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9. ABSTRACT

This document contains the papers, in English and in Spanish, presented at the international sorghum workshop in Puerto Rico, in January 1975. The production of new and more nutritive varieties of sorghum, the effect of insects, diseases and nematodes on the cereal, and the human utilization of sorghum in different parts of the world were some of the subjects considered at the workshop. Sorghum, one of the four major food grains of the world, is more tolerant to both drought and wet soil than corn, and it can produce more than one ratoon crop after harvest. The most important factor in limiting sorghum yields is moisture management. Weeds consuming moisture and moisture lost during tillage operations and surface evaporation are problem areas. A wide range of difference in digestability exists within sorghums. It is desirable to combine better digestability and satisfactory agronomic traits. It is possible to select and interbreed strains with improved amino acid balance and more starch components. Incorporation of these into agronomically acceptable strains is an integral part of the improvement program. About 400 million people are dependent on sorghum as a staple cereal. The major sorghum producing countries are Argentina and Mexico, but significant advances are possible in Brazil, Colombia, Uruguay, Paraguay, and Venezuela, by going to new and improved hybrids. Sorghum can also be used as fodder and stover to feed millions of animals which in turn provide meat and milk for human consumption. Other uses are molasses, fiber, fuel, and alcohol.

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INTERNATIONAL SORGHUM WORKSHOP

UNIVERSITY OF PUERTO RICO

MAYAGUEZ INSTITUTE OF TROPICAL AGRICULTURE

UNIVERSITY OF NEBRASKA

PURDUE UNIVERSITY

TEXAS A & M UNIVERSITY

January 7, 8, 9, 10, 11, 1975

University of Puerto Rico
Mayagüez Campus

Sponsored by the Purdue University, Texas A & M University, University of Nebraska, Mayagüez Institute of Tropical Agriculture and the University of Puerto Rico, with the support of the U.S. Agency for International Development.

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INTRODUCTORY REMARKS

Mr. Chancellor, Prof. Rafael Pietri Oms, Mr. Dean of Studies, Professor Salvador Alemañy Representatives from our cooperative Universities of Nebraska, Purdue and Texas A & M, representatives of AID; Mr. Director of the Institute of Tropical Agriculture, Dr. Frank Martin; distinguished guests; colleagues, ladies and gentlemen: On behalf of our Chancellor, Prof. Rafael Pietri Oms, and all the members of the College of Agricultural Sciencies which comprises the three basic functions of teaching, research and extension, I am priviledged and honored to welcome you to the Mayaguez Campus of the University of Puerto Rico. Specially, I want to extend a warn greeting to all of you have come from overseas, from far away places to join us in this important development.

I am deeply honored to have the opportunity to open this Workshop, activity which is sponsored by the Agency for International Development (AID) and the Universities of Purdue, Nebraska, Texas and Puerto Rico. We hope that all of you will profit by your stay here and that this meeting will serve as a positive step toward having scientists from all over the world work and thing together about seious problem of how to feed the fast growing population of the world.

The World is teeming with hungry people in spite of the great efforts of the most developed countries and of international agricultural agencies. This is dangerously magnified by the out of control population increase, the ever increasing cost of living accompanied by the decreasing adquisition value of money, the uncontrolled environmental factors, the unplanned industrialization process and by man made water, soil and air pollution.

Consequently, we must feel rejoiced and full of new hopes when one faces such a wonderful group of scientists joined with the unique and common purpose of bringing together the scientific knowledge gathered through a lifetime in different research centers of the World. This International Congress on sorghum comes at the most appropiate time in the appropiate place. Very interesting and important aspects such as the production of new and more nutritive varieties, the effect of insects, diseases and nematodes on the cereal, and the human utilization in different parts of the world, demand our undivided attention.

Aside from the honor it represents, the selection of Puerto Rico as the place to develop this undertaken seems most fitting and appropiate for several reasons: First, Puerto Rico is right in the middle of the tropical belt and the technology developed here may be transferred hopefully, to other tropical areas with a minimum of alterations or modifications and, secondly, Puerto Rico has served previously as the linking point between North and the South: there is no reason why we can not do it again. It is a well known tact that the advanced technology developed in the northern countries may be put to test here, adapted or modified and then transferred to our friends of the South. The Mayaguez Campus of the University of Puerto Rico and the Mayaguez Institute of Tropical Agriculture (formerly known as the Federal Agricultural Experiment Station) have the human and physical facilities to conduct the necessary research not only for local uses but also for the remaining parts of the tropical belt.

Our symposium deals, as I have already said, with one of the most promising agricultural enterprises. As you well know sorghum in one of the four major food grains of the world after wheat, rice and corn. Its better tolerance than corn to both drouths and wet soils and its ability to produce more than one ratoon crop after harvest, makes of it an advantageous cereal to grow. About 400 million people all over the world are dependent on sorghum and millets as staple cereal.

The uses of sorghum are many and various. Its fodder and stover is widely used to feed millions of animals throughout the world. These in turn provide meat and milk for human consumption. Other uses are mollasses, fiber, fuel and alcohol.

The local organizers of this technical meeting deserve special mention for their dedication and effort. Dr. Orrin Webster, who retired on January the 1st. after many years with the Federal Experiment Station has given us a wonderful hand. He devoted the most productive years of his life to the study of sorghum as a food source for human beings in an effort to alleviate the hunger prevailing in many tropical countries.

Another of our excellent local organizers was, our good friend and colleague in the University until yesterday, Dr. Antonio Sotomayor. Dr. Bernardino Rodríguez, from our staff in the College of Agricultural Sciences and in charge of international programs, did a very outstanding job. Certainly the efforts of these three colleagues was greatly stimulated by the enthusiasm and cooperation of you all.

I hope for all the success in this Congress. May all the objectives be met and we hope that after all the information is put together, it is published for the benefit of those who can not be here with us.

My colleagues, you have a great task ahead, good luck and the future will be your judge.

Distinguished delegates. Your meeting at this time in Puerto Rico is most opportune especially now that we are embarked in a new research program on sorghum in order to develop new and better cultivars for the tropics. It is our hope that in the near future we will be able to put together all possible inputs from the various AID's sorghum projects such as those being developed at the Universities of Purdue, Nebraska, and Texas into one unit in order to come with real positive results in a real joint effort. This meeting will be undoubtedly of great value to us in Puerto Rico and hope that it will be to all of you.

It is especially gratifying to me as Acting Dean of the School of Agriculture of the Mayaguez Campus to have all of you here and to wish all of you a happy and pleasant stay in Puerto Rico.

By Dr. Fernando del Rio, Acting
Dean; College of Agricultural Sciences
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POTENTIAL FOR SORGHUM PRODUCTION IN LATIN AMERICA COMMERCIAL POINT OF VIEW[1]

A. Bruce Maunder

One only needs to look at agricultural statistics for Latin America to see the strong relationship between rapidly expanding sorghum areas and those countries which have more than half of their land sown to hybrids. Argentina and Mexico, two pre-hybrid sorghum producing countries which now have more than half their area in hybrids, have increased hectares in sorghum by more than 30 and 12 times, respectively, since the pre-hybrid years of 1948-52.[2] On the contrary, El Salvador and Guatemala with less than 20% of their sorghum in hybrids and using domestic or native varieties, have increased land in sorghum by only 1 1/4 and 3 times, respectively. Also, Mexico and Argentina, which are now the major producers of sorghum in Latin America, possess temperate. to sub-tropical climates which were best suited to the U. S. developed germplasm available in the first sorghum hybrids. The Central American countries have also been classified as major producers in Latin America, however, because of their consistent history with the crop and relative good percentage of their cultivated crops in sorghum (table 1).

In addition to likely increases in these major producing countries there remain several potentially favorable producing areas in Latin America (table 2). Of this group Brasil with one of the few undeveloped areas of the world, the Amazon Basin, plus other regions even more

[1]Director, Sorghum Research, DEKALB AgResearch, Inc., Lubbock, Texas, U.S.A.

[2]estimate of 100,000 ha. for Mexico in 1948-52 as FAO statistics show no data available.

readily available for the cultivation of sorghum, offers the greatest possibility for a significant increase. Most of these potential producers will, however, require a much greater research effort to locate adapted hybrids or varieties as well as to determine suitable cultural and marketing practices.

Most of the statistical data for this discussion was obtained from the U.S. Foreign Agricultural Service. Generally their figures appear conservative as opposed to estimates from agronomists in the field. Also some comparative differences between countries may exist because of the difficulty in obtaining similar reporting periods.

Major Producing Countries

Argentina. The most recent harvested acreage of 2.4 million hectares for 1973-74 comes from 3.5 or more planted hectares of grain sorghum. A continually increasing area of grain sorghum may be expected as a substitute for wheat and cotton acres; as land is cleared in the Chaco of northern Argentina; and as the increasing demand for cattle production necessitates grain feeding and stubble for pasture. Forage sorghum, which accounted for one third of the total sorghum planted in 1969-70, has also increased substantially from 800,000 ha. in 1957-58. As a point of interest, as recently as 1967-68 more than 40% of the grain sorghum was not harvested but grazed with the figure down to about 30% for 1973-74.

Orlando Fagioli (personal communication) suggests the present 3.5 million hectare grain sorghum plantings could be increased without much problem to 5 million for grain and 4 million for forage. Such an increase of 40% assumes drying and storage facilities can be improved.

In 1973-74 for example, 1-2 million tons of production were lost in the field or in storage because of excessive moisture, by delayed harvest because of a lack of storage, or by improper drying and storage facilities.

Yields in Argentina have gone from 950 kgs/ha in the pre-hybrid years of 1948-52 to 2333 kgs/ha in 1973-74 for an increase of 145% which compares very favorably in percentage increase to the same period for U. S. grain yields. With more research emphasis on drought resistance and with the elimination of downy mildew through resistance, more consistency and higher total yields will be realized. In addition, insect resistance and improved seed production must be given high priority to maintain the favorable trend for this country with so much agricultural potential.

Mexico. As already mentioned, Mexico has experienced a very significant increase in area in sorghum with a 1973-74 harvest of 1.2 million hectares. Estimates by those closely associated with the crop suggest increases of 5-10% per year. Yields have been variable going from 2530 kg/ha in 1966 to a 1973-74 figure of only 1420 kg/ha due to weather losses in the important Matamoros growing area.

Since sorghum is the primary feed grain in Mexico, significant and rather immediate breeding improvements seem essential to raise this relatively low yield, stabilize production over years, and avoid the need for imports which may run as high as 400-500 thousand metric tons. Several varietal improvements now seem likely by a seed industry which appreciates the great sorghum potential of this country. First, two of the key production areas, Matamoros in the northeast and El Bajio in the central highlands have strong requirements for mildew and anthracnose

resistance, respectively. New hybrids being released will have good resistance to both diseases as well as good agronomic traits. Also, much of the sorghum in Central Mexico is or could be grown at altitudes above 1500 meters if sufficient cold tolerance was available. At present, cold tolerance, which is only partially dominant and thus needed on both sides of the cross, has been transferred into yellow endosperm males and low tanin or non-brown females. Thus, grain hybrids of good nutritive value as opposed to the brown seeded types of the first cold tolerance material are now ready for extensive evaluation.

This brings up another aspect of future grain improvement for Mexico and also Central America for that matter: much improved nutritive value. Where grain is grown for human consumption, this becomes even more important but could be a factor for acceptance and increased acreage throughout Latin America. In much of Mexico, increased drought resistance can not be stressed enough. Here again the future looks promising. Finally, to expand the crop into new areas, especially to the south, may require a greater use of tropical germplasm.

Central America. This area had over 200 thousand hectares in sorghum during the 1948-52 pre-hybrid period so has shown a very limited increase with 290,000 in 1973-74. Angel Salazar, however, (personal communication) projects a land area of as much as 350 thousand hectares by 1980. In the papers presented by Salazar you have heard that only 20-25% of the area was sown with hybrids (Costa Rica and Panama are exceptions). Native and unimproved varieties to the contrary made up more than 75% of the plantings. This no doubt explains in part the static yield level of the area with the largest producer El Salvador, (120,000 ha), for example, going from 1200 kgs/ha in 1948-52 to 1292

gs/ha in 1973. A favorable trend, however, away from the local arieties to improved hybrids does exist.

Certainly the seed industry should look upon the Central American situation as a real challenge to prove to the farmers and government that significant advances are possible by going to new and improved hybrids. A good starting point would be, of course, to show nutritive improvements since the human consumption of sorghum accounts for 25% of its use in Guatemala, El Salvador, Honduras, and Nicaragua. Present improved types and the results of efforts with the new high lysine germplasm can be of real value. A greater breeding effort to utilize the best germplasm as regards day length, wet-dry extremes, and the accompanying insect and disease problems seems in order. Price differences between crops has likely also held back cultural improvements of this crop but still the opportunity for higher yields from a much greater use of hybrids continues to make Central America an area of real potential from a commercial

Potential Producing Countries

Brasil. This country offers by far the greatest possibility for sorghum expansion in Latin America; yet for all practical purposes only began growing the crop in 1970. F.A.S. estimates suggest a 33% increase in area planted for 1974-75 over the 179 thousand hectares estimated for 1973-74. Area planted to sorghum has been increasing more slowly than many estimates of a few years back. Yields generally look promising and suggest this crop can be very competitive to corn. Also it can easily be rotated with soybeans and needs less favorable conditions including moisture than corn. Yields in 1973-74 were listed as 1955 kg/ha with

individual reports of 5400 kg/ha in Rio Grande do Sul and 8-10,000 kgs/ha in northern Sao Paulo.

Forecasts for the crop in the calendar year 1975 suggest 700-800,000 metric tons will be harvested. Utilization through livestock or export of this grain must be developed if the crop is to be a major factor in the Brazilian economy. Presently the poultry industry uses around 25% of all production. Also, in new areas heavy investment in farm equipment including drying facilities will be needed. Just how large the sorghum crop will get is as of now just speculation but one million to three million hectares are often talked about. Originally the Rio Grande do Sul area seemed most likely for sorghum but it is currently heavy in soybean production. Areas of Sao Paulo state look promising, but this is pretty good corn country. The Cerrado area (low pH) of Minas Gerais, Goias, and Matto Grosso and the arid northeast both give exclusive advantages to the genetic diversity of sorghum for adaptation as opposed to corn.

From a breeding standpoint, variety or hybrid requirements will vary considerably by area necessitating extensive testing within the country. Certainly disease and insect resistance will be critical for many areas as will be weathering resistance. This latter factor raises serious implications regarding the feasibility of seed production which may in fact be best suited to irrigated areas of the dry northeast. Although very little mildew has been observed, there will be strong pressure to see only downy mildew resistant hybrids grown with the thought that this will keep it from spreading to corn. Certainly in Argentina where there is much close association of the two crops this has not occurred. Trials in the state of Goias showed 90% or more of

the entries infected by possibly a Colletotrichum type organism, with only the crosses having excellent foliar resistance such as to downy mildew, remaining disease free. The entries with resistance to the graminicolum species in the U. S. were not resistant suggesting a different race or possibly the falcatum species. The resistant hybrids made yields up to 6000-7000 kgs/ha. All test locations contained some germplasm which performed quite well.

Midge, greenbugs, and Diatraea will limit yields to varying degrees. It seems obvious that greatly increased extension and research programs will be essential to developing appropriate cultural practices such as for the cerrado of low pH, and to locate the correct germplasm for a specific area. Because the crop is so new there are shortages of trained scientists and farm advisers both of which will hopefully develop with the expanding crop. Just as important as the agronomic aspects will be the need to provide farmers with the incentive through price and maintain the interest of buyers in this crop to assure a dependable market.

Columbia. The 90,000 hectares in 1973-74 was a sharp decline from 140,000 ha. the previous year. Weather and competitive crop prices e.g. for cotton, rice, and sugarcane temporarily slowed the growth of this crop in Columbia. The "de la Costa" area of the north seems best suited for sorghum with possible expansion to one million hectares. Prospects point to an increase in sorghum for 1974-75 with possibly in excess of 300,000 tons production. Although a new crop for Columbia and grown under very low latitude, yields have been generally above 2000 kgs/ha with about 75% of the land in hybrids. Also, the variety, ICA-Nataima, performs well.

Uruguay. Although adjacent to the vast sorghum production of Argentina, Uruguay has not generally been involved with this crop to much extent until recently when more than 100,000 ha is being grown. The area sown to sorghum seems to be quite dependent on wheat which will be up some 71% from the previous year. Therefore, only a substantial yield increase will alter sorghum production which may reach 220,000 mt for 1974-75.

Paraguay. A minor producer but with excellent opportunities for much expanded production, Paraguay grows only about 20,000 hectares with a potential of perhaps 500,000. Yields are low which reflects on a lack of mechanization and incentive because of marketing problems. Varieties such as Dwarf Hegari are grown to some extent. Birds seem to be a major concern for sorghum producers over much of the area.

Venezuela. Potentially this country could be a major factor in Latin American sorghum production with both the land and the past history of respectable yields. Only 10,000 hectares are now planted with sorghum imports for 1973-74 set at around 425,000 mt. Yields have generally been at or better than 2000 kgs/ha over years. With markets and prices favorable, 50,000 hectares seem quite possible in the next few years.

Other potential producers. Peru, Guyana, and the Dominican Republic produces around 5000 hectares each and Peru has shown an exceptionally strong yield level of 3200 kgs/ha. In situations where sorghums are grown in conjunction with sugarcane fluctuations will vary with relative pricing as well as rotation systems. This would be true for the Caribbean Islands which have the capacity for highly productive sorghum and a minimum of two crops per season. Bolivia in the "Santo

Cruz de la Sierra" could show a sizeable area in the next few years.

Although not included in the above statistical discussion by country, forage sorghums of both sweet and sudangrass types are of vital importance to the agriculture of Latin America. For example, Argentina plants 3 million hectares to forage and Uruguay has 120,000 ha. Brasil would appear to have excellent potential for forage sorghums. Fortunately good disease resistance such as to downy mildew and anthracnose is already available in Latin America.

Essential Characteristics for Successful Adaptation

Appropriate environment x genotype interaction. As with any crop the variety or hybrid placed in a new environment must be genetically suited for the wide range of environmental pressure to which it will be subjected. To some extent one can explain the success of hybrids in Argentina and Mexico to a latitude and climate which perhaps makes those growing areas reasonably similar to the Plains States of the U.S. from where many were developed. Certainly, however, the Chaco of Argentina cannot be equated to West Texas anymore than the sorghum area of Nicaragua to southeast Nebraska. Between these relatively diverse geographic areas specific germplasm shows good adaptation whereas other germplasm appears quite unacceptable. Generalizations then of broad adaptation of sorghums are therefore often misleading and all too simplifying. As a matter of fact the first cycle of U.S. hybrids (1956-1962) would fail miserably throughout almost all of Latin America for disease reasons alone. Also, the bird resistant types were not available in the first cycle of release but because of birds or more likely wet harvest conditions these sorghums have become very popular in

Latin America

Testing extensively within any potential sorghum area or country will not only show differences in relative adaptation but perhaps more importantly if the available sorghums are adapted at all. Testing too narrow a genetic range could be misleading as could a poor choice of planting dates. The early stages of varietal evaluations would be best spent reviewing the potential of large numbers of diverse types over locations and planting dates as opposed to intensive testing of perhaps 50 items, many of which may be related.

Breeding techniques will show more similarity between environment than will the germplasm utilized. Except for Northern Mexico and Argentina the sorghum potential of Latin America is within the tropical classification. Consequently, one should not expect maximum performance or adaptation by a liberal use of temperate germplasm, varieties, or hybrids such as from the U. S. In the last 10 years, however, specific trends or objectives in U. S. breeding have favored the development of asm more suitable for Latin America:

1. development of sorghums for the humid, semi-tropical southeastern U. S. where bird resistance, anthracnose resistance, weathering resistance and open panicle types were required.
2. heavy use of kaura sorghums of Nigerian origin as yellow endosperm parents which frequently carried a good source of anthracnose resistan
3. conversion of the World Collection with special emphasis on Zerazera sorghums of exceptional leaf disease resistance.

All of these modifications have departed from the initial kafir-milo breeding with its inherent disease susceptibility and reduced stalk quality. The shallu sorghums, used quite extensively in the southeast, are an exception as they frequently have suffered from disease and generally show unacceptable stalk quality such as in Brasil.

Improvement through random mating populations will no doubt be the long range objective for varietal or hybrid development. The U. S. Agricultural Research Service (Mayaguez, Puerto Rico) has recently released the sorghum population PR-1BR, developed of African and improved varieties with emphasis on insensitivity to day length in a subpopulation which should be day neutral. Not only will this be an excellent addition to any tropical improvement program but hopefully will allow for the development of later maturing, improved, grain types which could with sufficient nitrogen and water add measurably to potential yields. At present, most temperate sorghums, regardless of maturity, bloom in 50-55 days under the shorter days of the low latitudes. Work in Thailand by Richard Harwood et. al. has also been directed at lengthening the vegetative stage of the sorghum plant under shorter days. Both government and private research must be increased significantly if we are to see major gains in tropical sorghum performance and production.

Our work with populations adapted to tropical and subtropical areas of high humidity, birds, and associated disease and insect problems is only to an early stage of evaluation, but a few comments seem appropriate. The populations were formed of B and R-lines with an emphasis made to incorporate anthracnose and bird resistance. The original materials of grain type which were crossed in all combinations by emasculation to form the populations, provided a gene frequency of 0.5

for both brown seeded sorghums of high tannins and awns. Both populations of about 35,000 plants were then allowed to randomly pollinate with two generations per year utilizing south Georgia and the Chaco of northern Argentina. There was no sterility added but at harvest only the upper one fourth of the head was harvested to increase by as much as 2 x the rate of natural crossing. After seven cycles with only natural selection, except for obvious outcrosses of tall, forage types, plants were then selected for type with tagging used to differentiate the early maturing plants. Some 200 early and 200 intermediate maturing lines were selected in the Chaco from the B-population and 209 early and 219 intermediate from the R-population. The S_1's were grown in 1974 at Lubbock, Texas with the following observations:

1. differences between and within S_1 head rows suggested good natural crossing and avoidance of homozygosity.
2. B-lines approached 100% brown seeded with R-lines slightly less
3. B-lines were generally taller than R-lines
4. stalk quality was inferior to adjacent inbred material
5. most S_1's had awns
6. range of brown seed colors (tan-orange-purple)
7. comparable inbred evaluation from cycle 3 of reciprocal recurrent selection strongly favored those lines over these S_1's.
8. mean of early lines in B-populations was 64.1 days to bloom as compared to 64.7 days (N.S.) for intermediate when grown at Lubbock.

Testcrosses with these S_1's were made onto 3 tester lines for disease and combining ability evaluations. The maturity response was unexpected considering the selections were made in the semi-tropics and the evaluation was made in a temperate area. Also, the tendency for height and poor stalk as compared to the short, stiff stalk types in the recurrent selection program makes one question the success of random mating with natural selection pressures. Encouraging, however, was the apparent evolvement away from downy mildew during the generations grown in the Chaco. The R-line population was very susceptible in its first Chaco cycle but surprisingly clean in the seventh.

Disease and Insect Resistance. The higher humidity of most Latin American sorghum areas as compared to the Great Plains of the U.S. will tend to emphasize disease and insect problems. To the contrary, the hot dry areas also have their share of charcoal rot or stalk rot problems, (*Macrophomina phaseoli*). Downy mildew (*Sclerospora sorghi*) in Argentina and anthracnose (*Colletotrichum graminicola, falcata*) or races thereof in much of Latin America require a strong pathology emphasis when testing or developing germplasm. Resistance often means the difference between a successful crop and almost nothing.

Primary insect problems in key producing areas have been the sorghum midge and the stalk borer, *Diatrea*. More recently the sorghum greenbug has been noted in both Argentina and Brasil. Varying degrees of resistance to all three of these insect problems exist and are being incorporated into improved germplasm. The common problem with midge and greenbugs in North and South America has allowed for successful alternating nurseries with both insects.

Freedom from pre-harvest seed deterioration. For successful

production in the more humid areas seed weathering must be considered due to the exposed caryopsis in sorghum. Wet harvest conditions may in some cases be avoided by planting dates. Also the problem can be much reduced by using the higher tanin, brown seeded types. The brown seeded types were first thought most important for bird resistance but later the advantages of less mold and weathering as well as higher germinating seed production have become predominant. A great deal of variability exists with the "brown types" and the disadvantages will be discussed under "market demand."

Ability for local production. Economics would normally suggest that seed be produced within the country using it although there may be some very real exceptions to this such as where volume required is too low to justify it. Referring to the previous comments production of high quality sorghum seed can become very difficult in areas of high humidity or rainfall. In situations, such as Argentina, however, by going inland to drier areas and without irrigation a compromising problem of drought with its effects of low yields and missed nicks (simultaneous blooming of both parents) can offset the advantages of avoiding the wetter harvest conditions. Wherever possible, hybrids without splits (different planting dates for each parent) must be a breeding objective, especially if seed production will be under dryland conditions. Also, the requirement of high yielding female lines is obvious. Generally varietal (non-hybrid) seed production will have less problems except for weathering. Considering the present advancements in Latin America agriculture, however, this would not be justification to utilize a variety approach.

Strong market demand. With increasing need for food production

more emphasis will be given to utilizing the most productive crop or finding a crop which can produce under a difficult set of conditions. Nevertheless lack of a strong market demand or unfavorable pricing with competitive crops has frequently slowed the development of sorghum. Both government and private grain brokers must appreciate the advantages to the crop. Also, export arrangements must be considered. The value of sorghum to corn has been steadily increasing through grain quality improvements which affect the commercial crop and through processing techniques which give an increasingly greater percent feed efficiency and gain. As of December 18, 1974 the farmer of West Texas could expect 94% the price of corn for his sorghum, whereas the Gulf export price showed sorghum at 96.7% of corn. This is a significant gain compared to the 88-90% value not too many years back.

To maintain this comparison we must strive towards nutritive upgrading of germplasm which affects the future commercial crop. Certainly some of the yellow endosperm materials have made small gains which support the above pricing but recent findings at Purdue would suggest dramatic weight gains and feed efficiencies approaching half the present requirements. As Salazar reported in these meetings, more than 25% of the grain sorghum in El Salvador and Honduras goes for human consumption where increased lysine and percent protein can make the difference between normal or abnormal development. With countries such as Brasil and Argentina desiring to further increase livestock production for domestic and especially export purposes the chances for a much greater local market, which will benefit from improved feed value, seems assured.

This then brings up the somewhat delicate subject of the high tannin, brown seeded sorghum which, as already discussed, can have some real value in Latin America. The evidence now available, however, certainly suggests lower digestibility and reduced protein availability from this type grain. The immediate concern will focus on exporting countries which may face international marketing discounts or even refusal of grain movement. At present, for example, brown seeded types are not accepted by exporters in the U. S. A., but this type sorghum does get into international channels, elsewhere. Fortunately, certain commercial processing techniques, such as steam flaking, tend to bring up the feed value to a level comparable with the unprocessed non-browns. Also, dietary supplementation such as with choline or methionine may at least partially reduce the growth depressing effects of tannins. Under many growing conditions these brown types can be avoided but where they seem of real necessity efforts need to be made to look for variability in hopes of gaining the desired effect of brown types without as much nutritive loss.

Available drying and storage facilities. Estimates of losses as great as two million tons in Argentina for 1973-74 because of a lack of storage will be a factor for increased or new production of this crop. Drying facilities in the more humid areas and adequate insect control cannot be overlooked. Also, of course transportation at all levels is essential for increasing development of the crop.

Sorghum research and extension. To see the potential of this crop utilized we must see much more research activity by government and industry. Certainly cultural practices will vary by areas and will interact with germplasm utilized as well as utilization objectives. The

dissemination of information on varieties, hybrids, and their proper management will be essential for establishment of the crop in new areas and improving its competitive position in established areas. Purina in Brasil employs extension type fieldmen to help advise growers of this "new crop" and thus assure them a source of grain for which, incidentally, they pay a premium for the yellow endosperm types.

Role of Domestic and Foreign Seed Companies

ition to agricultural economy. The seed industry provides a package of research, seed production, and sales including distribution with strong continuity between all three aspects. In addition the seed company with a comprehensive research program has a wide range of genetic diversity in all stages of development. Thus rapid improvements and application over large areas can be accomplished with all the risks in the private sector. To pin down this contribution in monetary values is nearly impossible but certainly it would be enormous. The presence of research and extension staff which compliment government workers is of course also, a significant advantage. Since the seed industry is very competitive the emphasis on research and subsequent crop improvements benefits the farmer and the consumer more than anyone else.

