SECOND ANNUAL PROGRESS REPORT

concerning

BREEDING AND DEVELOPMENT OF ZOYSIAGRASS

Submitted by:

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EXECUTIVE SUMMARY
SECOND ANNUAL ZOYSIA PROGRESS REPORT
ZOYSIAGRASS BREEDING AND DEVELOPMENT

Principle Investigator: Dr. M. C. Engelke

Postdoctoral Research Associate: Dr. Michael P. Kenna

Research period for this report: September 1, 1984 to November 1, 1985

The USGA/TAES Zoysiagrass Breeding and Development Program is a diverse, multifacited approach to expand and improve upon the existing cultivars of the Zoysia species. Emphasis is placed on turfgrass adaptation to the natural environment through breeding and selection, rather than adapting the environment to turfgrasses with little natural adaptation. Constant observation of the Oriental and domestic zoysiagrass plant collection, or 'germplasm', reveals both the strengths and weaknesses of this turfgrass. Recently, unique leaf roll and leaf curl symptoms were observed on several Oriental accessions. The causal agent of this biological abnormality is an Eriophyd mite (Eriphyes zoysiae) and is new to the United States. However, preliminary observations indicate that resistence to the pest exists within the Oriental germplasm.

A taxonomic study of the Zoysia spp. germplasm was initiated to gain a better understanding of their breeding behavior. Initially 18 morpholgical characteristics were measured on a random sample (n = 46) of the original 731 Oriental zoysiagrass. Statistical analysis of these multiple traits suggest at least five distinct groups were present within this sample using both floral and agronomic traits. In a expanded evaluation involving 417 accessions, inflorescence length appears as a strong destinctive character to seprate the groups. Currently vegetative characters are being examined on a large sample of Oriental accessions to further develop and substantiate the current groups or species in the germplasm.

The genetic variability within the Oriental germplasm continues to be evaluated in the field, greenhouse, and laboratory. Field notes were taken during the last year for fall color, growth rate, leaf type, spring green-up, flowering habit, percent cover, dormancy, and canopy temperature. Significant variation exists within the germplasm for all of these characters, and the probability of creating genotypes which possess favorable gene combinations for several of these characters are excellent. A study investigating the cross-compatibility and self-incompatibility of the accessions in the germplasm was initiated during Spring 1985 in both the greenhouse and the field. This information will help determine if open-pollinated populations with little selfing can be used for effective genetic recombination of the important turfgrass characteristics.

A commercially available Korean zoysiagrass seed stock was screened for tolerance to high soil temperatures and low soil moisture. Plants selected for superior perfomancee during prolonged temperature and moisture stress (Population A), and those selected for their ability to recover from stress conditions (Population B) differed significantly from an unselected base population. A field study using the selected and unselected populations was initiated to further examine the tolerance of this plant material to heat and moisture stress in the natural environment. This field investigation will help substantiate the effectiveness of the greenhouse soil heat bench selection technique.

Attemps to produce single cross hybrids between individual zoysiagrass accessions were unsuccessful thus far. Several crossing techniques will be evaluated during the next year. A pollen storage method will also be investigated to help cross plants in which flowering times are not synchronized. A growth chamber constructed during the last year was useful in initiating plants to flower. Open-pollinated seedlings from plants which flowered in the greenhouse during 1983 and 1984 were planted to the field Summer 1985. Eighty-six families (i.e., the maternal parent and its open-pollinated offspring) were established in a replicated field trial to study the level of genetic variation for major agronomic characters, and provide accurate estimates of heritability. Such information is essential in determining the most effective breeding method to employ in cultivar development.

Forty cultivars were evaluated for sod strength and rate of regrowth after sod harvest. Three accessions (DALZ8501, DALZ8502, and DALZ8503) have outstanding rhizome regrowth potential while retaining excellent turfgrass characteristics. This finding should have a substantial impact on the sod industry in future years. These accessions, along with several others from the Oriental germplasm, and all the commercially available cultivars will be planted into a new variety trial in Spring 1986. A seed production trial was also initiated August 1985 to help determine the potential for a seeded zoysiagrass variety.

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the causal agent - namely a mite of the Eriophyes genus.

The species has been identified as Eriophyes zoysiae (Baker, Kono, and O'Neil) and is a new species of mite not previously reported in the United States. The mite is described as being 252 to 279 u in length and 34 to 40 u in width. Both males and females have been observed (Dr. Niki O'Neil, personal communication). The symptoms developed by mite infestation have been observed throughout the Orient, and it was originally believed to be caused by a virus. This malady is considered to be the third most important pest problem on zoysiagrasses in Korea (Dr. Do Yi Yeam, personal communication).

The buggy whip (Figure 2) results from the leaf tip being captured in the leaf whorl of the previous leaf. Mites appear to feed in the whorl of the leaf resulting in a tight leaf roll. The tip of the second emerging leaf becomes trapped in this leaf roll and as it continues to elongate, forms the buggy whip symptom which is characteristic of this mite. The mite is revealed as the leaf is unrolled and appears as "peas-in-a-pod" (Figure 3).

This mite appears to have a very narrow host range (Dr. Niki O'Neil, personal communication). Investigations are underway to propagate the mite colonies at TAES-Dallas. In cooperation with Dr. James A. Reinert, Resident Director and Professor of Entomology, TAES-Dallas, and Dr. Robert Crocker, Urban Entomologist, TAES-Dallas, techniques will be developed for effective screening procedures to identify genetic resistence to the mite within the host population. Preliminary observations indicate the that potential for resistance exists within the genus Zoysia.

Leafspot (Helminthosporium spp.) occurred on several zoysiagrasses in the greenhouse during early October, 1984 (Table 1). Iron chlorosis was also observed on a number of zoysiagrass accessions which were in greenhouse containers for the past 29 months (Table 2). An inventory of the Oriental germplasm received from USDA-BARC was completed Fall 1985 (Table 3).

B. TAXONOMIC CLASSIFICATION

1. Multiple Character Analysis and Chromosome Studies

Under the direction of Dr. Michael Kenna, Postdoctoral Research Associate, TAES-Dallas.

Introduction: The species of Zoysia Willd. are native in a wide geographical range from the Mauritius Islands on the Indian Ocean, throughout the Southwest Pacific to Manchuria, Korea, and Japan (4). Three species of Zoysia are utilized as turfgrasses: Z. japonica Steud., Z. matrella (L.) Merr., and Z. tenuifolia Willd. ex. Trin. (1). Two other species, Z. sinica Hance and Z. macrostachya Fr.&Sav. (6), may also have potential as turfgrasses, or contribute favorable characters to the germplasm pool for use in improving turfgrass varieties. Some botanists and agronomists consider the species within the genus Zoysia to be botanical varieties of a single species because they hybridize readily and have the same chromosome number (n = 20) (5,10). Information concerning the natural variation within the genus Zoysia will be useful in the planning and implementation of the breeding program.

Objective: Identify morphological and cytological similarities and differences among selected zoysiagrass accessions. Information of this nature will be useful for classifying the zoysiagrass germplasm assembled at TAES-Dallas into phenotypically distinct groups.

Progress: During the summer and fall of 1984, several morphological traits were identified in 50 zoysiagrass accessions which were randomly selected from among the 731 Oriental accessions assembled at TAES-Dallas. Subsamples consisting of five culms with an inflorescence were selected at random from each accession and subjected to microscopic and macroscopic determination of phenological characters. Significant variation was detected for the 18 characters examined in this study (Table 4).

A 'polythetic' classification system was employed to produce the phenotypically distinct groupings. This approach attempts to cluster individual plants together according to all their attributes considered simultaneously (9). A series of SAS (8) clustering procedures (see Semi-Annual Report, Spring 1985, p. 2) were used to produce five statistical groupings (Figure 4). Two of these groups contained a single plant. Cluster 2 contained plants primarily of Z. matrella and Z. tenuifolia. Cluster 1 was dominated by Z. japonica. The specific names of plants in clusters 3 and 4 have not been determined at this time, and the single plant in cluster 5 is believed to be in the species Z. macrostachya.

Floral characters alone did not predict individual plants into the five groups. Those characters contributing the most to the statistical groupings include:

Flag leaf length	4th leaf length	Inflorescence width
Node diameter	Floret length	Stolon length
Inflorescence length	Awn length	Pubescence (abaxial)

Seven inflorescence characters were then identified on 417 seed head samples taken from zoysiagrass accessions that were grown under greenhouse conditions in 1983 and 1984. These characters included: inflorescence length and width; floret length, width, and depth; floret number; and pedicle length (Figure 5). SAS (8) clustering procedures were used to produce a new set of five statistical groupings (Table 5 and Figure 6). Inflorescence length and the number of florets per inflorescence were highly correlated (R = 0.95), and a two dimensional plot of these characters indicates that they alone would be helpful in grouping zoysiagrass accessions (Figure 7).

