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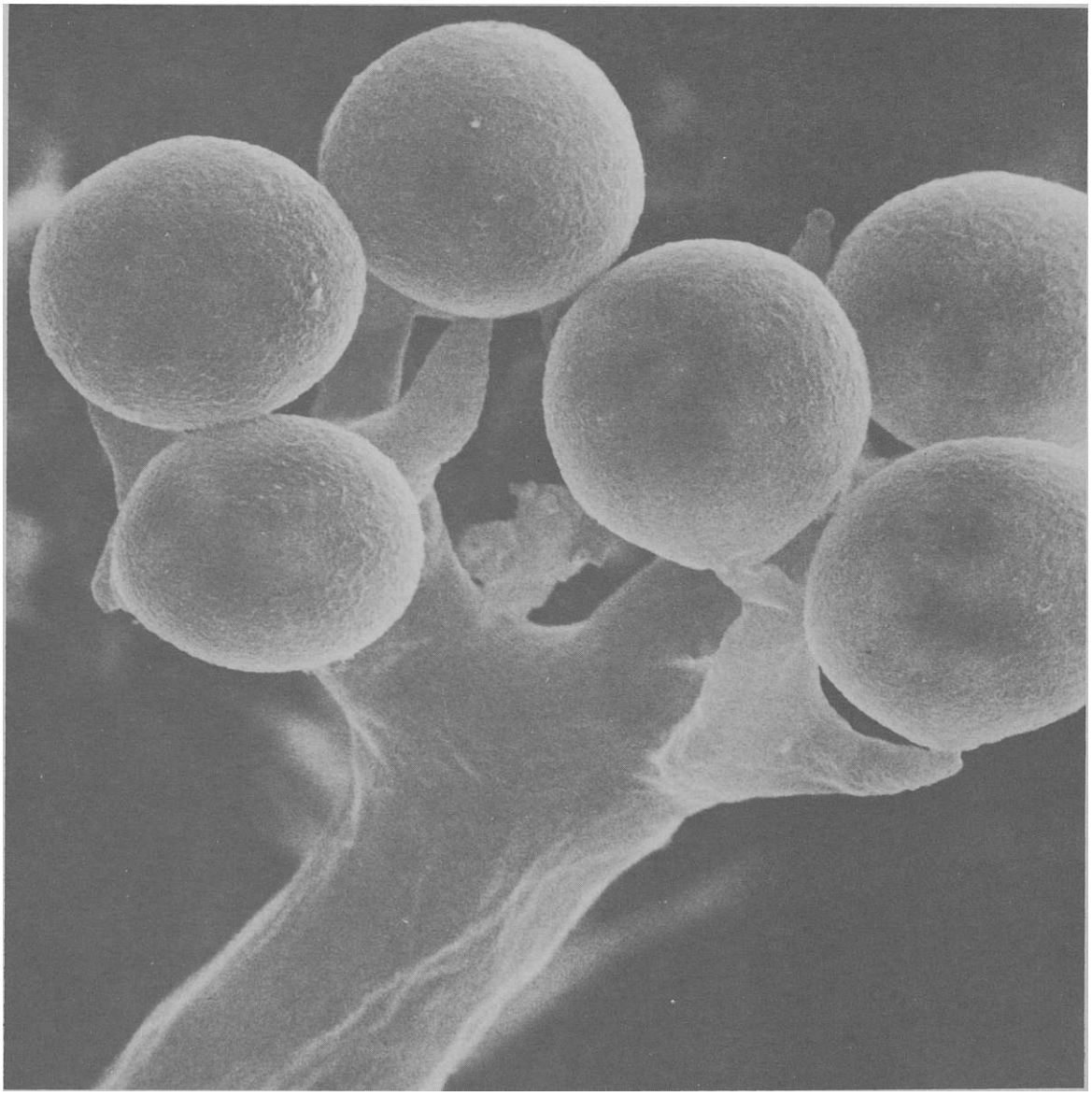
SORGHUM DISEASE AND INSECT RESISTANCE WORKSHOP



The Texas Agricultural Experiment Station • Neville P. Clarke, Director
The Texas A&M University System • College Station, Texas

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Proceedings of a

SORGHUM DISEASE AND INSECT RESISTANCE WORKSHOP

Sponsored by

The Texas Agricultural Experiment Station,
Corpus Christi, Texas

and

Texas A&M University,
Departments of Plant Sciences,
Soil and Crop Sciences, and Entomology
College Station, Texas

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Held at Corpus Christi, Texas, July 6-9, 1977 at the
Texas A&M University Agricultural Research and Extension Center
P.O. Box 10607, Corpus Christi, Texas 78410

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Cover photograph: Scanning electron microscope photo of conidia of *Solerospora sovgi* (sorghum downy mildew).

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Foreword

For the past 10 years the Texas Agricultural Experiment Station has conducted a sorghum disease workshop in South Texas. Initially these meetings were held to inform cooperating workers in private and public agencies about the seriousness of sorghum disease problems and the value of host resistance in their control.

But in the past 5 years these programs have been broadened to include insect problems and systems for reducing their importance in sorghum. The Station published two reports as a result of these sorghum workshops. The first was a technical report entitled "Report of a Workshop on the Downy Mildews of Sorghum and Corn," Departmental Technical Report No. 74-1. The second was a technical monograph on downy mildew, "Sorghum Downy Mildew ... A Disease of Maize and Sorghum," Research Monograph 2, December, 1973.

In 1977 the workshop, under the leadership of Dr. Richard Frederiksen, was directed toward programs that are of mutual interest for Latin American and North American sorghum workers. The meeting was sponsored in part by the U.S.A.I.D., contract Ta-C-1384. This support was greatly appreciated.

This publication on sorghum disease is an additional result of this international workshop and reflects strong participation from Latin America. The Texas Agricultural Experiment Station is pleased to provide this opportunity for coordinating the improvement of sorghum.

Neville P. Clarke, Director

Texas Agricultural Experiment Station

Summary and Accomplishments of the Workshop

Robert G. Pratt

The Sorghum Disease and Insect Resistance Workshop, sponsored by Texas A&M University, was conducted at the Texas A&M University Agricultural Research and Extension Center and at the Hilton Inn of Corpus Christi, Texas, July 6-9, 1977. The primary focus of the workshop was on problems, programs and goals in sorghum culture and improvement for disease and insect resistance and quality in the Western Hemisphere, and on how progress could be promoted through greater international awareness and cooperation. The sixty participants comprised staff and students from the main Texas A&M University campus and from research and extension centers at Lubbock, Corpus Christi and Weslaco; universities in other states where sorghum is an important crop; USDA scientists; representatives of private seed companies and foundations in the U.S.A.; university and government representatives from Mexico, Panama, Venezuela, Brazil and the Dominican Republic; and participants from several nations and agencies beyond the Western Hemisphere.

The workshop commenced with an informal reception at the Hilton Inn on the evening of July 6 to enable acquaintanceship of participants. Presentations on technical topics began on the morning of July 7 following a welcoming address by Dr. Thomas C. Longnecker, director of the A&M Center. Texas A&M University scientists presented overviews of their international breeding programs, including types and locations of field nurseries maintained to screen and evaluate sorghum germ plasm, the structure of the sorghum "conversion" program, and the specific and novel features such as disease and insect resistance, twin seed, tropical adaptation, drought resistance and high

lysine content in sorghum.

Scientists from Mexico, Panama, Venezuela, the Dominican Republic and Brazil next reviewed the importance of sorghum in their countries and regions, with discussions of the economic importance and uses of the crop; local insect, disease and agronomic problems; and the status of their sorghum improvement programs.

A field tour of entries in the sorghum midge and disease screening nurseries at the Corpus Christi Center was conducted in the afternoon, wherein participants observed lines resistant and susceptible to greenbug, midge, downy mildew, head smut, and leafspot diseases.

Additional technical reports were presented on the evening of July 7 and on the morning of July 8 on various insect and disease topics and on quality improvement. A general, round-table discussion was also conducted on needs and opportunities for international cooperative programs to screen sorghum lines for resistance to midge, anthracnose, head smut and other problems in diverse geographic areas of the Western Hemisphere.

On the afternoon of July 8, a "field diagnosis lab" was conducted at the Corpus Christi nursery by pathologists to illustrate symptoms of specific diseases. A bus tour was also conducted in Nueces County to enable participants to observe grain sorghum harvest by combines, elevators for storage of seed, and varietal disease reactions in a commercial sorghum nursery. On July 9, a special tour was arranged for foreign visitors to the head smut nursery at Berclair, Texas, where sorghum lines are evaluated for resistance to race 3 of that disease. Several participants then continued to College Station, Texas, to observe entries in the irrigated production nursery where sorghum is evaluated for yield potential.

One of the major accomplishments of the 1977 workshop was that it enabled sorghum workers from diverse geographic areas and academic disciplines to meet jointly to review their problems and progress in the improvement of the crop. Broad-based conferences of this nature are especially valuable in the present age of agricultural specialization, where agronomists, breeders, pathologists and entomologists seldom have opportunities to look beyond the confines of their own disciplines and observe, appreciate, and understand problems in other areas. The workshop at Corpus Christi, therefore, allowed and provided both international and interdisciplinary communication between participants. The personal contacts and knowledge attained will undoubtedly serve to facilitate and enhance international efforts and programs for sorghum improvement in the future.

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Sorghum Conversion Program and Related Activities at TAES

F. R. Miller

Sorghum, (*Sorghum bicolor* (L.) Moench), is produced on four to eight million hectares in Texas with the area divided about equally between grain sorghum and forage sorghums. The grain crop is valued at approximately $875 million annually. Texas produces more than 40% of the sorghum in the United States and is the major sorghum exporting state. The goal of the TAES Sorghum Research program is to develop sorghum which maximize yield and quality for human and livestock utilization. This approach requires many different scientific disciplines working toward the common objective (Figure 1).

The TAES has worked with sorghum for more than 70 years, laying the foundation for the story of progress you will see reviewed in this meeting. The success of current programs can be traced directly to basic information obtained in prior research. For example, because we know the inheritance of maturity, height, grain color, disease and insect resistance, male sterility and other genes controlling characters of economic importance, it is possible to make intelligent choices for parents of hybrids with considerable assurance that a desirable strain will emerge.