Advantages to foreign seed company. Quite obviously the seed company, with significant investment in a proprietary commodity, constantly looks for an expanding market for its product. Also, a reputation must be maintained in a competitive enterprise wherever demand for its product exists. Certainly the total market of 6.1 million planted hectares in Latin America (assuming the 4.3 million harvested hectares in 1973-74 resulted from a 70% harvest) offers real

incentive for investment by the seed company.

In addition to market potential the activities in Latin American countries speed up research for both their farmers and U. S. farmers by assuring two strong generations of research per year. This means, of course, that new developments can be incorporated in much less time and very significantly in our Latin American relationships, foundation increases can be made in the off season to put the improved product in the producers fields a year sooner. Winter testing, also, gains valuable additional replications over new environments giving more assurance prior to release. Screening for drought resistance, cold tolerance, or disease and insect resistance may be accomplished better in Latin America than anywhere else. At times international activities result in beneficial germplasm exchanges such as for nutritive value or specific adaptation. Not to be overlooked, and of major significance, is the satisfaction of seeing crop improvements improving the productivity of a country and the relative status of the individual farmer.

SITUACION ACTUAL DEL CULTIVO DEL SORGO EN EL SALVADOR

Ing. Roberto Arias

Importancia de los Sorgos Graníferos y Forrajeros

El sorgo ha sido un cultivo de relativa importancia en el país desde hace algunos años, y es ahora considerado como un suplemento lógico del maíz, debido a la creciente escasez de este cereal y el crecimiento exponencial de la población en nuestro país.

La producción de sorgo en áreas menos aptas para el maíz solventaría por lo menos en parte la escasez de harinas para la producción de tortilla, que es parte de la dieta básica de nuestro pueblo. Por otro lado la utilización del grano de sorgo en la alimentación animal permitiría que se usase menor cantidad de maíz para este menester y destinarlo a la alimentación humana.

En comparación con otros granos básicos, el sorgo ocupa el segundo lugar en lo que respecta al producto territorial bruto del sector agropecuario, como se demuestra en el Cuadro 1.

PRODUCTO TERRITORIAL BRUTO DEL SECTOR AGROPECUARIO
PRODUCTO A PRECIOS CORRIENTES
RETROSPECTIVA 1970-1972

Producto	Cifras absolutas 1970	1971	1972
	Millones en colones		
Total Agropecuario	724.8	723.5	740.5
1 Agricultura	550.6	551.0	549.4
Café	295.8	279.0	279.6
Granos básicos	105.3	105.5	71.6
Maíz	48.7	48.3	26.5
Sorgo	25.4	23.7	21.6

Producto	Cifras absolutas 1970	1971	1972
	Millones en colones		
Frijol	18.8	19.2	15.0
Arroz	12.4	14.3	8.5
Algodón	71.6	80.2	103.5
Fibra	56.9	62.9	82.3
Semilla	14.7	17.3	21.2
Caña de Azúcar	22.7	30.8	37.2
Azúcar	20.9	29.4	36.0
Panela	1.8	1.4	1.2
Otros Agrícolas	5.9	5.7	6.5
Tabaco	3.3	2.8	3.6
Henequén	1.0	1.1	1.0
Kenaf	1.6	1.8	1.9
Otros Productos	49.1	49.8	51.0
2 Ganadería	95.4	91.7	102.5
3 Avicultura	39.0	37.7	40.4
4 Silvicultura	23.5	24.5	25.6
5 Pesca	15.7	17.3	20.0
6 Apicultura	0.7	1.3	2.6

En el Cuadro 2 se puede observar la superficie, producción y rendimientos promedios nacionales en los últimos cinco años.

Cuadro 2. SUPERFICIE, PRODUCCION Y RENDIMIENTO DE SORGO EN EL SALVADOR

Año Agrícola	Superficie sembrada Ha.	Producción Ton.	Rendimiento Kg/Ha.
1968/69	113,803	122,273.64	750
1969/70	113,855	126,550.00	777
1970/71	124,180	145,440.91	818
1971/72	126,000	154,545.45	859
1972/73	130,480	144,090.91	773
1973/74 1/	119,000	154,545,45	909

1/ Pronóstico

Como se puede observar en el cuadro anterior, el rendimiento promedio nacional es bastante bajo, podemos afirmar que se debe a tres factores principales; 1°) El uso de variedades criollas con bajo potencial de rendimiento en la mayor parte del área sembrada, 2°) El 96% de la superficie sembrada de sorgo es en asocio con otros cultivos y 3°) Las tierras destinadas al cultivo del sorgo en El Salvador por lo general son zonas marginales.

Utilización de los Sorgos de Grano

El sorgo ha sido utilizado en la alimentación humana en nuestro país desde hace varios años, en el Cuadro 3 se puede observar el consumo aparente y percápita de sorgo para dos años agrícolas.

Cuadro 3. CONSUMO APARENTE Y PER-CAPITA DE SORGO

Año Agrícola	Consumo aparente Ton.	Consumo Per-Cápita lbs.
1972-1973	136,129	78
1973-1974	132,266	86

Otros usos del grano de sorgo se pueden observar en el Cuadro 4.

Cuadro 4. GRANO DE SORGO USADO POR LA INDUSTRIA COMO MATERIA PRIMA

Volumen y valor 1971-1972

Utilización	Año	Cant. Consumida Origen			Valor colones Origen		
		Nac.	Extr.	Total	Nac.	Extr.	Total
Tostadurías y moliendas de café.	1971	549	---	549	85,000	---	85,000
	1972	488	---	488	70,000	---	70,000
Fabricación de concentrados.	1971	19,620	---	19,620	3,135.00	---	3,135.00
	1972	14,306	---	14,306	2,028.00	---	2,028.00
Harina de sorgo para la fabricación de concentrados.	1971	2,159	---	2,159	350,00	---	350,00
	1972	2,588	---	2,588	331,00	---	331,00

La demanda de sorgo se ha incrementado con año, sin embargo la oferta en los últimos años ha sufrido un colapso, debido a problemas en aspectos de créditos para los productores y la comercialización del grano. Debido a la escasez de créditos adecuados los productores tienen que vender a los precios bajos que ofrecen los intermediarios transportistas.

La producción de 1974-1975 se incrementará, debido al gran impulso que se ha dado al cultivo del sorgo y debido a que ya se sembraron 2000 mz. de semilla mejorada producida por el Departamento de Fitotecnia del Centro Nacional de Tecnología Agropecuaria.

Investigación

Tomando en cuenta los factores que merman la producción, en 1971 el programa de sorgo se delineó de tal manera que a corto plazo se desarrollaran híbridos y variedades insensibles al fotoperiodo, con alto potencial de rendimiento, resistentes a plagas y enfermedades,

precoces y con características de planta baja.

Pensando en el sorgo como el lógico complemento del maíz en la dieta humana y como el substituto del maíz en la nutrición animal el programa de sorgo ha laborado con una política que permite formar variedades e híbridos aptos para el consumo humano y para la nutrición animal.

Objetivos

1. Desarrollar variedades de polinización libre con gran capacidad de producción, resistentes a plagas, enfermedades y pájaros e insensibles al fotoperíodo (cuatro cosechas en el año contando con riego y dos cosechas en el año bajo condiciones de temporal) y aptas para el consumo humano y animal.
2. Desarrollar variedades de planta baja con la idea de aumentar la densidad de población y como consecuencia la productividad.
3. Desarrollar híbridos con elevado potencial de rendimiento y características agronómicas superiores, utilizando esterelidad citoplásmica o androesterelidad.
4. Desarrollar variedades con valor nutritivo superior.
5. Obtener información sobre prácticas agronómicas aplicables a las nuevas variedades e híbridos.

Avances

1. Como resultado del mejoramiento genético por el método genealógico, en 1973 se obtuvo la primera variedad mejorada apta para el consumo humano. En el Cuadro 5 se hace una descripción de ella.

Cuadro 5. CARACTERISTICAS DE LA VARIEDAD MEJORADA CENTA S-1

Característica	Descripción
Rendimiento	6-6.5 Ton. M/HA.
Días a Floración	45-50
Días a Madurez	95
Ahijamiento	Poco
Altura de Planta	1.20 mts.
Tipo de Panoja	Compacta
Tamaño de Panoja	28 cms
Tamaño de Grano	Grande
Color del Grano	Blanco

En 1974 se obtuvieron 43 variedades nuevas de las cuales 28 fueron sometidas a ensayos de rendimiento, en el Cuadro 6 se muestran los rendimientos de las 12 mejores entradas.

Cuadro 6. RENDIMIENTO EN TON. M/HA. AL 15% DE HUMEDAD SANTA CRUZ PORRILLO, EL SALVADOR. 1974

Variedad	Origen	Altura de Planta	Rendimiento TM/HA.
I-22	E.S.**	2.90 M.	14.16
I-54	"	3.08 "	13.36
I-62	"	2.45 "	11.03
I-58	"	1.35 "	10.33
I-50	"	1.24 "	9.56
I-55	"	1.68 "	9.30
Dorado M*	Asgrow	1.27 "	9.30
I-51	E.S.	1.20 "	9.13
I-47	"	1.09 "	7.70
I-59	"	1.27 "	7.60
Centa S-1	"	1.22 "	7.55
Bravis-R*	Asgrow	1.22 M.	5.30

* Testigos
** El Salvador

Además en 1974 se obtuvieron 52 híbridos simples los cuales serán sometidos a ensayos de rendimiento en 1975.

Actualmente se cuenta con 1,000 líneas en diferentes fases de endogamia y se han realizado cruzas entre las variedades mejoradas y variedades criollas para obtener material segregante. Recientemente se introdujeron dos poblaciones de CIMMYT y una de Mayaguez como fuente de germoplasma.

ESTADO ACTUAL DEL CULTIVO DE SORGO EN MEXICO

Hermilo H. Angeles[1]

Importancia

El cultivo del sorgo ocupa un lugar de gran importancia en México dentro del grupo de los principales cultivos agrícolas del país. En cuanto a superficie, el sorgo en 1972 ocupó un cuarto lugar, ya que en ese año se sembraron más de 1.1 millón de hectárea con una producción total de 2,860,000 toneladas de grano y un rendimiento medio de 2,600 kilos por hectárea, como puede observarse en la Figura 1. En esta misma figura puede observarse también que en un período de 13 años, de 1960 a 1972, el cultivo del sorgo tuvo un incremento muy notable en México, tanto en superficie, cerca de 1 millón de hectárea, como en rendimiento unitario, más de 1,000 kilos por hectárea.

Este notable incremento es la importancia del cultivo del sorgo se debió en parte a la facilidad de su cultivo y a que, por la disponibilidad creciente para 1960 de híbridos de sorgo de alto potencial de rendimiento formados en los Estados Unidos de Norteamérica, pudo ser un sustituto satisfactorio en las zonas de riego para cultivos de exportación como el algodón, que por la inseguridad de su precio en el mercado internacional y por su alto costo de cultivo debido a las plagas y enfermedades que lo afectan se ha visto muy reducido en sus áreas de cultivo. Esto se corrobora por el hecho de que actualmente el sorgo ocupa en México el tercer lugar entre los cultivos agrícolas de riego.

[1]Jefe del Departamento de Maíz y Sorgo del Instituto Nacional de Investigaciones Agrícolas S.A.G. México.

El sorgo, aunque es uno de los principales cultivos bajo condiciones de riego, también es bastante cultivado en regiones de buen temporal y está empezando a ser cultivado cada vez más en regiones de temporal regular y escaso.

En la Figura 2 se muestran cuales son las regiones más importantes de cultivo del sorgo en México; estas regiones se encuentran localizadas principalmente en los siguientes estados, de acuerdo con su orden de importancia: Tamaulipas (riego y temporal), Guanajuato (riego y temporal), Jalisco (temporal), Sinaloa (riego y temporal), Michoacán (temporal) y en Nuevo León, Sonora y Coahuila exclusivamente de riego.

Utilización

Casi la totalidad de la producción sorguera en México se dedica a la alimentación pecuaria; aproximadamente el 85% se dedica a la elaboración de alimentos balanceados para aves y ganado; un 10% para forraje, un 3% para la elaboración de escobas, principalmente en los estados de Nuevo León, Coahiula, Tamaulipas y un poco menos en Michoacán y Sinaloa, y el 1.5% se dedica a la industria para la elaboración de gomas, pegamentos y barnices. El sorgo en México no ha sido utilizado en la alimentación humana, sin embargo este tipo de empleo ya empieza a ser explorado por las autoridades del país y no es de dudarse que en un futuro el sorgo pueda complimentar o substituir en parte al maíz como alimento humano.

Investigación Agrícola

Los trabajos de mejoramiento genético y agronómico del sorgo en México se realizan principalmente por el Departamento de Maíz y Sorgo

del INIA[2]. Este Departamento cuenta con ocho especialistas de diversos grados académicos que realizan investigación principalmente en sorgo en las diferentes regiones sorgueras del país y otros 36 investigadores, también de diversas categorías académicas, que aunque dedicadas también al maíz, realizan trabajos agronómicos y de evaluación de rendimiento, tanto de sorgos experimentales formados en los programas nacionales, como de sorgos comerciales nacionales y sorgos extranjeros, propiedad estos últimos de Compañías Privadas de Semillas. En parte estos trabajos se realizan para el Comité Calificador de Variedades de Plantas que es el organismo que decide en base a las pruebas de evaluación del INIA, que unidades deben recomendarse para siembra en las diferentes regiones. Los trabajos de investigación de prácticas culturales y de evaluación que realiza el INIA se efectúan prácticamente en todas las regiones agrícolas del país en más de 40 Estaciones Experimentales y en terrenos de agricultores cooperantes, mientras que los trabajos de mejoramiento genético sólo se llevan a cabo por el momento en los Centros Regionales de Investigación del CIAB en Roque, Guanajuato, del CIAT en Río Bravo, Tamaulipas y del CIAMEL en Chapingo, México.

Además del INIA, otras instituciones que realizan investigación en el cultivo del sorgo en México son: la Rama de Genética del Colegio de Postgraduados de la Escuela Nacional de Agricultura de Chapingo, México. Esta institución educativa realiza investigación en sorgo con profesores de tiempo completo y tesis de estudiantes de Maestría y Doctorado en Ciencias y ha enfatizado más su investigación sobre aspectos fisiotécnicos del sorgo, la resistencia al frío, esterilidad

[2] Instituto Nacional de Investigaciones Agrícolas, SAG, México.

ecológica y productividad del sorgo a alturas mayores a 2,000 metros sobre el nivel del mar.

Otras instituciones que también realizan investigaciones en el cultivo del sorgo en México son el Instituto Tecnológico de Estudios Superiores de Monterrey y el Centro Internacional de Mejoramiento de Maíz y Sorgo. Extra oficialmente se sabe que unas pocas Compañías de Semillas también realizan algo de investigación en el cultivo del sorgo.

Objetivos de la Investigación del INIA en el Cultivo del Sorgo

Los objetivos principales de estos trabajos son los de obtener variedades e híbridos de altos rendimientos y calidad nutritiva, así como de características agronómicas, superiores a la de los sorgos importados; entre estas características pueden mencionarse: precocidad, resistencia a escasa humedad, a bajas temperaturas, a enfermedades, plagas, acame y en general a otras eventualidades.

Los objetivos anteriores se pretende lograrlos mediante la realización de los siguientes principales proyectos de investigación que ya se encuentran en marcha:

A. Mejoramiento genético

1. Formación de variedades e híbridos para condiciones de riego y buen y mal temporal, tanto para las regiones tropicales secas como para las húmedas y para las regiones templadas de alturas intermedias sobre el nivel del mar, o para los Valles Altos, en los cuales hasta el momento no se cultiva sorgo porque los híbridos comerciales disponibles no producen grano.
2. Introducción de materiales experimentales adaptados de características agronómicas deseables tales como: resistencia a

Downy mildew, al carbón, a la mosquita midge, grano doble, planta baja, esterilidad masculina, mejor calidad nutritiva, precocidad, endosperma amarillo, etc.

3. Estudio de numerosas variedades provenientes de la colección mundial de sorgo para ver sus posibilidades de utilización directa o para fuentes de germoplasma en los programas de mejoramiento genético locales por contener algunas de las buenas características agronómicas mencionadas.

4. Utilización de la radiación para la creación de variabilidad genética

B. Estudios de prácticas culturales: fechas de siembra, densidad de población y espaciamiento, fertilización, sistema de siembra, doble cosecha, etc.

C. Trabajos de evaluación regional de rendimiento en materiales experimentales y comerciales para fines de investigación y de recomendación de siembra.

D. Como investigaciones especiales se tienen, entre otros, los proyectos siguientes:

1. Estudio de probadores de líneas A y R para determinar su Aptitud Combinatoria sin tener que realizar todos los cruzamientos posibles.
2. Estudios de tamaño y forma de parcela óptima experimental.
3. Corrección de fallas.
4. Selección individual y masal.
5. Estudios fenológicos de líneas progenitoras mexicanas y sus híbridos.
6. Estudios de heterosis y su abatimiento en generaciones

avanzadas.

7. Estudios de Estabilidad y de Interacción Genotipo - Medio Ambiente en los híbridos y variedades de sorgo formadas en México.

Resultados y Avances más Sobresalientes de los Programas del INIA

1. Obtención de los primeros seis sorgos híbridos mexicanos: Chichimeca, Punépecha, Olmeca, Tepehua, Nahuatl y Otomí con características agronómicas y de rendimiento similar, o en algunas cosas superiores, a los sorgos importados recomendados para las regiones del Bajío.
2. Obtención de las prácticas culturales más adecuadas en las principales regiones sorgueras del país sobre: recomendación de los híbridos más rendidores, fechas de siembra óptimas, mejores densidades de población, espaciamiento, fertilización y combate de plagas, enfermedades, y malas hierbas y en algunos casos sistema de siembra y doble cosecha.
3. De los trabajos anteriores se formaron en México grupos de líneas A con esterilidad masculina, sus líneas mantenedoras B y líneas restauradoras R. Con estas líneas se integraron 400 híbridos experimentales mexicanos de cuya evaluación sobre años y localidades y después de estudios de "Estabilidad", en 1975 se entregarán para producción comercial unos 20 híbridos más, para siembra en varias de las principales regiones sorgueras del país en los estados de Tamaulipas, Sinaloa, Sonora, Michoacán, Coahuila, Guerrero, Oaxarea, y Yucatán y otro nuevo grupo más para la región del Bajío en los estados de

Guanajuato y Jalisco, principalmente.

4. Durante 1975 se entregarán para producción comercial las primeras variedades mexicanas de polinización libre que con una alta seguridad producirán cosechas satisfactorias de grano en regiones de temporal de los Valles Altos del país con alturas sobre el nivel del mar entre 1,900 y 2,350 metros.

Problemas más Importantes en el Cultivo del Sorgo

1. Enfermedades principales: Downy mildew (Cenicilla vellosa), Antracnosis (muermo rojo), Manchas foliares (Tizones), carbón, pudriciones de tallo y raíz, y royas (chahuixtle).
2. Plagas principales: Mosquita midge, pulgón, cogallero y barrenador del tallo y pájaros.
3. Falta de aplicación de las mayores prácticas culturales recomendadas en: fertilización, densidad de población, fechas de siembra, variedad más adecuada, etc.
4. Falta de investigación para obtener variedades más precoces, más resistentes a deficiencia, o exceso de humedad y en general más rústicas y que puedan servir también para alimentación humana.
5. Falta de más personal científico, preparado y especializado, para realizar toda la investigación básica y aplicada necesaria en el país.
6. Falta de crédito y asistencia técnica al agricultor, así como de una mayor infraestructura agrícola.

Cooperación Internacional

Se considera que la forma más efectiva de ayuda de los organismos

internacionales a México en el cultivo del sorgo, sería compartiendo directamente con los programas de mejoramiento locales, que se están integrando con grandes esfuerzos técnicos y económicos, todos los materiales, experiencias y resultados de investigación que les sea factible.

Perspectivas para el Futuro Próximo

Debido al rápido crecimiento demográfico de México y en consecuencia de la demanda correspondiente de sorgo, es probable, que de no acontecer eventualidades perjudiciales climáticas, México será suficiente para abastecer una demanda interna de poco más de tres millones de toneladas en 1976 y de cuatro millones en 1982. Sin embargo, el rendimiento unitario se incrementará más lentamente porque en el futuro próximo se sembrará menos sorgo de riego y más de temporal regular y malo y la superficie, aunque también se incrementará, será a un ritmo mucho menos que el notable incremento observado en el cultivo del sorgo en México en los últimos 13 años.

PROBLEMAS AGRONOMICOS DE LA PRODUCCION Y DE LA UTILIZACION DEL SORGO EN VENEZUELA

Helio Campos Giral

Los problemas del sorgo en Venezuela son muy similares a los existentes en muchos países de la América Latina.

Problemas agronómicos de producción

1. Baja fertilidad natural del suelo con uso inadecuado de fertilizantes y, en ocasiones, sin uso de los mismos. Generalmente se piensa que el sorgo es un cultivo muy rústico, destinado a ser producido en tierras marginales y que, consecuentemente, "puede producirse en cualquier parte sin demasiado cuidado".

   De conformidad con experiencias provenientes de otras áreas agrícolas, hemos determinado que el sorgo responde tan bien o mejor que cualquier otro cultivo tanto a los fertilizantes como a las buenas prácticas agronómicas.

   Los niveles bajos de Fósforo resultan críticos para la producción económica, en tanto que niveles de Potasio extremadamente bajos también resultan limitantes. Se requieren niveles adecuados de Nitrógeno y se han determinado muy buenas respuestas a los reabonamientos de dicho elemento, especialmente cuando se trata de suelos arenosos.

2. Uso de suelos marginales altamente ácidos. Se han experimentado algunos fracasos cuando el sorgo ha sido plantado en suelos arenosos ácidos, con un elevado contenido de Aluminio y cuando esta condición no ha sido previamente corregida con Caliza Agrícola. Aplicaciones de 1 a 2 toneladas de Caliza Agrícola por hectárea, incorporadas por lo menos 20 días antes de la siembra, han demostrado ser

económicas.

3. Poblaciones inadecuadas de plantas. Existe la tendencia de emplear una población de plantas mayor que la recomendada. Se recomienda una población de 300.000 a 350.000 plantas por hectárea bajo perspectivas de lluvia relativamente buenas. La práctica actual de siembras al voleo parece requerir más pruebas para que puedan ser determinadas las poblaciones que deban recomendarse. Algunas observaciones realizadas directamente sobre el terreno indican que se requieren densidades mayores para lograr un rendimiento óptimo. Los agricultores han adoptado el sistema de siembras al voleo para obtener una operación más rápida y mayor economía.

4. Falta de uso de irrigación suplementaria. Como en muchas áreas la precipitación lluviosa resulta errática, con períodos cortos a medianos de sequía, aunque la cantidad total de lluvias pudiera ser mayor que la necesaria ocurren fallas en su distribución. A los fines de obtener mayores rendimientos debería disponerse de facilidades de irrigación durante la estación lluviosa.

5. Control de malas hierbas e insectos. Con miras a la obtención de mejores rendimientos es necesario prestar más atención al control eficiente de hierbas e insectos.

   Consideraciones especiales merecen el gusano "cogollero" (Spodoptera frugiperda), el jején o mosca del ovario (Contarinia sorghicola) y las aves migratorias, en especial el pájaro arrocero (Spiza americana).

6. Disponibilidad de buenos híbridos de sorgo. Los híbridos norteamericanos se usan común y ampliamente. Sin embargo, se necesitan materiales mejor adaptados a las condiciones tropicales. En la

"Productora de Semillas" (Proseca) hemos iniciado un programa de mejoramiento y contamos con nuevos híbridos muy promisores, que han mostrado comercialmente excelentes condiciones agronómicas y alto potencial de rendimiento.

7. Prácticas de cosecha. Para la producción comercial es una necesidad el uso de "combinadas" ó cosechadoras-trilladoras. Existe limitación de operadores bien entrenados, servicios y repuestos. Con los híbridos actuales no se puede esperar hasta que la humedad del grano baje al 15%, por consiguiente se requieren facilidades de secado cerca de las áreas de cultivo.

Problemas de utilización

El sorgo granero es un sustituto del maíz y del trigo en alimentos para animales. En los primeros años (1.942 - 1.960) existía en Venezuela suficiente maíz amarillo a precios convenientes. Posteriormente, debido a las inmensas cantidades de cereales requeridos, dependíamos del trigo US #2 importado de USA, que se encontraba en amplias cantidades y a precios bajos. En 1.970, por decreto oficial, se eliminó el subsidio del trigo, haciéndolo antieconómico para alimentos de animales. Para entonces, el único cereal barato era el sorgo granero y así, nos cambiamos para él.

Era la idea de que el arroz podría ser usado, pero sus extremadamente altos precios locales lo eliminaban para usarse en alimentos animales, agravado por la necesidad de trillarlo mermando en peso un 20% además del costo de trillado, con lo cual se encarece su parte útil.

Al mismo tiempo, los precios del sorgo granero no eran atractivos para que el agricultor lo cultivara, así que desde entonces hemos

estado importando el sorgo que se obtenía a muy bajos precios. Cuando el sorgo reemplazó al trigo en los concentrados, ocurrieron algunos problemas:

1. Cohesión de los gránulos (pellets). Los gránulos producidos usando sorgo eran fácilmente rompibles. Se agregaron algunos productos como una solución parcial (Ligno-sulfonatos). Esto es un verdadero problema en los alimentos para cerdos y aves.
2. Bajo aspecto cualitativo de los gránulos; lucen menos atractivos, y con aspecto sucio.
3. Algunos nutricionistas opinan que alimentos con sorgo son menos apetecibles para las vacas. Parece haber resistencia inicial a comer los gránulos con sorgo.
4. Menos energía disponible que en maíz o trigo, lo que hace necesario el agregado de algún aceite o grasa para mantener iguales niveles de energía.
5. El alto contenido de Taninos en algunos híbridos ha resultado dañino por reducir la rata de conversión para aves. Esto se puede resolver agregando a costos adicionales algunos aminoácidos esenciales.

Niveles de utilización

Como alimento para aves:

Para pollos de engorde ..... 57 a 65%

Para aves ponedoras ..... 60 a 65%

Como alimento para cerdos: entre ..... 65 a 75%

Los alimentos para aves y cerdos representan para nosotros casi el 95% de nuestra producción (45.000) toneladas por mes en dos plantas).

esde los comienzos de nuestras operaciones (1.942) Protinal ha estado onsiderablemente preocupada por el desarrollo agrícola del país. Gran arte del trabajo hecho en Venezuela en materia de producción de sorgo y soya tiene que ser acreditado a Protinal. Por primera vez el año pasado fuimos capaces en el país de producir más de 50.000 Tons. de sorgo, en tanto que los programas oficiales y privados para el presente año (1.975) aspiran a sembrar más de 100 mil hectáreas de sorgo, con perspectivas de producir más de 250 mil Tons. de granos, o sea, casi el 50% de nuestras necesidades.

RESUMEN DE LA SITUACION DEL SORGO EN NICARAGUA

Laureano Pineda L.[1]

El sorgo se cultiva en Nicaragua desde hace muchos años, el cual ha permanecido en manos de pequeños agricultores; sin embargo hasta hace poco tiempo ha venido experimentando cambios debido a las necesidades cada vez más crecientes de las industrias elaboradoras de alimentos concentrados tanto para aves como para ganado vacuno, los cuales demandarán grandes cantidades de sorgo para ser utilizados como materia prima.

Hasta la fecha, uno de los mayores obstáculos con que tropieza el desarrollo del sector agropecuario, es la defectuosa estructura agraria existente en el país, identificada por la concentración en pocas manos de la mayor parte de la tierra cultivable. Esto es muy importante puesto que la falta de tributación territorial constituye un factor desfavorable al mejoramiento del rendimiento de la tierra y productividad PER-CAPITA, lo cual perpetúa al estancamiento económico y social de un alto porcentaje de la población.

Zonificación Ecológica - El Sorgo en Nicaragua se siembra en una diversidad de climas.

El país está dividido en zonas que se detallan a continuación:

PN = Pacífico Norte

PC = Pacífico Central

[1]Jefe del Departamento de Fitotecnia del Centro de Enseñanza, Investigación y Extensión Agropecuaria. "CEIEA"

PS = Pacífico Sur

IN = Interior Norte

IC = Interior Centre

IS = Interior Sur

RA = Región Atlántic

Como puede observarse en el Cuadro 1, existen un total de 329,550 manzanas que se consideran como óptimas pero sin embargo sería conveniente localizar el área del Sorgo por cultivarse en aquellas zonas donde se pueda hacer una agricultura moderna.

