	CM	HL 1	14.7	93	6.0	1.7	4.2	8.1	2.1	6.3	11.9	69	8.6	27.6	11.9	116
15	RS	137-F	17.1	112	7.2	2.1	4.9	8.1	2.7	7.1	12.0	71	9.0	27.6	10.9	105
16	RS	138-F	16.1	139	7.1	2.0	4.9	8.0	2.7	7.6	12.6	72	8.7	27.8	11.6	113
17	RS	108-F	14.7	140	6.5	2.0	4.8	7.8	2.4	7.0	12.0	71	9.0	27.8	11.5	111
18	RS	152-F	16.1	120	7.0	2.0	4.8	7.8	2.6	7.2	12.4	71	7.8	27.6	12.7	124
19	RS	CX 349	14.7	113	8.0	2.5	5.0	7.7	2.8	7.4	14.0	72	8.9	27.6	12.2	119
20	RS	C-1211	14.7	144	6.9	2.1	4.7	8.0	2.6	7.4	12.0	71	8.1	27.6	11.8	115
21	BG	73	12.6	98	6.2	1.9	4.7	7.8	2.1	5.8	11.7	70	7.8	27.8	11.7	115
22	BG	4521	12.4	108	6.3	1.9	4.7	7.8	2.2	6.2	12.0	69	7.8	27.6	11.9	115
23	BG	3996	12.4	123	5.9	1.8	4.6	7.7	1.9	5.7	11.8	66	6.7	28.0	11.4	111
24	BG	3279	12.5	117	5.7	1.8	4.5	7.5	1.9	5.7	12.0	70	7.3	27.4	13.1	127
25	BG	6111	12.1	93	6.2	1.9	4.7	7.6	2.1	6.0	11.8	69	7.4	27.9	11.7	114
26	UG	AH(67)M	15.7	69	4.8	1.7	4.5	7.7	1.4	4.5	10.4	69	6.4	27.6	13.4	130
27	UG	BP 52/NC 63	14.4	110	4.9	1.7	4.3	7.8	1.4	4.3	11.3	68	6.0	27.6	13.5	131
28	UG	BPA 68	14.9	98	5.6	1.8	4.6	7.6	1.6	4.8	12.1	68	6.4	27.6	13.6	132
29	UG	CA(68)36	13.9	107	5.6	1.8	4.5	7.8	1.5	4.6	12.0	69	6.4	27.8	14.2	138
31*	UG	SATU 65	14.1	82	5.2	1.7	4.6	7.7	1.5	4.6	11.2	67	6.4	27.7	13.3	129
32	ZM	Albar 627	15.1	106	5.9	2.0	4.4	7.6	1.9	6.0	12.8	71	7.3	28.0	13.7	133
33	US	Coker 310	15.1	170	6.9	2.0	4.4	7.9	2.6	8.0	13.0	72	8.6	27.9	12.4	121
34	US	Stoneville 7A	15.3	132	6.8	2.2	4.6	8.1	2.5	7.1	12.2	71	7.2	27.6	12.0	117
35	US	Deltapine 16	16.5	130	7.2	2.2	4.5	8.0	2.7	7.7	12.7	74	8.1	27.8	11.9	116
36	US	Lankart LX 571	14.1	200	9.5	2.5	5.0	8.3	3.6	9.2	15.3	73	8.9	27.4	11.1	107
37	US	Lockett 4789-A	14.0	203	7.5	2.1	4.8	7.8	2.7	7.5	13.1	72	8.1	27.9	12.0	118
38	US	Paymaster 202	14.1	237	8.7	2.4	5.0	8.2	3.2	8.2	14.0	73	8.2	27.8	11.7	114
39	US	Westburn 70	12.9	220	7.8	1.9	4.9	8.1	2.9	7.5	12.8	72	8.5	27.5	11.0	107
40	US	Acala 1517-70	16.0	90	7.5	2.6	4.7	7.8	2.7	7.8	13.6	72	8.5	27.6	15.2	148
Number of Observations			15	10	50	50	50	50	50	10	10	4	4	4	4	4
Mean			14.2	130	6.3	2.0	4.6	7.8	2.2	6.2	12.1	71	7.8	27.7	12.2	119
Standard Deviation			1.4	45	1.1	0.3	0.3	0.3	0.5	1.3	1.0	2	0.9	0.2	1.1	11

*Entry No. 30 from UG, CA(68)41, was omitted because of poor stands in 1973.

†Discrete characters graded on all plants in the row.

‡Oiscrete characters graded from a 25-boll sample.