Prior to 1963 the quantity of germ plasm useful in the temperate zone was severely limited. Through a joint USDA-TAES effort, an ambitious program called the *Sorghum Conversion Project* was initiated in 1963. This project changes tall, late or non-flowering sorghums from the tropics of the world where sorghum originated (northeast quadrant of Africa) into short, early forms which can be used in the temperate zones of the world. This is done

by substituting up to eight genes which control height and maturity to obtain the desired genotypes. The procedure is outlined in Figure 2. Because sorghum originated near the equator, it is sensitive to length of day. Knowing the genetics of height and maturity and the response to daylength we were able to use facilities of the USDA's tropical experiment station at Mayaguez, Puerto Rico and our own here in Texas to make vast amounts of germ plasms available for further plant improvement. There are some 16,500 items in the World Collection of Sorghum. Because of limited manpower and resources, we must therefore convert only those sorghums with outstanding characteristics. Presently, there are 1204 items in the program. We have distributed over 180 fully converted varieties to breeders in the USA and the World—even back to Africa where the materials originated. The program is designed to release 60 - 70 new items each year. Materials from this program are already dramatically changing the grain sorghum grown in Texas and other production areas. Some of the important economic characteristics found are:

a) New sources of disease resistance: downy mildew, head smut, maize dwarf mosaic virus, foliar diseases, stalk and kernel rots, etc.

b) Insect resistance: sorghum midge, greenbug, corn leaf aphid, white flies and Banks grass mite.

c) Improved plant characteristics: drought, heat and salinity tolerance, stalk strength, twin-seed, easy threshing, erect leaves, lodging resistance, improved yield of grain, yield stability under diverse environments *[tropical adaptation).*

d) Outstanding kernel characteristics: thin pericarps, weather resistance, mold resistance, reduced discoloration of endosperm,

SORGHUM CONVERSION PROJECT

PUERTO RICO

TEXAS (USA)

11 Not Flower In U.S.

Will Flower In U.S.

Exotic Which Will Flower In U.S.

GOAL

X

P.R.

F-i -(P.R.)

Short-Early F_9(Texas)

After 5 backcrosses to Exotic

Exotic X Fo-(P.R.)

F_r(P.R.)

^—• F_2(Texas) continued
for 5 cycles each F^ is crossed back to Exotic

useful pericarp colors, etc.

e) Greater digestibility: higher protein, higher lysine and a more desirable balance of amino acids, waxy endosperm and superior food quality characteristics.

f) Reduced genetic vulnerability: new systems of producing hybrids.

As new sources of germ plasm with unique properties are found anywhere in the world, the material is entered into the Conversion Program. We solicit your cooperation by sending us your most useful materials so that we can change their response to daylength and make them more useful to sorghum workers throughout the world.

Current Status of International Nurseries and Cooperative Programs

D. T. Rosenow-'

In addition to the International Disease and Insect Nursery (IDIN) described by Dr. Frederiksen, other international nursery programs are also important. In the spring of 1977, a cooperative arrangement was agreed to between ICRISAT and TAES, whereby we could submit entries into some of the International Testing Programs of ICRISAT. We can enter materials either by sending seed to ICRISAT for later inclusion after seed increase, or by asking for entries and test locations and then sending the seed directly to each cooperator.

International ICRISAT nurseries for which such arrangments have been established are the ISLDN (leaf disease), ISDMN (downy mildew), ISGMN (grain mold) midge nursery, and yield nurseries. This agreement with ICRISAT allows the evaluation of our material in key international locations and a comparison with the other elite lines available internationally.

This past spring we began evaluation of selected hybrids and lines for yield and adaptation at several sites across Africa, Southeast Asia, and Central and South America.

Other nurseries we are involved with internationally are the anthracnose (ISAVN) and head smut (UHSN). Cooperative international work also exists with evaluation of food type sorghums.

Close cooperative ties exist between TAES workers and sorghum researchers in developing countries, and visits have been made to evaluate nurseries, problems, and breeding materials. Some of the countries to which one or more visits have been made include: India, Thailand, Senegal, Upper Volta, Nigeria, Niger, Egypt, Sudan, Ethiopia, Mexico, Venezuela, Columbia, Brazil, and Guatemala.
*/

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Mejoramiento de Sorgo para el Bajio de Mexico

A. Estrada Gomez

El mejoramiento genetico del sorgo para grano en Mexico, esta concentrado principalmente en la sede del Centro de Investigaciones Agricolas de El Bajio (CIAB), uno de los ocho centros que posee en todo el pais el Instituto Nacional de Investigaciones Agricolas (INIA).

El area de influencia del CIAB abarca los estados de Guanajuato, Michoacan, Jalisco y Queretaro (22 - 23 grados de latitud norte y 99 grados longitud oeste aproximadamente con 1500 - 1800 msnm). En dicha region el sorgo para grano tiene gran importancia ya que mas o menos se siembran uno mil Ion de hectareas bajo condiciones de riego y temporal. De esa superficie el 98% se siembra con hfbridos extranjeros y el *2%* restante se entre con semilla de seis hfbridos nacionales producto de dicho programa de mejoramiento.

Los objetivos principales de dicho programa se resumen en: 1) La obtencion de Tineas A, B y R para la formacion de hfbridos de alto rendimiento y buenos caracteres agronomicos. 2) La obtencion de metodologfas experimentales propias para las diversas condiciones de las distintas regiones sorgueras de Mexico. 3) Estudio de los labores culturales optimos para cada tipo de siembra o region de produccion. 4) Prueba de hfbridos comerciales y experimentales para su recomendacion especffica a los agricultores.

Actualmente en la region de el Bajfo no se tienen grandes problemas de enfermedades y plagas ya que los reportes de ataques de Mildew de sorgo, antracnosis or mosquita de la panoja son muy aisi ados en tiempo y lugar por lo que no se tiene suficiente expericencia al respecto, para enfocar el

programa de mejoramiento, al ataque de esos problemas que son de otras regiones.

Dr. Jarvis E. Miller, President Texas A&M University, exchanging views breeding for adaptation of dwarf sorghums in tropical Environments.

Mejoramiento Genetico del Sorgo para los Vail es Altos de Mexico

A. Carballo C.

En Mexico existen aproximadamente 1.5 mi 11 ones de hectareas con una altitud superior a los 1900 m. sobre el nivel del mar, en las cuales el maiz se siembra en condiciones limitantes de humedad. Para estas areas se ha considerado que el cultivo del sorgo puede ser una buena alternativa, pues prospera mejor que maiz bajo condiciones de escasa precipitacion pluvial. Existe sin embargo, el problema de que a altitudes superiores a 1900 m., las variedades comerciales actualmente disponibles, no producen grano debido a la presencia de bajas temperaturas antes de la emergencia de las panojas y durante la antesis.

El Instituto Nacional de Investigaciones Agricolas (INIA), a traves del Departamento de Maiz y Sorgo, inicio en 1960 un programa para el desarrollo de variedades tolerantes a bajas temperaturas, que produjeran grano en los valles altos del pals. Despues de identificar como fuentes de tolerancia al frio, a las variedades africanas Makere, Magune y Nyundo, se siguio con hibridacion y seleccion para derivar materiales tolerantes y con buenos caracteres agronomicos. Como resultado del mejoramiento genetico en 1973 se obtuvieron las primeras 10 variedades experimental es que producen grano en altitudes hasta de 2,350 m.

Mediante el uso de radiaciones ionizantes, se han logrado cambios . agronomicos favorables en la variedad introducida Nyundo que es de porte alto, de ciclo tardio y de grano color rojo obscuro. Algunos de los mutantes obtenidos han sido: porte, bajo, precoces, hojas erectas, grano claro, tipo forrajero, etc.

Adicionalmente se tienen resultados sobre fechas de siembra y practicas de cultivo en general. Se han conducido estudios y se tienen resultados sobre la fisiologia del sorgo en los valles altos; se han determinado las etapas en su desarrollo el las cuales la incidencia del frio produce androesterilidad; se tienen avances sobre un proyecto para aprovechar la esterilidad ecologica en la produccion de hlbridos y en el mejoramiento de poblaciones haciendo uso de la esterilidad genica (nis^) de la genico-citoplasmica y de la bolsa de plastico para propiciar recombinacion.

Cabe senalar finalmente, que el caracter "tolerancia al frio" deberia consideranse en los programas de mejoramiento para zonas templadas, pues ademas de ampliar la adaptacion del sorgo, le da mayor establidad en su comportamiento.

Mejoramiento de Sorgo para las Partes Bajas del Estado de Nuevo Leon Mexico

C. G. S. Valdes Lozano

El Programa de Mejoramiento de Sorgo de la Facultad de Agronomia y Centro de Investigaciones Agropecuarias UANL se desarrola en las partes bajas (0.750 msnm) del Estado de Nuevo Leon en Mexico, donde el sorgo ocupa un lugar preponderante pues se siembran alrededor de 30,000 has cada ano. En esta zona se produce tanto bajo condiciones de riego como temporal, siendo el ciclo de primavera el mas importante.

Los objetivos planteados por el programa son:

a) Formacion de variedades de alta capacided de rendimiento.

b) Incorporacion de genes de resistencia a downy mildiu, mosca de la panoja a los variedades que se obtengan.

c) Incremento de la variabilidad genetica en los lotes de progenitores.

c) Se plantea a futuro la formacion de hibridos.

La metodologia usada es seleccion por rendimiento individual bajo los esquemas de los metodos masivo (bulk) y genealogico, los cuales se efectuan dos ciclos al ano en cuatro localidades (Marin, Teran, Sabinas Hidalgo (Anahuac) y Gral. Bravo) los cuales representan las condiciones ecologicas del area de trabajo.

Para la formacion de variedades se utilizan principalmente las poblaciones segregantes provenientes de hfbridos comerciales, un reducido numero de Tineas del Texas A&M, una poblacion segregante obtenida en Tachai, China y dos 1ines A y B.

El programa se inicio en Marzo de 1976 y actualmente se cuenta con poblaciones F4 habiendose seleccionado plantas F5 los que permitiran ensayar Tineas F6 en las cuatro diferentes localidades en la primavera de 1978. Cabe senalar que el programa se desarrolla en estrecha colaboracion con el Instituto Nacional de Investigaciones Agncolas S.A. y R. H. y con el apoyo economico del Consejo Nacional de Ciencia y Technologia.

Aspecto de la Produccion de Sorgo en Panama

J. C. Cedeno

Panama es uno de los seis paises que forman la America Central y es un Istmo ubicado entre 8 y 9 grados de latitud Norte. El clima es tropical humedo, pero en la region costanera del Pacffico hay dos estaciones bien definidas: una lluviosa que va desde el mes de mayo hasta finales del mes de noviembre; y una estacion seca que se inicia en el mes de diciembre y se prolonga hasta fines del mes de abril. Hay zonas donde llueve mas de 3,000 milimetros durante el ano y otras donde caen en promedio 1000 milfmetros de lluvia cada ano.

El sorgo es un cultivo relativamente nuevo en mi pais y fue en 1974 cuando se hicieron las primeras siembras comerciales. Comparando la superficie sembrada con la de otros cultivos tradicionales, encontramos las siguientes cifras estadisticas en 1975.

Cultivo	Superficie (Ha)	Produccion - toneladas metricas
Arroz	112,200	196,620
Maiz	79,500	65,435
Sorgo	5,000	7,500*

* No fue un ano muy bueno para el cultivo del sorgo. Por lo que hubo bajo rendimiento.