AREAS DE PRODUCCION - De los datos obtenidos de la División Agropecuaria del Departamento de Estudios Económicos del Banco Central de Nicaragua, mostraron que la tasa media de crecimiento del cultivo del Sorgo durante los últimos años ha sido superior a la de maíz y frijol considerados estos como alimentos básicos en la dieta nicaraguense, Cuadro 2.

PROBLEMAS DEL CULTIVO - En Nicaragua el principal problema, es que este cultivo su mayor área se encuentra en manos de pequeños agricultores no tecnificados llegando esta al 80% que comparados con los cultivos más tecnificados que son aquellos para la exportación, como el algodón, caña, tabaco y banano cuya área tecnificada es del 90, 59, 93 y 100 por ciento respectivamente, hacen que el cultivo del sorgo sus promedios de rendimientos (16 qq/Mz) sean demasiado bajos, debido al bajo porcentaje de su área tecnificada 20%.

CANALES DE MERCADEO - Como en su mayoría el sorgo se consume internamente en Nicaragua, los canales de mercadeo pueden ser dos a saber:

1. Venta del Agricultor al Comerciante

Cuadro 1. Nicaragua: Zonificación Ecológica para el cultivo del Sorgo por regiones (Area en manzanas).

Rango de Adaptabilidad	REGIONES								
	P.N	P.C	P.S	I.N.	I.C	I.S	R.A	TOTAL	%
Optimo	95.850	177.500	-	-	42.000	14.200	-	329.550	18.8
Bueno	266.250	230.750	53.250	28.400	71.000	177.500	241.400	1063.550	61.1
Marginal	88.750	53.250	21.300	99.400	53.250	17.750	17.750	351.450	20.1
TOTAL	450.850	461.500	74.550	127.800	166.250	209.450	259.150	1759.550	

Fuente: UNASEC

Cuadro 2. Area de Cultivos Agrícolas

Cultivos	1969/70	1970/71	1971/72	1972/73	1973/74 1/	Tasa Media de Crecimiento 1969/70 - 1973/74
	Miles de Manzanas					Porciento
Algodón	155.0	136.2	156.0	210.9	259.4	15.17
Ajonjolí	16.4	14.0	11.0	7.3	9.7	4.0
Café	124.3	120.1	118.4	118.6	118.9	1.05
Caña	43.4	48.0	49.5	50.2	51.2	4.32
Arroz	35.8	36.0	37.3	37.4	40.8	3.42
Maíz	366.5	369.4	379.6	301.5	316.9	2.95
Frijol	83.2	87.7	88.9	87.0	91.0	2.32
Sorgo	80.4	80.6	79.4	53.9	79.1	3.40
Tabaco Habano	0.5	0.6	0.7	0.7	.7	9.17
Tabaco Rubio	0.9	0.9	0.9	0.9	1.1	5.57

1/ Cifras Preliminares
8 agosto 1974.

2. Venta del Agricultor al INCEI (Instituto Nacional de Comercio Exterior e Interior).

COMERCIALIZACION - Para la venta del producto existen ciertas normas de calidad cuando se venden al INCEI. Dichas normas son:

Humedad	%	13
Granos quebrados	%	4
Granos dañados	%	5
Materias extrañas	%	2

PRECIOS EN MERCADO INTERNO - No existe una política de parte del estado a fin de establecer un precio de sosten, Cuadro 3.

FINANCIAMIENTO - El Banco Nacional de Nicaragua así como otros Bancos de la República a través de sus cajas de crédito han venido otorgando préstamos, los cuales han sido distribuidos como los muestra el Cuadro 4.

USOS Y DESTINOS DE LA PRODUCCION - De la producción total se estima de la siguiente forma:

85% Consumo animal e industrial

8% Consumo Humano

4% Pérdidas

1.4% Semillas para siembras

1.6% Exportaciones

ESTIMACION DE COSTOS DE PRODUCCION - El costo de producción del sorgo para grano, varía de acuerdo con muchos factores entre los que se pueden mencionar: la zona del cultivo, la productividad del terreno, la maquinaria usada, la proximidad del mercado, la disponibilidad de maquinaria,

Cuadro 3. Precio en el Mercado Interno

			1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	1974
Precio de Garantía	$/qq.	INCEI							14.0	17.0	30.0	40.0
Precio al Productor	"	INCEI								25.0	39.8	
Precio al Productor	"	DEE-BCN	23.6	23.0	22.5	20.0	22.5	26.6	25.6	26.7		
Precio al Consumidor	$/lb.	INCEI	25.4	32.4	36.3	34.4	22.5	33.3	33.2	35.9	54.1	
Precio al Consumidor	$/lb.	MAG.	25.1	24.3	32.7	31.9	17.8	25.8	28.6	26.4	41.0	

FUENTE:

División Agropecuaria del Departamento de Estudios Agronómicos del Banco Central de Nicaragua.

Cuadro 4. Financiamiento Concedidos por el Banco Nacional y Otros Bancos de la República

		1968/69	1969/70	1970/71	1971/72	1972/73	1973/74
Habilitaciones Totales	Mzs.	13.736.0	16.111.0	4.093.0	7.964.0	6.071.0	16.511.0
Habilitaciones promedio por manzana	$/mzs.	485.4	486.1	333.3	590.3	525.9	661.7
Habilitaciones BNN	Mzs.	11.242.0	13.477.0	4.093.0	5.364.0	5.431.0	14.775.0
Relación % BNN/Total	%	81.8	83.7	100.0	67.4	89.5	89.5
Habilitación por manzana BNN	$/mzs.	453.0	467.2	333.3	421.9	523.5	665.6
Habilitación otros Bancos	mzs.	2.494.0	2.634.0	---	2.600.0	640.0	1.736.0
Relación	%	18.2	16.3	---	32.6	10.5	10.5

FUENTE:

División Agropecuaria del Departamento de Estudios Agronómicos del Banco Central de Nicaragua.

cosecha y secamiento, etc. Existen en los diferentes organismos relacionados con la agricultura en el país, estimaciones del costo del cultivo de sorgo, pero todas adolecen de una u otra deficiencia pues ninguna se basa en datos estadísticos recogidos en cada una de las zonas de producción del país.

INVESTIGACIONES REALIZADAS EN EL PAIS - Los servicios de investigacion en el país han estado a cargo del Ministerio de Agricultura, el cual tropieza con una serie de problemas para llevar a cabo sus objetivos, ya que hacen falta más centros de experimentación en las distintas zonas ecológicas y climáticas. Por otra parte, la escasez de técnicos especializados ha limitado los trabajos de investigación, además de que con presupuesto insuficientes no se ha podido estudiar ampliamente todos los problemas que conciernen a este cultivo.

ADELANTOS ALCANZADOS - A pesar de los problemas presupuestarios con que ha tropezado la investigación en el cultivo del sorgo, se ha logrado recopilar una información bastante satisfactoria tanto en el aspecto varietal como en el de prácticas agronómicas, ya que actualmente se siembran en el país 25,000 manzanas con variedades híbridas completamente tecnificadas.

TECNICOS QUE LABORAN EN EL PROGRAMA - Actualmente laboran en el programa dos técnicos, un ingeniero agrónomo, encargado del programa y un asistente, por otra parte hay alumnos de la Escuela Nacional de Agricultura y Ganadería que realizan Tesis

FACILIDADES CON QUE CUENTA EL PROGRAMA - Nicaragua cuenta con cuatro centros experimentales.

"Centro Experimental del Algodón" en la parte Occidental.

"Centro de Enseñanza, Investigación y Extensión Agropecuaria" en el Pacífico Central.

"Estación Regional de Diversificación Agrícola" en la parte Pacífico Central Oriental.

"Estación Regional El Recreo" Zona Atlántica.

Actualmente se cuenta con un laboratorio de Suelos y Entomología y a punto de montarse un laboratorio de Fitopatología Los liceos Agrícolas forman parte como entidades del Programa.

ESTADO ACTUAL DEL CULTIVO DE SORGO EN EL PERU

Hugo Sánchez Campos*

El sorgo se cultiva en las tres regiones del país. Prospera sobre todo en la costa norte donde, con temperaturas prevalentes más adecuadas, se siembra todo el año; se le cultiva también en la costa central y sur del país, en las zonas bajas y abrigadas de la sierra, teniendo un alto potencial en la región de la selva.

El cultivo del sorgo viene incrementándose en el país. La superficie cultivada con sorgo granífero fue de 555 hectáreas en 1967 para alcanzar 6,236 hectáreas en 1973. La producción en los años indicados fue de 1,593 y 18,935 toneladas, respectivamente.

El incremento señalado se debe a que el sorgo granífero viene constituyéndose en un complemento del maíz amarillo para la preparación de alimentos balanceados. En conjunto, el maíz amarillo duro y el sorgo granífero, totalizaron en 1973 una extensión de 80,574 hectáreas con una producción de 242,616 toneladas de grano.

Los organismos técnicos oficiales haciendo una proyección de los posibles incrementos del cultivo de sorgo, han considerado las siguientes metas:

Año	Hectárea	Toneladas
1974	9,350	30,921
1975	11,500	41,000
1976	14,000	52,800
1977	17,000	67,900
1978	21,000	86,500

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El sorgo granífero se utiliza básicamente en la preparación de alimentos balanceados para aves y cerdos, como forraje verde y en escala mínima, se utiliza en la alimentación de ganado lechero principalmente; en reducida proporción se utiliza también para la fabricación de escobas

La producción nacional de maíz amarillo y sorgo granífero señalada para 1973, no ha cubierto, sin embargo, las necesidades reales de estos granos para la elaboración de alimentos balanceados. Las restricciones oficiales para el consumo de carnes rojas en el país ha determinado un extraordinario desarrollo de la industria avícola y la consiguiente necesidad de alimentos balanceados. En 1973 se estimó una población de 50 millones de aves, que demandó una producción de 500 mil toneladas de alimentos aproximadamente. Fue necesario, por tanto, recurrir a la importación de estos dos granos, la misma que alcanzó en el año antes señalado a 219, 500 toneladas de maíz y 25,000 toneladas de sorgo.

De este modo, las 244,500 toneladas importadas unidas a la producción nacional (242,616 toneladas) totalizaron 487,116 toneladas de granos que se emplearon en la producción de alimentos para aves principalmente.

Los sorgos forrajeros vienen también promocionándose aún cuando el hectareaje a la fecha es reducido, empleándose la producción en la alimentación del ganado lechero.

Aún cuando hasta la fecha no se le ha dado toda la importancia que tiene la investigación en sorgo, existen sin embargo, varias entidades públicas y privadas que de una u otra forma tratan de llevar adelante los trabajos afines con esta gramínea.

Cómo entidades oficiales, dependientes del Ministerio de Agricultura se cuenta con las siguientes:

Con sede en Lima, en la Estación Experimental Agrícola de La Molina, funciona el Departamento de Pastos y Forrajes, que involucra trabajos de mejoramiento y agronomía, con el siguiente personal técnico: Ing. Agr., M. S. Rubén Zambrano Ruiz; Ing. Agr. Heine Bruno Angeles e Ing. Agr. Enrique Torres Ocampo.

Con sede en Ica, Lambayeque y Piura, vale decir, donde el cultivo tiene las mayores e inmediatas posibilidades, funcionan los respectivos Programas de Pastos y Forrajes que incluyen al sorgo en su aspecto agronómico mayormente.

Además de las dependencias del Ministerio de Agricultura, existen en la Universidad Nacional Agraria - La Molina las siguientes entidades:

Programa de Pastos y Forrajes, involucrado principalmente en estudios agronómicos, nutricionales, de manejo de pasturas y mejoramiento. Funciona con el personal técnico siguiente: Ing. Agr., Ph.D. Oscar de Córdova; Ing. Agr., Ph.D. Arturo Flores e Ing. Agr., M.S. Hugo Soplin.

Programa Cooperativo de Investigaciones en Maíz, a través de la docencia: Ing. Agr., M.S. Hugo Sánchez Campos.

La empresa privada desarrolla igualmente una importante actividad en la promoción del cultivo de sorgo: Northrup King & Co., con sede en Lima y red experimental en el país - Dr. Alexander Grobman T. - Mejoramiento - Agronomía. Hortus S. A. Firma licenciada y distribuidora exclusiva en el Perú de Northrup King & Co. - Ing. Agr., M. S. Carlos Herrera M. - Producción de Semilla.

La investigación en sorgo aún no es muy específica en el país.

Básicamente se ha limitado a hacer evaluaciones de material introducido, el mismo que cronológicamente fue del tipo forrajero y granífero. Sin embargo paralelamente a la evaluación por rendimiento ha

correspondido una selección para características de precocidad, altura, ataque de insectos y/o enfermedades.

Como consecuencia existen a la fecha "variedades" adaptadas, tanto como forraje verde o híbridos graníferos. Desde 1949-52, en que se inició en el Ministerio de Agricultura la evaluación y selección de las variedades forrajeras Sugar Drip, Early Sumac y Kansas Sourless, se tiene a la fecha otras variedades forrajeras como FS-22, Haygrazer, Royal ZSH-100, Pioneer 985, Sorgo Azucarado LM-73 e híbridos de la Serie Sudan y Trudan de Northrup King, como Sordan-67, Sudax Sx-11, NK-320, NK-330. Los rendimientos de materia verde por corte en estas variedades fluctúan entre 27 y 93 T.M./Ha, obteniéndose de 1 a 3 cortes en estas variedades por lo que se alcanzan rendimientos hasta 125 T.M. de forraje verde/Ha y excepcionalmente hasta 8 cortes con 194 T.M. totales de forraje verde/Ha.

Actualmente el Programa de Pastos y Forrajes de la Estación Experimental Agrícola de La Molina evalúa periódicamente variedades procedentes de la colección mundial de sorgos, facilitadas por la Universidad de Purdue, Indiana, E.E.U.U., con la que mantiene una información permanente.

La empresa privada ha promocionado los híbridos graníferos, por lo que se dispone a la fecha de una serie de híbridos NK distribuidos por Hortus S.A., entre los que se cuentan el NK-25, NK-133, NK-210 y NK-212, Savanna, etc. con rendimientos que llegan hasta los 4,000 Kgs/Ha. Ultimamente la firma mencionada está produciendo algunos de sus híbridos en el país, por introducción de los progenitores y con características de androesterilidad genético-citoplasmática.

En el Programa de Pastos y Forrajes de la Universidad Nacional Agraria - La Molina, además de evaluarse el rendimiento, la investigación se orienta fundamentalmente a determinar mejor época de corte, valor nutritivo, producción de materia seca/Ha y finalmente, manejo de campo.

En el Programa de Maíz de la Universidad Nacional Agraria - La Molina no existe realmente un programa de sorgo. Sin embargo, se imparte instrucción a través de la cátedra tanto de nivel no graduado como a nivel graduado, sobre la genética y el mejoramiento del sorgo en general.

Las condiciones ecológicas del país son favorables a una mayor difusión del sorgo, al punto que esta gramínea puede pasar a ocupar un lugar importante. Hasta ahora se circunscribe su cultivo, principalmente, en áreas marginales y con muy escasos recursos de riego. Sin embargo en muchas zonas de la sierra baja y principalmente en la selva alta del país, el sorgo puede significar un cultivo importante y de trascendencia en la limitación o disminución de las importaciones de granos.

La ayuda técnico-económica internacional podría orientarse a reforzar y/o unificar las acciones dispersas que sobre investigación en sorgo se realizan en el país, mediante la creación de un Centro de Investigación en Sorgo, que reciba el apoyo del siguiente orden:

Personal Técnico - Capacitado y en número suficiente para cubrir la investigación a nivel nacional.

Intercambio técnico y perfeccionamiento y/o capacitación en centros internacionales o programas avanzados.

Intercambio de material genético que permita a nivel nacional:

-Obtención de híbridos o variedades de alto rendimiento, con énfasis en la investigación para características especiales como: arquitectura y porte de plantas, densidades de población, etc,

-Ampliar la evaluación de material a nivel nacional e intensificar la experimentación sobre determinadas prácticas culturales y producción de sémilla.

-Intercambio de publicaciones técnicas afines.

-Facilitar la asistencia a reuniones o congresos de la especialidad.

SORGHUM RESEARCH IN HAWAII

Peter P. Rotar, Agronomist

The State is rather small in size, 6400 square miles, and has most of its arable land in sugarcane and pineapple production. The Islands support a $50 million dollar livestock industry which requires the importation of about 120,000 tons of feedstuff annually. Shipping costs, before the current fuel crisis averaged between $20 to $30 per ton. With recent changes in the agricultural industry of the state serious efforts have been made to produce feed grains locally. It has been recognized that sorghum could be a replacement crop for agricultural lands released from sugarcane production. A recent feasibility study indicated that sorghum could be a profitable enterprise if yields of 200 to 300 bushels per acre per year could be realized. These figures are realistic under ratoon culture in Hawaii with projections of 120 days for a plant crop and 105 days for each of two ratoon crops.

Total potential land area for feed grain production is about 20,000 acres. The maximum area could be much more depending upon the future of pineapple and sugarcane in Hawaii. Corn is the only other cereal grain of any importance within the State. We have a flourishing seed corn industry and there is considerable acreage of field corn grown for silage, greenchop, and for feed grain.

Sorghum research in the Hawaii Agricultural Experiment Station is carried out as an interdepartmental project which involves Agronomy and Soil Science, Plant Pathology, Animal Science and Entomology. Research work is carried out at two locations--The Kauai Branch Station at Kapaa on the Island of Kauai. The environment there is warm and humid with

about 90 inches of rainfall annually. All of our disease nurseries are at this location. Most of the agronomic testing is carried out at the Waimanalo Experiment Farm on the Island of Oahu. The environment there is warm and dry during the summer months. We cannot effectively screen for rust or leaf blight at this location during the summer months. We have one other experimental site in the Kohala District on the northern end of Hawaii which is used for yield trials etc.

The original objectives of the project were to develop grain and forage sorghums for the State. Grain sorghum operations within the State quickly ran into difficulties. Predicted grain yields, based on small trial plantings, were never realized. Several problems developed. Besides the lack of well-adapted hybrids; birds, insect pests and diseases caused more trouble than anticipated. Hawaii's landscape, so-well bisected by ravines, provides excellent nesting sites for birds adjacent to production fields and consequently we've lost large acreages. Rice birds, sparrows, doves, brazilian cardinals and pigeons have been observed feeding on the developing grain. Ricebirds are the worst offenders.

The sorghum midge has caused as much damage as rice birds. Commercial operations lost large acerages to midge during the 1973-74 winter season. Scarcity of aircraft fuel and inclement weather hindered proper control measures. Other insects which cause considerable trouble include aphids, plant hoppers, webworms, pineapple souring beetles, and corn earworms.

Major disease problems include rust, leaf blight and stalk rots. We have the sugarcane mosair virus present but have not had much trouble with it as yet. We do not have downy mildew in the State at this time.

Research has led to the development of multiple disease resistant stocks which are being evaluated for agronomic characteristics at this time. These stocks have resistance to leaf blight, rust, dowry mildew and sugarcane mosaic virus. We do have some midge resistant stocks and some lines appear to be less palatable to birds than others. So far we have not seen any truly bird resistant stocks.

At this time our major research efforts are being shifted toward the development of adapted forage varieties. We are still interested in grain sorghum but there are many problems to be solved before it will be successful in Hawaii.

We would be interested in cooperative efforts in developing midge bird and disease resistant lines which are well adapted to relatively warm-humid environments.

"PROGRAMA DE PESQUISA COM A CULTURA DO SORGO NO NORDESTE DO BRASIL".

Relatório do Instituto de Pesquisas Agronômica

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As secas frequentes e a insuficiência de tecnologia adequada para assegurar colheitas, de um ano para o outro, urgem esforços adicionais que possam ir de encontro as necessidades, numa escala ampla, para níveis crescentes de probabilidade de produção de alimentos, nas áreas não irrigadas, de poucas chuvas, das regiões semi-áridas do Nordeste brasileiro. Como já se sabe, ainda não ocorreu nenhum evento significativo de conhecimento na tecnologia da produção para as áreas nordestinas, em comparação com as áreas com suprimento assegurado de água. A "revolucão verde" ainda não alcançou o Nordeste. A ameaça de perda das culturas e a carência de alimentos está continuamente diante de nós. A seca de 1970 ainda não foi esquecida e a recente seca e os conseqüentes desastres no Sahel da África e o norte da Etiópia são exemplos que devemos ter em mente ao pensarmos no Nordeste.

Na última década e, principalmente, durante os dois

últimos anos, um programa sólido, interdisciplinar, tem sido desenvolvido, a fim de se obter uma melhor compreensão e desenvolvimento do sorgo, como uma cultura de possibilidade para o Nordeste.

Face à capacidade de tolerância do sorgo aos períodos mais intensos de seca e, ainda assim, oferecer uma colheita razoável, uma característica nitidamente superior à do milho, visualiza-se aquela cultura como tendo possibilidades de ser introduzida em áreas do Nordeste brasileiro, onde ainda não é cultivada. Isto, em razão da maior probabilidade de produção. Em outras palavras, o sorgo pode ser cultivado com menos risco e com maior produção de grãos do que o milho, nas extensas áreas secas do Nordeste.

Em pesquisa e educação, lidamos, principalmente, com idéias, e as pessoas desenvolvem, com mais freqüencia, as idéias, através da comunicação. É de se esperar que resultem deste Simpósio, ao lado das boas relações, significativos programas de trabalho.

Nosso interesse é o aprimoramento da produção envolvendo a adaptação. Supomos que as seleções iniciais de uma escala ampla de introduções deveriam ser efetivas. O melhoramento de planta - ou, na frase de Valvilov - "evolução ao desejo do homem", é, como toda evolução, dependente da variação. A chave para a utilização bem sucedida de variabilidade de grandes suprimentos de gens requer que o fitomelhorador tenha a noção exata daquilo que ele está tentando introduzir e do por que. Sabendo isto, ele pode ir em busca de linhas

adaptadas a serem introduzidas como variedades "per si", ou em busca de uma característica para incorporá-la geneticamente aos cultivares utilizáveis, híbridos ou sintéticos. Nos últimos 3 anos, selecionamos mais de 1.500 introduções para adaptações. Realizou-se a seleção e algumas linhas promissoras foram testadas e ainda estão sob testes de competição mais amplos, no que concerne à performance de produção, em diferentes locais do Nordeste do Brasil. O Quadro I mostra alguns dos resultados iniciais que foram obtidos durante as estações de crescimento em 1974, em Pernambuco. Nesse quadro, aparecem as produções de sorgo e de milho. Abaixo do quadro estão os dados de pluviosidade.

Os dados mostram a adaptabilidade de algumas seleções de sorgo a determinadas regiões agroclimáticas de Pernambuco. Observando as produções de milho e os dados da pluviosidade, está claro que o sorgo proporciona maior probabilidade de colheita do que o milho. Portanto, nossa hipótese foi provada como sendo verdadeira.

Naturalmente que, numa área onde o risco é grande, faz-se necessário pensar em termos de tecnologia mais de trabalho intensivo do que de capital intensivo, ou, em outras palavras, uma tecnologia com um mínimo de insumos onerosos. Um desses métodos é o de produzir variedades, de modo a permitir ao agricultor conservar suas sementes para plantio em vez de se introduzir o cultivo de híbridos F_1, onerando a produção com as constantes aquisições de sementes.

Como todos sabem, introduzir e melhorar uma cultura

numa área nova não é um mecanismo fácil. Deparamo-nos com uma série de pragas e de doenças que têm que ser superadas. No momento, convergimos esforços para introduzir, na composição genética das plantas, a capacidade de resistir aos insetos e às doenças. Dentre os insetos que estamos considerando, destacamos: "a mosca do sorgo", a Contarinia sorghicola (Coquillet), que ataca a planta na época do florescimento, alimentando-se do grão em desenvolvimento, e, dessa maneira, impedindo o seu amadurecimento, e a "broca do caule", Diatraea saccharalis (Fobr), e Elasmopalpus lignosellus (Zeller), que perfura o caule da planta em qualquer etapa do seu ciclo de crescimento. As doenças do sorgo incluem a "ferrugem", a "antracnose", a "mancha bacterial da folha" e a "podridão do colmo".

Nosso objetivo é obter variedades de sorgo que possuam um alto grau de tolerância à seca, altura média e que respondam às altas densidades de plantio, com elevado percentual de proteína e lisina.

Para superar os problemas de doenças e de insetos, a nossa metodologia visa identificar as fontes de resistência e orientar a hibridação e o trabalho de seleção que deverá ser bastante efetivo. Outra alternativa, que também está sendo seguida, é a adoção de métodos de melhoramento populacional. O programa de seleção recorrente está sendo desenvolvido em 3 populações: Uganda RS/R, Uganda RS/A, NP3 e NP5 de Nebraska. A seleção recorrente desenvolve-se como descrita por Doggett e Eberhart (1968) e Doggett (1970).

Devemos lembrar que, certamente, ocorrerão problemas novos, diferentes e inesperados. A história do melhoramento de plantas pode mostrar que isto é verdade. Esses problemas só podem ser enfrentados através do esforço contínuo de muitos indivíduos interessados.

Não quero encerrar sem fazer menção ao grande potencial de produção das variedades disponíveis, pelo aprimoramento do uso da água e da terra e o adequado manejo da cultura. Por esta razão é que temos, à parte do programa de melhoramento, uma pesquisa sobre a tecnologia da produção. Aceitamos o fato de que a maioria dos agricultores nordestinos não cultiva a terra com lavouras isoladas. A quase totalidade utiliza as culturas consorciadas e nossas pesquisas são também dedicadas a esse aspecto. Boa parte das áreas do Nordeste, justamente as que mais precisam aumentar a sua produção, é também caracterizada por agricultores de recursos limitados e de pouco capital, e a tecnologia tem que ser amplamente aplicável pela operação manual ou através de instrumentos simples. Este fato continuará a impor sérias restrições e a causar maiores diferenças entre os objetivos da pesquisa, quando considerada a metodologia mais adequada às necessidades do Nordeste e a que tem sido conseguida para suprir as necessidades das regiões mais desenvolvidas do mundo.

Quadro 1 - Performance dos testes de competição de sorgo em três locais, Pernambuco, Brasil. 1974.

VARIEDADES	L O C A I S			Médias t/ha
	Serra Talhada	Caruaru	Araripe	
IS 2740	4,465	2,246	2,152	2,954
IS 8093	5,853	2,809	1,712	3,458
IS 8236	4,067	2,786	2,055	2,969
IS 9826	5,200	2,531	2,013	3,248
Pu 4023-5	4,271	1,851	1,763	2,628
Pu 166041	4,391	2,499	1,217	2,702
Pu 22078	4,274	2,508	1,712	2,831
Serena	5,288	2,731	1,939	3,319
IPA 1154	4,488	3,633	1,490	3,203
IPA 1155	3,211	3,138	1,494	2,614
IPA 1183	4,895	3,518	2,439	3,617
Centralmex milho	4,659	3,309	0,638	2,868
Phoenix Latente milho	3,877	2,939	1,041	2,619
M É D I A S	4,533	2,807	1,666	3,002
CHUVA (mm)	671	525	686 (*)	

(*) A precipitação pluvial, durante os dois primeiros meses, foi de 633 mm.

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EL CULTIVO DEL SORGO EN CENTROAMERICA Y PANAMA[1]

Ing. Angel Salazar B.[2]

Importancia del sorgo en el área

Hasta principios de la década de los años 60, se cultivaba sorgo para grano usando variedades llamadas "criollas" en Guatemala, El Salvador, Honduras y Nicaragua. En cambio en Costa Rica y Panamá, este cultivo fue introducido en esa misma época y con variedades híbridas. En los 4 primeros países el sorgo ya tiene suficiente antigüedad como para que los agricultores llamen variedades criollas a las derivadas de las primeras introducciones hechas de Norte y Sud América. En estos mismos países se da uno o más de los siguientes nombres: "Maicillo", "Millón", "Millo" y "Trigo" a las variedades derivadas de la especie Sorghum bicolor (Linn.) Moench. Al presente se siembran variedades de sorgo granero y forrajero, usando semillas de libre polinización y de híbridos, en las áreas agrícolas de la Costa del Pacífico de los seis países del istmo Centroamericano. En la Costa del Atlántico de Honduras, se está sembrando además un área creciente, con híbridos forrajeros de sorgo por pasto Sudan e híbridos de líneas de pasto Sudan.