TABLE V

LOWER HALF BY ROWS OF THE DISTANCE MATRIX VALUES COMPUTED FOR 39 CULTIVARS BASED ON 53 CHARACTERS

Code No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.00																			
2	0.60	0.00																		
3	4.92	5.15	0.00																	
4	4.97	5.20	0.66	0.00																
5	3.15	2.86	5.05	5.14	0.00															
6	2.52	2.45	3.93	4.01	1.71	0.00														
7	1.08	1.08	4.38	4.44	2.45	1.60	0.00													
8	1.42	1.25	4.61	4.63	2.16	1.70	0.97	0.00												
9	1.20	1.16	4.49	4.53	2.71	1.97	1.01	0.86	0.00											
10	2.75	2.63	5.00	4.94	1.99	1.89	2.26	1.96	2.63	0.00										
11	2.20	2.12	4.46	4.52	1.63	1.20	1.62	1.30	1.58	1.87	0.00									
12	3.22	2.95	5.02	5.10	0.49	1.62	2.50	2.23	2.79	1.85	1.56	0.00								
13	1.76	1.90	3.54	3.64	2.61	1.68	1.16	1.31	1.31	2.60	1.68	2.68	0.00							
14	3.09	3.35	2.34	2.35	4.17	3.04	2.78	2.90	2.68	3.95	3.24	4.20	1.87	0.00						
15	0.99	0.93	4.78	4.85	2.41	1.90	0.91	1.03	0.94	2.34	1.38	2.46	1.52	3.15	0.00					
16	0.94	0.84	4.84	4.87	2.52	1.98	1.00	0.92	0.86	2.22	1.46	2.55	1.61	3.15	0.41	0.00				
17	1.16	0.96	4.92	4.98	2.13	1.77	0.84	0.97	1.24	1.97	1.39	2.16	1.65	3.37	0.56	0.66	0.00			
18	1.44	1.02	5.46	5.49	2.28	2.40	1.45	1.23	1.57	2.27	1.87	2.38	2.17	3.80	1.06	1.05	0.84	0.00		
19	1.89	1.59	4.96	5.02	1.62	1.56	1.43	1.24	1.56	1.90	1.05	1.60	1.95	3.61	1.04	1.10	0.87	1.16	0.00	
20	1.31	1.25	4.57	4.66	2.08	1.44	0.66	1.09	1.34	1.97	1.34	2.09	1.41	3.13	0.77	0.95	0.52	1.28	1.03	0.00
21	0.92	1.01	4.62	4.74	2.80	2.09	0.71	1.44	1.28	2.77	2.03	2.87	1.46	2.97	1.03	1.22	1.08	1.57	1.75	0.96
22	0.89	1.16	4.42	4.52	3.10	2.20	0.87	1.49	1.19	2.93	2.15	3.15	1.35	2.65	1.21	1.31	1.38	1.88	2.02	1.24
23	1.21	1.41	4.20	4.30	2.75	1.69	0.74	1.41	1.20	2.61	1.75	2.76	1.20	2.64	1.13	1.26	1.26	1.94	1.77	0.97
24	1.24	1.48	4.14	4.26	3.04	1.94	0.92	1.64	1.30	2.89	2.07	3.07	1.31	2.56	1.35	1.46	1.51	2.14	2.04	1.25
25	1.16	1.37	4.23	4.35	2.95	1.92	0.85	1.54	1.14	2.90	1.93	2.98	1.28	2.62	1.16	1.31	1.38	1.99	1.88	1.16
26	3.00	2.94	3.70	3.63	3.00	2.67	2.55	2.16	2.37	3.20	2.63	3.15	1.87	2.15	2.75	2.72	2.82	2.90	2.81	2.76
27	2.45	2.23	4.61	4.67	1.12	0.99	1.70	1.56	1.91	1.83	0.96	1.15	1.99	3.57	1.64	1.75	1.48	1.87	0.98	1.37
28	1.84	1.81	3.93	3.91	2.55	1.81	1.38	1.04	1.10	2.50	1.66	2.63	1.01	2.13	1.53	1.47	1.69	1.98	1.79	1.62
29	2.63	2.45	4.24	4.30	1.23	0.94	1.78	1.50	1.93	1.92	1.06	1.26	1.73	3.18	1.88	1.96	1.75	2.13	1.37	1.58
31*	2.29	2.32	3.42	3.40	2.72	1.77	1.71	1.54	1.44	2.78	1.80	2.79	1.11	1.83	1.92	1.90	2.11	2.48	2.11	1.97
32	1.83	1.56	4.62	4.65	1.63	1.48	1.19	0.97	1.44	1.92	1.26	1.72	1.56	3.18	1.15	1.22	0.96	1.17	0.81	1.00
33	1.28	0.93	5.42	5.40	2.59	2.46	1.51	1.20	1.48	2.11	1.92	2.63	2.22	3.70	1.12	0.86	0.97	0.72	1.31	1.42
34	0.87	0.55	5.18	5.20	2.61	2.29	1.15	1.06	1.09	2.35	1.78	2.67	1.90	3.43	0.68	0.49	0.72	0.74	1.24	1.13
35	1.25	0.92	5.71	5.70	3.10	3.03	1.85	1.62	1.66	2.80	2.44	3.20	2.50	3.85	1.41	1.22	1.44	0.97	1.85	1.88
36	1.08	1.11	4.94	4.92	2.95	2.30	1.34	1.29	1.28	2.21	1.86	2.91	1.94	3.23	1.03	0.70	1.11	1.42	1.53	1.34
37	0.92	1.08	4.58	4.59	2.76	1.89	0.84	1.12	1.14	2.07	1.70	2.73	1.53	2.94	0.91	0.74	0.92	1.51	1.51	0.92
38	1.50	1.72	4.46	4.37	3.44	2.61	1.68	1.58	1.63	2.41	2.36	3.41	1.84	2.64	1.79	1.51	1.85	2.13	2.32	1.91
39	1.32	1.21	5.67	5.61	3.35	3.04	1.90	1.71	1.81	2.53	2.54	3.37	2.60	3.84	1.64	1.35	1.59	1.42	2.09	1.97
40	1.57	1.19	5.71	5.71	3.22	3.23	2.01	1.77	1.83	3.12	2.75	3.36	2.56	3.80	1.74	1.61	1.75	1.16	2.11	2.13