Existen factores que limitan la produccion de sorgo en Panama. Uno de ellos es la condicion de los suelos. La fertilidad es limitante en suelos arenosos y el exceso de humedad es perjudicial en los suelos pesados.

Las malezas tambi§n limitan la produccion cuando no se controlan oportuna-mente. Estos problemas hemos aprendido a resolverlos con las aplicaciones de fertilizantes y herbicidas pudiendo asf, lograr plantaciones de muy buen aspecto. Las sequnas prolongadas cuando el cultivo del sorgo esta proximo a la floracion tambien afecta la produccion del grano, especialmente cuando se siembra muy tarde en la estacion lluviosa.

Procuramos realizar ensayos de rendimiento para recomendar los hibridos mejor adaptados. Pioneer 8417, Dorado M, NK 222, DeKalb E-57 son los hfbridos que actualmente se le estan recomendando a los agricultores. Las pruebas se hacen en las estaciones experimentales y luego los mejores hfbridos se llevan a ensayos regionales en fincas particulares para despues hacer las siembras comerciales con los hibridos mejor adaptados.

Otro de los problemas que limitan la produccion de sorgo en Panama al igual que en los otros paises de la region Centro-americana son las plagas y las enfermedades.

Desde temprana edad del cultivo se observan danos causados por insectos del suelo especialmente en los suelos arenosos. El grillo Talpa (*Gvyllotalpa* sp.), la gallina ciega (larvas de *Diabrotica balteata* y la arrieras *[Atta sexdens)* son las de mayor importancia.

Entre los insectos que atacan al follaje, el gusano cogollero, langosta *(Spodoptera fvugipevda)* causa danos economicos en plantaciones jovenes.

Los barrenadores del tallo (*Viatvaea Sacohavalis)* tambien se observan en las plantaciones de sorgo afectando el desarrollo de la planta y ocasionando la can da de las mismas al acercarse el periodo de maduracion del grano.

La mosquita del sorgo (*Contavinia sovghicola)* afecta economicamente las plantaciones de sorgo en la epoca de floracion reduciendo los rendimientos.

Los afidos, *Aphis maidis* que son insectos que se alimentan de la savia de la planta, pueden constituir una plaga de importancia econdmica, si se presentan poblaciones altas, especialmente durante los perfodos de sequfa prolongada.

Entre las enfermedades son comunes, las causadas por los hongos que afectan el follaje ocasionando una coloracidn ptirpura o rojiza de las hojas, que luego se secan. Tenemos indicios de que se asemejan a los sintomas que induce el hongo *Gleocercospova sorghi.* Tambien se observan con frecuencia pustulas de color cafe que son tipicas de la roya (*Puooinia purpurea).* La pudricion seca del tallo causada por *Macvophomina phaseoli* se ha observado en muchas plantaciones induciendo al acame de las plantas, reduciendo asf el tamano de las panojas y del grano.

Cuando los factores limitantes antes enumerados se logran controlar con buenas practicas de cultivo y el empleo de hfbridos bien adaptados, ha si do posible lograr en Panama plantaciones de sorgo que dan rendimientos que cubren con creces los costos de produccion.

El Sorgo en Venezuela

V. Barrientos y D. Tovar

El sorgo granero es un cereal de reciente introduccion en Venezuela, sin embargo tiene un gran potencial como cultivo economicamente importante debido a la creciente demanda de materia prima por la industria de alimentos concentrados para consumo animal.

La superficie de siembra en el pais ha fluctuado drasticamente desde su introduccion desde 7,500 Has en 1966 a 200,000 Has en 1977.

La siembras se ha efectuado con semilla certificada importada desde los Estados Unidos, sin embargo, actualmente la empresa privada nacional (PR0SECA) esta produciendo semilla hfbrida, pero satisfice solo un 23,3% de la demanda actual (3.5-4 mi 11 ones de kilogramos).

Los ...hibridos nacionales han superado a los importados en el rendimiento tanto a nivel experimental como comercial (10-15%). El rendimiento promedio nacional del sorgo es de 2,147 Kgs por Ha, superando los del maiz (1400-1500 Kg/Ha).

Entre los hibridos importados que han demostrado buena adaptabilidad en nuestras condiciones podemos senalar los siguientes: Dekalb E-57, E-59, c-42-A, Pioneer 8417, 8311, Topaz, NK 266, NK 222 y Savanna, con rendimientos entre 3.5-5 ton/Ha.

Los factores que han venido afectando el rendimiento del cultivo son los siguientes: 1) Utilizacion de Hibridos importados de pobre adaptabilidad a los condiciones de tropico humdeo, 2) Inadecuado manejo de la densidad de seimbra y la fertilizacion, 3) Control de malezas, 4) Incidencia de enfermedades y insectos entre los cuales resulten economicamente importante

los siguientes: a) Antracnosis, b) Downy mildiu, c) *Spodopteva frugi-pevda* (15-20% de perdidas), d) *Contavinia sovghicola* (20-25%).

El sector oficial (Ministerio de Agricultura y Cria) inicio un programa de investigacion en sorgo en 1966, cuya meta inicial fue la evaluacion de variedades e hibridos introducidos y el estudio del complejo agrondmico (densidad y distancias de siembra, fertilizacion, epocas de siembra y control de malezas).

Actualmente, se ha iniciado un programa de mejoramiento genetico para la produccion de variedades a corto plazo (2 anos) y de hibridos en 4-5 anos.

Dr. Douglas Tovar, Sorghum Breeder with the National Program in Venezuela; Dr. Paul Harvey; Dr. G. Teetes, TAES Entomologist; and Dr. Ken Starks, USDA Entomologist, Oklahoma, carefully monitor comments of Dr. M. Ricelli, Sorghum Breeder with PROSECA (Maracay, Venezuela).

El Sorgo en la Republica Dominicana

R. Perez D.

Las primeras siembras comerciales en el cultivar de sorgo comenzaron a realizarse a fines de la decada del 1960. El sorgo para produccion comercial ha adquirido importancia en los ultimos anos en la Republica Dominicana. Actualmente se siembran unas 6,000 Has. localizadas en la parte noreste, sur y suroeste de la is!a y las perspectivas de aumento del £rea son buenas por la infraestructura de riego que se esta realizando, adgmas porque se ha determinado que el sorgo puede cultivarse con un numero reducido de riegos en las £reas donde el agua no es barata. En la actualidad toda el area sembrada es con hfbridos de origen de los E. U. A. siendo los mas comunes el P-8417 y E-57.

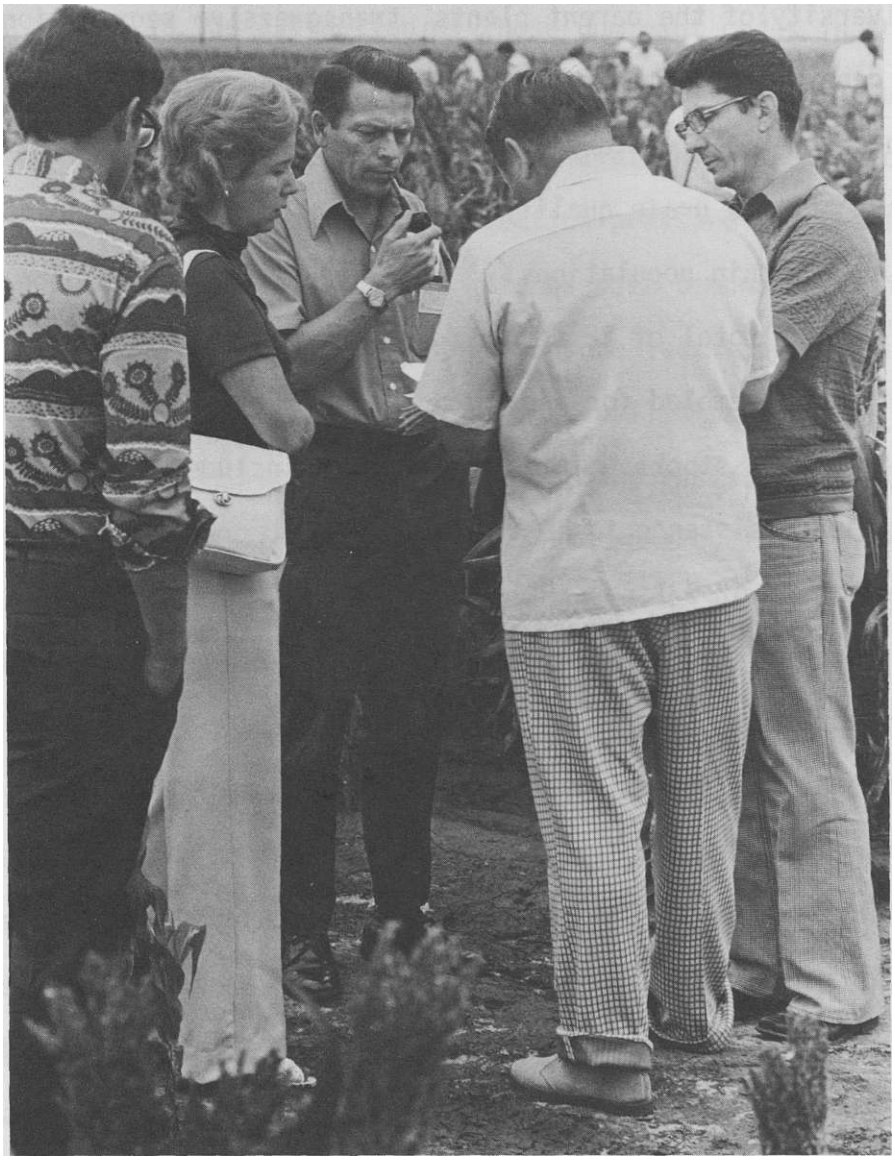
La mayorfa de las siembras se realizan enrotacion con tomate y toda la produccion es para consumo animal. El programa de mejoramiento en sorgo contempla los aspectos: a) Pruebas de adaptacion con variedades e hfbridos a escala comercial y experimental, b) Introduccion y seleccion con materiales de origen domestico y determinaciones de su comportamiento en localidades diferentes. c) Cruzamiento y seleccion con cepas prometedoras para aprovechamiento de nuevas recombinaciones.

Los mayores problemas de enfermedades e insectos en los que se pone much interes el las selecciones son:

Insectos: a) *Contarinia sovghicola* (sorghum midge) y b) *Spodopteva frugiperda* (armyworm). En menor grado se tienen problemas con afidos y barrenadores.

Enfermedades: Los mayores problemas son con antracnosis, *Pucoinia* (Roya), carbon del grano, pudricion seca del tallo. En menor grado afectan la mancha zonal y *Helminthosporium.*

Estamos interesados en recibir y probar nuevos materiales a la vez que nos ponemos a disposicion para cualquier informacion adicional.