En el cuadro 1 se presentan datos sobre área cosechada, producción y rendimiento de los sorgos, así mismo se puede apreciar la importancia del sorgo con relación a los otros tres cereales cultivados en Centro América y Panamá. El área con sorgo es de alrededor de 266,008 hectáreas,

[1]Contribución presentada en el "International Sorghum Workshop", realizado en la Universidad de Puerto Rico, Enero 1, 1975.

[2]Director de Operaciones de Semillas DeKalb para Centroamérica y Panamá.

Cuadro 1 - Area cosechada, producción y rendimiento de los cuatro cereales más importantes de Centroamérica y Panamá+

		Sorgo	Maíz	Arroz	Frijol
GUATEMALA					
Area Ha.	(1972)	50,438	663,104	19,957	177,987
Producción T.m.	"	36,320	740,020	59,020	63,560
Rendimiento K/Ha.	"	720	1,116	2,957	358
EL SALVADOR					
Area Ha.	(1973)	119,510	201,950	9,561	45,311
Producción T.m.	"	154,560	400,230	36,751	36,987
Rendimiento K/Ha.	"	1,292	1,982	3,893	816
HONDURAS					
Area Ha.	(1973)	31,700	282,800	9,500	74,100
Producción T.m.	"	53,200	331,800	16,400	54,500
Rendimiento K/Ha.	"	1,700	1,200	1,700	700
NICARAGUA					
Area Ha.	(1973)	55,607	222,780	28,682	63,973
Producción T.m.	"	57,607	201,440	79,849	46,262
Rendimiento K/Ha.	"	1,040	904	2,784	723

Cont. Cuadro 1

COSTA RICA					
Area Ha.	(1972)	3,753	51,888	65,458	26,681
Producción T.m.	"	7,661	52,442	104,009	11,031
Rendimiento K/Ha.	"	2,042	1,011	1,589	413
PANAMA					
Area Ha.	(1973)	5,000	69,000	105,000	17,000
Producción T.m.	"	10,000	57,546	142,695	7,701
Rendimiento K/Ha.	"	2,000	834	1,359	453
CENTROAMERICA Y PANAMA					
Area Ha.	(1972-1973)	266,008	1.491,522	238,157	405,052
Producción T.m.	"	319,380	1.783,483	483,724	220,041
Rendimiento K/Ha.	"	1,200	1,196	1,842	544

+ Datos obtenidos de: Dr. Víctor Urrutia, ICTA, Guatemala; Ing. Francisco Arias M., CENTA, El Salvador; Ing. Juan J. Osorto, DESAGRO, Honduras; Banco Central, Nicaragua; Ing. Nevio Bonilla, MAG, Costa Rica; e Ing. Ezequiel Espinoza, Universidad de Panamá.

lo que sitúa a este cultivo en tercer lugar, después del maíz y frijol. La producción, de 319,380 toneladas, es nuevamente tercera en importancia después del maíz y arroz. El rendimiento promedio de 1,200 K/Ha. es similar y superior al correspondiente al maíz y frijol.

El sorgo granero en Centroamérica y Panamá se cultiva en primer lugar, para la alimentación animal, pero también se le usa en cantidades variables, como sustituto del maíz, en la alimentación humana en Guatemala, El Salvador, Honduras y Nicaragua. Es el cereal que, no importa cuan seco sea el año, rinde una cosecha de grano y forraje para suplir las necesidades alimenticias de grandes sectores de la población rural de esta parte de las Américas.

Forma de Cultivo

Los sorgos tanto para grano como para forraje, se cultivan en el Istmo siguiendo dos formas: a) Tradicional y b) Moderna.

Cultivo Tradicional - Aproximadamente el 75% del área sembrada con sorgo en Centroamérica y Panamá, se cultiva en forma tradicional, es decir, usando semillas y prácticas no mejoradas. Los agricultores que practican esta forma de cultivo, son campesinos y pequeños agricultores que siembran los sorgos más que todo para subsistencia, que para el comercio. Alrededor del 50% del área cultivada en forma tradicional, se siembra en asociación con maíz y otros cultivos.

Los terrenos sembrados en forma tradicional son generalmente pobres en fertilidad y de topografía accidentada. Estos terrenos además, son preparados ligeramente mediante el arado de bueyes, o simplemente limpiados de malezas, a mano.

La siembra se practica usando el arado de bueyes y trabajo manual,

o simplemente a través del uso de implementos manuales. Cuando el sorgo se le siembra asociado con maíz, la semilla se deposita en grupos de 4 a 10 granos, en forma alterna con el cultivo asociado.

Las malezas, cuando se las controla, se hace en forma ineficaz, usando implementos de tracción animal, o herramientas manuales como la "macana", azadón o machete.

La aplicación de fertilizantes es casi nula, así como el control de insectos y otras plagas de este cultivo.

La cosecha se realiza nuevamente a mano, cortando las cabezas a la madurez. Estas, una vez secas al sol, se las desgrana mediante el aporreo con varas de madera; el grano se limpia de glumas y basuras y se ensaca para su conservación hasta su uso o venta.

El cultivo en forma tradicional se caracteriza más que todo, por el uso de variedades llamadas "criollas". Estas se caracterizan por ser variedades de ciclo vegetativo largo y sensitivas al fotoperiodismo. Cuando se les siembra al principio de la época de lluvias (mayo-junio), maduran al fin de la época de lluvias (noviembre), pero si se les siembra tarde, después de mayo o junio, la madurez ocurre siempre en noviembre, de modo que son variedades que permiten sólo una cosecha por época de cultivo.

Las variedades criollas son de plantas altas, de follaje abundante, tallos gruesos, que a la madurez son duros y de poco valor como forraje.

Las panojas pueden ser compactas o abiertas (Bandera) y el grano es de color blanco y textura cristalina, apropiado para hacer tortillas, ("arepas" o especie de pan).

El rendimiento de las variedades criollas en las mejores condiciones, puede alcanzar 1,950 kilos por hectárea, pero el promedio varía

entre 700 a 1,700 K/Ha.

constituye su gran resistencia a la sequía, ya que muy raramente el sorgo deja de dar algo de grano, aún ante las peores sequías que suelen ocurrir en esa área. Cuando el maíz, arroz o frijol deja de producir por la sequía, el sorgo proporciona al campesino una cosecha de grano.

Cultivo Moderno - Aproximadamente el 25% del área dedicada al sorgo en Centroamérica y Panamá, se siembra con híbridos introducidos en los EEUU y con variedades mejoradas localmente. Aunque desde 1962 se venía sembrando híbridos de sorgo granero en Costa Rica, no fue sino hasta 1965 que se comenzó a incrementar el cultivo de híbridos en el área. En el año mencionado ocurrió especialmente en Nicaragua, una sequía que obligó a un grupo de agricultores, que perdieron sus campos de algodón, a sembrar sorgo granero como una manera de reducir las pérdidas.

El cultivo moderno del sorgo, se caracteriza además del uso del híbrido y variedades mejoradas, porque está en manos de agricultores que siembran grandes extensiones de terreno, en los que se puede usar maquinaria para su preparación; por la aplicación de fertilizantes; control eficiente de malezas e insectos; cosecha mecánica y por que la producción es de carácter empresarial destinada a la industria de alimentos concentrados para las aves, cerdos y ganado vacuno de engorde y leche.

Los campos de sorgo híbrido reciben entre 32.5 a 65 K/Ha. de nitrógeno y también 32.5 y 16.8 K/Ha. de fósforo y potasio. Generalmente se aplica fórmulas completas de abono a la siembra y el nitrógeno en 2 aplicaciones.

Las malezas en los campos de sorgo híbrido se controlan mecánicamente, a través de 1 a 3 pases de cultivadora de tracción mecánica, pero

la forma más común y eficiente de controlarlas, es mediante el uso de herbicidas. La Atrazina en varias de sus formas comerciales, es el herbicida más usado, tanto de pre-emergente como post-emergente. También se usa en menor escala el 2-4-D.

Los varios insectos que atacan las raíces, follajes, flores y grano del sorgo, son controlados con insecticidas aplicado con avión. La "Mosquita del sorgo" (Contarinia sorghicola), es el insecto que causa las más graves pérdidas de grano, cuando no se la controla oportunamente. Los gusanos que destruyen los granos causan daños especialmente en variedades de panoja muy compacta.

El ataque de pájaros a los campos sembrados de sorgo granero, es un serio problema en Centroamérica. Solo puede reducirse las pérdidas de grano por esta causa, sembrando en épocas que escapen a las mayores concentraciones de pájaros y sembrando variedades resistentes a ellos.

La cosecha de los campos con sorgo híbrido se realiza con combinadas, las mismas que se usan en la cosecha del arroz. El grano así cosechado, es secado artificialmente y luego vendido o almacenado en graneros especialmente construídos.

El rendimiento promedio de los campos sembrados con sorgo granero en los que se siembran híbridos y usan prácticas mejoradas de cultivo, es aproximadamente 2,000 K/Ha. Los campos más productivos sin embargo, producen entre 2,500 a 5,000 K/Ha. El rendimiento máximo conseguido en Nicaragua hasta la fecha, fue de 7,740 K/Ha.

El área que se siembra con variedades mejoradas en Centroamérica es pequeña 9,500 con excepción del área sembrada con las variedades de El Salvador.

Los híbridos y variedades mejoradas de sorgo forrajero se siembran

aún en pequeña escala en Cencroamerica 7,500 Ha. aproximadamente. Honduras es el país que más área siembra con híbridos de sorgo x Sudan y bajo riego, para el engorde de ganado de carne. Estos híbridos se adaptan muy bien a la época de siembra de temporal (Mayo-Diciembre), así como riego (Enero-Agosto) en Centroamérica. Sembrados en condiciones apropiadas a fertilidad y con buen manejo, estos híbridos han permitido 6 a 8 cortes de materia verde por año. Cuando se les siembra al final de la época de lluvias, los híbridos de sorgo forrajero permiten, con la humedad residual, 2 a 3 cortes de forraje verde o para elaborar heno. En Nicaragua y Honduras se usa la variedad mejorada llamada Sart.

Utilización

El sorgo granero en el Istmo Centroamericano se cultiva principalmente para la alimentación animal, sin embargo, en Guatemala, El Salvador, Honduras y Nicaragua, se usa también en la alimentación humana. En el cuadro 2 se dan los datos por país, sobre la forma de utilizar el sorgo granero. Todas las variedades llamadas criollas tienen grano de endosperma blanco y cristalino, el que sirve para elaborar "tortillas" igual que con maíz blanco. El porcentaje de utilización animal y humana del sorgo granero proveniente de las variedades criollas, varía en cada año en los países mencionados de acuerdo a las condiciones de humedad de la época de cultivos. Si la humedad fue favorable, se cosecha suficiente maíz y entonces el sorgo es destinado exclusivamente para los animales domésticos y para la venta a la industria de alimentos concentrados. El forraje de las variedades criollas, aunque relativamente abundante, es de baja calidad.

El grano cosechado de las variedades mejoradas e híbridos, es de endosperma blanco o amarillo, pero la cubierta puede ser roja, café o

Cuadro 2 - Forma de uso del sorgo granero en Centroamérica y Panamá durante 1969 +

	Alimentación		
GUATEMALA	82.5	11.3	6.2
EL SALVADOR	70.8	25.4	3.8
HONDURAS	47.3	44.1	8.6
NICARAGUA	71.4	17.9	10.7
COSTA RICA	94.0	--	6.0
PANAMA ++	95.0	--	5.0

+ Datos obtenidos de "Estadísticas sobre la alimentación y la agricultura" 1972, SIECA.

++Estimación del autor.

morada. Toda la cosecha de estas variedades es destinada a la elaboración de alimentos animales. Las "tortillas" que se hacen con estas variedades adquieren un color oscuro, no grato a los consumidores. En especial los híbridos, llegan a la cosecha con gran parte del follaje aún verde, lo que produce un forraje de mejor calidad y más apetecible para el ganado. El forraje que producen los sorgos graneros híbridos es consumido por el ganado en el propio campo, o los agricultores hacen pacas de heno para su venta o uso en la época seca.

Los sorgos forrajeros se utilizan principalmente para la producción de forraje verde picado y en menor escala, para el pastoreo directo y para la elaboración de ensilaje y heno.

Centros de investigación oficiales

En el cuadro 3 se presenta información sobre las instituciones que realizan investigación con sorgo en Centroamérica y Panamá, así como la localización de los centros experimentales, los nombres y nivel académico de los técnicos encargados del trabajo con sorgo. Todos los ministerios de agricultura del área tienen proyectos de trabajo con sorgo granero y/o forrajero; en Panamá además, la Facultad de Agronomía de la Universidad Nacional realiza trabajos experimentales con sorgo. De los 15 técnicos relacionados con el trabajo experimental con sorgo, solamente uno, el Dr. Víctor M. Urrutia, está asignado a tiempo completo al programa de sorgo; los demás técnicos trabajan tiempo parcial para este cultivo, ya que los programas de maíz y sorgo están asociados en los otros países.

Objetivos y problemas de investigación

Los encargados del trabajo experimental con sorgo en Centroamérica y Panamá, informaron que los proyectos de sorgo se agrupan en dos

Cuadro 3 - Localización de los centros de trabajo con sorgo, personal y nivel técnico.

País e Institución	Localización	Nombre del técnico	Nivel técnico
GUATEMALA			
Instituto de Ciencias y Tecnología Agrícola (MAG)	Asunción Mita (Dept. Jutiapa)	Víctor M. Urrutia (Coordinador)	Doctor (Ph. D.)
	Guazacapan (Dept. Santa Rosa)	Guillermo León Lu	Bachiller (BSA)
	Monjas (Dept. Jalapa)	Manuel Alonso	Perito Agrícola
		César Catalán	" "
EL SALVADOR			
Centro Nacional de Tecnología Agropecuaria (MAG)	Santa Cruz Porrillo (Exp. Sta.) San Andrés (Exp.Sta.)	Roberto Arias (Coordinador)	Ing. Agrónomo
		Hugo Córdova	Master in Scienc Mejoramiento Cultivos
HONDURAS			
Ministerio de Agricultura	La Lujosa, Choluteca (Exp. Sta.)	Juan José Osorto (Coordinador)	Ing. Agrónomo
		Roduel Rodríguez	Ing. Agrónomo
NICARAGUA			
Ministerio de Agricultura	La Calera, Managua (Exp. Sta.)	Leonardo Arguello (Coordinador)	Ing. Agrónomo
COSTA RICA			
Ministerio de Agricultura	Guanacaste, Liberia (Exp. Sta.) Pacífico Sur	Nevio Bonilla (Coordinador)	Master in Science+
		Leopoldo Pixley St. C.	Ing. Agrónomo
PANAMA			
Facultad de Agronomía Universidad de Panamá	Tocumen, Panamá (Exp. Sta.)	Ezequiel Espinosa (Coordinador)	Master in Science Mejoramiento Cultivos
		Alfonso Alvarado	Ing. Agrónomo
		Diego Navas	Master in Science Entomólogo
Ministerio de Desarrollo		Carmen D. Chea	Ing. Agrónomo

+ Mejoramiento Cultivos

categorías: a) Prueba y desarrollo de variedades y b) Mejoramiento de prácticas culturales.

Los seis países del área tienen proyectos locales de prueba e introducción de variedades de sorgo granero y forrajero. Además, estos países cooperan en un programa internacional de prueba de variedades de sorgo llamado "Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios" (PCCMCA). A través de los programas locales y cooperativos se ha probado un gran número de híbridos y variedades mejoradas de sorgo granero y forrajero en cada uno de los seis países. Los resultados de los trabajos de variedades con sorgo y de prácticas culturales, han sido publicados en los informes de las reuniones anuales del PCCMCA en los últimos 10 años (1963-1973).

A través del Programa Internacional de Sorgo, coordinado por la Universidad de Purdue, EEUU; los programas de sorgo de Guatemala, El Salvador, Nicaragua, han seleccionado colecciones de sorgo granero con características de grano y planta deseables en las condiciones de estos países. Algunas de estas selecciones están ya siendo distribuídas entre los agricultores de Guatemala y El Salvador.

Las prácticas de cultivo que permiten expresar el potencial de rendimiento de las variedades mejoradas de sorgo, son también objeto de experimentación por parte de todos los programas oficiales de sorgo del área. Los seis países tienen proyectos de trabajo para determinar las mejores prácticas de control de malezas e insectos. En Guatemala, Honduras, Costa Rica y Panamá, están en marcha proyectos de experimentación para determinar las densidades de siembra de los sorgos. En estos mismos países se está trabajando en las prácticas de fertilización más adecuadas a sus condiciones de cultivo del sorgo y en Guatemala, El

Salvador y Honduras, hay trabajos sobre rotaciones y asociaciones del sorgo. Finalmente, en Costa Rica está en desarrollo un proyecto de investigación sobre las épocas de siembra del sorgo en las diferentes áreas de cultivo del país.

Sugerencias para el establecimiento de un programa internacional

Las respuestas obtenidas al requerimiento de sugerencias sobre cómo un programa coordinado internacionalmente, puede ayudar a resolver problemas locales de sorgo en Centroamérica y Panamá, pueden agruparse como sigue:

1. Un programa coordinado internacionalmente puede ayudar a resolver problemas del cultivo del sorgo, que son no solamente propios a cada país, sino que se repiten en uno o más de ellos. Así se puede hacer más eficaz y menos costosa la obtención de información.
2. El intercambio de germoplasma de sorgo y de información sobre este cultivo, se vería grandemente estimulado con un programa coordinado internacionalmente.
3. El establecimiento de un "Nursery" para estudiar las enfermedades del sorgo en el área, sería posible mediante la cooperación en un programa internacional.
4. El adiestramiento de personal para el trabajo en proyectos de sorgo sería factible de establecerse en un programa internacional de cooperación con sorgo, tal como ocurre con los cultivos de maíz y trigo en el CIMMYT en México y con arroz en el CIAT, en Colombia.
5. Mediante un programa coordinado internacionalmente se puede auspiciar reuniones periódicas, para discutir problemas de

sorgo e intercambiar información sobre este cultivo.

6. La producción de líneas o de semilla híbrida de sorgo en Centroamérica, podría intentarse con la cooperación de un programa internacional de sorgo.

7. Un programa organizado y apoyado adecuadamente, puede obtener la información necesaria para realizar al máximo el potencial de rendimiento de los híbridos y variedades mejoradas actualmente en uso en Centroamérica y Panamá.

8. Ya que en cuatro países de Centroamérica se usa el sorgo para alimentación humana, el desarrollo de variedades de grano de calidad alimenticia superior, puede realizarse mejor y más rápidamente con la ayuda de un programa internacional de investigación de este cultivo.

The Sorghum and Millets Improvement Program for The Near East

Support Base

The Arid Lands Agricultural Development Program (ALAD) is a function of the Ford Foundation. The program began in Lebanon in 1967 and the improvement of sorghum, millets, and maize was included among its projects. Improvement of these crops was initiated by Dr. Lawrance C. Curtis. With time, it was felt that these projects should be strengthened and in 1971 I was invited to participate in this research taking leadership in the effort for the improvement of sorghum and millets. I joined the group in December of that year remaining on the field staff of the Rockefeller Foundation. Research for the improvement of chickpeas, broadbeans, and lentils was initiated in 1972. The International Development Research Center (IDRC) of Canada is now providing two senior scientists and substantial grant support for the research and training functions of the sorghum, millets, and food legume projects. This support began in November of 1973.

The Region

The region is defined to include countries from Turkey to the Sudan and Afghanistan to Morocco. The project is not active in all countries within the region and in addition is cooperating with improvement programs in Pakistan and Ethiopia. The approach has been more exploratory in countries of the Near East and Iran and more directly involved in countries in the Southern portion of the region where sorghum and millets are important crops and frequently where established research programs have existed for many years.

The situation is summariezed in the following table:

Country	Area** Sown Sorg.&Mil. (Hect.x1000)	Crop Importance	Existing* Research Programs	Project Involvement
Sudan	2650	Staple	Well Established	Cooperating
Ethiopia	4450	"	" "	"
Egypt	210	"	" "	"
N.Yemen	370	"	Beginning	"
Saudi Arabia	66	"	"	"
Morocco	67	Important	Not known	None

* Government or University Institutions.
** From FAO Production Year Book 1971.

Country	Area** Sown Sorg.&Mil. (Hect.x1000)	Crop Importance	Existing* Research Programs	Project Involvement
Algeria	3	Not important	None	None
Tunisia	12	" "	"	"
Libya	2	Minor	Kufra Project	None
Jordan	1	Not important	None	"
Syria	25	Minor	Minor	Minor
Lebanon	1	Not important	None	Project Center
Cyprus	-	" "	"	None
Turkey	34	Minor	Beginning	Beginning
Iraq	5	"	None	None
Iran	30	Not important	Beginning	Beginning
Afghanistan	-	" "	None	None
Pakistan	1320	Staple	Well Established	Cooperating

* Government or University Institutions.

** From FAO Production Year Book 1971.

Clearly, the project is most involved in those countries where the crop is of greatest importance. The program has been expanding to more locations and further expansion is anticipated as strength is gained.

Cooperating Agencies

The ALAD Program centers in Lebanon and operates as guests on the stations of the Ministry of Agriculture, Lebanon. Outside of Lebanon, the sorghum and millets project cooperates with improvement programs of the respective ministries of agriculture. Cooperation in the Sudan is with the Agricultural Research Corporation; and, in Ethiopia with the College of Agriculture, Haile Selassi I University.

ALAD has been recognized as an outreach station by ICRISAT for the improvement of sorghum, millets and chickpeas. Some sorghum, millets, and legume seeds have been sent to ICRISAT and ALAD has begun to provide an off-season opportunity for ICRISAT's chickpea program.

Objective and Approach

The objective falls into two broad categories; exploration of the use of sorghum primarily for feed and forage in the Near East, and cooperation to strengthen research in those countries where the crops are staple foods and important feed crops.

The approach has been to attempt to broaden the germplasm base and help evaluate new introductions, and to conduct and support several training functions.

Procedure

A nursery ranging from approximately 2200 to 4000 entries was grown in 1972 at Izmir, Turkey (39°N); Tel Amara, Lebanon (36°N); Cairo, Egypt (30°N); Dirab, Saudi Arabia (24°N); and Wad Medani, Sudan (15°N). The objective was to evaluate the nursery in a north-south direction in the region. The nursery was primarily of sorghum, but pearl millet, proso, and foxtail millets were included. A major portion of the world collection of sorghum was increased in Lebanon and the Sudan; and, the collections of pearl millet, proso, foxtail, Japanese barnyard, common millet, finger millet, and Kodra (*Paspalum scrobiculatum*) were increased in Lebanon. The finger millet and Kodra failed completely. Virtually, all entries of pearl millet made seed and early types were selected as well as taking a bulk increase. The proso and finger millets increased well and some entries of the Japanese barnyard millet did well.

Composites begun by Hugh Doggett in Uganda, but added to in India were evaluated. Seed was harvested from early, mid season, and late male-sterile heads and pooled in these categories. These were to form a base to build locally adapted composites.

A crossing block was organized to begin crossing and to determine the problems of organizing a crew to make crosses. There was no problem in organizing a crew and some 700 crosses were made. The F_1's were advanced to F_2 in an off-season nursery program begun at Wad Medani, Sudan.

The nurseries in these five locations were evaluated; the results are presented in the appendix of the projects first progress report. From this evaluation several uniform regional nurseries were organized and distributed for the 1973 season; one for grain sorghum, one for sudangrass, and one for dual purpose types. In addition, a small regional pearl millet nursery was distributed.

Pearl millet was found to do well throughout the region; proso and foxtail showed variable promise in the northern portion of the region and little promise in the south. Other millets were dropped.

The program expanded to several new countries and to new locations within countries in 1973. Selections from nurseries in 1972 (plus the regional nurseries mentioned above) provided a base for nurseries in 1973. A crossing block was organized in Lebanon based on the best selections from 1972 and local types. Pools of pollinator types were crossed onto genetic steriles in the early and late composites selected in 1972. Crosses were made onto selected cytoplasmic steriles to initiate a hybrid program in the Sudan. Yield trials were sown at several locations but for one reason or another failed. Seeds from the various F_2's increased in the winter nursery at Wad Medani were evaluated at Wad Medani, Sudan; Shandaweel, Egypt; and Tel Amara, Lebanon.

The range of grain sorghum types was reduced by further selection and began to show regional specificity. Introductions frequently did not show much promise over local types for yield - the big value is in diversification of the germplasm base. This observation has encouraged a major effort to cross exotic with local entries in an effort to get superior types from segregates in advanced generations.

Sudangrass has generally proved to be a better forage than pearl millet though more evaluation is needed particularly in the very hot portions of the region. Both sudangrass and pearl millet produce substantially more forage than proso or foxtail and research priority on these crop types is dropping.

Composites of grain sorghum, forage sorghum, and pearl millet are being developed as a long range component of the program. It appears that initial promise will come in this project by selection within introductions and particularly from advanced generations from single crosses.

High lysine has been introduced and some 270 lines of exotic and local type have been crossed onto one or the other of the first two identified sources. In the off-season nursery this winter extensive crossing is planned on P721 from Purdue.

In summary, an attempt has been made to broaden the germplasm base in breeding programs in the region; to use entries from the first nurseries to expand to new locations; and to undertake direct evaluation of new introductions, to begin crossing, and to develop composites so that the program will have a good level of variation available for selection for many years.

High lysine has been introduced and many crosses have been made. An off-season nursery for the region is going into the third season in the Sudan and the first season in Ethiopia. Sorghum and several millets have been evaluated for food and feed use and research priorities are becoming better defined.

Training

The improvement of sorghum and millets in many countries of the region is closely correlated to trained manpower availability. Even in countries with established programs there is interest in training to strengthen outlying stations. In order to meet this need, a seven month training program was organized. The period coincides with a full growing season and trainees spend much of their time in the field. Lectures are given to support field activity and to expand the knowledge base. The training is directed toward junior scientists and senior technicians and is designed to increase efficiency of operation and problem identification. Eleven trainees from seven countries participated in the first course in 1973, and ten trainees from six countries participated in the second course given this year. It is now anticipated that the training program will be given every other year, alternating with a legume training program.

Six posts of research associate are available for outstanding young men of the region. To date, there have been seven young men involved from four countries. Research associates participate in all activities of the crop improvement program and travel extensively in the region for the project.

Opportunity is also provided for advanced study. To date, two young men are studying toward the masters degree at the American University of Beirut. Two other young men are studying toward the Ph. D. at Universities in the USA using fellowship support from The Rockefeller Foundation.

It is felt that this effort to improve the technically trained manpower in the region is of great importance, necessary to effective crop improvement programs in many countries of the region.

Leland R. House

January 1975.

COMMUNICATION, INFORMATION, AND DOCUMENTATION SYSTEM (CIDS) FOR GENETIC RESOURCES (GR)

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I. Identification and Relation of the Genetic Resources CIDS

As early as 1965, members of the Taximetrics Laboratory under my direction were involved in problems related to information systems and genetic resources. Specifically, in 1967 our team began the development of the TAXIR system which was a generalized, computer based, information storage and retrieval system. TAXIR was used by Deitz of USDA at Pullman, Washington, in 1969 on his collection of Phaseolus species. I used TAXIR and related taximetrics methods for the taxonomic study of the species of the genus Manihot and the cultigen Manihot esculenta Crantz. In 1972, we began considering the expanded problem of international communication, information, and documentation systems for plant genetic resources in general. We had the opportunity to present the findings of our research at the March, 1973, Technical Conference on Plant Genetic Resources, In Rome, sponsored by FAO and the Inter-

national Biological Program. As a result of that conference and several of the resolutions passed by it, FAO increased their regular program budget in the Crop Ecology and Genetic Resources unit to augment and improve their work on genetic resources and documentation of the genetic resources. I was employed as the Documentation Officer for this function. In parallel, the Consultative Group for International Agricultural Research created the International Board for Plant Genetic Resources whose primary concern was any specific work across all crops all all areas of the world with respect to genetic resources. The International Board has determined, upon consultation with our staff, and FAO, that the computer-assisted communication, information documentation system is of exceptional importance and has consequently awarded the first of a series of contracts to us at the University of Colorado to work on the development of GRCIDS. FAO has placed me in Colorado as Project Director. Upon examination of the problem posed by documentation for genetic resources, it became evident that a computer-aided documentation system was necessary, but not sufficient for the needs of improvement and utilization of GR data. As a result of this understanding, we expanded the concept, a passive one of simply recording the data in some computerized system, to a larger function which included the communication of these data (information) to all individuals that might be involved in crop improvement programs. Further, there was the concommitant need to develop a network system on a global basis so that the information about any aspect of crop improvement based on genetic resources could be communicated to workers in the same crop.