TABLE V (Continued)

Code No.	21	22	23	24	25	26	27	28	29	31*	32	33	34	35	36	37	38	39	40
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
12																			
13																			
14																			
15																			
16																			
17																			
18																			
19																			
20																			
21	0.00																		
22	0.51	0.00																	
23	0.71	0.61	0.00																
24	0.77	0.53	0.39	0.00															
25	0.66	0.49	0.37	0.32	0.00														
26	2.91	2.85	2.83	2.92	2.87	0.00													
27	2.12	2.37	1.95	2.23	2.13	2.73	0.00												
28	1.77	1.67	1.58	1.70	1.64	1.44	1.88	0.00											
29	2.24	2.40	2.00	2.27	2.20	2.29	0.75	1.59	0.00										
31*	2.14	2.02	1.83	1.93	1.86	1.40	2.00	0.71	1.67	0.00									
32	1.61	1.87	1.67	1.92	1.80	2.17	1.04	1.31	1.15	1.66	0.00								
33	1.72	1.89	1.95	2.13	2.01	2.95	2.07	1.93	2.32	2.45	1.42	0.00							
34	1.25	1.42	1.50	1.67	1.52	2.86	1.95	1.71	2.20	2.21	1.32	0.58	0.00						
35	1.84	1.97	2.21	2.32	2.18	3.15	2.62	2.22	2.85	2.75	1.90	0.74	0.81	0.00					
36	1.56	1.54	1.54	1.70	1.61	3.00	2.20	1.77	2.37	2.19	1.68	0.94	0.85	1.31	0.00				
37	1.14	1.11	1.00	1.17	1.15	2.87	1.96	1.59	2.10	1.97	1.52	1.24	0.99	1.65	0.69	0.00			
38	1.99	1.78	1.86	1.93	1.95	2.70	2.76	1.74	2.70	2.08	2.17	1.68	1.66	1.93	1.11	1.16	0.00		
39	2.01	2.04	2.24	2.35	2.27	3.37	2.80	2.35	3.00	2.86	2.17	0.87	1.09	0.87	1.03	1.44	1.49	0.00	
40	1.98	2.11	2.44	2.50	2.37	2.94	2.81	2.21	2.94	2.75	1.97	1.21	1.23	0.73	1.77	2.02	2.19	1.38	0.00

*Entry No. 30 was omitted because of poor stands in 1973.