Dick Creelman, Agronomist TAES; Carmen Gonzales, USAID Contracts Office; L. H. Otto, USAID, Washington D.C.; Earl Leng, USAID, Washington, D.C.; and Jerry Eastin, Plant Physiologist, Nebraska, discuss insect resistance at Corpus Christi, Texas.

Recent Work with Genetic Male Sterile Facilitated Sorghum Populations

J. Scheuring

Sorghum plants from one to almost an infinite number of sources can be easily interbred using genetic male sterile plants (ms_g) as females. Although the genetic diversity of an interbreeding population is limited by the diversity of the parent plants, transgressive segregation in advanced generations often results in entirely new plant types quite unlike the parents. Desirable plant characters like pest resistance, twin-seeds, combine height, and grain quality can be stacked up by recurrently selecting parent plants within populations.

In Texas, a total of 22 sorghum populations have been established. Each population was assembled for a different reason and has been based on appropriate parent stocks. Texas populations include waxy grain, elite lines, twin-seed, and resistance to MDMV, downy mildew, greenbugs, midge and lodging. They are composed of B lines, R lines and B-R mixtures. Most of the populations have been randomly intra-mated, but few of them have been subjected to rigorous and consistent selection.

The established Texas populations have been maintained from one generation to the next by harvesting all outcrossed seed set on male sterile heads from random matings within the population. Theoretically, gene frequencies remain unchanged in random mating populations. However, recent evidence indicates that random mating does not occur in two sorghum populations, TP10 and TP11. Although each population is based on monofactorial dominant genes, Krish resistance to MDMV *(K)* and twin-seed (Ts), there is a steady decrease in MDMV

resistant and twin seeded plants each time the populations are advanced by harvesting seed set on randomly pollinated male sterile heads. In two random matings, MDMV resistant plants in TP10 decreased in frequency from .63 to .56. In three random matings, twin seeded plants in TP11 decreased from .32 to .18 and then to .15. True random mating does not occur. If selection against Krish resistance and twin seed continue random mating will eventually result in the extinction of those dominant genes in the populations.

Random mating may be an effective approach to establishing a population, but it is certainly an ineffective means of maintaining and exploiting the population. The breeder must impose selection pressure for the trait for which the population was established. It has been demonstrated in several crops that the most efficient selection pressure is through full-sib matings; *i.e.* in a twin seeded population, twin seeded pollen parents are crossed with twin seeded male sterile parents; or in a lodging resistant population, only lodging resistant plants are intermated. After one cycle of crossing large headed selected parents in the elite TP4 population, tremendous progress has been made this past year at College Station.

Full sib matings result in F-j (S^) plants which are highly heterozygous. Many recessive traits are not expressed in F-j plants and many of the excellent appearing F-j plants produce gametes carrying undesirable traits. It is then no surprise that the efficiency of recurrent full-sib matings is greatly increased by making them in alternate rather than in successive generations. Large numbers of selected parents are full-sib mated, the F-j generation grown out in bulk, and full-sib matings are again made in the bulk F_2 (S_2). Such recurrent selection is well suited for Texas where we can make full-sib

population crosses under our conditions in the summer and grow out the bulk F-j in Puerto Rico in the winter.

There are currently about 1204 items in the Sorghum Conversion Program. Only 183 fully converted lines have been made available publically. The exploitation of the genetic diversity available in the conversion program is usually made by the individual evaluation of each converted line. The population, TP15, has been established to make available much of the genetic diversity represented in the 1204 conversion program items. A bulk of the conversion program lines was full-sib crossed as males onto TP5 male sterile plants. TP5 is composed of 83 conversion program lines. Fifty plants from converted lines in different exotic cytoplasms were emasculated and crossed with TP5 males heterozygous for male sterility [Msgns^). Male sterile plants were recovered from F^ segregating progeny in the different exotic cytoplasms and are used as female parents in the establishment of TP!5. The TP15 population has been established and will be maintained by large numbers of full-sib crosses. There is a tremendous diversity of plant types, flower structures, anther behavior, and pollen production which would be quickly eliminated by random outcrossing. TP15 should provide a rich and broad-based diversity which can be readily exploited by the use of genetic male sterility.

North American Sorghum Disease Nurseries

R. A. Frederiksen

Genetic vulnerability became a major concern in agriculture during the 1970's but as early as 1963, sorghum workers concerned with reducing sorghum vulnerability to disease and other problems, began the conversion program. In 1968, workers at the Texas Agricultural Experiment Station began a series of uniform disease nurseries and by 1971 established a program which remains essentially unchanged today. Uniform disease nurseries provide information on pathogen variability as measured against superior sources of host resistance. Currently there are four U.S. disease nurseries: the All Disease and Insect Nursery, the International Disease and Insect Nursery, the Uniform Head Smut Nursery and the International Anthracnose Virulence Nursery. Two virus nurseries and an International Grain Mold test have also been conducted intermittently during the past ten years.

One of the most variable pathogens of sorghum, *Sphacelotheca reiliana,* was the first to be evaluated by a collection of sorghum lines known as the Uniform Head Smut Nursery (UHSN). This nursery was initiated in 1967 by J. M. Wilson and in 1968 it was used to locate and define race 3 of *S. reiliana.* Since 1968 the UHSN has been grown in Africa as well as Mexico and several U.S. sorghum growing areas. The nursery was instrumental in identifying race 4 and is now being used to determine the rapid distribution of this race. Similarly, R. W. Toler and A. J. Bockholt distributed a sorghum maize dwarf mosaic (MDM) nursery for several years. This nursery proved to be useful in demonstrating the wide variety of symptoms of MDM.

However, there are numerous sorghum diseases and to maintain a nursery for each one would be cumbersome. Consequently, in 1969, a program of combining these lines into an All Disease and Insect Nursery (ADIN) was initiated for testing the reaction of host varieties to the major pathogens of sorghum. In this nursery, representatives of advanced and elite disease resistant entries are continually monitored throughout the U.S. and northern Mexico for their response to these diseases (Table 1). In 1972, we identified new sources of resistance to leaf blight and Fusarium head blight in the ADIN. It was also useful in detecting resistance to grain mold (weathering), insecticide damage, midge resistance, root and stalk rot resistance and resistance to numerous foliar pathogens. More recently, the ADIN has been used to evaluate erosion of resistance to head smut.

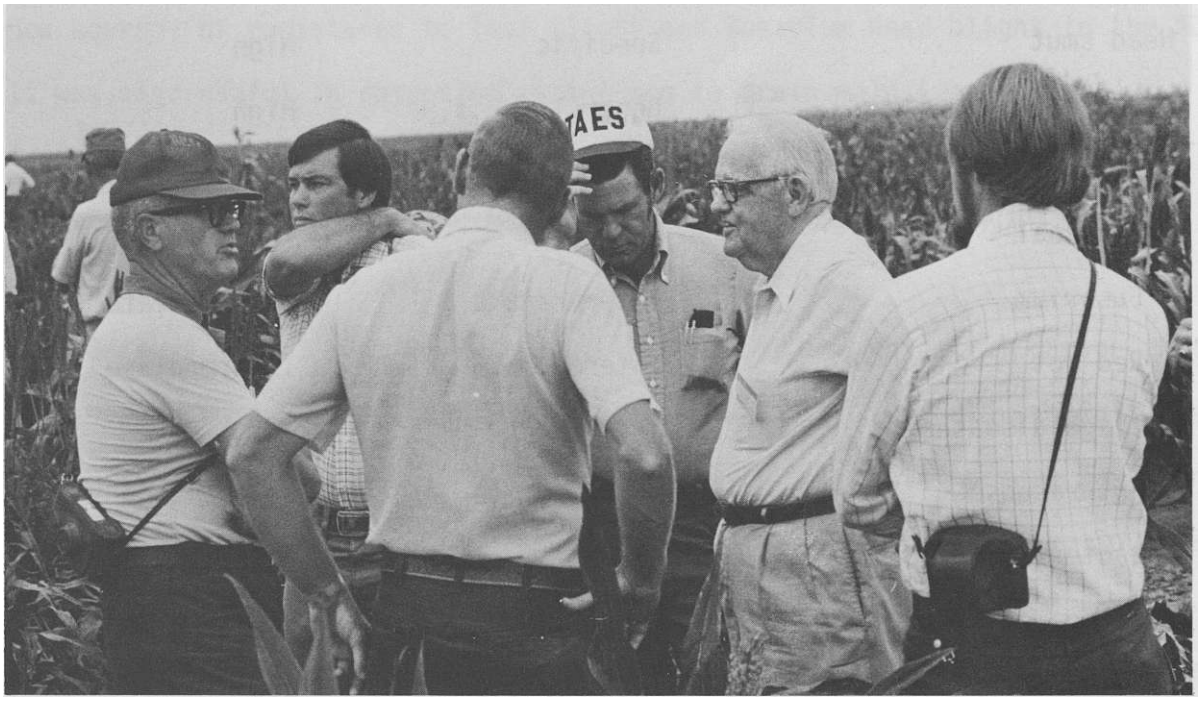
Because of interest in foreign pathogens and the potential damage that they could cause, in 1971 an international version of the ADIN was initiated--the International Disease and Insect Nursery (IDIN). This nursery has been distributed throughout the sorghum growing regions of Africa, Asia, South and Central America. Specifically, this nursery serves as an advanced warning system for evaluation of resistance to internationally important sorghum pathogens. In Nigeria, head smut races are different than those in the U.S. Also, the virulence patterns of anthracnose appeared to be different between West Africa and the U.S. Perhaps the most valuable aspect of the IDIN has been the evaluation of lines for resistance to diseases not present in the U.S. This is true for downy mildews of Asia, smuts and witchweed in Africa and anthracnose in South America.

Disease resistance through genetic manipulation of the host remains a

Table 1. Characteristics of certain key sorghum disease problems.

Major disease problems in sorghum	Genetic nature of host parasite interaction	Degree of genetic vulnerability
Downy mildew	General	Low
Head smut	Specific	High
Maize dwarf mosaic	General	High
Stalk rots:		
Charcoal	General	Low
Fusarium	Intermediate	Intermediate
Red rot	Intermediate	Intermediate
Foliage diseases:		
Anthracnose	Intermediate	Low
Bacterial stripe	General	Low
Cercospora leaf spot	General	Low
Helminthosporium blight	Intermediate	Low
Rust	Intermediate	Low
Zonate leaf spot	General	Low
Root rot:		
Pythium	Unknown	Low

priority means of control for feed crops. Broad-based testing and evaluation of host resistance through uniform nurseries is a valuable resource for the continual monitoring of disease resistance.



Dr. R. D. Lewis (second from right), director emeritus of the Texas Agricultural Experiment Station, confers with scientists concerning the sorghum disease research at the Corpus Christi, Texas center.

Seed Molding of Grain Sorghum in Texas

L. L. Castor and R. A. Frederiksen

One of the causes of grain deterioration in the field is colonization by fungi. Seed molding fungi attack sorghum kernels prior to harvest whenever environmental conditions are favorable. Fungi of several genera, including *Altemaria, Colletotrichum, Curvularia, Fusarium, Helminthosporium* and *Thoma,* have been reported in the literature as contributing to this disease.