Because of the expanded function, it was recognized that a larger

budget was required than that provided by the regular funds of FAO. Fortunately, there was recognition on the part of an independent organization, the Consultative Group on International Agricultural Research, that the problems of genetic resources merited a separate body under its direction, which would coordinate and aid in the funding of global activities with respect to genetic resources. The body formed is entitled the International Board of Plant Genetic Resources, which had its first meeting in Rome in June, 1974. At this first meeting, it was proposed by FAO that the communication, information, documentation system we proposed be supported. Further, it was proposed that because of the complex nature of the work and the need to assemble a competent team of interdisciplinary experts in CIDS, a contract would be initiated with the University of Colorado, specifically the Taximetrics Laboratory under my direction. More details are given on this function in an appended portion of this paper.

II. Concept of GRCIDS

It is the objective of our work to develop a network of compatible systems for data management for international and national agriculture research centers, and in each center to provide a useful computer-based information management system for those individuals involved in the several aspects of genetic resources and their improvement. Each individual in any center generates some type of useful data:

- -- In exploration and collection
- -- In gene banks (storage units)
- -- In evaluation
- -- In utilisation (breeding, selection and so forth.)

To begin this work, a computer-assisted information storage and retrieval system developed in the Taximetrics Laboratory -- TAXIR/STIRS is being used for the various purposes where data management is required. Furthermore, since there are many additional functions with data than simple retrieval of the data, we have embedded the TAXIR/STIRS information storage and retrieval system in a larger, more complete information management system, which we entitle EXIS (= EXecutive Information System). EXIS will associate the information storage and retrieval system with such other statistical analysis methods, clustering methods, and simulation models as are important for use by genetic resources workers, including that very important group, the plant breeder. This integrated system should speed the data processing problems up, so that decisions about programs of breeding, for example, will not be hampered by the arduous task of hand-manipulation of the data from stage to stage.

III. Use of EXIS

The various international and national agricultural centers chosen through a policy-making body, namely the International Board of Planned Genetic Resources, in conjunction with FAO, should receive or establish an information storage and retrieval system either in the center itself (if appropriate facilities exist), or at the nearest computer center available. In many cases, such agricultural centers have relations to universities or larger agricultural functions in the vicinity where adequate computing facilities exist. The purpose of establishing EXIS in these centers is to provide each worker with an automated information retrieval capability that he can use in

conjunction with his colleagues in that center. The specific set of computer programs (software) are to be installed by our team, following the policies established by the International Board and FAO. Further, we are obligated to aid the users in understanding that software and indicating means of efficient use for their own data. Thus the individual develops a data bank of his own information, and his data bank may be merged with similar data banks from other workers who cooperate in the program on an international basis, thus allowing rapid interchange of information through the network.

IV. Basic Questions.

Essentially, a need of GR workers is to answer the question "Who has got what GR material and where?" Several types of data will be required, therefore, to answer such broad questions; primarily, it will be necessary that we access data banks which contain information on the crop itself, as well as wild relatives or other GR material needed by the breeder -- where it came from, its qualities, its adaptability to certain environments, its uses, and so forth. Secondly, there should be data banks containing information on the scientists themselves, their areas of activity, their crop materials and their institutions. By combining these two types of data, we have the opportunity to answer the basic questions posed above. Of course, there are secondary uses for such data banks, and these secondary uses fall under the category of planning and decision-making. Related to allocation of research funds, it is necessary to answer the question "What GR material is available where and what more is needed for crops A, B, C and D, and what policies are necessary to accomplish any chosen task?"

V. Becoming a Part of the EXIS System.

As mentioned above, national and international centers participate in the applications of this system. The most appropriate mear by which we suggest those involved in sorghum studies start to become involved is through a pilot project. We have initiated pilot projects with several national and international institutions on several crops (including corn, potatoes, cow peas and common beans), and in each crop it has been important to discover the data problems of importance as determined by the scientist working on the crop. The scientists, in cooperation with members of our team, design a pilot project. After an agreement is reached to work on the project, one aspect is to determine the means by which to install the systems in centers selected by the workers involved in the project. Then the applicability of the system (or lack thereof) to sorghum or other crops, and the needs for various types of data processing considered integral to the pilot study is discovered.

A stepwise process using real data from the crop to aid the scientists in the pilot project to understand how the system (CIDS) works is followed:

A. Take a sample of all types of data presently used for the crop;

B. Show the similarities and differences existing between different data requirements in different centers;

C. Use the system to demonstrate how all types of data may be made compatible;

D. Find out how and where the system can be installed to serve the purposes of the sorghum specialists; and

E. Demonstrate how the results may be shared on a worldwide basis.

VI. The Process of Continued Use.

From the pilot study, any new requirements or developments in the system can best be determined, and modifications of a system can be made to meet the needs of the sorghum scientists. With the improved or modified version, the data sets (or data banks) initially used in the pilot study may be expanded to the full extent of available data. Once the systems are installed and the individuals trained in their applications, our team continues monitoring the system to determine if it is indeed meeting the needs of the individuals, and whether improvements or additions suggested by the scientists can be added to assist in their further work.

VII. Summary and Request for Assistance.

By careful perusal of the enclosed appendix, one may get a feel for our means of operation and our desires to assist where possible in the complex process of data management for crop genetic resources. It is my desire while here in Puerto Rico to confer with you about your data requirements, your desire to install a computer based system for sorghum, and to begin, if possible, to start the process of building a pilot project. I will be available during the sessions and afterwards to determine your desires in this regard.

APPENDIX

Explanation of GRCIDS Functions

Background and Objectives

Our initial premise is that within each genetic resource unit, and among all genetic resource workers, there is an extant system to communicate, document and manage the flow and analysis of information about extant genetic resources, whether in collections, undergoing improvement or concepts concerning further genetic resource collection, evaluation, storage, improvement, utilization, etc. There is also a basic need to analyze the functional activities within the current system and to investigate the probable increase in demand for genetic resource information and for genetic resources. We also wish to determine the role of genetic resources in crop improvement and to better understand their probable utilization. There is an additional need for a decision-making analysis using the information developed for those using or working with genetic resources. Many individuals feel that there is a definite need for improvement in the current system, and that the system can be improved with new computer-assisted methods which can be cost effectively implemented for users. We (and others) assume that if all genetic resource workers had similar operating systems and concepts of information flow, effective utilization of genetic resources and communication of genetic resource work would be facilitated considerably.

It is our intention to discover what current genetic resources communication documentation information system is presently employed and by what means it might be best improved, given the availability of

very limited resources to execute such improvement. We have defined the concept of genetic resources as broadly as possible, fully realizing that the primary initial responsibility is to insure that the detailed information about the world supply of genetic resources be made available through the use of computer at some international central point. We anticipate that an international center can be developed where information may be freely exchanged about global activities in genetic resources, where genetic resource material can be evaluated for any given characteristic, and where methodological assistance in genetic resource information or data processing, etc. can be obtained.

Systems Analysis

The starting point for any systems improvement is a detailed and rigorous systems analysis. From such an analysis suggestions for some systems modifications or redesign will be possible. The starting point in this specific case is the extant genetic resources network, which is already partially global in nature. Such an analysis will provide a descriptive understanding from which a cost effectiveness evaluation can be made of the operation of the network. The network is visualized as consisting of genetic resource operating units. These units are, in fact, individual genetic resource workers either operating individually or at centers which have a genetic resource component.

There are two interrelated components of this analysis, the macro, that analyses the interactions between units (or between different centers), and the micro, that analyses information flows and processes between individuals within a single center.

The macro analysis of this network basically will describe the following:

APPENDIX

(1) What is the composition of the composition of the network?

a. what (who) are the units

b. what does each do

c. what does each unit plan to do within the next reasonable time period

d. what genetic resource material does each unit have

e. what information concerning genetic resource material is available

f. what more information is needed

g. what more material is considered necessary

h. what specific expertise with regard to genetic resources does each unit posses.

(2) How do these units communicate with each other concerning the exchange of information, materials or technical expertise?

(3) In evaluating this exchange mechanism, what is the desire of the individual units to improve this information and material transfer?

(4) For those units which are essentially decision-making units concerning genetic resources for a nation or a multi-nation region or globally, what information is required concerning the interoperation of these genetic resource units to direct funds and resources to assist the cooperation of these units in their work? Futhermore, what is the redundancy among such units and how can these units be helped to make conscious decisions based on the value of such redundancy?

The micro analysis of the network is concerned basically with the operating system within any given unit with respect to genetic resource work. Although one might consider the work at the unit level to be beyond the scope of the work at the International Board for Plant Genetic

Resources, it is essential to point out that what occurs within the unit system is what will essentially create the macro demand for material and communication. A fairly good understanding must be available of the work at the micro level in order to perceive the need for genetic resources and the communication of information about genetic resources on a global level. Further, regardless of the effectiveness of a macro system, a micro system must be relatively effective and should have some of its components in common with other units, if indeed there are to be effective macro systems at reasonable costs. It is therefore necessary that a good analysis be made concerning the decisions that in any way relate to genetic resource material at the micro level and an analysis of the need for information (type, validity, reliability, quantity, methods of processing, inference, timing, sources, etc.) to and within the individual units and the methods that are used to handle this information flow for and to the decision points. Although this analysis would appear to be long and costly, it need not be since there are general commonalities among the functional operations of units.

Development of strategies for systems redesign

From the analysis and evaluation of the current GRCIDS macro-micro, several points emerge. The first is the determination of whether or not improvements (changes in effectiveness) of the extant GRCIDS can be made and at what costs (the cost factors must include the essential resistance to change). If at any level it is determined that increased benefits or improvements can be derived, what strategies can be used develop and implement the mechanisms for realizing benefit changes and again at what cost levels.

These strategies must be based on currently available techniques

such as the use of the computer including computing software to effect change as well as developments that can be derived and made operational in the very near future and the capacity of any operating group (or groups) to transfer this technology for actual use at the unit level and for use by any units on the international level.

Also the feedback response to a continuing analytic function to determine whether the strategy is appropriate and thus the methods of utilization and transfer are effective and that the procedures or methods are actually meeting the needs of the operating units. Often the primary or preliminary needs will be met but due to the availability of new techniques, users recognize what might be termed secondary needs and create a demand for additional and sometimes very important assistance. This can be viewed as the "technology awakening process" and is valid even among relatively sophisticated scientists. It is essential to recognize these secondary needs and it is often very, very profitable and possible to meet these needs.

Such feedback response can effect the development, transfer, planning and implementation as required with some central means of determining the priorities of such changes as suggested in the development.

SOME INFORMATION AND DOCUMENTATION COMPONENTS OF AN L. D. C. - FOCUSED SORGHUM NETWORK

Dorothy Parker

The increased production of Sorghum is of major interest to everyone here. In order to achieve increased production many factors are involved including improved grains, disease and pest control, improved agronomic practices, improved water conditions, etc., and the dissemination of information concerning better techniques and knowledge of advances in science.

Libraries should be deeply involved in the dissemination of knowledge. For many years, librarians have exchanged information freely and formed networks to disseminate information. The reason for doing this has been twofold; first, to obtain information that the libraries do not have and second, to satisfy the needs of the local clients.

Recently, the librarians of the international institutes of agriculture (which are funded by various philanthropic agencies such as the Ford, Kellogg, and Rockefeller Foundation and national agencies including AID, CIDA, several from Europe and Japan as well as the World Bank, the Inter American Bank and FAO) met and agreed to form a network for their mutual benefit. It was learned that several of the institutes had similar projects. For example; four of the institutes have begun to work on multiple cropping systems. Each librarian had planned or even started the collection of materials on this subject. When they found that they all were planning to conduct a search for the world-wide literature on the subject, they agreed to cooperate and divided the world into four geographic units. By exchanging their bibliographic compilations, much time and effort can be eliminated.

AID is currently engaged in efforts to bring about a wider dissemination of the scientific and technical advances which have been produced by their overseas projects. Many of these results would greatly assist the scientists and technicians in the L.D.C.s if the results were more widely known. AID is helping the dissemination of information by receiving copies of all publications which have resulted from AID contracts. The citations of these publications will be made available to the major bibliographic publications such as the Bibliography of Agriculture, the Commonwealth Agricultural Bureaux' Series of Abstracts and Reviews and the Medlar's Service of the National Library of Medicine. With the publication of the bibliographic citations, agricultural libraries all over the world can learn of the appearance of new literature. This will assist librarians in making their clientele aware of new and pertinent information.

Fortunately for the scientists and technicians who work on Sorghum, there is in existence a bibliography on Sorghum which covers world-wide literature.

A few years ago a training program for science information specialists was undertaken by the Biological Sciences Communications Project of Georgetown University. Four students; one from California, one from the National Agricultural Library, one from Uganda, and one from Mexico were involved. While these students were working for a Masters Degree in Library Science, they contributed as part-time assistants in the preparation of a bibliography on Sorghum. The bibliography covered international literature on this subject. A total of 746 periodicals were searched for citations. The publications were published in 26 of the world's languages and it was necessary to obtain assistance from

language specialists to translate and/or transliterate the subjects.

The bibliography was organized as follows:

I. A list of the abbreviations of the periodicals consulted was followed by the general citations consulted, including:

   A. Bibliographies

   B. Books

   C. Reports

   D. History

II. Details of the Sorghum plant broken down by subject matter, such as:

   A. Anatomy and Morphology

   B. Physiology-biochemistry

   C. Taxonomy and Biosystematics

   D. Genetics and Cytology

   E. Breeding

   F. Varieties and Hybrids

III. The next major division included Sorghum growing:

   A. Agricultural Meteorology, climatic influences and crop-weather relations

   B. Soils

   C. Irrigation

   D. Drainage

   E. Water supply

   F. Water requirements

   G. Soil-plant-water relations

   H. Water management

IV. This was followed by agronomic references and were subdivided into the following categories:

A. General

B. Cropping systems

C. Fertilizers and plant nutrition

D. Harvesting

E. Planting

F. Rates

G. Spacing

H. Seasons and locations

I. Cultivation

J. Soil management and tillage

K. Weeds and weed control including herbicides

L. Johnsongrass

M. Forage and pastures

V. The next major division consists of citations to publications on mechanization.

VI. Then the category of seeds and seed production are followed by references to plant protection and seed treatment.

VII. The next category is devoted to diseases of Sorghum. These are divided into those of:

A. General

B. Seed rot

C. Seedling diseases

D. Seed treatment

E. Root and stalk diseases

F. Folial diseases

1. Fungal leaf spots and blights

2. Rusts

3. Downy mildews and sooty moulds

G. Inflorescence and grain diseases

H. Parasitic flowering plants and nematodes

VIII. The next category is devoted to insect pests with the following subdivisions:

A. General

B. Arachnida

C. Coleoptera

D. Diptera

E. Hemiptera (Heteroptera)

F. Hemiptera (homoptera)

G. Hymenoptera

H. Lepidoptera

I. Orthoptera

J. Thysanoptera

IX. Other pests including birds and rodents

X. The Sorghum product is the next category and includes:

A. Storage

B. Drying

C. Milling

D. Analysis and composition

E. Food and human nutrition

F. Feed and animal nutrition

G. Livestock poisoning

H. Other uses

XI. The next category concerns the Sorghum Product:

A. General citations

B. Silage

C. Forage pastures and greenchops

D. Grain

E. HCN and livestock poisoning

F. Technology and commercial uses

XII. The last category of citations are those related to economic and social aspects.

XIII. The three indices complete the bibliography:

A. One is an author index. (This consists of references to each of the authors and is followed by the number of the entry which permits a quick location of the citation).

B. The second index is a subject index. (Each subject is followed by the number of the citation or citations and each number is followed by a letter which indicates the language in which the publication was written).

C. The third index is a geographic index. (The geographic area to which each citation pertains is listed alphabetially and is followed by the number or numbers of the citations in the bibliography and the symbol for the language in which the publication is written).

This bibliography covered the years of 1930 to 1963. Another publication which is a supplement to the first bibliography was prepared by Baljeet Kaur, Dr. Leland R. House and Anne List. It covers the literature for the period 1964-1968. For the supplement, the same format was used with minor changes. A total of 30 languages were encountered

in the compilation of the supplement and these were gleaned from a total of 809 periodicals.

Since these two bibliographies were completed, a new service covering the world's literature on Sorghum has been instituted by the National Agricultural Library in Washington. With this service, it is possible to obtain the printout of the world's agricultural literature that has been stored in the computer program of NAL. This service obviates the necessity of making a manual search for references on Sorghum.

It is suggested that libraries all over the world which have an interest in Sorghum literature to serve the needs of the library clientele collaborate in forming an international network for the dissemination of Sorghum literature. It would be useful if AID could sponsor the collection of information concerning libraries which would like to cooperate in exchanging information, data, reprints or whatever would be deemed useful. Often it is difficult for scientists in one part of the world to gain data or statistics on a crop in some other part of the world. Cooperating librarians in an international network could assist each other greatly in some of these problems.

The interest of librarians located at the international research institutes has already been demonstrated and they have expressed their willingness to assist. In addition there are many research centers and institutions which would be interested also.

In the formation of a network, there should be a flow of infor- ation from and to other members of the network. We have mentioned here he importance of getting the results of research to the L.D.C.s. It is ust as important that research results be sent quickly from the L.D.C.s

to the D.C.s. As an example of this, the team of U.S. scientists who went to China earliers this year, learned of a technique that had not been previously known to them, i.e. China is producing quantities of fertilizers that do not depend upon petroleum for their source. In a time of crises such as confronts the world today, this could be of significance. The developing countries cannot afford vast programs of scientific research and if they could utilize the results of research accomplished elsewhere, their limited budgets could be directed to their most pressing needs. Libraries particularly are costly to acquire and to maintain. If each library could acquire the basic literature that is pertinent to its needs, the exchange of information and photocopies, etc., would make the smallest library more useful and effective. A network could assist in this accomplishment.

SORGHUM IN HIGH PRODUCTION CROPPING SYSTEMS

Jerry W. Maranville

INTRODUCTION

The importance of sorghum as a feed or food crop is becoming more and more evident as the need for more high quality food increases. Sorghum ranks among the top cereals in cultivated area worldwide following wheat, rice, and maize. Table 1 (6) compares sorghum production on a world basis. One of the striking observations is the increase in area planted to sorghum in the Latin American countries over the 10 year span from 1954-1964. The present production in Latin America is now nearly twice that reported in Table 1, indicating the trend is not diminished (16). Similarly, yield increases have improved in an impressive manner, resulting largely from the acceptance of hybrids and better management. These factors, when coupled together, have resulted in significant increases in total production. Argentina, for example, has nearly doubled sorghum production in a five year span going from 2.1 million tons in 1965-66 to 4.7 million tons in 1970-71 (16). In comparison to other crops on a worldwide basis, sorghum has shown an increase in productivity five times that of the mean of four major feed grains (16). In the USA, the crop ranks second in importance as a feed grain (25). Clearly, producing sorghum in high production cropping systems is a goal worth pursuing. This paper will deal with this topic in three categories: 1) monoculture; 2) ratoon cropping; and 3) multi-cropping.

SORGHUM IN MONOCULTURE

In Europe and North America, sorghum is generally grown in areas where the average summer temperature exceeds 20 C and the frost-free season is 125 days or more. Yields are often limited by the length of the growing season which dictates the maturity class generally grown. Maturity genes influence leaf size and panicle weight (24), thus ultimately influencing yield. Longer maturity classes of sorghum tend to produce larger plants and greater yields (5). Highest yields in the USA are generally reported from Arizona. California, or Texas where the crop is grown under irrigation. These yields from farmer production fields can exceed 13,000 kg per hectare (10). Maximum grain production, of course, also involves optimum crop management and plant populations, as well as supplies of water and nutrients.

Moisture Considerations

Grain sorghum is best adapted to medium-textured soils and can tolerate medium-high pH's (25). When moisture is not limiting, lighter textured soils tend to produce better growth than heavier textured types.

Table 2 (18) illustrates that under conditions of unlimited moisture, grain sorghum can consume large amounts of water. The total water use shown certainly represents more water than is often received by precipitation in areas where the crop is grown. It also represents a generalized water use figure on limited genetic material. Sorghums differ in patterns of water extraction (29), and it is logical to suspect that a difference can exist in total water consumption. Sorghums are also more tolerant than corn to excess moisture, and can withstand brief periods of flooding without drowning out (10).

In order to produce 6200 kg per hectare yield in the southern part of the US Sorghum Belt, the total water use is generally 53 to 58 cm per year (10). The crop use averages about 0.65 cm per day from boot through dough stage (18).

Although sorghum has the ability to remain dormant during a drought period, and is perhaps best known as a dryland crop, it responds well to irrigation in certain areas. More than 25% of the sorghum in the USA is under irrigation including most areas in California, New Mexico, Arizona, and a considerable area in Texas (25). Timeliness of irrigation is critical to yields. If the soil moisture falls below 25% in the upper 60 cm, yields can be reduced (25). It is generally undesirable to apply water to the crop once the grain is in the dough stage since this encourages tillering and a delay in plant drying at harvest.

A stress day index has been proposed as a useful tool in determining need and scheduling of irrigation (8). By this approach, irrigation is started when the daily index reaches a predetermined critical level determined by the product of the plant water deficit and the susceptibility of the crop to that deficit at a given growth stage.

Sorghum possesses xerophytic characteristics which are of value in drought endurance (29). However, the ability to recover after drought conditions appears to be the major factor allowing it to yield reliably under adverse moisture situations (6).

Fertilizer Considerations

Sorghum tends to deplete the soil of nutrients by removal of large amounts during the course of a season (25). Grain in a 6200 kg per hectare crop generally removes about 112 kg nitrogen, 15.5 kg phosphorus, and 15.5 kg potassium per hectare. Nitrogen is most often the limiting

element in production, but iron deficiencies are noted on calcareous soils (19). Amounts of nitrogen applied generally depend substantially on soil type. Sandier soils may require more nitrogen since leaching occurs. Table 3 (20) illustrates the yield response of two soil types in Texas from preplant application. In the clay loam soils, large amounts of nitrogen are not leached out by water as in the fine sandy loam, and unused nitrogen may even accumulate from year to year in the heavy soils. However, responses are generally obtained in any soil type showing that nitrogen should be applied each year in order to maintain adequate yields (20).

Rates of nitrogen application vary depending also on moisture available during the growing season. Under conditions of dryland culture, 25 kg to 50 kg per hectare are common rates with as much as 75 kg per hectare being applied in better dryland areas (25). Where yields are reduced due to moisture stress during a given season, it is not entirely correct to assume that the reduction in nitrogen uptake is proportional to yield reductions. Table 4 (17) shows that there is generally an inverse relationship between yield and protein content in sorghum. Higher percentages of protein in lower yielding crops often results in considerably more nitrogen being removed than yields would indicate. This stems from the fact that much of the protein in the grain is found in the embryo and aleurone layer, structures formed at the initiation of grain formation. Reductions in the total protein of lower yielding crops illustrated in the Table, are reflected in reductions of endosperm protein which is deposited during grain filling. Differences also exist among sorghums with respect to the ability to produce more protein at given yield levels (3).

Rates of nitrogen applied to irrigated sorghum generally ranges from 125 to 175 kg per hectare (25). Higher rates have been used, but the economical return at extremely high rates is very likely slight or non-existent. Table 5 (9) shows data from a subirrigation experiment conducted in Nebraska to determine optimum rate and time of application of nitrogen. Yields were similar for all methods and rates indicating that under these conditions, 112 kg per hectare nitrogen applied once early was sufficient to produce maximum yields. Other research, however, indicates a beneficial response by splitting the nitrogen application (20).

Starter fertilizer is sometimes used as a means of applying some of the fertilizer to the crop. However, yields are benefited only in certain rather well-defined situations. Where soil fertility is normal or high, and planting dates are normal, no yield increases due to this practice have been observed (14). Where deficiencies of an element such as phosphorus exist, the practice of using starter fertilizer may be quite beneficial as shown in Table 6 (14). Earlier blooming of plants in plots fertilized with a fertilizer containing phosphorus was primarily responsible for higher yields in this experiment. The fact that phosphorus rather than nitrogen produced the response was confirmed in another experiment (15). An insufficient time for grain filling to occur before the first killing frost significantly reduced yields in the unfertilized plots. This is also evidenced from the fact that the early NB-505 did not respond to the fertilizer. In this case, there was sufficient time for maximum production to be attained in both fertilized and unfertilized treatments, even though the fertilized plots had bloomed considerably earlier.

Sorghum seems to respond well to all forms of nitrogen carriers (25). The type used may depend largely on availability, cost, and time which the application is made.

Populations and Row Spacings

Yields generally increase as plant population increases providing soil moisture and other factors are not limiting. Research[1/] in Nebraska, however, shows little justification for planting grain sorghum at stands greater than 40,000 plants per hectare. Yields of 9500 kg per hectare can be attained at this rate under dryland conditions where rainfall is likely to exceed 80 cm per year. Under irrigation, maximum yields are also obtained at this rate or perhaps slightly higher (10). Table 7 shows suggested seeding rates according to expected moisture during the growing season and different row widths to obtain desired populations. Better management often requires planting seeds on a given number per row length basis rather than a kg per hectare basis since grain sorghums range from under 6800 seeds to over 9100 seeds per kg (10). Failure of seeds to produce plants may be due to inferior seed, insufficient moisture, pests, or other factors. Recommended seeding rates generally reflect a 65% to 75% field emergence rate.

Sorghum has the ability to compensate for either too great or insufficient stands as well. When stands are thinner than those which the soil moisture and environment may support, tillering often occurs and more heads are produced. Tillering is often more pronounced on

1/ Information provided by Dr. K. D. Frank and Dr. D. H. Sander, Extension Agronomists, University of Nebraska.

heavy or clay-type soils than sandy soils during favorable seasons (25). There is also an inverse relationship which exists between head size and population at a given environmental regime (27).

Row spacing varies according to individual systems of management. It can generally be shown that 50 cm row widths produce more grain than 100 cm row widths (2, 13, 28). Apparently, narrow row sorghum provides an effective feeding area around each plant and a canopy which lowers soil temperature and decreases evaporation (10). However, some research indicates that the improved light interception patterns in narrow row sorghum is the factor primarily responsible for increased yields (4).

Double-row planting (1,7) is common in some areas. This provides some ease in irrigation and cultivation. The method essentially duplicates narrow row sorghum. For example, planting two rows 30 cm apart in beds with 100 cm between centers of row sets will produce a population average the same as two rows 50 cm apart. Where cultivation is to be the primary means of weed control, row spacing should be as narrow as can be cultivated. Rows narrower than this such as in close drilled sorghum, must rely exclusively on chemicals for weed control.

The preceding sections have dealt with sorghum production from a limited management viewpoint. It is recognized that many other aspects of management are important such as tillage, pest control, and others. Some of these will be covered in detail in other papers at this conference. Reviews on these subjects are also available elsewhere.

RATOON CROPPING

An excellent review on ratooning was made by Plucknett et al (23), and to go into detail on the subject in this paper is not feasible. Rather, some generalities will be mentioned with respect to grain

sorghum in the way of introducing the topic since areas of Latin America may be subject to this type of cropping system.

Ratooning is a practice in the tropics or subtropics which simply implies more than one harvest from a single plant. Grain sorghum has been grown as a ratoon crop in India, Egypt, Australia, Hawaii, Arizona, California, and the Philippines (23), as well as Africa (6). It seems logical to assume that the method holds some possibility for any tropical area or other area not subject to low temperatures during the growing season. The fundamental basis for ratooning is the ability of plants to be perennial in nature and continue growth beyond one harvest cycle, a category in which sorghum falls.

The striking potential for ratooning in the tropics is illustrated by the work of Mackenzie and Parbery (12) in Australia. Yields of 9000 kg and 13,500 kg per hectare were obtained for hybrids RS-610 and Alpha, respectively from one sown and one ratoon crop. This equals or exceeds the best yields produced in a monoculture system in the USA.

The effect of increased tiller density with successive ratooning appears to be critical in grain sorghum (23). An inverse relationship of yield with density of tillers may be noted. This relationship apparently predominates when not all tillers produce seed in the first year after their development or are different in size and age. Tiller density is influenced by rate of planting (11). Generally as planting rate increases, tiller production decreases. Poor tillering can also reduce ratoon growth such as in a situation of broadcast seeding versus row seeding where excess shading is a factor (22).