Publications:

Kenna, M. P., M. C. Engelke, and V. G. Lehman. 1985. Multiple Character Analysis of Exotic Zoysiagrasses. Texas Turfgrass Research - 1985, PR-4327.

Future Work: Vegetative characters, such as leaf length and width, will be identified on a large sample of zoysiagrass accessions. Information collected on the field grown zoysiagrass accessions will be combined with inflorescence characters to help confirm phenological groupings.

C. FIELD ASSESSMENT

1. Evaluation of Morphological and Agronomic Characters

Under the direction of Dr. Michael Kenna, Postdoctoral Research Associate, TAES-Dallas.

Introduction: The most widely used zoysiagrasses include 'Meyer' (Z-52) (*Zoysia japonica* Steud.), 'Emerald' (*Z. japonica* X *Z. tenuifolia* Willd. ex Trin.), and FC13521 (*Z. matrella* (L.) Merr.) (1). In an effort to expand the number of and improve on commercially available cultivars, a portion of the Oriental zoysiagrass germplasm is being evaluated under the natural field conditions at TAES-Dallas.

Objective: Characterize the genetic variability among zoysiagrass accessions under field, greenhouse, and laboratory conditons for characters of taxonomic and agronomic importance.

Progress: Oriental zoysiagrasses, which did not express symptoms of Eriophyid mite infestation in the greenhouse, were planted in a replicated field nursery during June 1984. The remaining 400 plants which had expressed symptoms were planted in non-replicated field nurseries. The cultivars 'Meyer' and 'Emerald' were included as standard references. A 5 cm diameter clonal propagule of each individual zoysiagrass accessions was planted into a 0.09 m^2 area on 1.8 m centers.

Field notes were taken during fall of 1984 for leaf type (fine = 1 to coarse = 9), growth rate (e.g., plant spread, where low = 1 to high = 9), and plant color (brown = 1, brown and purple = 2, purple = 3, and green = 4). Field notes were recorded in Spring and Summer 1985, for date of green-up (first sign of green, actively growing tissue), rate of green-up (determined by weekly visual estimates of green vs. brown tissue), anthesis date (first sign of anthesis), percent anthesis (plants in anthesis recorded weekly), rate of growth (e.g., plant spread and percent coverage), and canopy temperature.

Only one percent of the oriental zoysiagrasses did not survive the Winter of 1984. An analyses of variance was performed on the accessions for each character in the study. Significant variation ($P \leq 0.01$) among the accessions was present for all agronomic characters (Table 6). Variance components estimated from the mean squares were used to calculate broad sense heritability estimates (H_{bs}) which indicates the proportion of genetic variation present for the characters studied (Table 6) (3, 4). As suggested by H_{bs} estimates, faster progress can be anticipated in selecting for leaf type, percent coverage, plant spread, and anthesis date than for fall color or spring greenup.

Each accession was then classified according to its country of origin (Japan, Korea, Philippines, and Taiwan) and leaf type (e.g., fine = 1 to 3, medium = 4 to 6, or coarse = 7 to 9) to facilitate further data analysis (Table 7). Analyses of variance for characters classified in this manner indicated significant ($P \leq 0.01$) sources of variation for country of origin, leaf type, and the country by leaf type interaction for all the characters except fall color.

Accessions collected from the Philippines (9 ° - 17 ° N latitude) and Taiwan (20 ° - 27 ° N latitude) generally did not green-up as fast as plants from the more northern latitudes of Korea and Japan (31 ° - 46 ° N latitude). Rate of green-up also indicated an earlier and faster response for accessions in all three leaf type groups from Japan and Korea when compared to accessions from Taiwan and the Philippines (Figure 8).

Plant spread differed significantly ($P \leq 0.05$) among the leaf types and the countries of origin for the ratings given in the fall on 0.09 m^2 plots (Table 8), and in the spring for ratings on the enlarged 0.8 m^2 plots (Table 9). The percent plant coverage, with respect to the 0.8 m^2 plot area, also substantiates the differences observed for plant spread. The overall mean for percent coverage (mean = 23.4 %, range 5 to 80 %) translates to a 150 % increase in area covered when compared to the original 5 cm diameter plug (Table 10). The fine and medium leaf types from Taiwan consistently had the poorest performance for plant spread and percent coverage among the four countries of origin, while the medium leaf types from Korea were consistently the highest.

Canopy temperature was measured on 21 August 1985 using an infrared thermometer held 1 m above the individual plants (Table 11). Temperatures were taken in the morning, and then again in the afternoon. No canopy temperature differences were found among the leaf types and the countries of origin for the morning reading. However, canopy temperature did differ significantly ($P \leq 0.05$) among the countries of origin for the afternoon measurement. We have no explanation for the physiological causes of the differences in canopy temperatures for zoysiagrasses from the different countries.

The percentage of plants in anthesis varied for the countries and leaf type groups during the period from 28 March to 19 May (Figures 9 and 10). However, there were periods during the spring where anthesis was occurring for all three leaf types and four countries simultaneously. Uniformity of anthesis indicates that open-pollinated progeny can be produced from a large base population containing a wide range of individual genotypes. The genetic recombination that occurs among a genetically diverse population will permit a mass recurrent selection program to be more effective. Recurrent selection schemes increase the gene frequency of desirable traits. Therefore, the probability of creating genotypes which possess favorable genes for several agronomically important traits is improved greatly. Additionally, this overlap in flowering will facilitate the controlled hybridization of selected parents and enable us to more readily incorporate desirable gene combinations.

Publications:

Kenna, M. P., and M. C. Engelke. 1985. Field Evaluation of Oriental Zoysiagrasses for Growth and Flowering Characteristics. Texas Turfgrass Report - 1985, PR-4319.

Kenna, M. P., and M. C. Engelke. 1985. Agronomic and Morphological Characterization of Exotic Zoysiagrasses. Agronomy Abstracts, ASA Annual Meeting, Chicago.

Future Work: Currently dormancy ratings are being taken to evaluate the genetic variation of response to decreasing photoperiod and temperature. The Fall 1984 notes indicated that anthocyan production (purple coloring) occurred at various degrees for the germplasm. During this time the percent green, purple, yellow, and brown plant tissue will be recorded. The last date green, actively growing tissue is observed will also be recorded. The date of winter dormancy combined with spring green-up will demonstrate the large amount of genetic variation present for length of growing season. A study investigating the cross-compatibility and self-incopatibility of the accessions within the germplasm was initiated during Spring 1985 in both the greenhouse and the field. This information will help determine if open-pollinated populations with little selfing can be used for effective genetic recombination of the important turfgrass characteristics.

The information collected, thus far, is compiled into a large data base for the 731 Oriental zoysiagrass accessions. This information is now being evaluated to select elite plants for increase during Winter 1985. A new Replicated Turf Trial (RTT) will be planted in Spring 1986. Ten of the "best" Oriental genotypes will be included in this RTT along with the commercially available zoysiagrasses and experimental varieties which have performed well in other studies at TAES-Dallas.

subirrigated, and the soil temperature returned to ambient temperature (22 °C or 72 °F). On 19 November, the remaining population was again screened using the same grid method and selection criteria described above (Population B).

Approximately 95 percent of the Z. japonica population that was established entered dormancy or did not survive during the 5 weeks of high soil temperature and low moisture stress. Further research will be conducted to verify if population A genotypes have the ability to tolerate high soil temperatures, low soil moisture, and maintain active growth under field conditions. This characteristic could be important in maintaining high quality turf with minimal irrigation during the summer stress periods.

The individual plants within population B were selected 5 weeks after the environment was returned to more favorable conditions (i.e., ambient soil temperature and adequate soil moisture). This second selection period would, theortically, place more emphasis on identifying genotypes which can escape drought periods through dormancy, and recover rapidly when adequate precipitation is received.

The three populations (A, B, and Base) were evaluated for: number of stolons, number of stolon nodes, and tillers per plant; total stolon length per plant (cm); and total stolon weight (g). Internode length (cm) was estimated by dividing the total stolon length per plant by the total number of nodes per plant. Significant differences ($P \leq 0.05$) among the three populations were present for all six continuous characters in the study (Table 12). Population A and B differed in every character except number of stolons and nodes per plant. Both population A and B differed from the base population for all the characters studied except internode length. Population A was not significantly different ($P \leq 0.05$) from the base population for internode length. If the early detection of differences found among individual genotypes grown in the greenhouse correlate well with differences found under field conditions, then more emphasis will be placed on this selection technique that would accelerate the breeding, selection, and development of new turfgrasses.

The presence or absence of adaxial (upper) and abaxial (lower) leaf hairs was recorded for each plant. Stolon color was recorded as either purple or yellow (5). A very high proportion of the plants within the three populations had adaxial and abaxial leaf hairs (Figure 11). Percent presence and absence of abaxil leaf hairs in population B was significantly different from population A (chi-square = 3.439, P = 0.10-0.05) and the base population (chi-square = 4.932, P = 0.05-0.025). No differences were found among the populations for adaxil leaf hairs and stolon color. Forbes (5) suggested that the inheritance of several reliable marker genes should be investigated to facilitate the identification of hybrids at the seedling stage. He reported

Progress: Genotypes from all five species were selected for hybridization. A controlled growth chamber was completed during the Winter 1984/85 to help initiate flowering. Photoperiod and temperature can be manipulated in such a manner that plants which do not normally flower under the same environmental conditions can be put into phase with each other.