The most common fungi isolated from sorghum grain in Texas during the last two years have been species of *Altemaria, Fusarium* and *Curvularia. Altemaria* spp. were by far the most common; however, since these fungi do not reduce germination and have rarely been isolated from excised embryos, they do not appear to be as important as *Fusarium* and *Curvulavia.* For these reasons most of our work to date has been with species of *Fusarium* and *Curvularia.* The species of importance in these genera include *F. moniliforme, F. semitectum, C. lunata* and *C. protuberata.*

In 1976, an experiment was carried out at Lubbock with eight sorghum lines which included genotypes known to be susceptible (Tx2536) and resistant (SC0279) to grain deterioration. Ten random heads were used for each of five treatments which were applied at flowering on August 29. The five treatments included inoculation of heads with a) a mixture of *Fusarium* isolates from both species and b) a mixture of *Curvularia* isolates from both species and controls consisting of c) a water spray, d) no treatment with bagging of heads, and e) no treatment without bagging. In addition to treatment d, treatments

a, b and c were also bagged on August 29; all heads remained bagged until harvest on October 15.

Fusarium spp. were more damaging than *Curvularia* spp. under the conditions of this study. *Fusarium* reduced yield, test weight, 1000 kernel weight, percent moisture, and germination compared with non-inoculated controls (Table 1). In addition, seeds from *Fusarium* inoculated heads showed evidence (split seed coats above the embryo) of greater sprouting in the head (16%) compared with non-inoculated controls (6%).

Fusarium moniliforme has been found to produce a pinkish pigment within colonized kernels. By cutting individual kernels longitudinally through the embryo and observing the pattern of discoloration, evidence has been obtained on where this fungus enters the seed and how it affects germination. *F. moniliforme* apparently invaded the seeds near the hilum. Colonization then proceeded through the scutellum and endosperm tissue adjacent to the scute!lum and hilum. In some cases, the scutellum was discolored and reduced in size while the embryo remained normal in appearance.

Much of the damage from *Fusarium* colonization occurred prior to an early harvest date. Results from our research and that of others indicate that sorghum plants are most susceptible around flowering and become more resistant after flowering. Colonization and damage of kernels may begin at a very early time.

Kernels from *Fusarium* inoculated heads had very little discoloration and appeared nearly normal when observed in the field. However, fungal mycelium was hidden frequently by the glumes and became visible only after threshing. Therefore, visual ratings of kernels in heads for seed molding may be less

Table 1. Average values[a] for eight sorghum lines grown at Lubbock in 1976,

	No spray Not bagged	No spray Bagged	H_20 spray Bagged	*Curvularia* Bagged	*Fusarium* Bagged
Yield (g)	604	448	497	422	376
Moisture {%)	18.5	16.5	16.4	15.2	13.0
Test weight (kg/hi)[b]	79.6 (61.5)	78.2 (60.4)	77.3 (59.7)	77.8 (60.0)	74.7 (57
1000 kernel weight (g)	30.2	27.6	28.9	27.7	25.5
Field rating[0]	2.0	1.7	1.7	1.9	1.8
Germination {%)	92.4	96.6	94.5	94.0	77.1
Curvularia (%) ^	0	8	11	80	0
Fusarium	4	28	29	36	100
Split seed coat (%)	1	6	6	8	16

10 heads per treatment

^Values in parentheses are lbs/bu

[c]Ratings based on a 1-5 scale where 1 = seed bright, free from mold damage and 5 = very susceptible, seed essentially all dead.

^Isolated after surface sterilizing in 1% NaOCl for 5 min.

reliable than other methods, especially with *Fusapium* spp.

We are continuing our studies on seed molding to determine the time and point of entry of these fungi into developing kernels and whether *Fusariim* spp. do stimulate sprouting of kernels in the head and how this happens.

Dr. Paul Harvey$_5$ USDA National Program staff, Dr. Keith Shertz, USDA Sorghum Geneticist, Dr. R. D. Lewis, Director Emeritus, Texas Agriculture Experiment Station, and Dr. L. E. Clark, Sorghum Breeder, TAES, discuss sorghum disease and insect problems in the field at Corpus Christi, Texas.

Inoculation Techniques with *Siphacelotheoa Teiliana,* the Cause of Head Smut

R. C. Miller

Head smut has become a very serious disease of corn and sorghum in Texas. One of our major problems in working with this disease to date has been to screen large numbers of breeding lines for resistance using definitive artificial inoculation techniques. The genetics of resistance of the host and virulence of the pathogen could be accomplished if these techniques are found.

The techniques that I am evaluating stem from what we have learned from the infection process. The sorghum seedling becomes vulnerable to infection shortly after the seed coat is ruptured by the growing radicle. It has been reported to remain so until the seedlings are nine weeks old. Most infection occurs before the first true leaves unfold.

The teliospore has to be near the growing coleoptile if infection is to occur. It probably takes 24 hours from initiation of germination of the teliospore until penetration of the host.

The best inoculation technique which has been developed so far is the hypodermic injection of sporidia into the growing point (1). A drawback of this method is that it is laborious and requires considerable skill. The natural resistance mechanisms of the plant could be overcome (2). Maximum infection has been very difficult to achieve.

Other inoculation techniques include the use of spore-soil mixes. The number of spores in a gram of infested soil has gone from a few to over 50% spores with variable results.

Another difficult technique requires the use of a partial vacuum. As an example, the tips of the coleoptile are clipped and submerged in sporidial suspensions. Evacuation of the coleoptile under partial vacuum forces sporidia into the intercellular spaces. A high seedling death rate is usually encountered as well as low levels of infection.

Currently, I am evaluating the rolled towel technique adapted from work with *JJstilago* spp. Controlling the environment in a rolled towel should make it easier to reproduce infection levels as compared to a complex soil.

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Physiologic Specializations of *Colletotvichum graminicola*

J. Foster and R. A. Frederiksen

In 1975, the International Sorghum Anthracnose Virulence Nursery (ISAVN) was initiated by workers in Mississippi and Texas to obtain data and confirm suspicions that there are physiologic races of *Colletotrichum gvcaninicola* (Ces.) Wilson sorghum.

As early as 1974, differences in anthracnose ratings on selected sorghum lines in different states suggested that different races of *C. graminicola* on sorghum were present. In 1975, data from the newly formed ISAVN essentially confirmed the presence of the physiologic specialization of *C. graminicola* on sorghum. The ISAVN demonstrated differences between isolates in Nigeria and locations in the Western Hemisphere (Table 1). The varieties, MN960 and TAM428, were very susceptible in Nigeria but were resistant to infection in the Western Hemisphere except in Venezuela. The varieties, TX398 (Martin) and PB846, demonstrated no infection in Nigeria but were very susceptible at locations in the Western Hemisphere where reactions to *C. graminicola* were adequate for evaluation. By 1976, anthracnose developed on TAM428 in Puerto Rico confirming that this virulence group is present in the Western Hemisphere.

Additional evidence for physiologic specialization of *C. graminicola* came from Venezuela. The variety, Wiley, was moderate to highly susceptible in Venezuela but highly resistant in other areas of the Western Hemisphere and Nigeria.

The most damaging disease of sorghum in South America was anthracnose.

		No ant	hracnos	e infec	tion	Gainesville, Florida
		No ant	hracno<	e infec	tion	Poza Rica, Mexico
						Experiment, Georgia
						Meridian, Mississippi
						College Sta., Texas
						Los Guayos, Venezuela
						Samaru, Nigeria
						Experiment, Georgia
						Meridian, Mississippi
						College Sta., Texas
						Mayaguez, Puerto Rico
						Isabela, Puerto Rico

This disease appears to be a limiting factor in most of the semi humid tropics where disease resistance is not available.

Loral Castor, Graduate Student in Plant Pathologhy, examines smutted sorghum plant.

Inheritance of Resistance to *Exsevohilum turcicum*

R. A. Frederiksen, D. T. Rosenow and J. H. Foster

F-j, F_2 and F_3 row progenies from hybrids of SCI03-12 and SC326-6 were evaluated for their reaction to *Exsevohilum tuvcicwn* at College Station, Texas during 1976. Using the whorl drop method of inoculation, excellent resolution between the resistant SC326-6 and susceptible SCI03-12 was obtained (Table 1). Most F-j plants were resistant; however, several F-j plants developed susceptible lesions when SCI03-12 was the maternal parent. Similarly, there was a higher frequency of susceptible plants in F^ rows of SCI03-12 x SC326-6 than among plants of SC326-6 x SCI03-12. Data from plants evaluated as F_3 rows suggest that there is at least one major gene derived from SC326-6 conditioning resistance to *E. tuvcicwn* (Table 1). We propose to designate this gene as Et-j. Cytoplasmic effects will require further evaluations. The data suggest that SC326-6 cytoplasm is conditioning some resistance to *E. tuvcicum.*

Table 1. Reaction of SC103-12 and SC326-6 and their progenies to *Exserohilum turoicum* at College Station, Texas, 1976,

	Designation	Stand	% infection
Parents	SC103-12	318	94.3
	SC326-6	317	0.4
F_1	SCI03 x SC326	67	17.9
	SC326 x SC103	13	7.1
F_2	SCI03 x SC326	179	20.1
	SC326 x SCI 03	276	11 .2

F_3 rows SC326 x SC103 (unselected)

	Susceptible	Segregating	Resistant
Observed	32	58	25
Expected	28.5	57	28.5
Ratio	1	2	1

p = 0.50 - 0.30, 1 *df*

SC326 x SCI03 (selected as resistant in F_2)

Observed	6	23	30
Expected	14.8	29.6	14.8

X = 22.3 N.S.

Factors Affecting Infection from Inoculation with Oospores of *Solerospora sorghi*

J. Craig

Attempts to determine the susceptibility of sorghum cultivars to sorghum downy mildew by inoculation with oospores have not been consistently successful. I am conducting studies of the causes of the erratic results associated with oospore inoculation. This work has not been completed, but information obtained to date indicates that the variability of inoculation results can be reduced.

The frequent colonization of oospores by fungi and bacteria indicates that low viability of oospores limits the potential for infection. If so, the amount of inoculum would be a critical factor in determining the incidence of infection. The results of my studies indicate that different lots of inoculum vary widely in the amounts needed to obtain high levels of infection.

I have compared various methods of infesting soil with oospores. These included mixing soil with an aqueous suspension of oospores; grinding dry leaves, which contained oospores and mixing the leaf debris with the soil; and macerating green leaves containing oospores and mixing with soil. None of these methods were superior; all gave good results in some trials and failed to produce infection in others.

Tests were conducted to determine the effect of variations in soil moisture on disease incidence. I found no significant differences in disease incidence among soil treatments of 20%, 25% and 35% of soil water holding capacity.