Factors similar to those important in monoculture are also important in ratooning. Sufficient moisture, fertilizer, weed control, and

freedom from insects and disease are critical t production. Removal of stubble after harvest to a height of 10 to 15 cm generally produces significant increases in grain yield of the ratoon crop (12). An early irrigation in order to stimulate rapid and vigorous ratoon growth is practiced for sorghum, generally immediately after stubble removal. The crop is, however, quite resistant to water stress in a ratooning situation (12). As with other crops or systems of production, adequate moisture must be available during the ratoon growth in order for maximum yields to be obtained.

Fertilizer rates mav need to be increased for each succeeding ratoon crop. Optimum sugar cane yields, for example, were obtained in Egypt by applying 125 kg, 225-245 kg, and 270 kg per hectare of nitrogen for the plant crop, first ratoon, and second ratoon, respectively (21). The optimum rate for ratoon crops is generally considered to be 55 kg per hectare higher than for plant crops (23). The high yields mentioned previously in Australia were obtained by applying 225 kg per hectare nitrogen to the plant crop and an equivalent amount to the ratoon crop.

Success or failure of this system may depend on factors of crop management. Other factors, perhaps not related to management directly such as a monsoon season which might impair harvest of the ratoon crop, also are important considerations. Certainly, selection of genetic material which adapts well to ratooning may well be one broad objective in sorghum breeding.

SORGHUM IN MULTI-CROPPING

Sorghum generally does well following any crop. In certain areas of the USA, sorghum is generally associated with wheat and cotton in cropping sequences. A common rotation in the cotton producing states is sorghum-soybeans-cotton while in areas of Arizona and California, wheat or barley often precede sorghum (10).

Sorghum does have some potential in the double cropping of land, even where growing seasons are not particularly long. Table 8 (15) shows the yields which were obtained in Nebraska from a double cropping experiment conducted in 1970. The crop was planted immediately following winter wheat which yielded 3360 kg per hectare. The highest yield of sorghum was 4700 kg per hectare giving a total production of over 8000 kg grain per hectare. The results are for a season ideal for double cropping in this area. Climatological data indicate that when planting during the first week in July, there will be a 90% chance that only 86 days will be available for growth before the first frost. Variations in length of the growing season predominately determine success or failure of sorghum as the second grain crop from the same unit of land. Planting after the first of July in this area is risky.

Another possibility for sorghum in double cropping for these areas, is to use the small grain as a forage. Table 9 compares various cropping sequences where small grains are produced for forage and sorghum is harvested for grain. By harvesting the cereals in this manner, the second crop can be planted in mid-June allowing sufficient time for grain to be produced. Winter wheat appears most favorable for this sequence since it could be harvested earlier than the others at the time of

maximum forage value. Triticale and rye, however, produced greater yields (Emiro A. Rojas, personal communication).

The data show that yields were drastically reduced over normal monoculture yields in 1973 where the crops were not irrigated. Considerable reductions were also evident in 1974 where moisture was not limiting, but not as dramatic as 1973. Sorghum appears to do best following triticale in this type of cropping practice, but may also have potential to follow wheat or rye. The yield reductions observed in 1974 when moisture and growing season length were not limiting indicated that other management factors are extremely important. It was generally observed that weeds and cereal regrowth were difficult to control, and this accounted for some of the yield reductions. Adequate stands may also be difficult to obtain if irrigation is not applied immediately after planting, since dry hot weather in mid June tend to dry the surface layer of soil rapidly. Greenbug infestations are likely and unless controlled, will severely damage sorghum which is small during the latter part of June and early July.

Sorghum does have some potential in a double cropping system although yields may be reduced over production in monoculture. The system provides a broader choice of cropping practices and crops which can be grown on a given land area during the same season. Livestock production, for example, may make forage an essential element in cropping systems in certain areas. Research on specific management practices should improve the feasibility of using sorghum in double cropping.

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Table 1. Area under sorghum, in thousands of hectares. (Figures are tentative, China and the U.S.S.R. omitted).

Region	1954	1960	1964
Europe	40	35	75
North America	4,740	6,310	4,850
Latin America	465	985	1,480
Near East	1,195	1,590	1,730
Far East	18,020	17,860	18,730
Africa	9,850	11,255	11,700
Oceana	85	105	140
World total (excluding China and U.S.S.R.)	34,395	38,140	38,705

Table 2. Water use of grain sorghum according to growth stage.

Growth Stage, Emergence to:	Cumulative Water Use (cm).
30 cm	10-13
Boot	23-25
Grain Dough	46-50
Maturity (Frost)	56-60

Table 3. Effect of rate of nitrogen application on grain sorghum yield in contrasting soil types.

Soil Type	N Rate (kg/ha) 90	135	180
Fine Sandy Loam	5710	6325	7670
Clay Loam	6550	6830	6385

Table 4. Relationship between yield, percent protein and total protein production under two cropping regimes.

Hybrid	Regime	Yield (kg/ha)	% Reduction	% Protein	Total Protein (kg/ha)	% Reduction
NB-505	I*	6450		9.5	612.8	
	CC**	3760	42	11.4	428.6	31
Asgrow RR-A	I	7775		7.8	606.5	
	CC	2620	66	10.2	267.2	56
RS-610	I	7160		7.9	565.6	
	CC	5330	26	8.9	474.4	17
RS-650	I	7660		7.6	582.2	
	CC	4885	37	9.6	469.0	19

* irrigated
** continuous crop

Table 5. Trends in grain yield and percent protein, in RS 626 grain sorghum produced by different rates and time of nitrogen application.

Rate (kg/ha)	Method	Grain Yield (kg/ha)	% Protein
0		6,166a	7.09a
112	applied once	8,187b	10.08b
224	applied once	8,974b	9.24c
336	applied once	8,317b	10.03b
112	tri-split	8,729b	9.48c
224	tri-split	8,873b	9.63c
336	tri-split	8,617b	9.62c
112	continuous	8,316b	8.96d
224	continuous	8,547b	9.24cd
336	continuous	8,031b	9.63c

Table 6. Sorghum yields for five hybrid planted June 8 using liquid row applied fertilizer in a low phosphorus soil.

Hybrid	6-23-0 Fertilizer	kg/ha Yield
NB-505	+	6850
	-	6800
RS-610	+	7000
	-	5250
E-57	+	7650
	-	6850
RS-671	+	7200
	-	5000
Pioneer 814	+	7600
	-	6850

Table 7.* Suggested planting rates for grain sorghum in Nebraska assuming a 65% emergence.

Row Width (cm)	Annual Rainfall (cm) Less than 50	50-65	65-80	Greater than 80
	Seeds per 3.3 meter row			
25	4-6	5-10	8-15	10-20
50	8-12	10-20	12-30	20-40
75	10-17	13-30	15-40	30-60
100	15-22	20-40	22-60	40-80

*Data from K. D. Frank and D. H. Sander. Extension Agronomists. University of Nebraska.

Table 8. Yield of three sorghum hybrids at two dates of planting in a double cropping experiment.

Hybrid	Planting Date	Yield (kg/ha) None	N	N + P
MM-54BR	July 1	4075	3575	4580
	July 10	2070	3260	4015
A-25	July 1	3010	3135	4700
	July 10	750	1130	3765
NB-505	July 1	3200	2820	4140
	July 10	690	1570	2570
Ave.	July 1	3430	3175	4475
	July 10	1170	1985	3450

Table 9.* Yields of sorghum as a summer crop following winter cereals or oats harvested as forage.

Winter Crop	Yield, 1973 Non-irrigated kg/ha	Yield, 1974 Irrigated kg/ha
Centurk Wheat	682	2950
Rye	720	2927
Triticale	741	3625
Oats	671	1563
Fallow	6183	5328

*Data are from research conducted by Emiro A. Rojas in completion of the Ph.D. degree.

MANAGEMENT PRACTICES AND FACTORS LIMITING SORGHUM YIELDS IN LOW PRODUCTION SITUATIONS[1]

D. L. Oswalt[2]

INTRODUCTION

The traditional farming practices of most subsistence agricultural (low production) areas have evolved through minimized capital investments and reduced risks to prevent complete failures of food production for their society. This has often resulted in subsistence farmers practicing shifting cultivation of hillsides or slopes with minimal land preparation, fertilizer usage, and power. It is the combined interactions of soil, environment, cultivars, management practices, marketing systems, storage facilities, and man which have resulted in the yield levels presently obtained in a given sorghum producing area. Few situations provide ideal conditions for the best integration of all yield factors. Each farmer must deal with something less than optimal conditions. Management is difficult when judgments relative to correcting limiting yield factors are based on narrow experiences, limited knowledge of

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causes of losses, traditions, and social pressures which discourage innovative trial and error or even the open desire for improvement.

Hard work and low income have often led to the identification of farming as an undesirable occupation. This discourages the current farmers and prevents innovative young persons from selecting farming as a vocation. The development and utilization of pertinent forms of education and efficient farming methods are essential to improve the social image, financial conditions of farming, and farm living standards if yields are to be substantially increased.

Changes introduced to increase yield must be based on the soil, climate, and man's social development of each area and must prevent or minimize any possibility of risk to the food supply of the farmer. A subsistence farmer will initially direct his efforts to produce food by his traditionally selected scheme and then only give secondary efforts to new innovations. This often results in drastically reduced yields from new management practices or new varieties due to competition for the farmer's time and efforts. Most significant yield increases have resulted when cash (export) crops provided substantial increases to the farmer's income without the need for storage, long distance transportation, or his development of a market. Such capital and risks have usually been initially provided by the government or outside agency for the export crops.

To identify and correct the often subtle factor(s) limiting yield in an area of traditional agriculture is difficult and elusive, but essential if total production is to be increased. Selected factors which limit sorghum yields in low production areas will be discussed in general. This is not an attempt to itemize research topics, but is

an expression of concepts and experiences. Major emphasis will be directed toward the integrated relationships of soil, water, environment, cultivars, and man that can be arranged in more favorable combinations to increase sorghum yield. The bias of the author is acknowledged and the views expressed are the responsibility of the author.

ENVIRONMENTAL CONTROL AND PREDICTABILITY

Climates are often less predictable and more extreme in low production areas. Intensity and variability of rainfall patterns, extreme fluctuations of water table level, severe drainage limitations, severe storms, less predictable length of growing season, shorter length of day, quality and intensity of light, periodic and diurnal temperature fluctuations, a narrower balance between photosynthesis and respiration rates, competition between micro and macro organisms, improper plant populations, and competition among plant species (weeds) for the uptake of soil nutrients, are a few of the interrelated factors of the environment which influence yields. Experiences indicate that even positioning of plots relative to slope in order to maximize temperature control, light reception, crop ventilation, and carbon dioxide concentrations, and to minimize wind damage, surface drainage, and erosion will influence yield. The considerations of photosynthesis and respiration rates, as well as light intensity, quality, and duration are essential in testing potential cultivars and varieties within a cultivar which can be utilized within a given farming area for increased production. The unreliability of early plantings due to the rainfall variation and uncertainty may necessitate the selection of short growing season varieties which are planted at a later time. However, selection of a short season

variety often results in inherent lower yields and difficulty in harvesting and drying of the mature plants.

The variety's selection and management practices presently utilized in an area are the accumulation of farming procedures and adaptations to the specific environments which have prevented complete crop failure. Many varieties in such situations will not respond by an increased yield to improved fertility or management practices.

The above-ground environment is an area of high competition in that weeds, insects, diseases, rodents, birds, large animals, and other plant species are in direct competition with crops. Sorghum has a relatively small seed and is characteristically slow in initial stages of growth. In order to minimize this yield reducing factor it is essential that seedbed preparation, seed placement, seedling density, seed and seedling protectants and planting time be coordinated with the most ideal soil moisture and temperature conditions. Vigorous seedlings have less potential for damage due to insects and diseases and will more rapidly develop ground cover to conserve moisture and aid weed control. It is extremely important that necessary thinning be done early without damage to remaining plants. It is essential that all weeds be removed before they have reached a 5 cm height. This will prevent one of the most common yield losses and conserve nutrients and moisture for the development of the crop seedling. Deficient soil nutrients should be applied early within the moisture and seedling-root zones, but not in direct contact with the seed or directly below the seed, to insure the development of potentially high yielding seedlings.

The diversity in sorghum germplasm demonstrates its relative tolerance to adverse combinations of environmental conditions. The

mechanisms available to increase yields both genetically and agronomically are present within the germplasm bank of grain sorghums. Methods for identification of varieties which respond to specific combinations of adversities are limiting. To date, the only reliable procedure is to actually grow representative varieties in the environments in test plots before large scale production is undertaken.

WATER MANAGEMENT

The relationship of water management to crop yield and man's welfare is critical. In semi-arid areas, water is often much more limiting than land itself. Water management requires long-time investments of labor which have been rejected or unrecognized in many low yield regions However, provision for a dependable water supply must be obtained before consistent yield increases can be gained. The continued transport of household water across great distances, and the absence of irrigation attempts in many low agricultural production areas is indicative of the rejection by the societies of a long-term investment of labor in water management for either man or his agricultural production.

Observation of fields and experimental plots result in more evidence of inadequate water management than any other single factor. It is seldom that one hectare can be found without at least one section where yield is reduced due to inadequate water management.

Experiences in a tropical savannah showed that diverting surface water and planting local varieties on small ridges, or in other situations in small trenches, resulted in significant long-time yield increases. When planted on ridges, root growth was encouraged and the ultimate tilth of the soil was improved. This contributed to increased and stabilized

yields over a ten-year period of continuing cultivation without application of fertilizers.

Establishment of water management practices and the identification of plant cultivars which can adjust to specific water conditions must be criteria for testing germplasm to improve yield. This requires major capital investments of labor and planning which is usually beyond the attainability of the individual farmer. The government of the area, therefore, influences the success and stability of agricultural water supplies by its priorities and leadership in providing improved management without loss of farmer confidence and security.

SOIL PHYSICS AND CHEMISTRY

It is essential that the soil physical structure be and remain favorable for plant growth before improved cultivar selections and management practices can be utilized. Farming has usually been started in areas least difficult to work naturally, and which have the most ideal combination of soil chemical and physical properties. As additional land area is required, crop yields are limited unless the physical and chemical properties of many soil deficiencies are corrected and its productivity conserved. New lands are often of heavier texture and more difficult to work, thus requiring increased investments in power. The potential of a given soil and its environment can often be evaluated by micro variability in localized situations (such as termite mounds, ash heaps, and animal waste disposal areas) which visually show an increased yield. The study of these isolated examples of superior growth can be used to demonstrate the potential of an area and can be a key to designing trials for area improvements.

Yield losses are often caused by inadequate and improper seedbed preparation. This is often due to very difficult clay systems which become either too wet or too dry before the farmer can prepare a seedbed using his inadquate power and limited tools. Therefore, poor germination due to inadequate soil and seed contact, weak seedlings, or plantings without proper seed spacing result in the farmer's inability to subsequently control weeds, to efficiently apply fertilizer, or to control pests. Thus, the farmer's yield is often irrecoverably limited by his traditional seedbed preparation and planting procedures employed to maximize his low supply of energy and to reduce the risk of complete food crop failure.

The higher temperatures of the soil in many low production areas result in the soil chemical reactions progressing at five or ten times as rapid as they might occur in a temperate soil area. This results in rapid decomposition of parent material and organic matter, releasing plant nutrients to erosion processes, fixation or the accumulation of toxic levels of compounds. Tropical forest areas recycle a major portion of their available plant nutrients in the growing plants. Removal of the growing vegetation and introduction of forms of clean cultivation can be disastrous by reducing nutrient availability. The application of fertilizer without consideration for the maintenance of a balance in available nutrients can cause the development of micro and macro nutrient deficiencies at much more rapid rates than anticipated. Deficiencies of the parent material, low pH, low cation exchange capacity, low levels of organic matter, or rapidly oxidizing organic matter, salt accumulation due to improper drainage or high rates of evaporation, potential toxic organic residue accumulations, and rapid weathering are all factors

that can potentially limit plant nutrient availability and recovery in many low production areas. The general low pH and high content of aluminum and manganese of many warm region soils result in unexpected lowering of yields when high rates of fertilizers are applied. Therefore, heavy rates of liming to raise the pH may alter the micro bacteriological activity of the soil and precipitate or render other elements inactive or unavailable resulting in increased disease and insect damage and low yields.

The marginal levels of numerous factors in the soil-root environment aggravate the competition among soil micro and macro organisms and among plant species for uptake of available soil nutrients. Broadcast and large soil applications of fertilizer may be uneconomical compared to banding or foliar applications of nutrients.

The mobility, volatility and general low levels of nitrogen in low production soils necessitate the selection of plant types which efficiently use nitrogen, can fix nitrogen or which can respond to single or multiple applications of nitrogen to the soil or to the foliage. In addition, the high soil temperatures will result in its rapid denitrificiation or susceptibility to leaching. Selection of cultivars that can capture the nitrogen at the beginning of the growing season or soon after it is applied for later utilization in growth establishment of rotations containing nitrogen-fixing cultivars and interplanting of legumes with non-legumes can increase yields.

The incorporation of large amounts of carbonatious material in the soil often makes the carbon-nitrogen ratio very critical. Thus, the competition for nitrates by micro organisms when they decompose the organic matter is greater than the ability of the plant roots to obtain

the nitrogen in the soil.

The selection of cultivars to respond to the specific physical and chemical properties of a soil is an approach to increased yield; however, it is generally only possible to go to certain limits without ultimately correcting the deficiencies or abnormalities found in the soil itself. Testing of cultivars for tolerances to aluminum and manganese toxicity and salts and for maximum utilization of the low levels of phosphorus and sulfur is essential for the development of new varieties to initially increase yields in many sorghum production areas.

CULTIVAR SELECTION AND GENOTYPES

Extremes within one crop season relative to day and night temperature, water intensity, water logging or flooding, drought stress, relative humidity, wind velocity, disease intensity, insect populations, changes in soil pH and nutrient availability, leaching, salt accumulations, limited fertility, credit availability, limited use of power machinery, acceptability of crop for food, feed or utilization, numerous potential pests, and limited accumulated experiences have resulted in the selection of a group of crop species and the development of genotypes within a species for dependable yield in selected areas. These varieties presently used for food production have permitted consistent existence, but are not likely the best genotypes for greatest response to improved management practices. Crops newly introduced in these areas are usually export crops which are accepted because they are not food crops of the locality and storage facilities and marketing systems are brought directly to the area without risk to the farmer. Cash crops, introduced as new crops, with a total management package have been

accepted and successful until food production is reduced to severely low levels. Then the low production farmer gives food production his first priority. Sorghum is most commonly grown as a food crop; therefore, changes necessary to utilize it as a cash crop and make its yields more profitable involve replacing present traditional management practices with improved varieties and management procedures, without initial added costs or risks.

It is essential that breeding and agronomic programs be conducted in connection with potential water management practices, fertilizer trials, planting methods and adaptability to the climate in specific production areas in order to select cultivars that will respond most efficiently to improved types of management practices with increasing fertilizer and capital investments. The development and utilization of the pertinent training of the farmer in identifying these multiple limiting factors and the selection by the breeder of cultivars which can satisfactorially compete with the environmental conditions of specific areas are basic to increasing yields in low production areas.

The studies of the genetic manipulation and physiological feasibility of genotypes relative to nutrient uptake, nutrient translocation, improvement of photosynthesis rates, involvements of respiration, the identification of more acceptable plant phenotypes, the resistances of varieties to disease and insect infestations, and the improvement of nutritional quality and flavor, as well as the storage potential and the ultimate utilization of a product or crop are within the control of man. The variability of given crop selections and the procedures for managing these crops must be identified and assured that they will increase production for a given farmer before introduced to many farmers in a

production area. Research data indicating successful yield increases in a given environment must then be transmitted through an educational program to the actual farmer for his consideration and ultimate acceptance if yields are to be increased in a given low production area. Underlying the philosophy and social structures of the farmer are his traditional management practices associated with yield factors.

MAN'S ACCEPTANCE AND UTILIZATION

Man's responses to more limiting environments have typically resulted in shifting cultivation with minimal land preparation prior to seeding. Intensive short-period demands have been placed on labor, (planting, cultivating, harvesting) utilizing all the family and community members in highly developed social patterns which insure the food for life. Such societies are usually based on fatalistic views of nature and man's potential. A balance between farm products and the people and animals has been established at a low level of reserve in most low agricultural production areas. Such rural societies result in discrimination against individualism and experimentation, thus discouraging man's desire to improve his physical situation. Therefore, one of the basic factors limiting yields in these areas is related to changing man's attitude toward soil, water, climate, crop production, use of credit, himself and his society. Techniques aimed at village or even tribal change will be needed in addition to individual or personal demonstration of successful innovations. Often those who will experiment are already outcasts of the society; therefore, what they do is unacceptable to the society's mainstream, or if they do experiment against the will of the elders they will be cut off from their society. Few stable,

alert individuals are willing to take such risks which are related to their total security. This does not mean that the farmers are ignorant, or slow to change and to accept improvement, in fact, they quickly accept improvement when risks of social unacceptability and the failure are removed. However, the limited availability for alternate forms of family labor other than agricultural production tends to stifle the desire to change or make more efficient the subsistence farming practices. Underlying the philosophy and social structures of the farmer are his traditional management practices associated with yield factors. These can be altered as improved varieties and management practices are developed or introduced for increased yields; however, when management practices increase production, utilization of a product must also be increased, or the farmer will not produce or harvest the crop beyond his forseeable requirement. Physical limitations caused by distances, types of carriers, lack of market information, poor communications, losses which occur between producer and consumer, (storage, rodents, contamination, lack of credit for insuring quality production, and investment in marketing costs, lack of market, low prices, price fluctuation, or unacceptability of products) and insecurity due to marketing of excess labor and farm produce often pose risks beyond the capabilities of the producer. It is often a shock to accept change when the present total production package has permitted the known level of subsistence culture to continue for untold generations.

The need for adequate, safe storage facilities cannot be overemphasized as a limiting factor in crop production in most areas. This applies not only to surplus products, but even to valuable seed stocks for succeeding plantings. The losses to rodents and storage insects

may reach at least 20-30% of the low production yield per year. This is especially true of crop products not directly needed or used for food. Additionally imposed on difficult soil and environmental situations are land tenure, traditions and political policies which have been designed for social security rather than maximum crop production.

No area follows an ideal plan. In many of the areas of low yields 70-80% of man's time is taken for existence only. Therefore, the introduction of new practices by evolutionary procedures will undoubtedly be much more successful in changing a total society than a revolutionary change. Considered in this is a 12-month growing season that exists in many of these areas when water is managed and the fact that three to five crops per year may be produced, such that total yield would be greater in producing more crops rather than one very high yielding crop. The essential thing is that the factor which is presently causing the yield to be static needs to identified, and removed, and the art of farming be enhanced so that the farmers themselves see the value of working toward increased production. This can result in increased food and increased marketable products for use in trading for other needed and desired items.

It is important to recognize that the biological factors of a given area are not transferable. They can; however, be improved and altered to meet the desires and needs of man and cultivars or individual varieties can be selected to meet the components of the biological environment in such a way that the efforts of man result in increased production and a more worthwhile life on the farm.

SUMMARY

Sorghum is grown in a wide range of generally adverse soil, climate and management situations, chiefly as a food crop in low yield areas. The evolvement of sound, secure, productive, community crop management alterations, with visible improvement in the social well-being of all the people involved, and with no initial risks or costs makes the task very difficult, but such are the initial requirements to insure actual long-term yield improvement. The total community must be involved, otherwise the community will return to the traditional practices once an innovator leaves the area. However, introduction of genotypes that will respond to more fertile soil areas are resisted by the subsistence farmer because he cannot actually work the heavier, more difficult soils with the tools and power that he has available. Multiple cropping and short season varieties which could develop securities for society are not currently appreciated due to unsatisfactory storage and marketing facilities for profitable use of excess farm produce. The acceptance of new and more productive food crops is often as difficult or greater than their actual production. However, this is often necessary in order to insure good yielding combinations and to improve the total production of a particular area. The meeting of the numerous potentially limiting production factors of sorghum is a challenge to visionary scientists and scientific administrative personnel. Sorghum is grown, or can be advantageously introduced into vast geographical areas. The impact of a slight increase in sorghum grain yield would greatly alter the well-being of a large number of people. The present technology of sorghum production only needs to be adapted and accepted by farmers to make significant yield

increases a reality. This; however, is extremely difficult due to the diversity of people and the attitude of man that food is something which is necessary, but not something that one would market to make a financial or social gain. Until this basic attitude is changed through significant educational procedures and methods of marketing the product, it will be difficult to anticipate or expect acceptance of improved management practices and high yielding sorghum varieties. Research is needed to provide communication systems that will enable low production area farmers to apply corrective techniques to their yield-limiting factors without risk to their food supply under present social and economic conditions, which involves men, women and children of all ages. Sorghum technology is presently developed for low production areas to where yields have been doubled in demonstration plots, but the adjacent farmer has not accepted what he has seen others do. It is; therefore, essential that: a) localized techniques and production supplies to insure stable yields be identified, proven and provided, b) that responsive genotypes with resistances to diseases, pests and adversities of the local environment be provided which are of good quality and which are palatable to the consumers, c) that storage, distribution, and utilization facilities be obtained, and d) that the producer in his social environment be accepted and advanced by the increased products of his efforts as dictated by his felt needs, if sorghum production in low production areas is to be significantly and permanently increased (Figure 1).

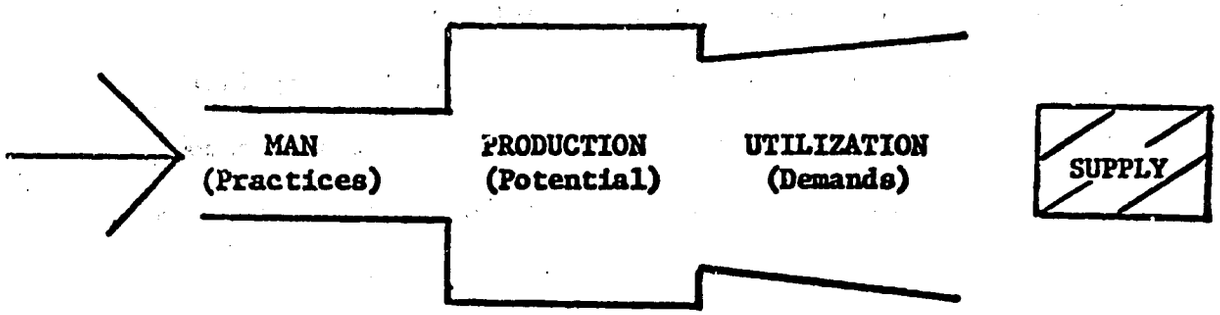

Figure 1. Factors limiting the yield of food crops in low production areas.

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Genetic Variation in *Sorghum bicolor* (L.) Moench for Tolerance to High Levels of Exchangable Aluminum in Acid Soils of Brazil*

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Aluminum toxicity is an important growth limiting factor in many acid soils. The problem in Brazil is particularly serious in strongly acid subsoils that are difficult to lime. Acid subsoils with aluminum at toxic levels reduces root penetration and increases the probability of injury by drought (Foy, 1974a).

The "cerrado" constitutes one of the vegetation types most widely distributed in Brazil occupying more than two million square kilometers concentrated principally in the States of Goiás, Mato Grosso and Minas Gerais (Cruz, 1972). The soils associated with "cerrado" vegetation are generally acid, low in phosphorus and high in toxic aluminum. Mendes (1972) summarized the results of 1,200 soil samples of "cerrado" vegetation types from Minas Gerais, the Federal District, and Goiás analyzed by the soils section of the Agriculture Research Institute of the Central-West (IPEACO) of the Ministry of Agriculture of Brazil. Of

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these samples, 32.5 percent had a pH of less than 4.30 and an additional 66.4 percent had a pH between 4.31 and 5.49. In addition 28.4 percent of the samples had exchangable aluminum levels between zero and 0.50 meg/100 g, 17.8 percent between 0.51 and 1.00 meg/100 g, 11.3 percent between 1.01 and 1.50 meg/100 g and 42.5 percent greater than 1.50 meg/100 g. Exchangable aluminum less than 0.3 meg/100 g is considered to be low while values greater than 1.00 meg/100 g are considered to be high. Of these same samples 72 percent had phosphorus levels considered to be low or very low. Textural analysis indicated that 88% of the samples were either a sandy loam, clay, sandy clay loam, or clay loam. These soils have a very low water holding capacity. Because of this low water holding capacity and periods of one to two or more weeks without rain commonly occuring even during the rainy season, these soils are considered to be droughty.