A 9 to 10 hour photoperiod with temperatures maintained between 20 and 30^{o} C has successfully initiated flowering among a subsample of 80 zoysiagrasses. Attempts to determine cytological and fertility information on the parents and their F_1 hybrids were unsuccessful during spring 1985. Most of the crosses attempted thus far were between *Z. matrella* and *Z. macrostachya*. Additional work is needed to evaluate several of the crossing techniques currently used on open pollinated grass species.

Future Work: Plants are currently being prepared to make additional crosses. This work will be carried on through the Winter of 1985 and Spring 1986. Pollen storage techniques will also be investigated as a means to facilitate hybridization of plants whose flowering is not synchronized. Pollen storage techniques have been successful in bahiagrass (*Paspalum notatum* L.) and are presently being studied in bermudagrass (Dr. Wayne Hanna, personal communication).

2. Narrow Sense Heritability Estimates for Turf Characters in Zoysiagrasses

Under the direction of Dr. Michael Kenna, Postdoctoral Research Associate, TAES-Dallas.

Introduction: Genetic variation for quantitative characters is a prerequisite for initiating changes in plant populations for those characters. The more accurate the estimates of genetic variances, the more efficient the plant breeder can be to change the population in the desired direction. Generally, genetic variances are estimated in the following way. Relatives are developed by a system of matings (mating design) and then they are grown in a set of environmental conditions (environmental design). Analyses of observations for characters of interest lead to estimates of variance and covariance which are interpreted genetically and environmentally (3). An investigation of the Oriental zoysiagrass germplasm which employed a random mating design and multiple years as environments was implemented in 1985 to estimate genetic information more accurately.

Objective: Estimate the narrow sense heritability of several quantitatively inherited traits important to turfgrasses using the parent-offspring regression method. This information will help determine if mass recurrent selection would be an effective breeding method for these turfgrass characters.

Progress: During 1983 and 1984 seed heads were harvested from zoysiagrass plants grown in the greenhouse. A total of 440 accessions had from 1 to 5 seed head samples taken during this time. The seed heads were then bulked for each individual accession producing half-sib (HS) families, and 357 of these HS families had enough mature seed heads to thresh. In February 1985, the thresh seed was cleaned, scarified for 30 minutes in potassium hydroxide (KOH), dried thoroughly, and given a 48 hour continuous light treatment (7). The seed were then planted in 10 cm pots filled with a modified soiless media.

Eighty-six accessions produced a sufficient number of HS seedlings to conduct a field study with three replications. Female parents for each of these HS families were propagated asexually in the spring 1985. Several of the characters mentioned in the other field assessment studies will be evaluated on the HS progeny and their common maternal parent. This study will not only provide an estimate of the phenotypic variation present, but will also allow estimation of genetic effects (i.e., that which is "heritable" or passed on to progeny genetically).

Future Work: Data collection on this study began in Fall 1985 with dormancy notes. Persistence during the winter and spring green-up will be collected Spring 1986. Other growth and flowering characteristics will also be evaluated during 1986 and 1987.

F. REPLICATED TURF TRIALS (RTT)

1. Experimental Variety (EXPERVAR) Evaluation Trials

In cooperation with Mr. Brian Maloy, Research Associate, TAES-Dallas, and Dr. Michael P. Kenna, Postdoctoral Research Associate, TAES-Dallas.

Objective: Provide information on regional adaptation and performance of several commercial and experimental varieties.

Progress: A RTT of 40 domestic accessions was planted at TAES-Dallas in July, 1981. Field notes were taken during 1982/85 and were presented in previous progress reports. In July 1985 sod was harvested from the entire study. Sod strength (Kg/cm^2) was determined at the time of harvest using a sod stretcher equipped with a load cell. Regrowth notes (Number of plants/ 0.09 m^2) were then taken to establish the amount of time required before sod could be reharvested.

Two experimental varieties, DALZ8501 and DALZ8502, have demonstrated a significantly ($P \leq 0.05$) greater regrowth potential than the current commercially available cultivars (Table 13). These early results indicate that considerable variability exists for rapid regrowth potential. It should be possible to develop zoysiagrasses which establish faster, and which are more economical to produce. Sod strength was high for most all the entries in this study. This information will be particularly important to sod producers planning to enter or further develop the zoysiagrass market.

A new RTT for evaluating seed production was initiated during July 1985. Sod harvested from the study above was used to establish replicated (4 reps) seed production plots. Currently the only commercially available zoysiagrass seed originates from Korea. This seed is highly heterozygous and does not always establish a uniform turfgrass stand. Information on the flowering habit and seed production potential of some of the elite experimental varieties identified at TAES-Dallas will be useful to the turfgrass industry.

Future Work: Investigations concerning sod regrowth potential will be continued through the Spring and Summer of 1986. Special emphasis will be given to the percentage of the plot area covered by the individual genotypes. The zoysiagrass seed production study will be evaluated during 1986 and 1987. A new RTT will be initiated in the Spring of 1986. The outstanding genotypes from this current RTT will be included along with material from the Oriental germplasm and the available cultivars.

G. SALINITY TOLERANCE

In cooperation with Dr. Garald Horst, TAES-El Paso, cooperator.

Experimental zoysiagrasses were transferred 5 October 1981 for evaluation under saline soil conditions using a screening method developed by Dr. Garald Horst.

H. WATER USE EFFICIENCY

In cooperation with Dr. James Beard, TAES-College Station.

Experimental zoysiagrasses were transferred 6 September 1984 for water use effeciency evaluation using criteria developed by Dr. James Beard.

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Engelke, M. C., M. P. Kenna, and V. G. Lehman. 1985. Soil Temperature Bench for Turfgrass Germplasm Evaluation. Agronomy Abstracts, ASA Annual Meetings, Chicago.

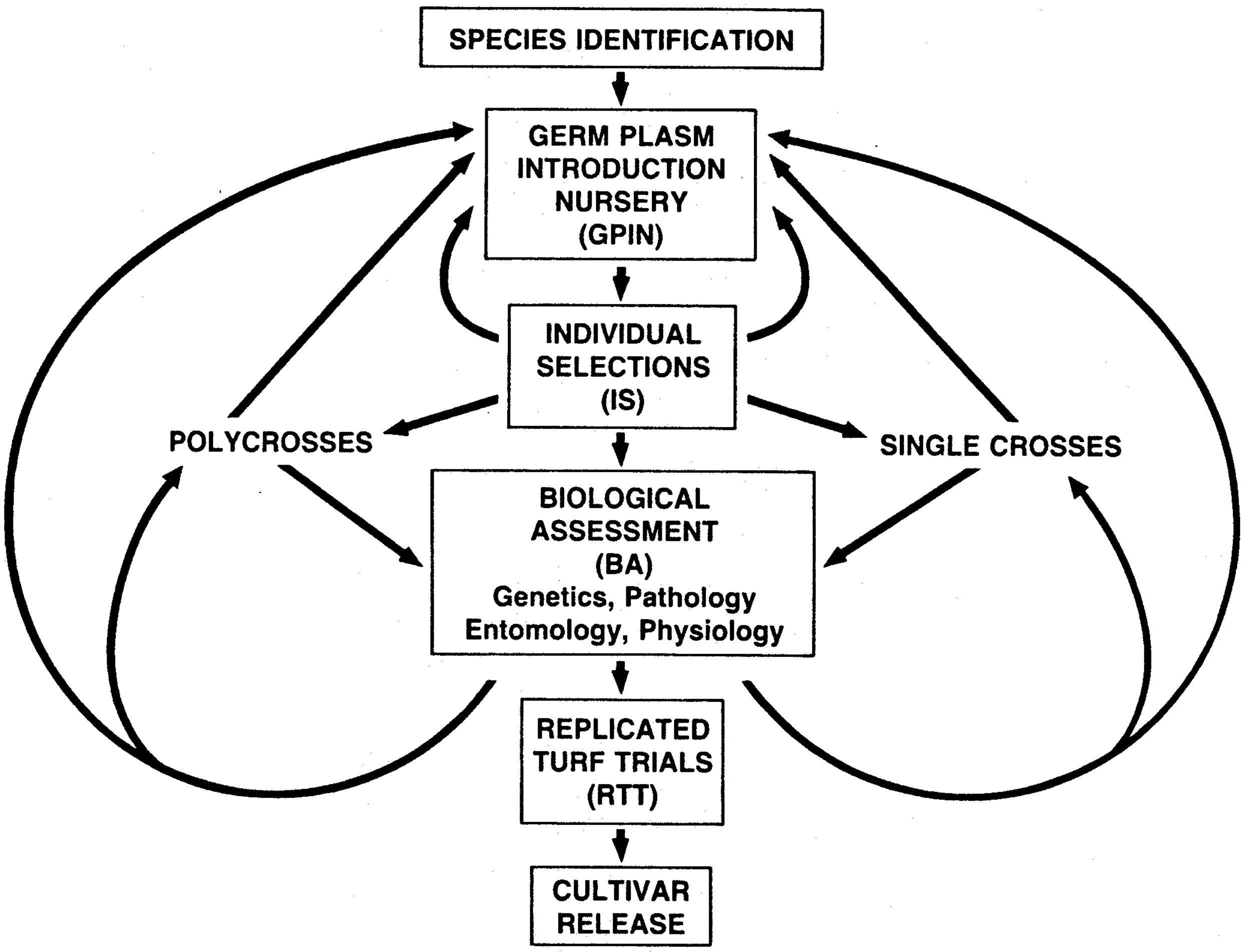

FIGURE 1. FLOW DIAGRAM DEPICTING MAJOR ELEMENTS AND EVENTS IN DEVELOPING GRASSES INTO ACCEPTABLE TURFGRASS CULTIVARS.