In some trials the death of infected plants before emergence reduced the number of infected plants observed. Stand counts of sorghum planted in

infested soil were significantly lower than those of sorghum planted in untreated soil. When seed were germinated before planting, plant stands in infested soil were lower than in untreated soil, but the difference was less than that observed when ungerminated seeds were planted.

My observations of inoculation results during a period of several months indicated that temperature and relative humidity were important factors in disease development. The incidence of disease from oospore inoculation was reduced by low relative humidity and high temperature.

My studies indicate that the steps listed below would improve the effectiveness of oospore inoculation:

1. Inoculum should be made from leaves of infected sorghum collected after oospore formation and before severe leaf necrosis. The leaves should be dried quickly at a temperature of 40 °C or lower.

2. Inoculum should be tested at different concentrations to determine the amount needed, per unit of soil, to produce a high level of infection in a susceptible cultivar.

3. Seed should be germinated before planting in infested soil.

4. Tests to determine the reactions of cultivars to downy mildew should be conducted in an environment in which the maximum temperature does not exceed 32°C, and the relative humidity is 70% or above.

Factors Affecting Germination of Oospores of *Sclerospora sorghi*

R. G. Pratt

Oospores of *Solerospora sorghi*, causal agent of downy mildew of sorghum and corn, were observed to germinate following incubation on porous membranes in soil in close proximity to growing roots of sorghum and other plants. No germination was ever observed under any conditions in which growing roots were not present. The morphology of germinating oospores and germ hyphae is described, and biological and physical factors which affected frequency of germination were evaluated.

Leaves of downy mil dew-infected sorghum plants were collected from the field in Nueces County, Texas, in 1976, dried at room temperature for two to four weeks, shredded, and stored in paper bags at room temperature (22-28 °C) or at 4 °C for up to 12 months. To obtain oospores, 2.0 grams dried leaf pieces were comminuted by blending for 60 seconds in 100 cc distilled water, and the mixture was immediately filtered through double-layer cheesecloth to remove leaf tissue fragments. Oospores were concentrated by pipetting off upper portions of solutions following sedimentation of spores to the bottom.

Nucleopore membranes (47 mm diameter, 8 micrometers pore size) were used to incubate spores in soil with roots. Concentrated suspensions of spores were pipetted over one half of each membrane on paper towels, so water was drawn through and spores were deposited on the membrane surface. After half of the membrane was evenly covered with spores, a second membrane was applied over the surface. Each double membrane was then placed on the inside edge of

a six ounce styrofoam drinking cup with the spores present in the lower half. Cups were filled with soil (sandy clay loam, sieved #20 mesh screen) which was immediately saturated with distilled water. Seeds of sorghum or other plants were planted along the edge of the cup, behind and adjacent to the upper edges of membranes, and cups were maintained at a 45 degree angle on the lab bench to promote growth of roots adjacent and appressed to inside edges of membranes.

After four to eight days under continuous fluorescent light, portions of cups adjacent to membranes were cut away, and sections of double membranes with oospores, against which roots were appressed, were cut away with a scissors and transferred to slides. Double membranes were gently stripped apart in droplets of distilled water using a forceps and dissecting microscope (12x), and coverslips were applied over sections of single membrane with oospores on the upper surfaces. All membrane sections were observed at lOx to count germinated oospores.

In most experiments, a few to frequent germinated oospores were observed on membrane sections against which sorghum or other roots had been appressed. No germinated oospores were ever observed on membranes in the absence of roots. Spore germination always occurred at low frequencies (less than 1%), but effects of treatments could be compared according to numbers of oospores germinated per unit area of membrane examined.

Prior to germination, contents of oospores appeared homogeneous, with finely clumped cytoplasm and slightly thinned walls. Only one germ tube emerged from each oospore. Germ tubes were thick (4-6 micrometers diameter), always coenocytic throughout their length, usually unbranched, hemispherical at the tips, and grew in a straight, curved, or undulating course. Occasionally

bulbous swellings developed at points of emergence of germ hyphae, and single, short side branches developed in a small minority of germ hyphae.

Soon after cytoplasm commenced to flow into a germ tube, a vacuole appeared in the center or distal region of each germinated spore, and this enlarged to fill the spore cavity after most or all cytoplasm passed into the germ tube. Thus, oospore germination appeared to involve translocation of existing cytoplasm from within spores to the germ tubes, but with no apparent growth or net increase in cytoplasm.

Young germ tubes (hyphae) were evenly filled with dense cytoplasm, but during elongation vacuoles developed in basal portions of hyphae and only the apices remained filled with cytoplasm. In old germinated oospores, when all cytoplasm was evacuated from within spore walls and basal portions of germ tubes, origins of germ hyphae were difficult to ascertain. After germ tubes elongated to up to 500 micrometers, further extension ceased and all cytoplasm became fragmented between vacuoles or disintegrated.

True oospore germination in *s. sorghi* was morphologically distinguishable from "false" germination, in which hyphae of mycoparasitic fungi emerged from within former oospores which had been invaded without destruction of oospore walls. Hyphae of mycoparasitic fungi usually emerged at multiple points from within oospore walls and were usually septate, thin (2-4 micrometers diameter), much branched, and often pigmented.

Oospores of *S. sorghi* stored in leaf pieces at room temperature for eight to nine months germinated readily on membranes in the presence of sorghum roots, while oospores stored at 4°C seldom germinated. Freshly collected oospores never germinated. When oospores were tested zero to six

weeks after removal from 4 C to room temperature, germination increased at each interval and was significantly greater after four and six weeks than after zero or two weeks. More germinated oospores were observed after four days from planting of seed than after eight days. Daily watering of soil in cups to saturation depressed oospore germination in comparison to only initial watering. Oospores germinated similarly with soil, autoclaved soil, or sand in cups. Seedlings of different sorghum varieties differed in the extent of induction of germination of oospores, but these differences were not related to resistance or susceptibility of varieties to downy mildew. Germination of oospores also occurred in the presence of roots of corn, wheat, oats, cotton and soybean seedlings.

Results of these experiments suggest that the mechanism of resistance to downy mildew in sorghum is not related to the relative ability of host roots to induce spore germination in soil, and that growth of nonhost crops in soils infested with *s. sovghi* might provide biological control through induction of oospore germination and consequent reduction in inoculum potential.

Virus Disease Resistance in Sorghum

R. W. Toler and A. Huebner

Virus and virus-like diseases tnat have been reported in sorghum either occurring naturally or experimentally include Sugarcane Mosaic Virus (all strains), Maize Mosaic Virus, Barley Yellow Dwarf Virus, Cucumber Mosaic Virus, Brome Mosaic Virus, Oat Pseudo-rosette, Maize Chlorotic Dwarf, Sugarcane Rattoon Stunt, Lucerne Dwarf, Maize Streak, Rice Stripe, Sorghum Red Streak, Yellow Sorghum Stunt, and Maize Dwarf Mosaic Strain A and B. The virus causing the greatest economic damage wherever sorghum is grown probably is Maize Dwarf Mosaic Virus Strain A. Mechanisms of resistance to Maize Dwarf Mosaic Strain A (MDMV-A) observed over the last decade include tolerance to MDMV-A which was first identified by Toler and Bockholt in 1968. Martin, TX414, RS625, RS621, and Tx09 were found to have high levels of tolerance. Immunity was first found in Krish by Teakle and Prichard in 1971. Krish is a forage sorghum derivative of 2N-20 *Sorghum halapense* x *S. roxburghii.* In 1972, Perse!ey reported a new source of immunity in Q7539 (Nigerian entry IS7596) but IS7596 does not show immunity as does Q7539. Toler and Miller working with material from the All Disease and Insect Nursery selected and isolated immune material from SC0120. SC0120 is an accession from the sorghum conversion program. In addition, resistant materials with low levels of infection have been observed. Smith and Toler selected resistant progeny lines from New Mexico-31 after treatment of seed with Gamma Irradiation mutagen. Generation M_3 (76-369-13) had only 7A% infection and M_3 (76-369-2) 6.0% infected plants. Toler and Miller isolated low infection materials SC0097-14,

with only 5.8% diseased plants. Rosenow, Johnson, Toler and Frederiksen, 1975, observed field resistance or resistance to natural infection by aphids in IS2549C, IS2816C, IS12612C, IS666C, Variety Rio and TAM2566. Although these materials were susceptible under field mechanical inoculations, they failed to develop high levels of disease under natural conditions of aphid transmission in the field.

Tolerance has been accepted by and is widely used in commercial hybrids. The dominant Krish gene is a stable source of MDMV immunity although breeders have had difficulty in separating various forage sorghum characteristics from the immunity allele. Perseley's Q7539 (IS7596)-3 to -7 by ex 11-97-H74 appears to be immune; however, some Q7539 material, in spite of repeated selfing of uninfected plants displays low levels of infection as Q7539 (IS7596)-3 Aex 80Gw/h-74 = 5.0%; SC0534 (IS7596)CS = 58%; SC0534 (IS7596)PR = 10% infection when inoculated in the greenhouse at College Station. Also, it appears there is more than one type of resistance mechanism in some sorghum backgrounds as immunity and field resistance were observed in material selected from SCO!20 and immunity and high level resistance from Q7539 (IS7596). Low levels of infection (high level of resistance) is a new offering to grain sorghum breeders that provides new mechanisms of resistance for the future from materials as Q7539 (IS7596)-3 Aex 80Gw/h-74, SC0534 (IS7596)CS, NM-31(M)-76-380-13, NM-31(M_c)-76-369-2 and SC06097-14 as well as field resistance in IS2549C and others.

Reaction of sorghum lines and hybrids to Maize Dwarf Mosaic Virus Strain B were reported by Ford and Hill in 1976. Of the twelve sorghum virus differentials tested, only four became diseased when inoculated with MDMV-B. Virus symptoms developed and virus was recovered from Tx09, Tx412,

PI35038 and SA394.

Bush, Toler and Bradfute in 1976 reported isolation of Brome Mosaic Virus from naturally infected sorghum in Texas. Reaction of the twelve sorghum differentials to inoculation with Brome Mosaic Virus included no infection Tx7000, Tx3197 and SA394; low infection mild symptoms Tx09, Tx412, PI35038 and Tx3048; intermediate mottling and infection Tx414, Tx398 and Tx378; high rate of infection and heavy mottling Tx7078 and NM-31. Although these two viruses occur in sorghum, the sources of resistance could be readily brought to bear if they become economically damaging. Sources and workers reporting mechanisms of resistance to MDMV-A, MDMV-B and BMV are presented in Tables 1, 2 and 3.

The sorghum differentials described by Toler and Bockholt continue to be useful in separating viruses and virus strains. The differentials will be expanded to include Krish, Q7539 (IS7596) and SC0097-14.