These "cerrado" soils frequently have a topography which makes them suitable for mechanized agriculture and are located in geographical areas with adequate infrastructure for intensive agricultural development. The utilization of these soils for economic intensive agriculture requires plant species and varieties which are more efficient in phosphorus utilization and tolerant to toxic levels of aluminum in the soil. Foy (1974a) reported that a wide range of tolerance exists between and within plant species. Differences have been reported in wheat, barley, alfalfa, rice, soybeans, and corn (Foy, 1974a and Clark and Brown, 1974). Varietal differences for this characteristics have not been reported for sorghum.

Sorghum has been envisioned by many scientists to have a future in the "cerrado" of Brazil because os its drought tolerance. Considering

the nature of the "cerrado" soils, rainfall distribution, and cost of lime and fertilizer, a sorghum variety must be developed which has greater tolerance to high levels of aluminum, a deeper root system, and more efficient phosphorus utilization.

During the 1973/74 agricultural year, Schaffert (1974) noted a wide range of drought tolerance in one replicated trial of experimental sorghum hybrids during a period without rain during anthesis. A relative scale of one to five was used to record these observations where a rating of one was given to plots with plants showing no visable stress and a rating of five was given to plots with plants near permanent wilting point. The trial was conducted on a typical "cerrado" soil near Sete Lagoas, Minas Gerais, Brazil where three tons of lime had been applied prior to planting. The soil pH at the time the observations were made was 4.8 with an average of 0.68 meg Al/100 g and 24 ppm P. The results are presented in Tables 1 and 2. An examination of the root systems indicated a high correlation between root development and drought tolerance. Foy (1974b) interpreted these data as variations in tolerance to toxic levels of aluminum in the soil.

Two experiments were conducted to verify if the differences observed were due to variation in tolerance to aluminum toxicity or some other factor. A virgin "cerrado" soil high in exchangable aluminum was selected from IPEACO for greenhouse studies. Soil analysis results were: pH 4.6, 1.56 meg Al/100 g, 2 ppm and 0.06 meg K/100 g. The soil was classified as a clay. In the first experiment 48 two liter plastic pots were filled with the above soil after adding 100 ppm of N as ammonium sulfate, 100 ppm P as phosphoric acid and 100 ppm K as potassium chloride. A randomized complete block design replicated four time was

ABLE 1. Production and drought resistance notes on experimental hybrids at IPEACO (Sete Lagoas, Minas Gerais, Brazil) for the 1973/74 agricultural year.

Treatment	Pedigree	Production*	Resistance to Drought**
01	PU932242 x TX2536	2.0	1.5
02	PU932242 x TX2555	2.5	2.5
03	PU932242 x PU932204	3.0	3.0
04	PU932242 x TX2523	2.0	1.0
05	PU932242 x KS-2	3.0	3.5
06	IS8361 x TX2536	3.0	1.0
07	IS8361 x TX2555	2.5	1.0
08	IS8361 x PU932204	4.0	3.0
09	IS8361 x TX2523	2.0	1.5
10	IS8361 x KS-6	4.0	3.0
11	IS0418 x TX2536	3.0	1.5
12	IS0418 x TX2555	2.5	1.5
13	IS0418 x PU032204	3.5	4.5
14	IS0418 x TX2523	2.5	3.5
15	IS0418 x KS-10	3.5	4.5
16	CK-60 x TX2536	2.0	1.5
17	CK-60 x TX2555	2.5	2.5
18	CK-60 x PU932204	4.0	3.0
19	CK-60 x TX2523	3.0	2.5
20	Redlan x PU932204	3.0	3.5
21	Redlan x TX2523	2.5	4.0
22	Redlan x TX2540	3.0	2.5
23	KS-4 x TX2536	2.5	1.5
24	KS-5 x TX2536	2.5	1.5
25	KS-52 x TX2536	2.5	1.0
26	KS-51 x TX2536	3.0	1.0
27	KS-48 x TX2536	2.5	1.0
28	KS-47 x TX2536	3.0	2.0
29	Ag 1001	2.5	1.5
30	RS-610	4.5	5.0

* A relative scale 1 to 5 where 1 is high production and 5 is low production. (RS-610 in an adjcent replicated trial produced 2.70 t/ha and Ag 1001 produced 5.37 t/ha of dry grain under similiar conditions)

** A relative scale of 1 to 5 where 1 = tolerance to drought and 5 = severe damage due to drought.

TABLE 2. Production and drought resistance notes averaged across males and females on experimental hybrids at IPEACO (Sete Lagoas, Minas Gerais, Brazil) for the 1973/74 agricultural year.

Pedigree	Type of Line	Number of hybrids used in average	Production*	Resistance to Drought**
PU932242	A	5	2.50	2.30
IS8361	A	5	3.10	1.90
IS0418	A	5	3.00	3.10
CK-60	A	4	2.90	2.40
Redlan	A	3	2.80	3.33
TX2536***	R	10	2.60	1.35
TX2536	R	4	2.50	1.48
TX2555	R	4	2.88	2.38
PU932204	R	5	3.50	3.40
TX2523	R	5	2.40	2.50
KS-2	R	1	3.00	3.50
KS-6	R	1	4.00	3.00
KS-10	R	1	3.50	4.50
TX2540	R	1	3.00	2.50
KS-4	A	1	2.50	1.50
KS-5	A	1	2.50	1.50
KS-52	A	1	2.50	1.00
KS-51	A	1	3.00	1.00
KS-48	A	1	2.50	1.00
KS-47	A	1	3.00	2.00

* See notes for Table 1

** See notes for Table 1

*** Averaged over PU932242, IS8361, IS0418, CK-60.

used to study twelve sorghum varieties. Eight seeds were planted per pot on October 9, 1974 and thinned to four plants per pot after germination. The varieties used were, IS8361 B, Redlan B, PU932204, TX2536, IS8361 x PU932204, IS8361 x TX2536, Redlan x PU932204, Redlan x TX2536, RS-610, Taylor-Evans Y-101, Asgrow Dourado M and M35-1. Thirty days after planting the soil was removed from the roots by washing. Length of the longest root, average length of the secondary roots, shoot length, dry root weight and dry shoot weight were recorded for the four plants in each pot.

The data are presented in Table 3. Highly significant differences were observed for the five traits studied. Comparing the four lines, TX2536 did not have the characteristic dark brown discolored roots that is commonly associated with aluminum toxicity (Foy, 1974a). PU932204 was significantly inferior to the other lines in the study. PU932204 had more leaf discoloration resembling bronzing in rice that is caused by excess aluminum in certain soils of Ceylon. TX2536 did not express this bronzing.

The hybrid combinations with PU932204 were inferior to TX2536 in root development but not shoot development. Heterosis was present for all the traits studied with the hybrid superior to the mid-parent in all cases and superior to the best parent in all cases except secondary root length for the hybrid Redlan x pU932204. In hybrid combinations, IS8361 was slightly superior to Redlan in root and shoot weight but nearly equal in root and shoot length. The failure to observe greater differences was probably due to the extremely high level of aluminum in this trial as was indicated by the second experiment.

Taylor-Evans Y-101 and Asgrow Dourado M, hybrids reported to have

TABLE 3. Average root and shoot length and dry weight of 12 sorghum varieties grown for 30 days in an acid "cerrado" soil with 1.56 meg Al/100 g.

Variety	Root Length		Shoot Length	Dry Shoot Weight	Dry root Weight
	Longest cm*	Secondary cm*	cm*	g**	g**
IS8361 B	18.7	9.5	26.2	0.29	0.07
Redlan B	20.3	12.5	25.1	0.28	0.11
TX2536	18.2	11.9	19.6	0.21	0.08
PU932204	7.7	5.0	18.5	0.17	0.05
IS8361 x TX2536	26.7	13.3	30.8	0.47	0.23
IS8361 x PU932204	20.8	12.3	33.6	0.54	0.17
Redlan x TX2536	26.4	13.4	30.6	0.43	0.20
Redlan x PU932204	19.9	11.5	28.6	0.41	0.13
Taylor-Evans Y-101	25.1	14.4	32.9	0.49	0.27
Asgrow Dourado M	22.2	13.1	30.2	0.46	0.21
RS-610	18.1	10.4	28.6	0.44	0.14
M35-1	11.0	6.6	25.5	0.32	0.08
$s\bar{x}$	1.34	1.11	1.28	0.029	0.016
LSD.05	3.85	3.20	3.68	0.085	0.046

* Average of four plants

** Total weight of four plants.

more drought tolerance in "cerrado" soils (Schaffert, 1974) were superior to RS-610 reported to be highly suceptible to drought for the traits observed. M35-1 was intermediate between the tolerant and nontolerant lines in root development.

A second greenhouse experiment was conducted using the same soil as the first experiment with six lime rates. The rates were zero, 250, 500, 1,000, 2,000, and 4,000 parts per million lime (80% Ca_2CO_3 and 20% $MgCO_3$). These rates corresponded to zero, 0.5, 1.0, 2.0, 4.0, and 8.0 tons per hectare of lime, respectively, The lime was mixed with the soil and incubated for ten days prior to planting. One hundred ppm N, 100 ppm P and 126 ppm K were applied as NH_4NO_3 and KH_2PO_4. Two corn lines, OH40B and B-57, and five sorghum varieties, PU932204, TX2536, IS8361 x TX2536, RS-610 and Taylor-Evans Y-101 were planted on November 1, 1974 in two liter pots using a randomized complete block design with 3 replications. The pots were thinned to 4 plants per pot after germination. Twenty-five days after planting the soil was removed from the roots by washing with water. The data are currently being tabulated and analyzed.

The two corn lines used in this experiment, OH40B and B-57 have been reported by Clark (1974) to be suceptible and tolerant, respectively, to high levels of aluminum in the soil. The root development of B-57 was slightly superior to OH40B in the no lime treatment. The differences were greatly increased at the 250 ppm (0.5 t/ha) lime treatment. The differences were less dramatic at the higher lime rates and appeared to disappear at the 2,000 and 4,000 ppm rates.

Of the two sorghum lines, TX2536 and PU932204, in this experiment TX2536 had superior root development at the lower lime rates. The

greatest differences were at 250 ppm (0.5 t/ha) and 500 ppm (1.0 t/ha) of lime. The differences in root development between the sorghum hybrids, IS8361 x TX2536, Taylor-Evans Y-101 and RS-610, were also the greatest at 250 and 500 ppm lime. IS8361 x TX2536 and Taylor-Evans Y-101 were similiar in root development and much greater than RS-610. The differences in root development in sorghum lines and hybrids were less dramatic at the higher lime rates and appeared to disappear at the 2,000 and 4,000 ppm rates.

Root development appeared to have been slightly reduced at the 4,000 ppm (8.0 t/ha) for both corn and sorghum.

Sorghum was evaluated, using preliminary techniques, for tolerance to high exchangable aluminum in the soil. A large amount of genetic variation was observed for root development indicating that selection for tolerance to high exchangable aluminum should be successful. IS8361 and TX2536 appeared to be tolerant to high exchangable aluminum and PU932204 was not tolerant. These preliminary studies are being followed up with additional greenhouse and field studies.

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STOMATAL BEHAVIOUR OF GRAIN SORGHUM AND ASSOCIATED RESPONSES

P. M. Saint-Clair

INTRODUCTION

The stomatal behaviour of plants plays a very important role in its physiological processes as it governs major phenomena such as transpiration, photosynthesis and respiration. Grain sorghum is often compared to maize with respect to stomatal reactions. For WILLIAM and JOSEPH (1970), "the well known superiority of sorghum over maize in dry climates appear to be due to the continued functioning of the stomata of the former". SANCHEZ-DIAZ (1971) viewed the problem within a comparable line of approach as he observed that the stomata of sorghum closed more slowly than those of corn. He also noted that "a smaller reduction in water content of the 1st crop for a given reduction in water potential" can be considered as a drought-resistant feature. SHEARMAN et al (1972) found that CO_2 uptake of the hybrid RS610 was reduced and leaf diffusive resistance enhanced under stress conditions (soil water potential near -25 atmospheres). They also point out that information regarding the effect of water stress on photosynthesis and respiration is "varied and inconclusive". Reference to the work of BLUM et al (in SULLIVAN, 1972) suggests that in some cases it is feasible to consider transpiration as regulated not only by stomatal control but also by other factors.

The current works aim at clarifying the stomatal behaviour of sorghum varieties through different techniques. As they are part of a general program on drought tolerance, the potential applications of the results will be given some thought.

MATERIALS AND METHODS

The investigations with grain sorghum include the following aspects:

1. Determination of the transpiration rations of 3 pure lines: (M 35-1, CE-90 and 69-4), 5 hybrids (NK300, C-42Y, RS626, RS610 and NB9776K) and 2 selections (Meloland and G393) generally referred to as varieties. Experiment 1.

2. Leaf diffusive resistance and leaf ψ versus soil ψ . Plant material: G393, M35-1, C-42Y, CE-90, 69-4 and Meloland. - relationship between these and the size of the transpiration ratio. Experiment 2.

3. Photosynthesis and respiration versus water stress. Plant material: M35-1, CE-90 and 69-4. Experiment 3. Details of the experimental procedures.

Experiment 1. The work was undertaken in a greenhouse inside which the night and day temperatures were 34° and 22°C respectively, the relative humidity 70%, the light regime 12 hours. A light intensity of 1816 ft.-c. (282 microeinsteins/cm^2/sec) was supplied at the plant level by sets of Gro-Lux cool white lamps intermingled with incandescent ones. On sunny days, the Intensity raised considerably. (3) Pots holding 2.4 Kg of sandy soil covered with a 2.5 cm - thick layer of vermiculite were employed. Six seeds were sown in each pot. The density of plants/pot after emergence has been thinned out to three. Three arrays of 20 pots, 10 being watered every day (T_1), the 10 others every 4 days (T_2) were used. T_2 treatment started when the plants reached the age of 3 weeks. There was then 1 pot/variety/treatment/array. Between these pots were displayed a) reference pots without plant (5 / treatment). b) a batch of 30 pots (3 / variety) watered every day.

The plants which were therein raised were harvested at the commencement of the stress treatment. They were used to determine the initial dry weight of the material (P_1).

The water loss by transpiration was evaluated by taking into account the evapotranspiration data (given by planted pots) and the transpiration ones (given by the pots mentioned in a) They were 2 sets of measurements, one involves the treatment T_1 and the other T_2.

Final harvesting and dry weight determination occurred with 45-day old plants. The transpiration ratio was calculated as follows:

$$\text{Transpiration ratio (syn. transp. coefficient)} = \frac{\text{Water lost by transpiration (ml)}}{P_2 - P_1 \ \text{(g)}}$$

The T_1 - treated plants constituted the main material of the experiment. The T_2 ones were used only to check DE WIT'S opinion (1958, 1969) according to which, the transpiration ratio is "independent of the availability of water".

Experiment 2. The material was grown in a growth chamber Model EY 15. Details concerning the temperature and light regimes, the relative humidity, the type of lamps and pots are mentioned in the preceding experiment. The light intensity was 3860 ft.-c. (563 microeinsteins/ cm^2/sec) at the plant level. Prior to sowing, Wescor psychrometers - hygrometers were horizontally buried (1/pot) in the centre of the pots soil with the connecting wires emerging. Each variety was assigned 6 pots (2 plants/pot), 3 labeled T_1 (watered every day) and the others T_2 (water - stressed 48 h before the beginning of the operations). Rewatering whenever mentioned only involves the T_1 material. Three plants/ variety/treatment i.e. 1/pot served to determine the leaf diffusive resistance and the leaf ψ . To record the data on the last feature,

six discs (diameter about 1/4 inch) were punched out the 2nd leaf (from the top) of the plants and sealed in a cup of a C-51 Wescor sample chamber. The temperature inside this chamber was monitored with a potentiometer. A HR-33 Wescor dew point microvoltmeter was coupled to the C-51 to record the microvoltage output. This was later turned into bars through a calibration curve. This was likewise done to determine the soil ψ . The leaf diffusive resistance was measured with a Lambda diffusion porometer (L1 - 60). The recorded information bore on 5 - week old plants.

Experiment 3. The photosynthesis work was carried out in environmental conditions similar to those given in Experiment 2. Plant age and the number of replicates were also the same. Here, however only 24-hour water stress was used. Moreover, the water potential of the pots was not monitored, due to technical failure.

The photosynthesis respiration equipment worked in a closed circuit. It comprised a CO_2 Analyzer Model Beck-man 215 A, 2 pomps to regulate the air flow and to create turbulence in the plant chamber, a cooling bath associated with a dessicant and a recorder. The plant chamber was made out of plexiglass. The volume of the system was 9,910 CC.

The formula reported by STICKLER et al (1961) was used to measure the leaf area:

$$S = L \times 1 \times 0.747$$

S = Leaf area

L = leaf length

1 = maximum width

The amount of CO_2 assimilated or evalved was determined by use of the

formula:

$$F(mg/CO_2/dm^2/h = \frac{\Delta C.V.273.P.44 \times 10^{-3}}{t.\ A.T.760.\ 22414} \times 60$$

F = Net Photosynthesis or Respiration;

ΔC = Variation of the CO_2 concentration in ppm;

t = time in minutes

V = Volume of the system (in CC)

A = Leaf area in dm^2

P = barometric pressure in atm.

T = temperature of the assimilation chamber

$\frac{44 \times 10^{-3}}{22414}$ = conversion factor to change ppm into mg/cm^3

RESULTS

The sets of observations are presented in Tables 1, 2, 3 and Figs. 1A, 1B, 2A, 2B, 3A, 3B, 4A, 4B, 5A, 5B, 6A and 6B.

TABLE 1 - Transpiration coefficients of 10 grain sorghum varieties (T_1 plants used).

Varieties	Transpiration coefficients	
	Basis: Total dry matter	Basis: Dry matter of aerial parts
M35-1	126	176
NB9776K	163	221
C-42Y	129	200
NK300	131	186
CE-90	148	224
G393	125	190
RS626	129	183
RS610	136	200
69-4	160	234
Meloland	129	190

MAXIMOV (in LEVITT, 1972) has found values ranging from 168-196. These appear to be more closely related to calculations grounded on the