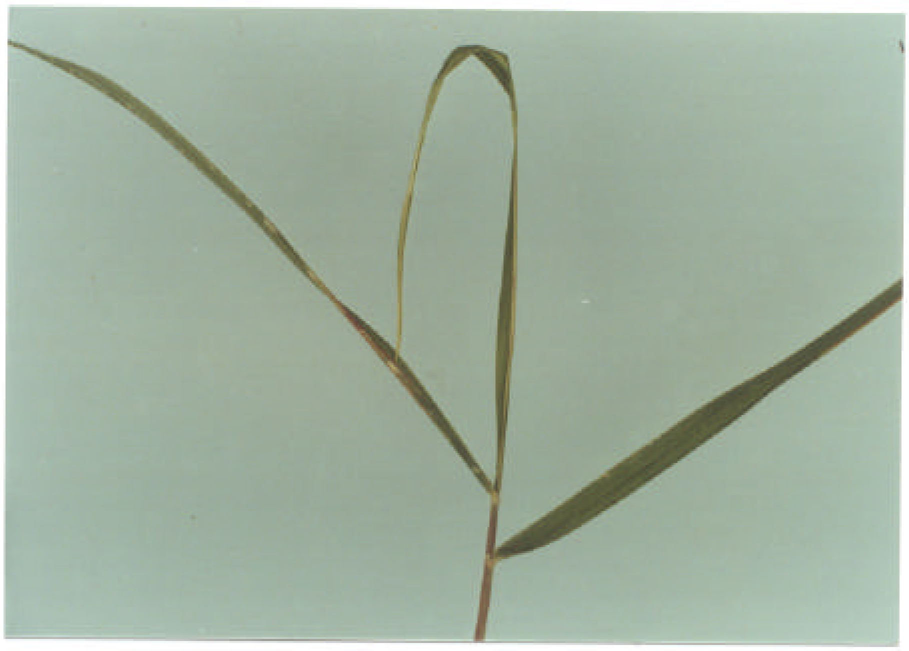

Figure 2. Eriophyid mite damage on zoysiagrass leaf displaying the discoloration, leaf roll, and buggy whip symtoms.

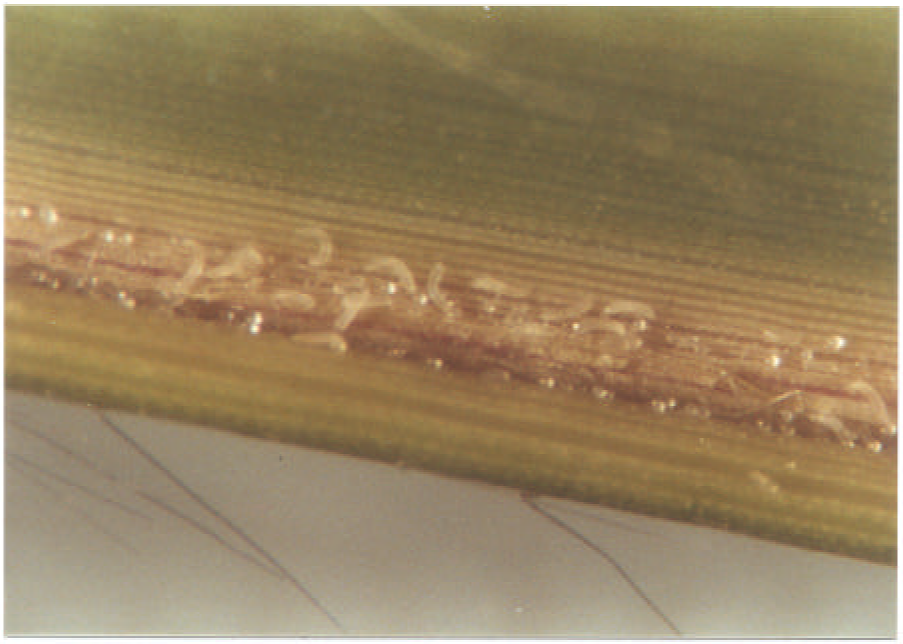

Figure 3. Eriophyid mites in rolled leaf of infested zoysiagrass. Dissecting the rolled part of the leaf reveals mites lined up like 'peas-in-a-pod.'

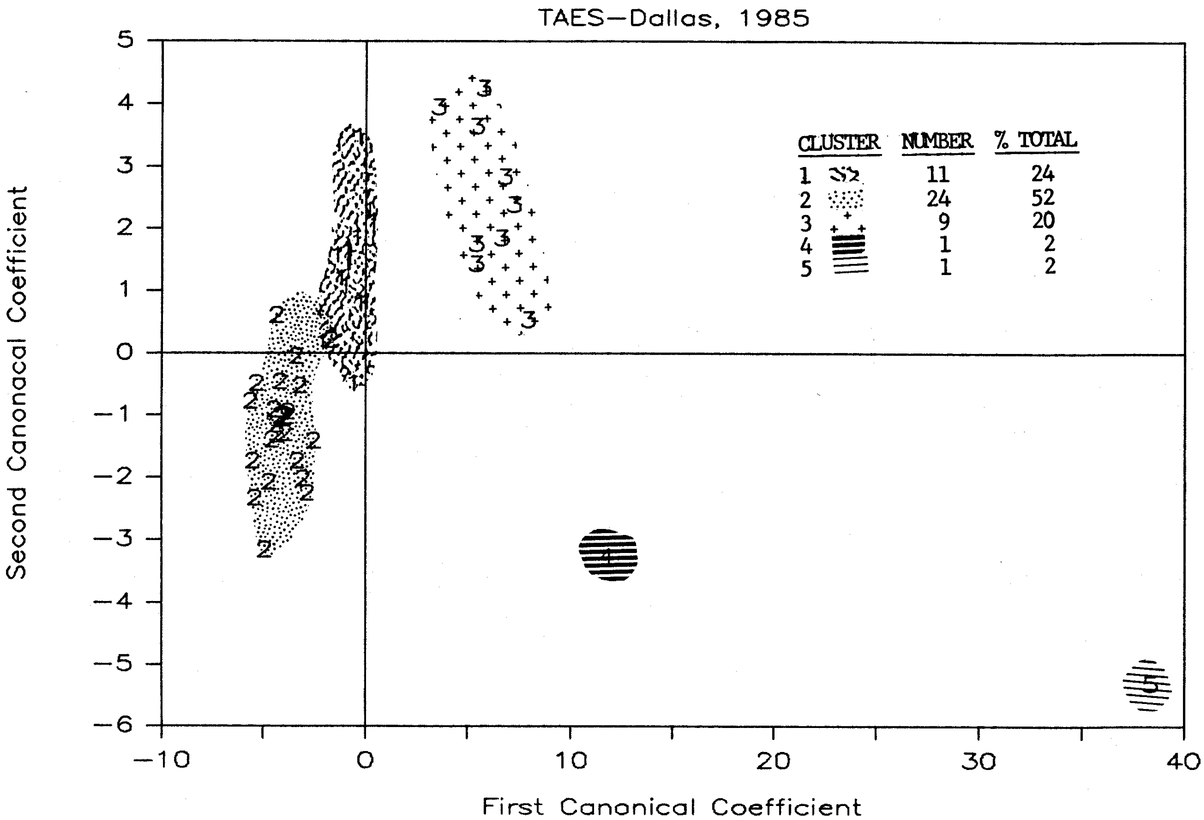

Figure 4. Canonical discriminant analysis of floral and vegetative characteristics depicting five clusters of 46 accessions of *Zoysia* spp. from the Orient.