Table 1. Reactions of grain sorghums to maize dwarf mosaic virus strain A

Workers	Entry	Mechanisms
Toler and Bockholt, 1976	RS621	Tolerant
	Tx414	Tolerant
	RS625	Tolerant
	Tx398	Tolerant
	Tx09	Tolerant
Rosenow, Johnson, Toler and Frederiksen, 1975	IS2549C (SC0228)	Field resistant
	IS2816C (SCO!20)	Field resistant
	IS12612C (SCO!12)	Field resistant
	IS12666C (SC0175)	Field resistant
	Rio	Field resistant
	TAM2566	Field resistant
Teakle and Prichard, 1971	Krish (*S. halapense* x *S. roxburghii*)	Immune
Perseley, Greber and Moore, 1972	Q7539 (IS7596)(-3 to -7 x exll-97-H74)	Immune
Miller, Toler and Scheuring, 1976	SCO!20-14E, (73-CS-31 ,32)	Immune
Perseley, 1976	Q7539 (IS7596)(3Aex80Gw/h-74)	High level resistance
Toler, Miller and Scheuring, 1976	SC0534 (IS7596)PR	High level resistance
Toler and Miller, 1976	SC0097-14 (73-CS-271,72)	High level resistance
Smith and Toler, 1976	NM-31, M_3(76-380-13)	High level resistance

Table 2. Reaction of grain sorghum virus indicators to maize dwarf mosaic virus strain B (Ford and Hill, 1976)

Entry		MDMV-B	
BTx378	Red!an	0/22[a]	0.0
SA7000	Caprock	0/29	0.0
Tx414	7078 der.	0/29	0.0
SA7078	7078	0/29	0.0
BTx398	Martin	0/27	o.o[d]
Tx09	Comb. Wh. Fet.	1/21	5.0
NM-31	Weskan x Redbine 60	0/12	0.0
Tx412	(Tx09 x Tx403)	26/41	63.0
BTx3197	Comb. Kafir 60	0/39	0.0[e]
SA394	Combine Shallu	6/29	21.0[r]
PI35038	Sumac	4/39	10.<£
BTx3048	Redbine sel.	0/32	o.o[e]

[a] Number of plants infected/total number of plants inoculated

k Percent infected

c Occasional yellow streak suggesting resistant reaction

Bright yellow systemic mosaic (all sorghums infected with MDMV-A displayed these symptoms)

[e] Purple local lesions

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Table 3. Reaction of sorghum lines and hybrids to brome mosaic virus (Bush, Toler and Bradfute, 1976)

Entry		Reaction
BTx378	Redlan	3[a]
SA7000	Caprock	1
Tx414	7078 der.	3
SA7078	7078	4
Tx398	Martin	3[k]
Tx09	Comb. Wh. Fet.	1[0]
NM-31	Weskan x Redbine 60	4
Tx412	Tx09 x Tx403	2
Tx3197	Camb. Kafir 60	1
SA394	Combine Shallu	1
PI35038	Sumac	2
Tx3048	Redbine sel.	2

a Disease rating 1 = no infection no virus recovered, 2 = low infection mild mosaic, 3 = intermediate mottling and infection, 4 = high level of infection bright yellow mottling, 5 = hypersensitive red leaf.

k Yellowing no virus recovered.

0 All differentials inoculated with MDMV-A developed chlorotic mottling.

Stability of Sorghum Midge Resistance Among Different Resistant Sorghums

M. A. Faris

Ten sorghum resistant lines were compared for stability of their resistance to the sorghum midge when grown at fourteen planting dates in a nursery where the midge population is maintained throughout the year on wild sorghum grown under irrigation. Stability is described by average number of emerging adults from explored heads, and regression of the average number of adults on an environmental index. The environmental index is the average number of emerging adults at each planting date from a very susceptible cultivar. A line with stable midge resistance should have a low average adult emergence and b = 0.

Sorghum line AF-28, from the Agriculture Institute of Pernambuco (IPA) was shown to possess the most stable source of resistance to the sorghum midge.

Single Seed Selection of High Lysine Sorghum via Scanning Electron Microscopy

R. D. Sullins and L. W. Rooney

Sorghum is the fourth leading cereal crop in the world and, as with all other major cereals, lysine is the first limiting amino acid for nonruminant nutrition. High lysine mutant genes have been found in corn, sorghum and barley which significantly increase the lysine content of these grains. Unfortunately, these high lysine types are associated with abnormal kernel characteristics such as floury endosperm, reduced kernel weight, and in some cases an unusual dented shape. These defects render them agronomically undesirable and unable to compete with normal (plump, semi-corneous) types that produce greater yields. Breeding efforts to improve the kernel phenotype and to increase yields of these high lysine types have met with little success. The high lysine cereals in their present condition are therefore of limited value for commercial production.

A major difficulty in developing acceptable high lysine cultivars has been the identification of high lysine kernels which have been modified to a desirable (normal appearing) kernel phenotype. Chemical analysis for lysine generally requires several grams of sample and the analysis is destructive to the seed, making a selection scheme difficult to practice. An alternate approach (via Scanning Electron Microscopy) is the selection of high lysine kernels based on morphological differences in protein structures observed by microscopic examination.

Light microscopy studies on corn and sorghum kernels have shown that the number and size of the alcohol soluble prolamines (protein bodies) in the

endosperm are inversely related to the lysine concentration of the grain (1,2). Microscopic examination of high lysine corn (opaque -2 and floury -2) confirmed a substantial reduction in protein body size and number (1,3). A similar reduction of protein body number and size was observed in high lysine sorghum (4). Therefore, it becomes evident that sorghum kernels with high lysine levels have far fewer alcohol soluble protein bodies than kernels with normal levels of lysine. It is therefore possible to examine large numbers of kernels with the SEM for reduced amounts of protein bodies that would indicate an increase in the lysine level. However, some form of a rating system had to be established for evaluating the number of protein bodies present in a given kernel.

The sample selected for SEM evaluation of protein bodies and the establishment of a protein body rating system was (BTx378 x SC0110-9-pL-l-1-1-1-6-3) x BTx615. The parents of the cross were two intermediate textured normal sorghums (Red!an and ZeraZera) and an intermediate textured (Kafir) waxy endosperm sorghum. The sample was produced in 1975 on the Texas A&M University Plantation at College Station, Texas. Kernels were prepared for examination by hand dissection of the top one-third of the kernel. This crown portion of each kernel was treated with alpha-amylase enzyme to remove the starch for better exposure of the protein structure. The treated sections were mounted on rectangular aluminum stubs and coated with 200 A of gold-palladium. The samples were then viewed with a JEOL JSM-35 Scanning Electron Microscope at an accelerating voltage of 25KV.

Only corneous to semi-corneous textured endosperm kernels were selected for SEM evaluation.

Ratings were assigned from one to five as illustrated in Figure 1. A rating of PB#1 was assigned to those kernels with a protein body size and number equivalent to the original Ethiopian high lysine sorghums. A PB#3 rating was given to those kernels whose complement of protein bodies was equal to normal sorghums and PB#5 demonstrated a greater than normal concentration of protein bodies. The preliminary examination revealed that by far the great majority of the kernels had a normal or larger than normal number of protein bodies. However, a few kernels had a reduction in protein body number and size indicating the screening method would be feasible.

The entire preparation time and cost averages about three minutes per kernel at a cost of 20<£. The mounted seed are viewed with the SEM at a magnification of 1600x for one minute to establish the protein body rating. This permits examination of 60 kernels per hour with SEM at a cost of 33<£ per kernel. Cost of scope time including operator is about 45<£ to 50<£. This means total cost per kernel is approximately 70<£.

Chemical analysis for protein by micro-kjeldahl analysis and lysine by ion exchange column chromatography would cost $25 to $30 per sample. At the present time, effective chemical analysis at the individual seed level are not available. Single seed examination by SEM allows very critical selection pressure on a large population by identifying the phenotypic potential of the subsequent generations as well as being economical.

Once the methodology and rating system was established, it was necessary to begin examination of high lysine crosses for single seed with reduced prolamine content. The sample selected for screening by SEM was TP6Bx(BTx378 x SC0110) x BTx611 x P-721. This cross consisted of a normal

Figure 1. Scanning Electron Photomicrographs of Protein Body Ratings.

A = PB#1, B = PB#2, C = PB#3, D = PB#4, E = PB#5;

PM = Protein Matrix, PB = Protein Body, SG = Starch Granule,

SV = Starch Void and AL = Aleurone Cells.

Protein body size and number decrease from rating #1 to #5.

PB#1 rating is equivalent in size and number of protein bodies to those found in the original Ethiopian dented high lysine sorghum.

PB#3 ratins is equivalent in size and number of protein bodies to those found in normal endosperm sorghum.

PB#5 rating is greater in size and number of protein bodies than those found in normal endosperm sorghum.

A
SV
PM
PB
AL
6U
B
SV
PB
PM
AL
6U
C
SV
PB
6U
D
PB
SV
6U
E
PM
SV
PB
PM
SV
PB
AL
6U

plant from a random mating population times a normal, intermediate textured cross of Red!an x ZeraZera. This was crossed to a waxy intermediate textured Kafir line and then a floury endosperm high lysine mutant. The same was produced at the Texas Agricultural Research and Extension Center at Lubbock, Texas. The F_2 heads of the selected grain were individually hand-harvested and strung on wires for proper drying. After drying, heads were threshed and cleaned and damaged kernels were eliminated from the sample. The remaining grain was separated according to endosperm texture over an opaque light box. Only semi-corneous to corneous kernels were selected for SEM screening. All opaque or floury kernels were omitted from the study. Kernels were prepared in the same manner as previously described for the rating system. Approximately 1600 normal appearing kernels were bisected for SEM evaluation. The kernels examined indicated a wide variability in protein body number but again the majority of the kernels appeared normal or had a greater than normal concentration of protein bodies. However, approximately 4% (66 kernels) of the F_2 seed had a significant reduction in protein bodies (Table 1) relative to normal kernels.

The embryo portion of these 66 kernels were planted in peat pots, incubated in a germinator and then transferred to the greenhouse. Plants were left in the greenhouse until F^ self-pollinated seed was obtained from the PB#1 for field increase at Lubbock and Puerto Rico. After harvest of the F_3 greenhouse seed, the plants were transplanted to the field and allowed to ratoon for seed production at College Station. Ten embryos from each of the PB#3, 4 and 5's were also planted at College Station for further examination.

Table 1 also illustrates the protein body distribution of the College

Table 1. Protein body ratings.

College Station, Texas

F_2 seed	PB#1	PB#2	PB#3	PB#4	PB#5	Total
No. kernels	3	63	923	493	117	1599
%	0.2	3.9	57.7	30.8	7.3	

College Station, Texas

PB#Vs produced two F^ heads; ten kernels from each were examined by SEM and had protein body ratings as follows:

F_3 seed	PB#1	PB#2	PB#3	PB#4	PB#5	Total
No. kernels	2	1	13	3	1	20
%	10.0	5.0	65.0	15.0	5.0	

Puerto Rico

F^ seed from Lubbock sent to Puerto Rico for seed increase (19 plants produced from 20 F^ kernels).