TABLE VI

LOWER HALF BY ROWS OF THE DISTANCE MATRIX VALUES COMPUTED FOR 39 CULTIVARS BASED ON 16 CHARACTERS

Code No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.00																			
2	0.32	0.00																		
3	3.21	3.41	0.00																	
4	3.22	3.43	0.32	0.00																
5	2.02	1.85	3.53	3.62	0.00															
6	1.63	1.62	2.64	2.70	1.10	0.00														
7	0.63	0.72	2.95	2.98	1.64	1.10	0.00													
8	0.80	0.74	3.21	3.22	1.49	1.19	0.63	0.00												
9	0.68	0.75	3.01	3.00	1.82	1.30	0.66	0.45	0.00											
10	1.45	1.29	3.35	3.40	0.66	0.83	1.09	0.91	1.21	0.00										
11	1.44	1.36	3.03	3.06	1.00	0.64	1.05	0.81	0.99	0.53	0.00									
12	2.10	1.93	3.49	3.57	0.15	1.08	1.71	1.56	1.87	0.71	1.01	0.00								
13	1.00	1.18	2.51	2.55	1.86	1.08	0.62	0.86	0.77	1.39	1.14	1.90	0.00							
14	1.90	2.16	1.72	1.67	2.97	2.05	1.81	1.99	1.73	2.55	2.21	2.98	1.31	0.00						
15	0.62	0.56	3.18	3.19	1.52	1.15	0.45	0.47	0.51	0.91	0.88	1.59	0.92	2.05	0.00					
16	0.60	0.51	3.23	3.23	1.61	1.27	0.62	0.48	0.44	0.99	0.94	1.67	1.01	2.06	0.22	0.00				
17	0.75	0.60	3.31	3.34	1.35	1.15	0.53	0.57	0.77	0.77	0.90	1.43	1.06	2.25	0.29	0.44	0.00			
18	0.90	0.63	3.74	3.76	1.50	1.60	0.96	0.80	1.04	1.00	1.24	1.60	1.49	2.61	0.68	0.69	0.53	0.00		
19	1.20	1.02	3.37	3.40	0.97	0.96	0.94	0.78	1.01	0.36	0.61	1.02	1.33	2.47	0.65	0.71	0.54	0.78	0.00	
20	0.86	0.82	3.07	3.11	1.31	0.91	0.37	0.67	0.84	0.79	0.85	1.38	0.84	2.07	0.45	0.65	0.35	0.86	0.67	0.00
21	0.55	0.67	3.02	3.06	1.80	1.33	0.35	0.83	0.84	1.29	1.30	1.87	0.76	1.85	0.63	0.76	0.65	1.01	1.14	0.55
22	0.54	0.78	2.85	2.88	2.00	1.42	0.49	0.87	0.75	1.48	1.38	2.06	0.60	1.55	0.76	0.83	0.88	1.23	1.32	0.78
23	0.80	0.95	2.68	2.72	1.76	1.06	0.42	0.83	0.75	1.26	1.10	1.80	0.45	1.55	0.69	0.81	0.81	1.28	1.14	0.59
24	0.79	1.00	2.59	2.63	1.94	1.21	0.53	0.97	0.82	1.45	1.29	1.99	0.47	1.43	0.82	0.92	0.96	1.40	1.31	0.76
25	0.71	0.90	2.68	2.71	1.88	1.17	0.43	0.87	0.71	1.36	1.20	1.92	0.47	1.50	0.70	0.79	0.85	1.29	1.20	0.67
26	1.26	1.37	2.80	2.77	2.06	1.42	1.07	0.93	0.91	1.55	1.33	2.09	0.85	1.45	1.20	1.20	1.36	1.61	1.51	1.26
27	1.58	1.47	3.15	3.19	0.73	0.60	1.15	1.08	1.29	0.36	0.47	0.73	1.38	2.47	1.00	1.11	0.92	1.25	0.53	0.85
28	0.91	1.01	2.80	2.79	1.82	1.16	0.73	0.60	0.46	1.24	0.98	1.85	0.64	1.51	0.74	0.73	0.96	1.29	1.13	0.90
29	1.62	1.55	2.98	3.03	0.86	0.49	1.13	1.00	1.23	0.57	0.38	0.85	1.19	2.27	1.07	1.18	1.04	1.40	0.79	0.90
31*	1.24	1.38	2.46	2.43	1.96	1.08	0.95	0.95	0.74	1.42	1.05	1.96	0.68	1.30	1.02	1.04	1.24	1.63	1.33	1.11
32	1.02	0.89	3.27	3.29	1.15	0.94	0.66	0.60	0.87	0.53	0.71	1.21	1.09	2.28	0.50	0.63	0.38	0.72	0.40	0.43
33	0.78	0.51	3.67	3.67	1.67	1.65	1.01	0.77	0.88	1.11	1.25	1.75	1.47	2.49	0.65	0.54	0.64	0.39	0.82	0.97
34	0.55	0.32	3.47	3.47	1.68	1.51	0.76	0.62	0.68	1.09	1.16	1.76	1.23	2.27	0.41	0.32	0.48	0.47	0.80	0.77
35	0.82	0.58	3.84	3.83	2.03	2.02	1.24	1.05	1.08	1.51	1.63	2.12	1.68	2.58	0.95	0.83	0.97	0.65	1.23	1.28
36	0.54	0.50	3.26	3.24	1.82	1.46	0.75	0.64	0.46	1.20	1.12	1.88	1.10	2.03	0.41	0.23	0.64	0.80	0.90	0.84
37	0.48	0.57	3.00	3.01	1.72	1.20	0.38	0.58	0.43	1.13	1.02	1.78	0.75	1.80	0.29	0.34	0.53	0.91	0.89	0.55
38	0.56	0.77	3.01	2.98	2.23	1.69	0.86	0.85	0.48	1.64	1.45	2.29	0.94	1.59	0.82	0.73	1.07	1.25	1.40	1.14
39	0.75	0.57	3.75	3.74	2.10	2.01	1.21	1.01	0.98	1.55	1.61	2.18	1.61	2.46	0.92	0.77	0.99	0.74	1.26	1.29
40	0.87	0.68	3.93	3.92	2.17	2.17	1.32	1.15	1.20	1.66	1.80	2.26	1.76	2.62	1.10	1.00	1.10	0.74	1.41	1.40