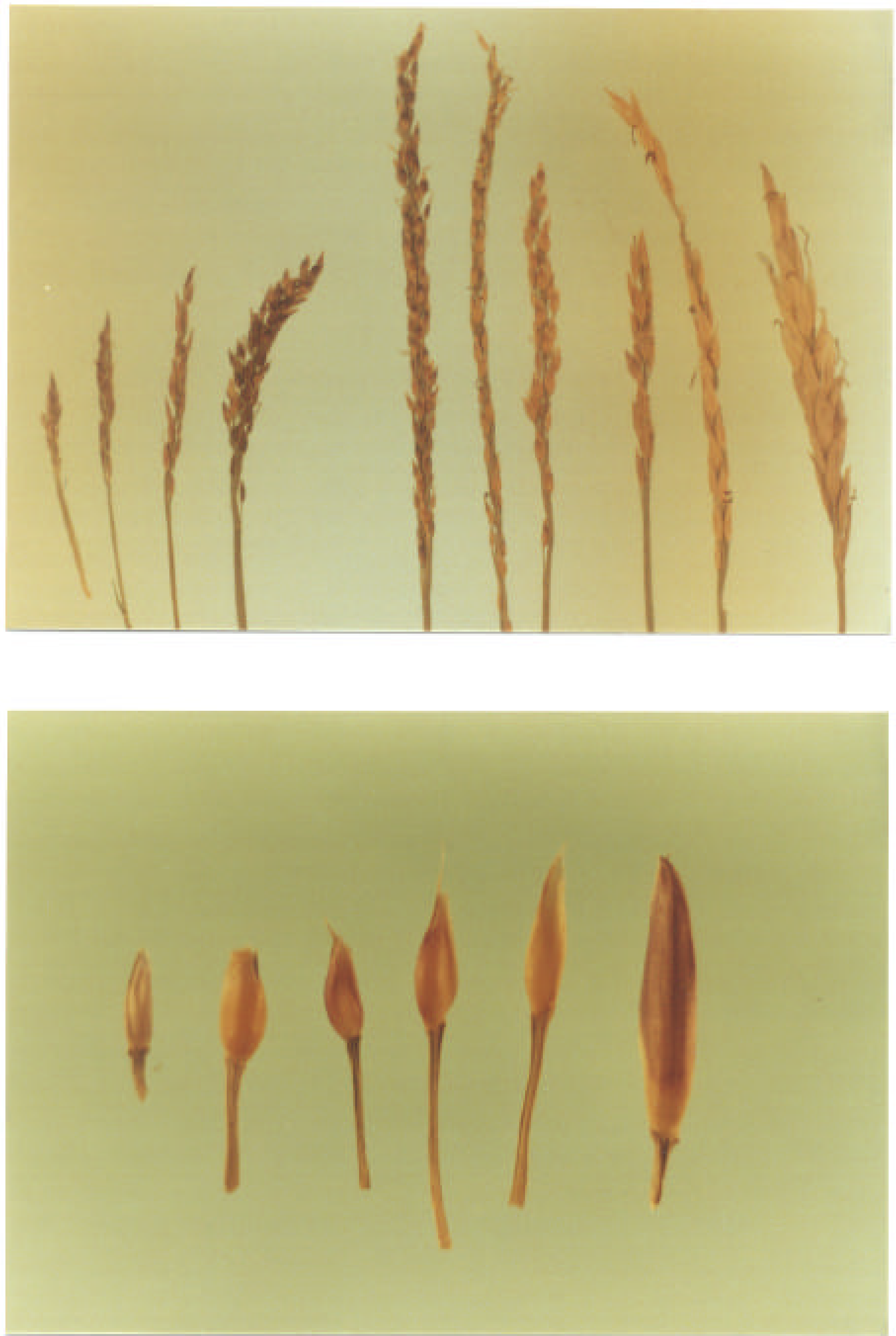

Figure 5. Inflorescence characters identified on 417 Oriental and domestic zoysiagrass accessions. These characters included: inflorescence length and width; floret length, width, and depth; floret number; and pedicle length

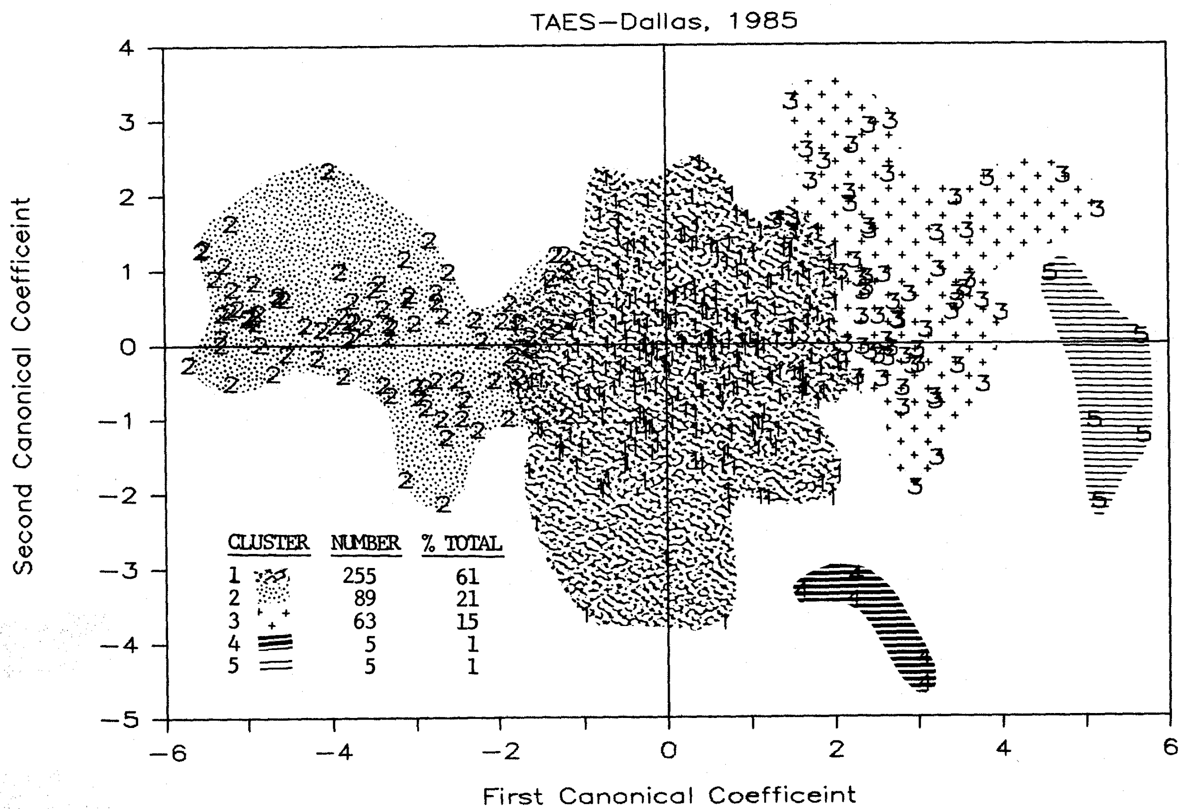

Figure 6. Canonical discriminant analysis of floral characteristics depicting five clusters of 417 accessions of *Zoysia* spp. from the Orient and USA.