F_5 seed	PB#1	PB#2	PB#3	PB#4	PB#5	Total
No. kernels	2	18	194	66	14	294
%	0.7	6.1	66.0	22.4	4.8	

Station F_3 seed. The PB#1 and 2 ratings increased greatly over that of the original F_2 grain screened. There was also a slight increase in the percentage of PB#3's with a reduction in the PB#4 and 5's.

The F_5 seed produced in Puerto Rico also indicated a definite change in protein body distribution. From the 20 F^ seed sent to Puerto Rico, 19 produced grain. Sixteen corneous kernels from each of the 19 heads were examined by SEM as well as being analyzed for protein by micro-kjeldahl and Udy dye binding capacity.

The data from the F^ samples indicates an increase in percentage of the PB#1, 2 and 3's with a decrease in PB#4 and 5's. This again would indicate our selection method is allowing the selection of individual kernels away from high numbers of protein bodies. From the 19 F^ heads included in this data, one had a high protein value and Udy dye binding capacity. When the 16 kernels from that particular head was examined, 12 kernels were given a PB#2 rating with the remaining kernels rated as PB#3's. As of yet, we do not have lysine data on these samples but from the data we are accumulating by SEM, it appears that we have been successful in skewing the protein body concentration in corneous endosperm kernels away from the norm and shifting it toward that concentration found in the original high lysine grain. The real advantage to this progress is that the chance of developing a good sound corneous high lysine kernel appears more realistic now than before. However, it will still require several more generations of critical selection pressure by SEM plus chemical analysis to completely transfer the high lysine characteristics to a corneous, agronomically acceptable grain that can be used in a successful breeding program. This research will be continued and hopefully in the near future we will be able to ascertain how much improvement in lysine content we can expect to be transferred to the corneous sorghum.

Review of Literature

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The Quality of Tortillas Made from Sorghums with Various Kernel Characteristics

D. Meckenstock, M. N. Khan and L. W. Rooney

Laboratory procedures were developed to produce masa from 50 g samples of sorghum and from 454 g of sorghum. The use of a 50 g procedure permits analyses of sorghum samples from genetic studies and from the sorghum world collection. The objectives of the research were to develop repeatable laboratory procedures and use them to evaluate the properties of tortillas made from several sorghum lines with wide variation in kernel characteristics. The basic procedure was to boil the sorghum in 0.8% lime, soak the boiled sorghum, rinse the sorghum and neutralize the pH and grind the grain with a hand grinder or stone grinder into masa. Then, the masa was pressed into tortillas and they were cooked on a grill. The boiling time for sorghums with corneous, intermediate and floury endosperm texture was 45, 30 and 20 minutes respectively. The optimum soaking time was four hours.

In these studies, 14 sorghum samples were made into tortillas. Considerable variation in sorghum tortilla color from light greenish-yellow to dark green or brown was observed, In general, the sorghum tortillas had a poor color compared to those of corn. Ascorbic acid treatment of the boiled sorghum produced lighter colored tortillas. Some white sorghums produced tortillas with a much lighter color and better acceptability than other white sorghums which indicates that some progress could be made toward selection of sorghums with better characteristics for use in tortillas. The brown sorghums produced tortillas that had exceptionally dark color. Additional studies are underway to determine variation in tortilla making potential among sorghums with white pericarp without pigmented testa (subcoat).

Field Deterioration of Sorghum: Differences Among Sorghum Lines and the Relationship to Characteristics of the Grain

J. A. Glueck

Introduction

Deterioration of sorghum grain in the field prior to harvest (grain weathering) results from physical, physiological, and chemical changes in the seed. The ultimate expression of grain deterioration is loss of seed viability and breakdown of seed integrity. Deteriorated grain usually has a dark, discolored appearance, chalky endosperm, discolored germ, decreased test weight, density and hardness, possible sprouting, as well as reduced viability and vigor. Substantial economic losses due to field grain deterioration (FGD) in sorghum were realized during the 1974 growing season on the Texas High Plains and in 1976 in South Texas. FGD is also a major problem in other areas of the United States and especially in the subtropic sorghum producing areas of the world. FGD in South Texas in 1976, was due primarily to seed sprouting or the initiation of the germination processes, and FGD in the High Plains of Texas in 1974 was due primarily to pathogen invasion of the seed with subsequent breakdown of seed components. Depending on environmental conditions, either type of FGD may predominate and usually both types contribute to the final state of grain deterioration.

Causes and results of field grain deterioration

Although the major expressions of FGD are seed sprouting and pathogen invasion, the cause of FGD is probably best described as an interaction among environment, pathogens, and grain and/or plant characteristics of the sorghum. Extensive rainfall and high humidity with possible alternate periods of wetting

and drying during grain maturation and post physiological maturity favor FGD. Pathogen type and population are affected by environmental conditions. Certain grain and plant characteristics predispose grain to FGD. Ample moisture (30%) for prolonged periods is necessary for germination of sorghum seed. Water uptake triggers growth by the embryo with subsequent enzyme production for breakdown of structural protein and carbohydrate fractions for use by the developing plant. Initial food reserve utilization appears to be in the scutellum area with subsequent mobilization of endosperm reserves. Pathogens appear to enter the seed primarily through the water uptake pathways with subsequent colonization of the germ and endosperm causing breakdown or alteration of the structural protein and carbohydrate fractions. Enzymatic alterations of the germ and endosperm cause the discolored appearance of the germ, as well as, the chalky appearance of the endosperm.

Reported grain and/or plant characteristics imparting FGD resistance

The producer has little control over environmental conditions which influence FGD, and chemical control of pathogens is not economically feasible. The likely alternative is screening and breeding for FGD resistant types of sorghum. Grain and plant characteristics believed to be needed for resistance include:

1) open heads with the seed completely enclosed with long papery glumes (Murthy, 1975);
2) brown seed with high tannin content and the presence of a regimented testa (Ellis, 1972; Harris and Bums, 1973; Murthy, 1975);
3) seed with thin, smooth, translucent pericarp (Leukel and Martin, 1943 and Ellis, 1972); and

4) corneous endosperm texture with normal endosperm type (Clark, *et al.*, 1973).

Theoretically a combination of these characteristics should yield a FGD resistant sorghum type. Unfortunately this is not true, at least not a line with acceptable agronomic characteristics. The open-headed, long glume characteristic seems related to yield reductions. The brown-seeded, high tannin characteristics may impart varying levels of resistance to FGD; however, high polyphenolic content generally has detrimental effects on utilization as food or feed. Vast variability exists among lines in pericarp characteristics and endosperm texture and type; however, no generalizations can be made on combinations which impart resistance to FGD.

Statewide field grain deterioration tests

Realizing the potential economic and energy losses possible with field grain deterioration, active selection and evaluation of lines has been initiated by the Texas Agricultural Experiment Station. Tests were conducted throughout Texas during the 1975 and 1976 growing seasons. Lines with potential resistance to FGD were included with resistant and susceptible checks. Field ratings as well as physical, chemical and microscopic studies are being conducted to identify lines with resistance to FGD. In addition, possible screening techniques and resistance mechanisms are also being studied.

Evaluation of sorghum lines for resistance to grain deterioration is dependent on favorable environmental conditions for expression of the syndrome and is confounded by maturity and insect and disease interactions. Twelve lines selected from the 1975 tests illustrate the effects of field grain deterioration when comparing excellent quality grain with grain which had mildly to

severely deteriorated. Excellent quality grain was harvested at Lubbock and mildly and severely deteriorated grains were harvested from College Station at physiological maturity (35-40 days past 50% bloom) and 60-75 days past 50% bloom, *i.e.,* first and second harvest, respectively.

Field ratings: Subjective ratings based on a one to five scale were made on all lines prior to harvest. A 1.0 rating represents grain free of microorganism growth and essentially 100% seed viability; whereas, a 5.0 rating represents seed with complete coverage by microbial growth and lack of viability.

The susceptible checks Tx2536 and SC414-12E were rated as having the greatest FGD at most locations; whereas, SC279-14, SC748-5, 74PR759, SC566-14 and SCI03-12 were consistently ranked as more resistant lines.

Maturity of lines has a primary effect on time of grain exposure to inclement environment and therefore expression of FGD. The susceptible checks were generally late to flower and therefore any maturity effect should favor the susceptible checks since their grain is exposed to the environment for a shorter period than most of the more resistant lines.

Standard germination: Germination percentage closely correlates with field ratings for most lines. Lubbock samples all germinated above 90%; whereas, some lines harvested at physiological maturity at College Station (first harvest) had already lost considerable viability. After considerable FGD, only the brown seeded SCI03-12 and BTx398 maintained viability above 50%. Other lines had reduced germination, yet not to the extent of the susceptible checks Tx2536 and SC414-12E.

Tannins: Tannin content, measured by the modified vanillin - HC1 method

(Maxson, 1970), was greatest for SC103-12 which has a pigmented testa. Many of the more resistant FGD lines had low tannin content.

Test weight: Test weight of grain is influenced by seed size and shape, endosperm texture, and amount of extraneous material present in the sample. With FGD, test weight decreases, especially with the more susceptible lines. Removal of glumes and extraneous materials from the samples increased the test weight of more deteriorated grain 1-3 Ib/bu.

Density: Density primarily reflects the endosperm texture of the grain of the lines. Density decreased as FGD progressed.

1000 kernel weight: One thousand kernel weight primarily reflects seed size and endosperm texture. As FGD progresses 1000 kernel weight decreases.

Seed size and hardness: The larger seeded lines included SL97-14, SCI02-12 and BTx398, whereas the smaller seeded lines included SC263-14 and SC748-5. Hardness values primarily reflect endosperm texture, or relative amounts of corneous to floury endosperm. Hardness values tended to decrease as FGD progressed.

Seed leachates and water uptake

The grain of more susceptible lines was characterized by increased rates of conductivity of seed leachates over a sixty minute time span. In addition, grain of susceptible lines seems to have more rapid leachates and water uptake increases (compare Lubbock with College Station samples). Differences among lines in conductivity of seed leachates and water uptake suggest possible structural and chemical variations in the seed that may be directly related to FGD. These tests may also serve as preliminary screening methods for lines with FGD.

Conclusion

With prolonged exposure to inclement environment, most lines will eventually deteriorate; however, observations indicate that certain mechanisms limit the rate of deterioration in lines categorized as resistant. Several lines (SCI03-12 and BTx398) appear to resist the initial attack of the seed by microorganisms. Other 1ines—SC279-14, SC748-5 and 74PR759—seemed to lose viability, yet the endosperm was not readily damaged.

Evaluation of lines for FGD is complicated by maturity, grain characteristics as well as other uncontrolled variables which may influence subjective and objective measurements.

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