TABLE VI (Continued)

Code No.	21	22	23	24	25	26	27	28	29	31*	32	33	34	35	36	37	38	39	40
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
12																			
13																			
14																			
15																			
16																			
17																			
18																			
19																			
20																			
21	0.00																		
22	0.34	0.00																	
23	0.46	0.40	0.00																
24	0.50	0.34	0.21	0.00															
25	0.45	0.32	0.16	0.13	0.00														
26	1.26	1.10	1.10	1.14	1.10	0.00													
27	1.37	1.54	1.25	1.43	1.35	1.62	0.00												
28	0.92	0.78	0.70	0.78	0.70	0.58	1.29	0.00											
29	1.36	1.47	1.16	1.35	1.28	1.42	0.44	1.14	0.00										
31*	1.19	1.04	0.86	0.90	0.85	0.71	1.35	0.49	1.19	0.00									
32	0.88	1.08	0.92	1.10	0.99	1.25	0.68	0.93	0.80	1.16	0.00								
33	1.07	1.20	1.27	1.37	1.25	1.53	1.34	1.17	1.49	1.52	0.83	0.00							
34	0.81	0.93	1.00	1.09	0.98	1.38	1.28	0.97	1.39	1.32	0.73	0.29	0.00						
35	1.22	1.31	1.48	1.54	1.44	1.70	1.73	1.39	1.86	1.76	1.20	0.41	0.55	0.00					
36	0.84	0.86	0.90	0.97	0.85	1.26	1.31	0.78	1.38	1.09	0.84	0.56	0.36	0.76	0.00				
37	0.51	0.53	0.50	0.58	0.46	1.11	1.18	0.63	1.20	0.90	0.72	0.82	0.55	1.05	0.42	0.00			
38	0.91	0.71	0.90	0.86	0.79	1.08	1.72	0.73	1.68	0.97	1.26	1.05	0.84	1.08	0.61	0.63	0.00		
39	1.19	1.24	1.42	1.47	1.37	1.63	1.75	1.30	1.86	1.66	1.23	0.47	0.53	0.20	0.66	0.98	0.93	0.00	
40	1.27	1.36	1.57	1.62	1.53	1.74	1.90	1.49	2.00	1.87	1.33	0.62	0.72	0.26	0.93	1.18	1.15	0.35	0.00

*Entry No. 30 was omitted because of poor stands in 1973.

VITA

Carlos Ernesto Samayoa-Armienta

Candidate for the Degree of

Doctor of Philosophy

Thesis: QUANTITATIVE ANALYSES OF PHENOTYPIC RELATIONSHIPS AMONG SELECTED CULTIVARS OF COTTON, GOSSYPIUM HIRSUTUM L.

Major Field: Crop Science

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Personal Data: Born January 26, 1939, at Jalapa, Veracruz, México, the son of Ernesto Samayoa and Matilde A. de Samayoa. Married Sandra Leticia Navarro, August 3, 1965. A daughter, Sandrita, was born March 3, 1967, and a son, Carlos, was born January 1, 1971.

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Member: Sociedad Agronómica Mexicana, Sociedad Mexicana de Fitogenética, Asociación Latinoamericana de Fitotecnia, American Society of Agronomy, and Crop Science Society of America.