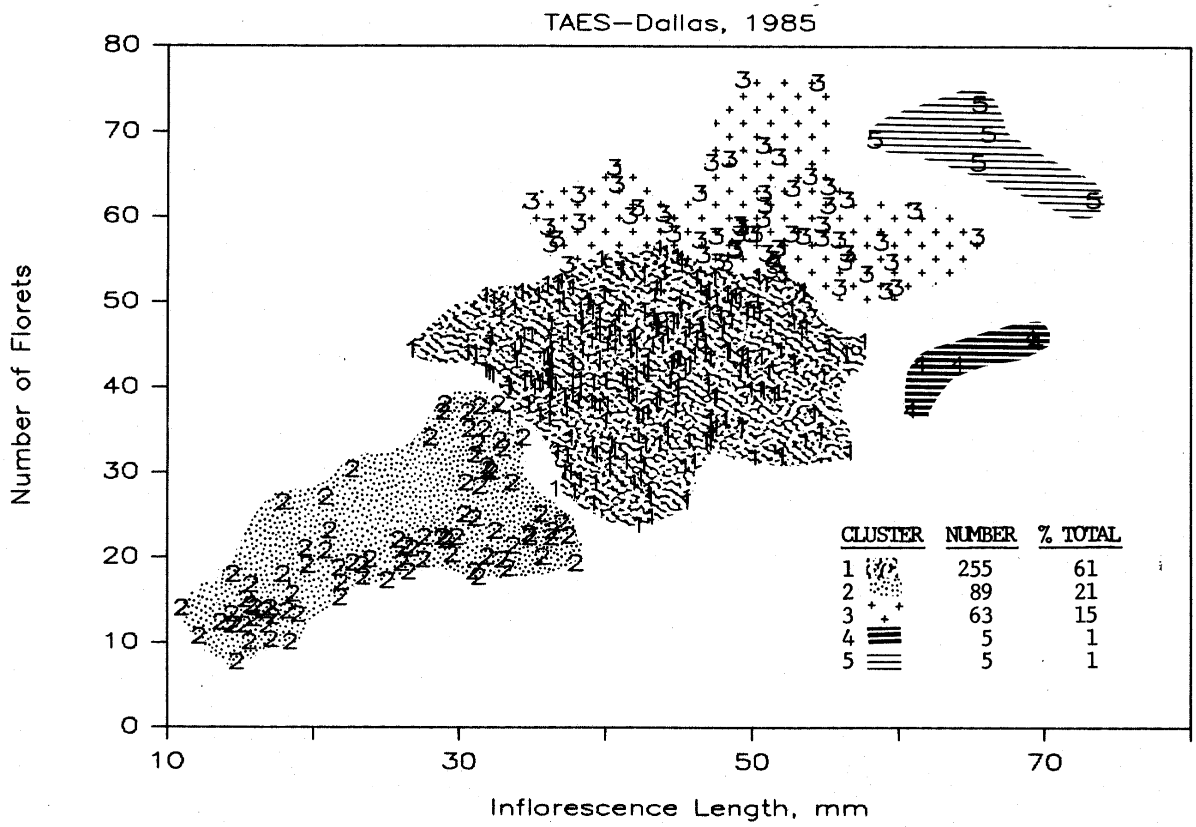

Figure 7. Plot of inflorescence length (mm) vs. floret length (mm) characteristics depicting five clusters of 417 accessions of Zoysia spp. from the Orient and USA.

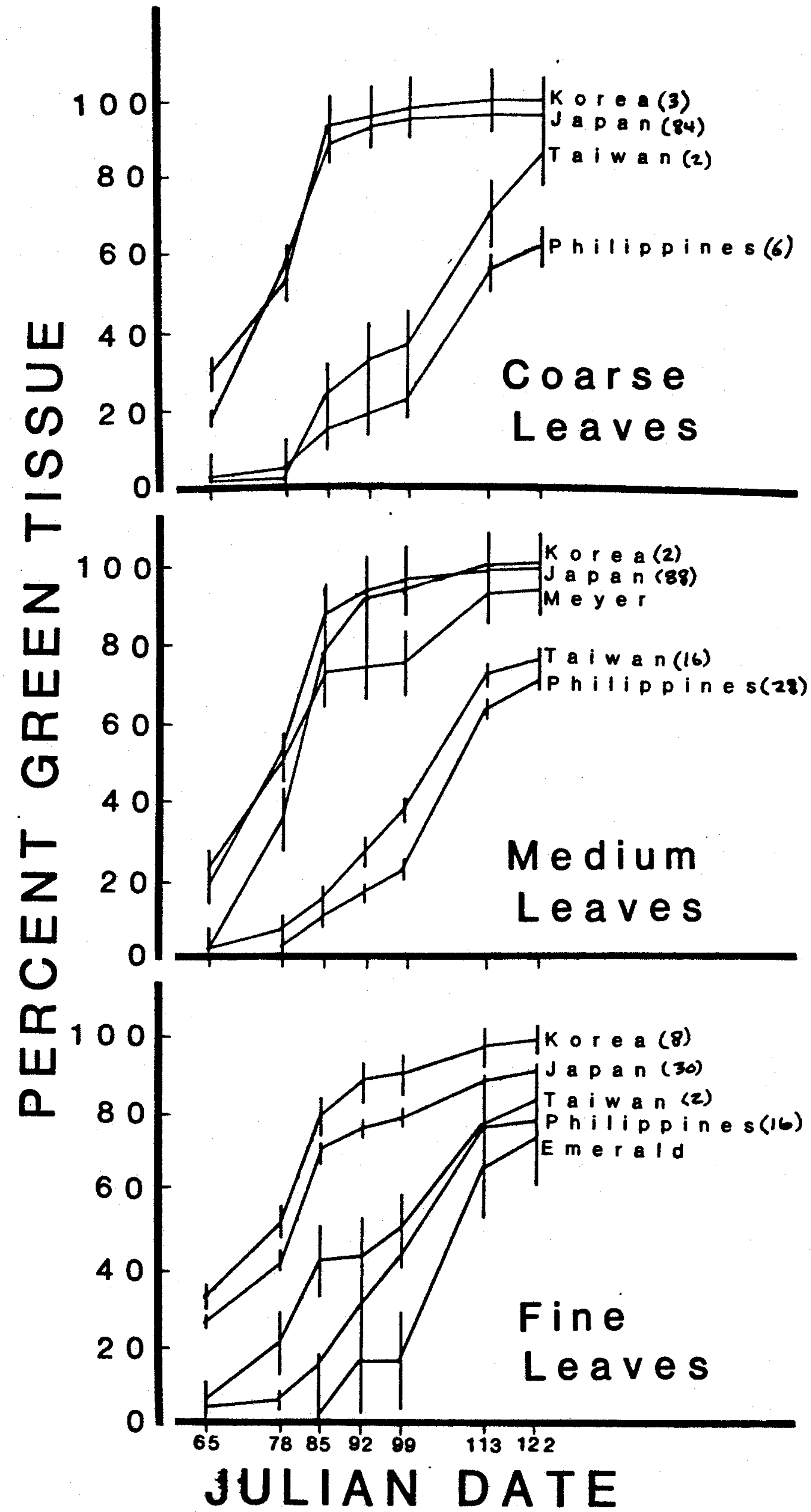

Figure 8. Rate of field green-up expressed as percent green tissue for the different countries and leaf types within the Oriental zoysiagrass collection. The number of plants for each country within the different leaf type groups are indicated in parentheses.

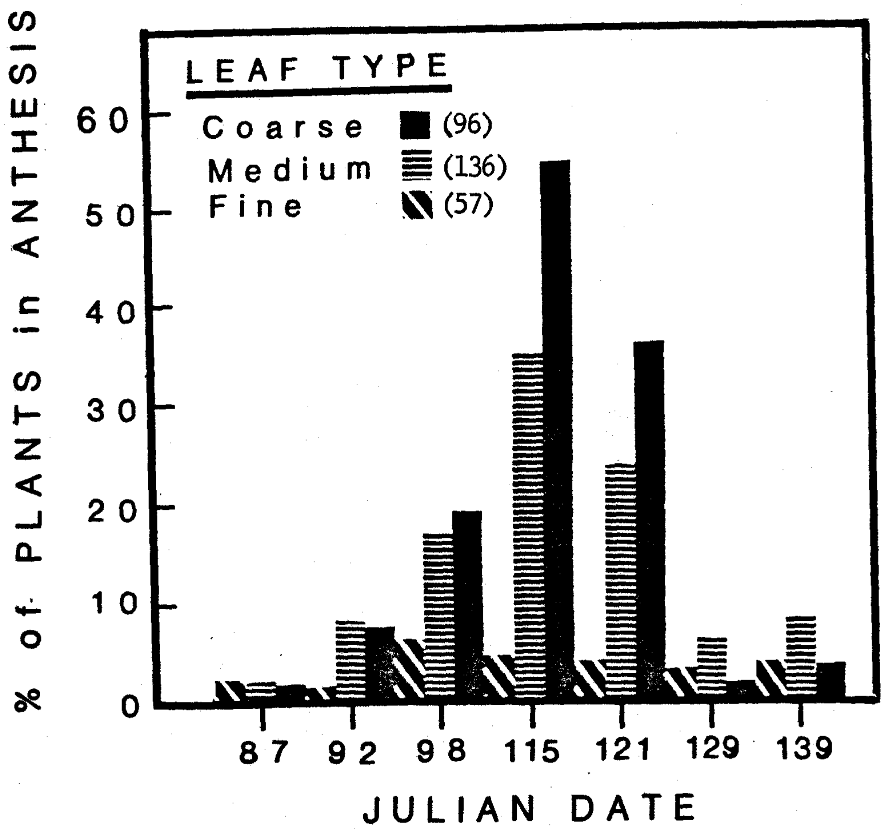

Figure 9. Percent of total number of plants within the different leaf types groups in which anthesis was occurring. The number of plants within each leaf type group are indicated in parentheses.

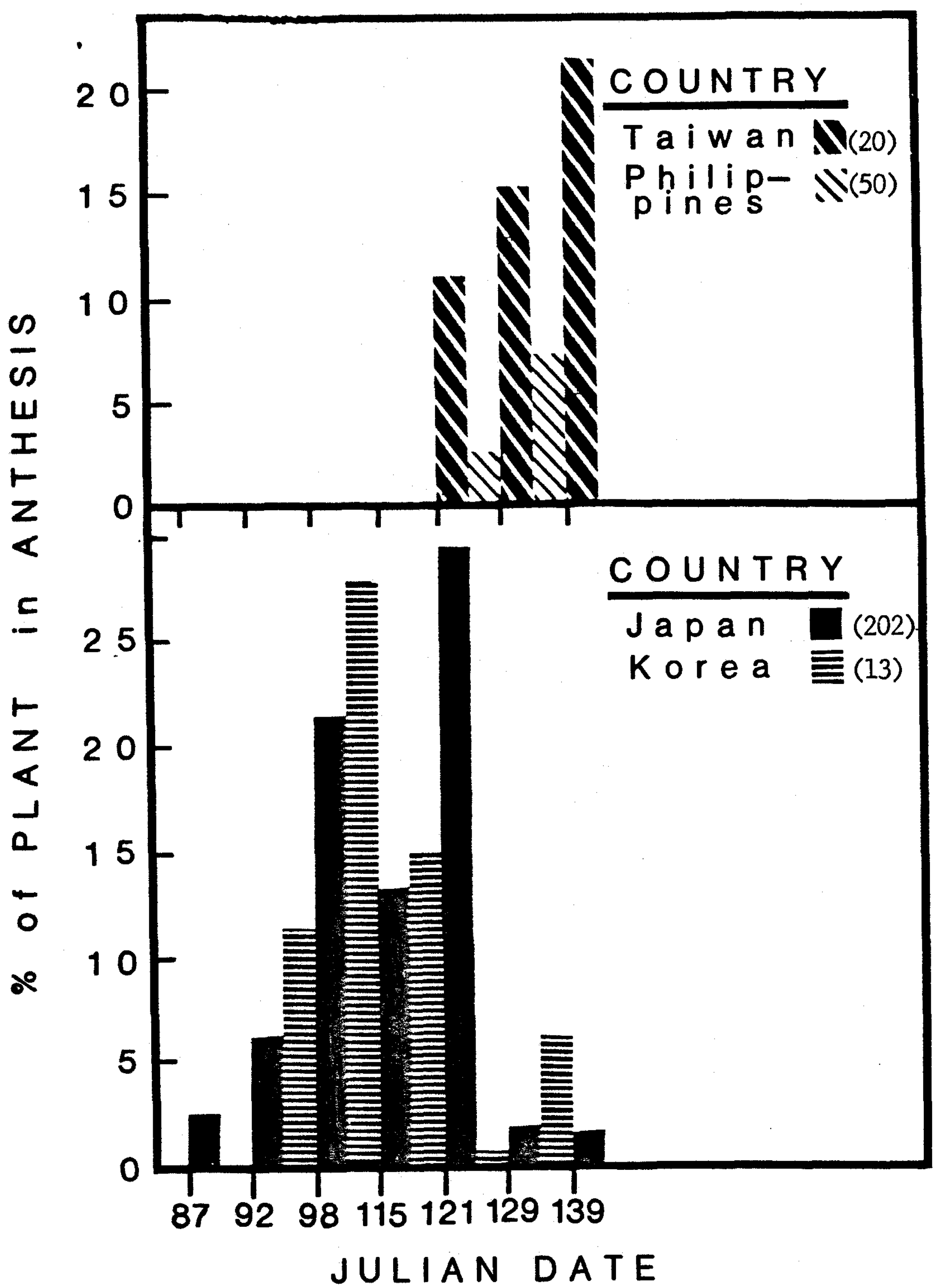

Figure 10. Percent of total number of plants from within the different countries in which anthesis was occurring. The number of plants from each country are indicated in parentheses.

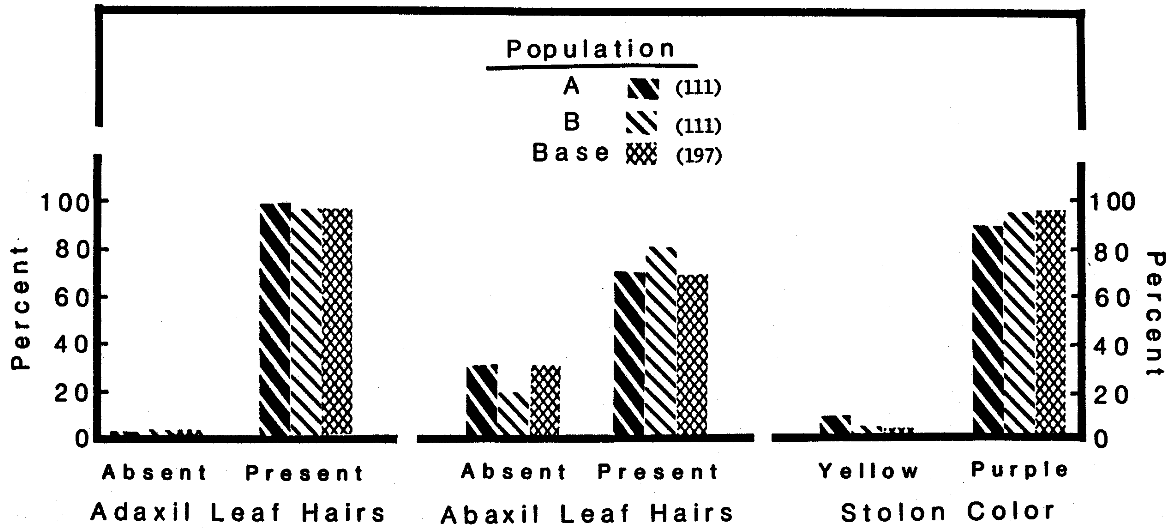

Figure 11. Leaf hair and stolon color character state percentages for an unselected base population and two populations selected under high soil temperature and low moisture stresses.

VII. LIST OF TABLES

Table 1. *Helminthosporium* leaf spot on zoysiagrasses in the greenhouse.

Disease	No. of Plants	% of Total
Present	48	6.1
Absent	753	93.9

Table 2. Iron cholorosis on zoysia- grasses in the greenhouse. house.

Plant Condition	No. of Plants	% of Total
Normal	486	59.2
Some Chlorosis	236	28.7
Chlorotic	68	8.3
Very Cholorotic	12	1.5
Dead	19	2.3

Table 3. Oriental zoysiagrass inventory summary, October 1984, TAES-Dallas.

Country of Origin	Plants Received			Greenhouse			Field		
	Date	Zoysias spp.	Other spp.	Survived	"Syndrome" Expressed	Missing	Planted	Survived	Dead
Philippines (P)	2/83	52	2	49	0	2	49	48	1
Taiwan (T)	2/83	21	3	16	0	2	17	17	0
Japan-Fukuako (JS)	6/82	97	0	91	93	6	93	93	0
Japan (J)	6/82	398	17	336	177	45	369	359	10
Korea (K)	6/82	172	7	148	148	17	141	140	1

Table 4. Mean, range, standard deviation (SD), and coefficient of variation (CV) for morphological and anatomical characters measured on 50 zoysiagrass accessions growing under greenhouse conditions.

Characteristic	Mean*	Range	SD	CV
	mm			%
Inflorescence				
base width	0.7 ± 0.1	0.3 - 1.3	0.2	30.6
widest point	1.3 ± 0.1	0.5 - 2.4	0.4	30.1
length	34.7 ± 3.4	11.9 - 55.8	11.7	34.2
Spikelet				
Awn Length	0.9 ± 0.2	0.1 - 3.1	0.7	78.7
Floret length	3.1 ± 0.2	0.2 - 6.4	0.8	25.5
Anther length	1.1 ± 0.2	0.1 - 2.0	0.5	46.6
Pedicle length	3.4 ± 0.4	1.2 - 6.2	1.2	35.9
Flag leaf to inflorescence	37.6 ± 7.9	1.4 - 147.2	27.5	73.2
Flag leaf				
length	38.2 ± 14.8	3.3 - 209.3	53.3	66.3
width	2.1 ± 0.2	0.3 - 4.6	1.0	48.5
Internode length	30.9 ± 5.7	8.6 - 72.1	16.3	52.6
Node diameter	1.2 ± 0.1	0.5 - 1.8	0.3	28.4
4th leaf				
length	59.2 ± 9.7	13.3 - 163.2	34.8	58.8
width	3.3 ± 0.2	0.6 - 5.5	1.1	31.5
midrib diameter	0.6 ± 0.1	0.3 - 0.8	0.1	22.5
Ligule hair	2.1 ± 0.2	0.8 - 3.8	0.7	34.3
Leaf hair length				
upper	1.9 ± 0.2	0.6 - 3.3	0.6	34.0
lower	1.4 ± 0.1	0.6 - 2.5	0.4	34.8

*Means and their 95% confidence intervals.

Table 5. Mean, range, and standard deviation for morphological and anatomical characters measured on 417 Oriental and domestic zoysiagrass accessions growing under greenhouse conditions. TAES-Dallas, Texas.

Cluster	Number of Plants	Inflorescence		Floret				Pedicle Length
		Length	Width	Number	Length	Width	Depth	
		mm	mm	no.	mm	mm	mm	mm
2	89	25.4* 11.0-37.9** 7.4+	0.3 0.12-0.54 0.1	21.5 7.0-38.0 7.6	3.1 2.2-6.8 0.6	0.9 0.5-1.4 0.2	0.6 0.4-0.9 0.1	2.3 1.0-4.7 0.8
1	255	42.5 26.7-57.7 5.9	0.4 0.2-0.7 0.1	42.5 23.7-56.3 6.9	3.0 2.1-6.1 0.5	1.0 0.7-1.4 0.1	0.6 0.4-2.5 0.1	3.9 1.7-0.6 1.0
3	63	49.7 34.9-65.3 6.8	0.5 0.3-0.8 0.1	59.1 51.3-76.0 5.0	2.9 2.3-3.7 0.3	1.0 0.8-1.3 0.1	0.6 0.5-0.8 0.1	4.7 2.7-9.4 1.2
4	5	64.9 60.8-69.4 4.1	0.4 0.4-0.6 0.1	42.7 37.3-45.7 3.4	3.0 2.6-3.3 0.3	1.0 0.9-1.1 0.1	0.6 0.6-0.7 0.1	4.5 3.3-5.6 1.0
5	5	65.7 58.4-73.3 5.3	0.5 0.4-0.6 0.1	68.0 62.0-73.2 4.2	3.1 3.0-3.2 0.1	1.1 1.0-1.2 0.1	0.6 0.5-0.6 0.1	5.0 3.7 6.2 1.2

* Mean

** Range

+ Standard Deviation

Table 6. Variation present for Oriental zoysiagrass characters evaluated during Fall 1984 and Spring 1985. TAES-Dallas.

	Leaf type[1]	Fall Color[2]	Spring Green-up[3]	Plant Spread Sept 85[4]	Plant Spread May 85[5]	Percent Coverage[6]	Anthesis Date[7]
	— rating —		— days —	— rating —		— % —	— days —
Mean	5.4	2.9	65.4	4.2	3.6	23.4	105.4
Range	1 - 9	1 - 4	61 - 122	1 - 9	1 - 9	5 - 80	85 - 139
SD	0.8	0.7	8.9	1.1	0.9	6.7	8.6
C.V.,%	15.0	23.0	1.0	27.2	25.6	28.7	1.0
σ^2_{clone}	2.9	0.2	33.0	1.0	0.9	56.4	238.5
H_{bs}	0.82	0.28	0.29	0.45	0.51	0.56	0.76

[1]Leaf type, where 1 = fine and 9 = coarse.

[2]Fall color rated (1 = brown tissue, 2 = brown and purple tissue, 3 = purple tissue, and 4 = green tissue) on 3 October 1984.

[3]Number of days from 1 January 1985 to first sign of any green, actively grrowing tissue.

[4]Plant spread from a 5 cm diameter plug rated (1 = poor to 9 = excellent) for accessions in a 0.09 m^2 plot on 7 September 1984.

[5]Plant spread of accessions rated (1 = poor to 9 = excellent) on 6 May 1985 in a plot expanded from 0.09 m^2 to 0.8 m^2.

[6]Percent coverage ratings relative to the area of a 0.8 m^2 plot covered by green, actively growing plant tissue.

[7]Average number of days from 1 January 1985 to anthesis. The last sampling day was 19 May (139 days), and some plants were still entering anthesis at that time.

Table 7. Mean field green-up date of Oriental zoysiagrasses according to leaf type and country of origin. Spring 1985, TAES-Dallas, Texas.

Country of Origin	Average Green-up date (Julian date)*			
	Fine leaves	Medium leaves	Coarse leaves	Overall
Philippines	69.0 b1 **	72.7 c2	80.2 c3	72.5
Taiwan	67.0 a1	78.4 b2	73.5 b12	76.8
Japan	63.4 a12	61.8 a1	63.4 a2	62.7
Korea	61.3 a1	66.0 a1	61.0 a1	62.0
Overall	65.1	66.4	64.7	65.4

*Mean number of days from 1 January 1985 for the first sign of any green, actively growing tissue.

**A least squares means analysis was used to test for significant differences. Means followed with a different letter in columns or a different number across rows are significantly different at 0.05 probability level.

Table 8. Mean plant spread of Oriental zoysiagrasses according to leaf type and country of origin. Fall 1984, TAES-Dallas, Texas.

Country of Origin	Spread (1 = low and 9 = high)*			
	Fine leaves	Medium leaves	Coarse leaves	Overall
Philippines	4.9 a1**	5.0 a1	4.8 a1	4.9
Taiwan	3.0 b1	3.6 b1	4.5 ab1	3.6
Japan	4.4 a1	4.0 b2	4.0 b2	4.1
Korea	4.4 a2	5.8 a1	3.0 c3	4.3
Overall	4.5	4.2	4.0	4.4

*Plant spread from a 5 cm diameter plug rated for accessions in a 0.09 m^2 on 7 September 1984.

**A least squares means analysis was used to test for significant differences. Means followed with a different letter in columns or a different number across rows are significantly different at the 0.05 probability level.

Table 9. Mean plant spread of Oriental zoysiagrasses according to leaf type and country of origin. Spring 1985, TAES-Dallas, Texas.

Country of Origin	Spread (1 = low and 9 = high)*			
	Fine leaves	Medium leaves	Coarse leaves	Overall
Philippines	3.5 b1**	3.7 b1	2.9 b2	3.5
Taiwan	2.2 c1	2.8 c1	2.2 b1	2.7
Japan	3.9 b1	3.7 b1	3.7 a1	4.2
Korea	4.6 a1	5.2 a1	2.5 b2	4.2
Overall	3.8	3.6	3.6	3.6

*Plant spread of accessions on 6 May 1985 in a plot enlarged from 0.09 m^2 to 0.8 m^2.

**A least squares means analysis was used to test for significant differences. Means followed with a different letter in columns or a different number across columns are significantly different at the 0.05 probability level.

Table 10. Mean percent coverage for Oriental zoysiagrasses according to leaf type and country of origin. Spring 1985, TAES-Dallas, Texas.

Country of Origin	Percent Coverage *			
	Fine leaves	Medium leaves	Coarse leaves	Overall
Philippines	29.4 a1**	24.4 b2	18.9 b3	25.3
Taiwan	18.8 c1	17.0 c1	13.8 b1	16.9
Japan	23.0 bc1	23.2 b1	24.5 a1	23.7
Korea	26.3 ab1	32.5 a1	18.3 b2	25.4
Overall	24.9	22.9	23.7	23.4

*Percent coverage scores relate to the area of a 0.8 m^2 plot covered by green, actively growing plant tissue.

**A least squares means analysis was used to test for significant differences. Means followed with a different letter in columns or a different number across rows are significantly different at the 0.05 probability level.

Table 11. Mean canopy temperature for Oriental zoysiagrasses according to leaf type and country of origin. Spring 1985, TAES-Dallas, Texas.

Country of Origin	Canopy Temperature*
Philippines	37.8 c**
Taiwan	37.5 c
Japan	39.5 bc
Korea	41.4 ab
Overall	39.1
Sd	2.5
CV	6.5

*Canopy temperatue taken with an infrared thermometer on 21 August 1985.

** A least squares means analysis was used to test for significant differences. Means followed with a different letter within columns are significantly different at the 0.05 probability level.

Table 12. Mean values for six morphological characters measured on an unselected base population and two zoysiagrass populations selected under high soil temperature and low moisture stresses.

				Stolon		
Population	Stolons	Nodes	Tillers	Length	Weight	Internode Length
	number			cm	g	cm
A	1.3 a*	8.9 a	5.3 b	22.7 b	0.55 b	2.3 b
B	1.3 a	9.1 a	6.4 a	33.1 a	0.73 a	2.9 a
Base	0.8 b	3.1 b	3.6 c	8.5 c	0.19 c	1.9 b
Mean	1.1	6.2	4.9	18.9	0.43	2.3
C.V., %	76.7	81.8	52.3	99.9	98.4	65.4
SD	0.8	5.1	2.5	18.2	0.42	1.5

* A least squares means analysis was used to test for significant differences. Means followed with a different letter within columns are significantly different at the 0.05 probability level.

Table 13. Means for sod strength and regrowth on selected zoysiagrass cultivars and experimental cultivars. Summer 1985, TAES-Dallas, Texas.

Accession or Expervar	Strength	Regrowth	Regrowth
	-- Kg/cm2--	-- plants/ft.2 --	-- plants/ft.2 --
DALZ8501	1.5 cd	53 a	98 a
DALZ8502	2.3 abc	22 bc	94 a
Z. matrella	2.1 abcd	17 bc	57 b
KLS 9	2.0 abcde	25 bc	57 b
KLS 21	1.4 cdef	26 b	50 bc
34-35B	1.6 cdef	9 bc	37 bcd
KLS 3	3.0 a	14 c	34 cde
KLS 13	1.2 cdef	20 bc	32 cdef
Emerald	1.7 bcdef	9 c	30 cdefg
DALZ8503	1.2 cdef	21 bc	29 cdefg
KLS 11	1.9 abcdef	3 d	13 efg
Z. tenuifolia	1.8 bcdef	4 d	13 efg
Meyer	1.2 cdef	3 d	11 g

*Values with different letters differ significantly ($P \leq 0.05$) according to Duncan's Multiple Range Test.

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Bibliography:

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