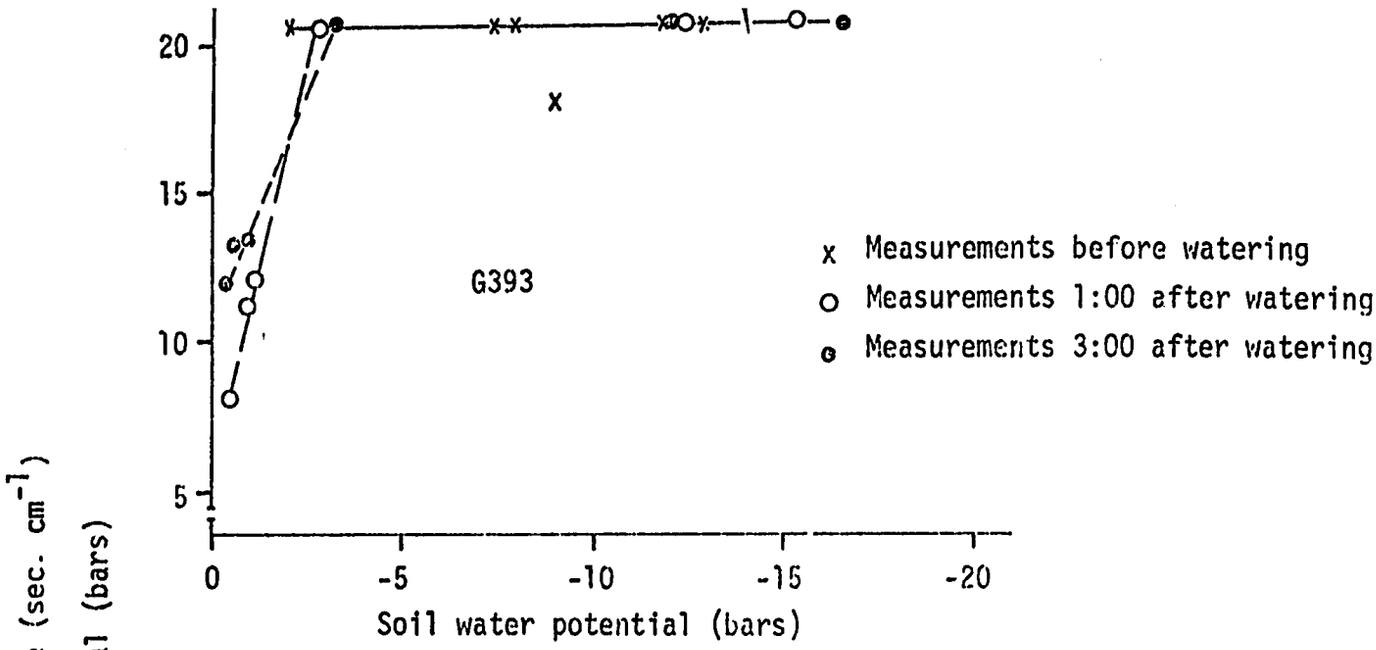

Fig. 1A: Relationship between leaf diffusive resistance and soil ψ

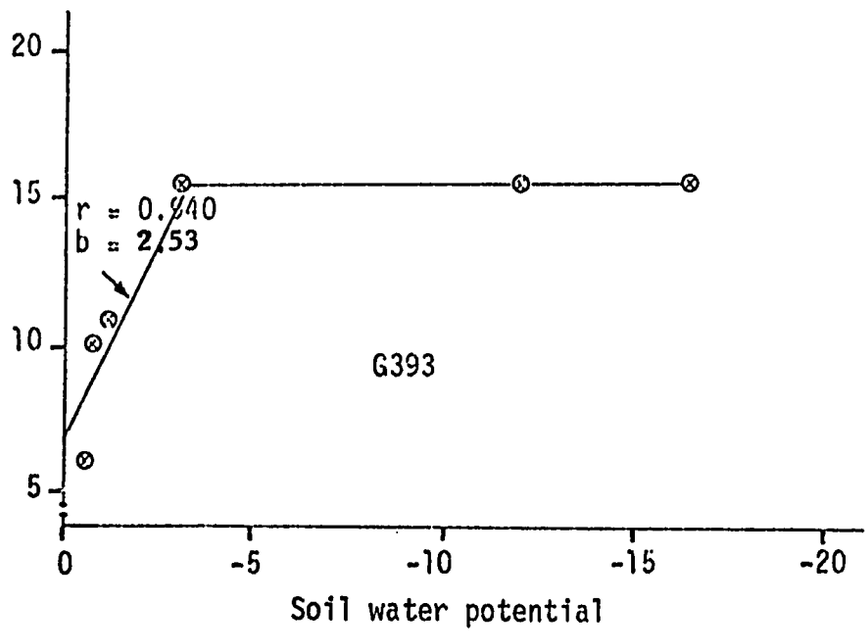

Fig. 1B: Relationship between leaf ψ and soil ψ

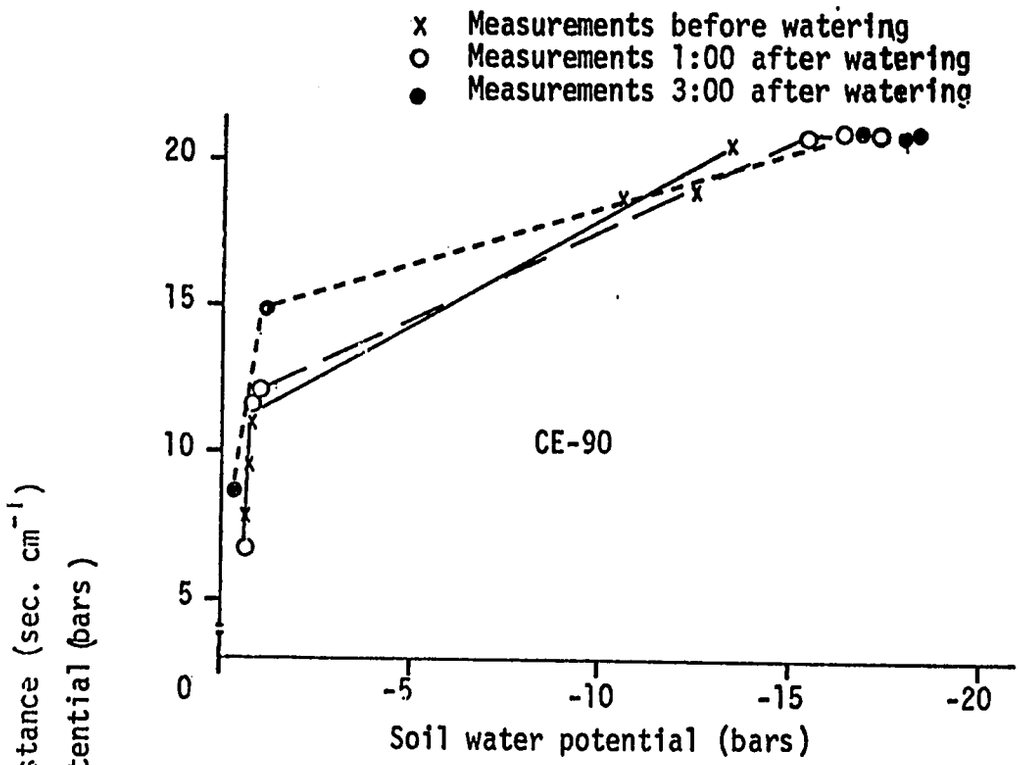

Fig. 2A: Relationship between leaf diffusive resistance and soil ψ

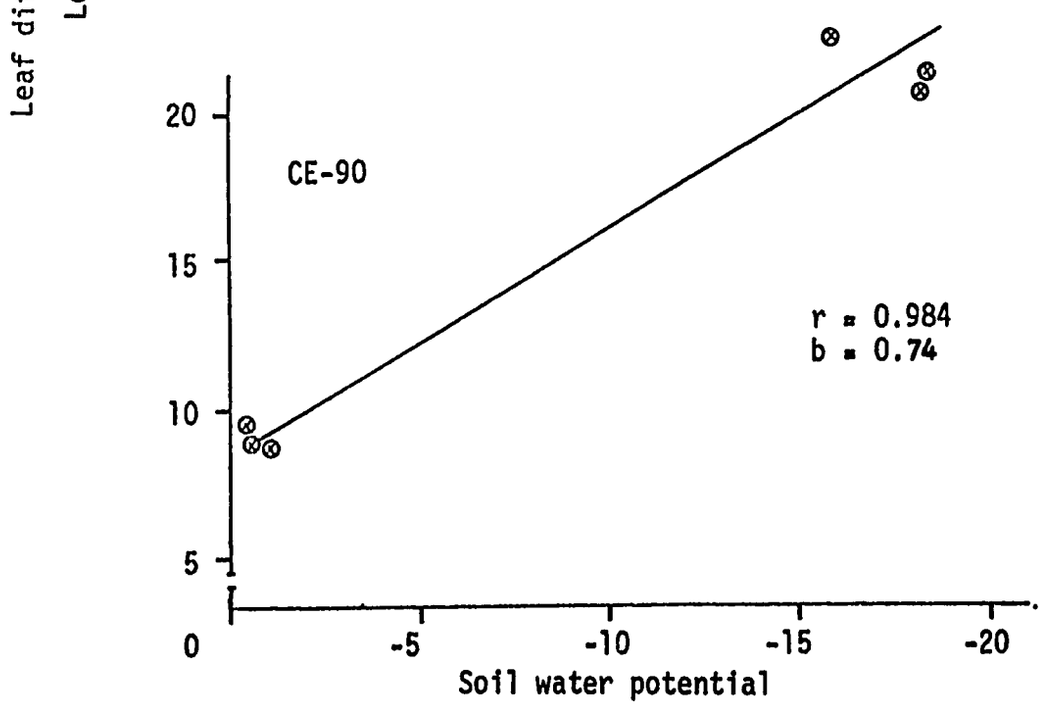

Fig. 2B:. Relationship between leaf ψ and soil ψ

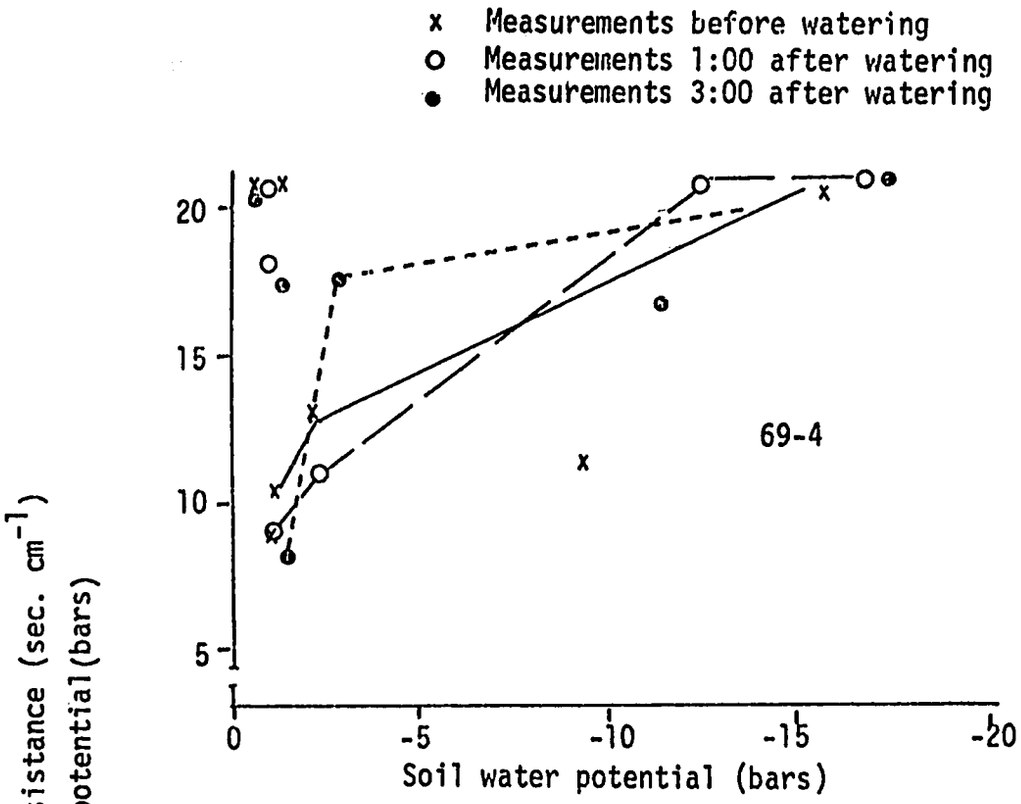

Fig. 3A: Relationship between leaf diffusive resistance and soil ψ

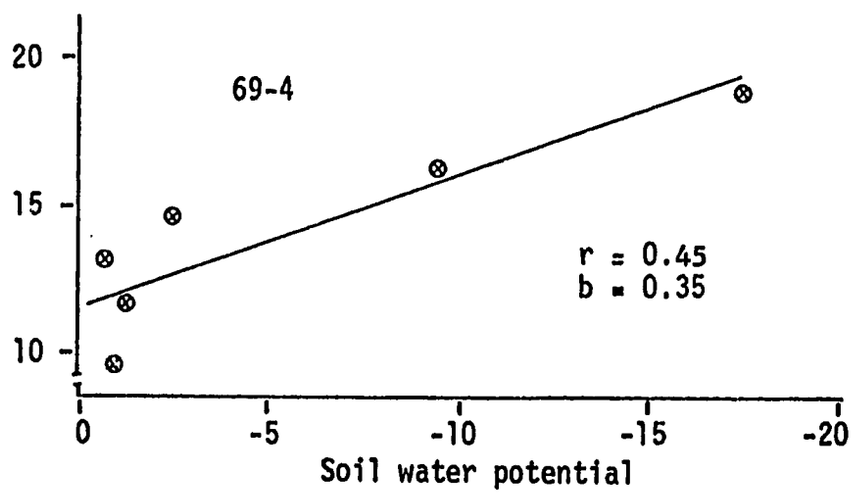

Fig. 3B: Relationship between leaf ψ and soil ψ

x Measurements before watering

o Measurements 1:00 after watering

● Measurements 3:00 after watering

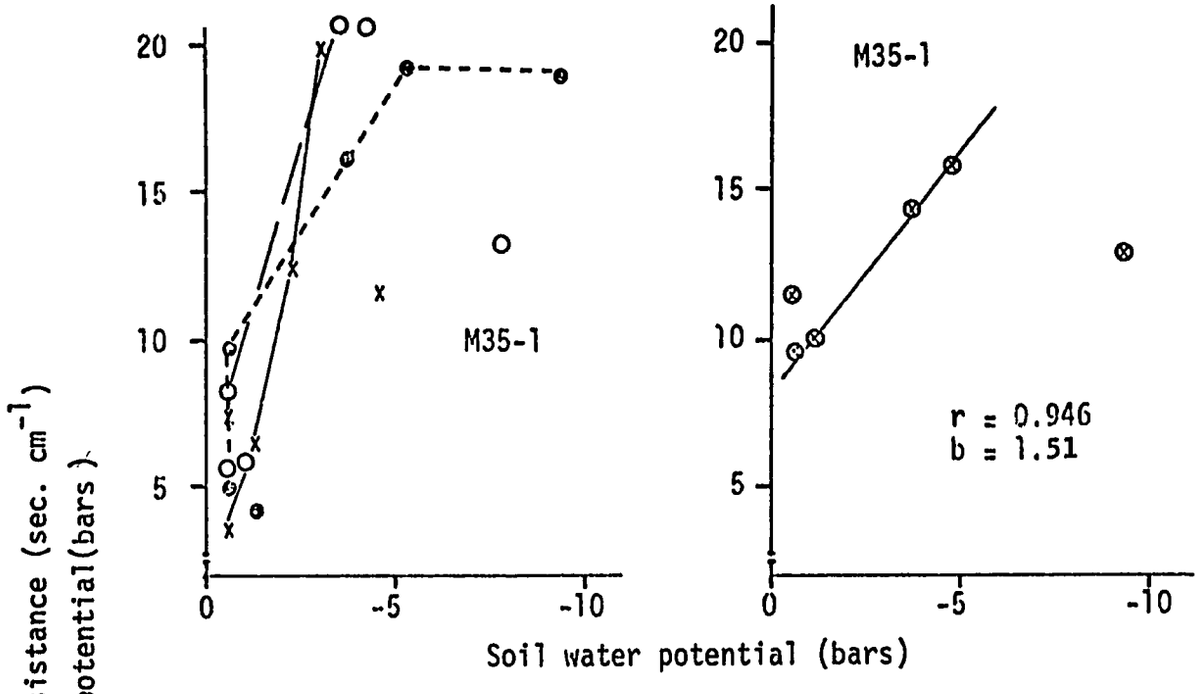

Fig. 4A: Relationship between leaf diffusive resistance and soil ψ

Fig. 4B: Relationship between leaf ψ and soil ψ

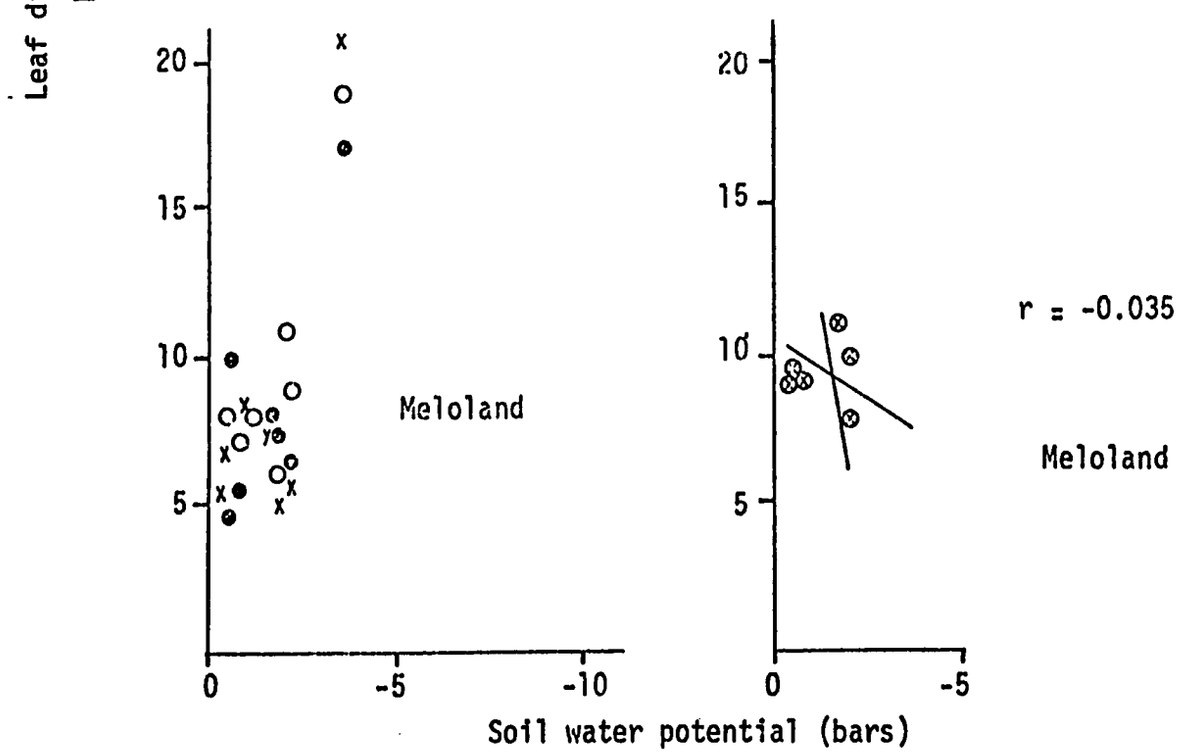

Fig. 5A: Relationship between leaf diffusive resistance and soil ψ

Fig. 5B: Relationship between leaf ψ and soil ψ

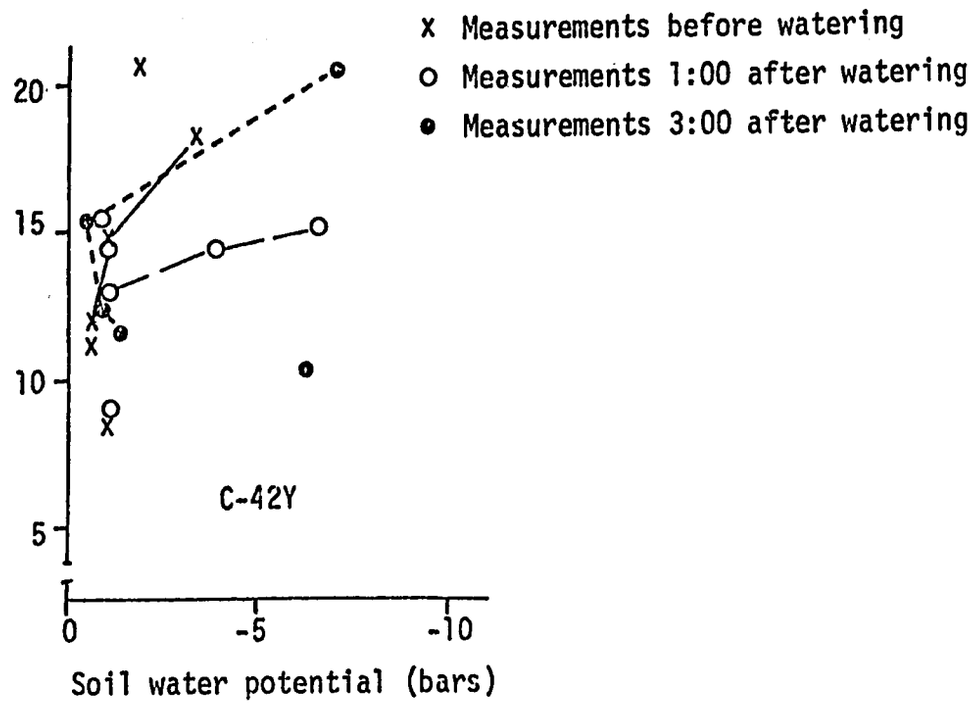

Fig. 6A: Relationship between leaf diffusive resistance and soil ψ

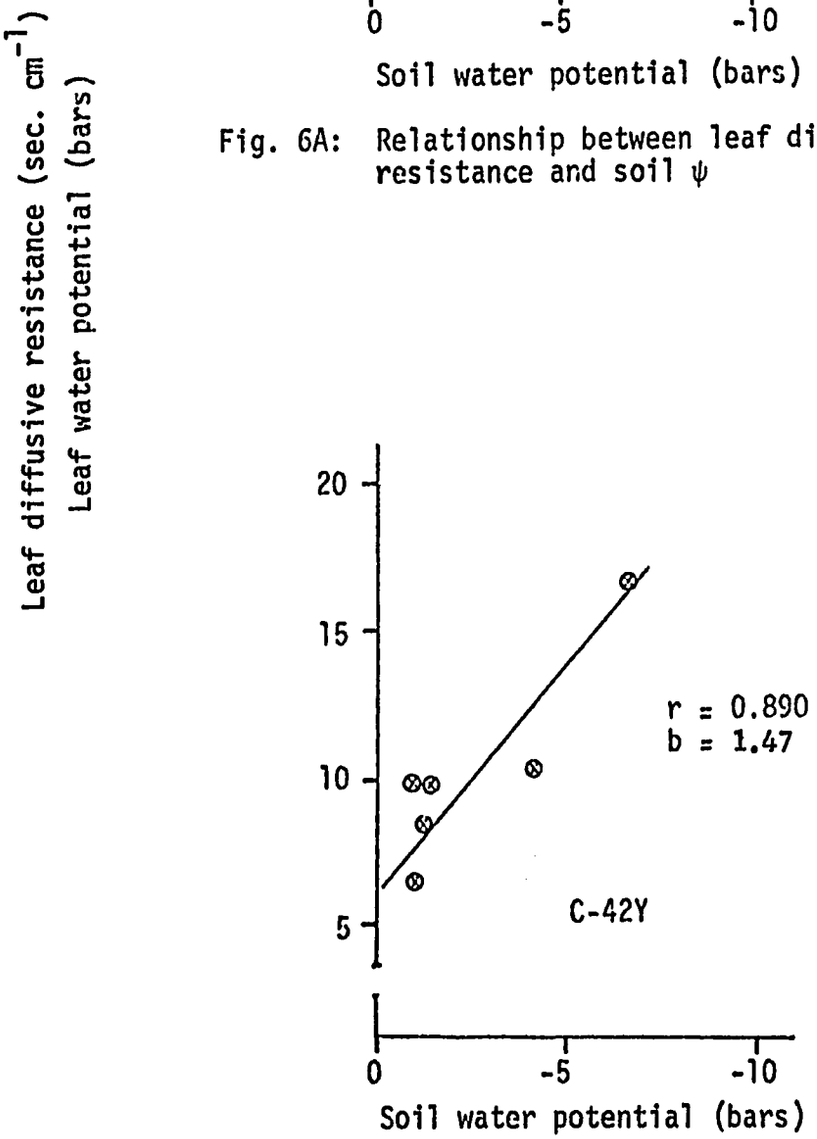

Fig. 6B: Relationship between leaf ψ and soil ψ

aerial part basis.

Coefficients recorded with T_2 plants pointed to the pertinence of DE WIT'S idea as expressed in the section materials and methods. In 7 cases out of 10 deviations falling into the range 0.3 - 19.5% were observed when comparing the T_1-based to T_2-based coefficients.

TABLE 2 - Soil ψ (bars) corresponding with the lowest values of leaf ψ (highest absolute values).

Varieties	Soil ψ	Leaf ψ
G393	- 3.06	- 15.21
CE-90	- 18.35	- 20.90
69-4	- 17.51	- 19.18
M35-1	- 4.7	- 15.61
Meloland	- 1.95	- 11.65
C-42Y	- 6.46	- 16.80

TABLE 3 - Net photosynthesis and respiration (in mg $CO_2/dm^2/h$) of M35-1, CE-90 and G9-4 as influenced by a drought period of 24 hours, P and R stand respectively, for photosynthesis and respiration of the reference, P_1 and R_1, for those of the stressed plants.

Varieties	Reference			Treatment		
	P	R	P-R	P_1	R_1	P_1-R_1
M35-1	19.48^a	2.34^b	17.14^c	12.79^d	2.07^f	10.72^h
CE-90	20.37^a	2.35^b	18.02^c	17.58^e	2.34^f	15.24^i
69-4	18.49^a	2.34^b	16.15^c	16.88^e	2.76^g	14.12^i

The values presented with the same letter within a column are not significant at the level of 5%.

Comparaisons between the results of the 3 experiments lead to these reasonings:

- varieties which have a low transpiration ratio (G393, M35-1 and C-42Y) closed their stomata at lower water stress than the others (CE-90 and 69-4).

- this trait seemed to be the cause of the larger reduction in the assimilation rate of M35-1 versus CE-90 and 69-4. Reduction in the rate of photosynthesis of water stressed sorghum is reported by SHEARMAN et al (1972). Plants of the hybrid RS610 were involved in the experiment. BLUM and SULLIVAN (1972) found that leaf segments submitted to stress-inducing relative humidities showed depression in O_2 evolution. Nevertheless, in both cases, varietal differences were also observed.

- the slope of the straight line drawn from leaf ψ versus soil ψ of G393 C-42Y (which have a lower transpiration coefficient) is bigger than that of CE-90 and 69-4. This means that the 1st group of varieties shows less plasticity than the second and in the long run is more liable to be endangered under serious stress conditions.

The data of table 2 involve some elements of Figs. 1b, 2b, 3b, 4b, 5b, and 6b. Complementary comments may be restricted to noting that the leaf ψ of the first group of varieties (forementioned) appears to be too high for the given soil ψ .

DISCUSSION AND CONCLUSIONS

The general information brought about by the experimental results calls for much caution in evaluating the drought tolerance of plant

material. The idea that "water saving" per unit of dry matter produced by a variety is a good trait, mainly when marginal areas are concerned, should not be overestimated. As mentioned by LEVITT (1972), a plant that adapts simply by closing its stomata, in this way decreasing transpiration would decrease photosynthesis simultaneously. Avoidance-like characteristics which enable a plant to escape serious effects of water stress are valuable. It may be underlined, however, that the need for further research becomes necessary to corroborate the information dealt with in the present papers. More profuse root system developed for instance in natural conditions might affect the universality of the data but it is likely that some aspects discussed in the note would remain unchanged, irrespective of the environment.

The values of the transpiration ratio are not liable to be affected by water availability.

In field conditions, 24-hour stress may be insufficient to cause the photosynthesis of M35-1 to be sharply depressed. Assuming that the stomatal behaviour of this variety is governed by internal factors makes reasonable to anticipate that the CO_2 assimilation will be impaired at a rate as high as will permit the water deficit in the soil.

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CLIMATIC FACTORS RELATED TO CROP YIELD

Max D. Clegg

The climate of an area determines many facets of crop production. Yet, the climate of an area cannot be controlled. The climatic factors of drought, flood, freezes, tornadoes, hailstorms make farming an uncertain enterprise. More realistically, the subtle climatic aberrations which occur on a daily basis no doubt cause crop losses which far exceed losses due to the aforementioned factors.

Gross climatic changes are easy to relate to crop yield reductions, however, within a crop some types are influenced less than others. Relating this yield variation to climatic changes becomes more difficult, and these types of relationships are probably more important for the adaptation of a variety of hybrid to maintain a predictable yield level year after year. For this reason, climatic data should be recorded at frequent intervals and at the same time record different developmental events of the crop of interest.

Meteorologists and agricultural climatologists have over the years obtained some very good files of data. However, much of this data is never put to use. This is illustrated in that most of the scientific journal articles pertaining to field experiments have minimal climatic data as an implement for interpretation. Minimal use of climatic data probably is the result of, in the past, being unable to manipulate the vast amounts which can accumulate. This is not a serious problem today because of the development of computers with adequate data storage and efficient input and output systems.

The purpose of this paper is to present climatic data based on a

climatic week (Rosenberg, 1964) in relation to the growth cycle of grain sorghum in Nebraska. With a more frequent display of climatic and crop physiological factors, more precise interpretation with respect to yield should be obtained.

Twelve years' dryland grain sorghum yields from two locations in Nebraska are shown in Table 1. The differences of yield level due to location is evident. The climatic differences of the two locations are that the temperatures for Western Nebraska are lower, rainfall is less (approx. 432mm as compared to approx. 635mm) and the growing season is shorter. The yield variations over years is also very evident. Yields for 1967 and 1970 are low and the yield reductions were attributed to lack of moisture. In Western Nebraska grain sorghum yields for 1962, 1963, and 1965 are also low. In Eastern Nebraska the grain sorghum yields for these same years were at a respectable level. This could be attributed to additional late precipitation and the additional season for late hybrids to mature. Thus, variation in yield was reduced in these data because the hybrids ranged in maturity from early to late.

A comparison of the average yields of six selected grain sorghum hybrids for the years 1972, 1973, and 1974 with the seasonal temperatures and precipitation are shown in Table 2. Growing degree units (GDU's) as a temperature index relate well with sorghum plant growth (Clegg, et. al., 1970, Soza, 1973). Climatically, the GDU's and precipitation data would indicate that the seasons were quite similar and yields should predictively be the same. However, the grain sorghum yield levels are very distinctively different.

Individual physiological and yield data of these selected grain sorghum hybrids and climatic data on a climatic week basis allow a

Table 1. Twelve years grain sorghum yields at two locations in Nebraska 1/.

Years	Yield (kg/ha)	
	eastern Nebraska	western Nebraska
1962	6554	3245
1963	6427	2291
1964	5027	4136
1965	5918	1972
1966	8018	4454
1967	7635	2418
1968	4900	4836
1969	7445	4200
1970	4200	509
1971	8081	4009
1972	8399	5663
1973	6490	5218

1/ from Nebraska Grain Sorghum Performance Tests, Outstate Testing Cir. No. 104,111,116,120,126,130,135,140,144,148,153, and 159. Agr. Exp. Sta., Univ. of Nebr.-Lincoln, College of Agr..

Table 2. The average yields of six grain sorghum hybrids and some climatic factors for 1972, 1973, and 1974.

Year	Yield 1/	GDU's 2/	Precipitation 3/
	kg/ha	C	mm
1972	8538	837	256
1973	6545	897	259
1974	3185	828	272

1/ from Nebraska Grain Sorghum Performance Tests, Outstate Testing Cir. No. 153, 159, and 166. Agr. Exp. Sta., Univ. of Nebr.-Lincoln, College of Agr..

2/ Growing degree units (15.5 C base temperature).

3/ for May through August.

closer analysis of crop and climatic relationships. Table 3 shows the days to bloom, test weight and yield of six grain sorghum hybrids for 1972, 1973, and 1974. The hybrids represent a maturity range from early to late. The hybrids bloomed earlier in 1973 than in 1972 and 1974. The greatest variations are observed in the later maturity hybrids. Test weights (an indication of grain quality) of grain was highest in 1973, followed by 1972 and the lowest was in 1974. Grain yields for the same years showed the same relative response. Generally the longer season hybrids were responsible for the greatest changes in yield and test weight.

By evaluating the seasonal climatic patterns in relation to bloom, test weight and yield, several relationships can be observed. Figures 1 and 2 show the GDU's and precipitation for a six year period (1969-1974), 1972, 1973, and 1974. Superimposed upon these figures is the general developmental sequence for grain sorghum at this location.

The six year average of GDU's depicts the general growing season of grain sorghum (Figure 1). The greatest percentage of GDU's occurs from mid-June through August. Also, the precipitation pattern for the six year period shows the greatest amount of precipitation occurs in April, May, and June (Figure 2), and faily well distributed smaller amounts occur throughout the rest of the season.

In 1972 the growing season as indicated by GDU's (Figure 1) was exceptionally long. A cool period in mid-June and the first of July delayed maturity as can be seen in Table 3. With the long season and well distributed precipitation (Figure 2), conditions were excellent for grain sorghum and this was reflected by the high yields obtained in direct relation to maturity. Thus, under optimum conditions, a good

Table 3. Days to bloom, test weight and yields of six hybrids for 1972, 1973 and 1974.[1/]

Hybrid	Years			average
	1972	1973	1974	
		Days to bloom		
NB 505	62	61	62	62
RS 626	69	66	72	69
NB 634	73	67	85	75
NB 635	72	67	82	74
RS 671	75	69	80	75
NB 691	77	69	93	80
average	71	67	79	
		Test weight (g/l)		
NB 505	743	709	762	738
RS 626	705	652	761	706
NB 634	760	716	584	687
NB 635	764	724	625	704
RS 671	723	645	655	674
NB 691	750	709	419	626
average	740	692	634	
		Yield (kg/ha)		
NB 505	7255	6045	2745	5348
RS 626	7955	6364	4916	6412
NB 634	8527	6554	2965	6015
NB 635	9100	6808	3483	6464
RS 671	9100	6109	4107	6439
NB 691	9291	7389	912	5864
average	8538	6545	3185	

1/ from Nebraska Grain Sorghum Performance Tests, Outstate Testing Cir. No. 153, 159, and 166. Agr. Exp. Sta., Univ. of Nebr.-Lincoln, College of Agr..

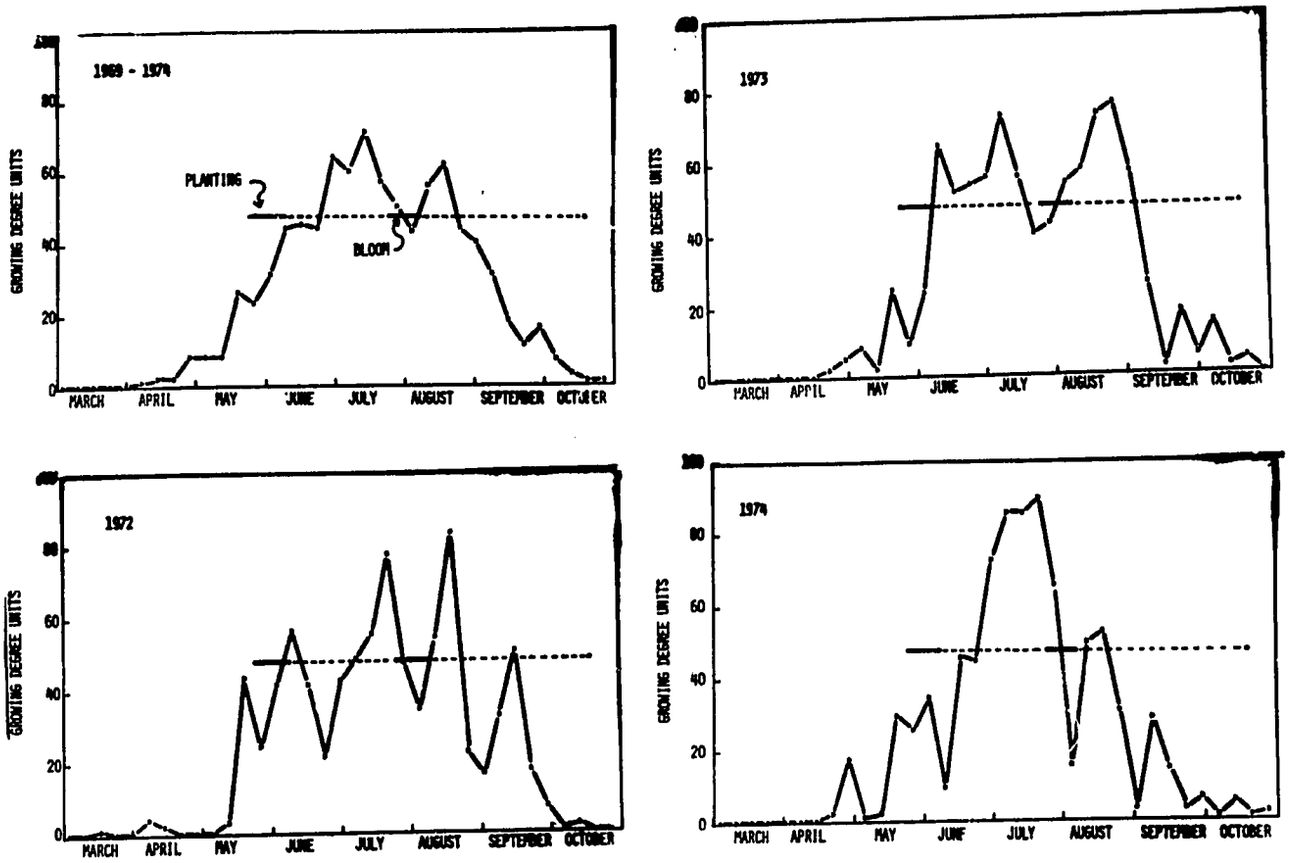

Figure 1. Growing degree units (base temperature 15.5 C) received at Mead, Nebraska for the six year period 1969-1974 and 1972, 1973, 1974 seasons.

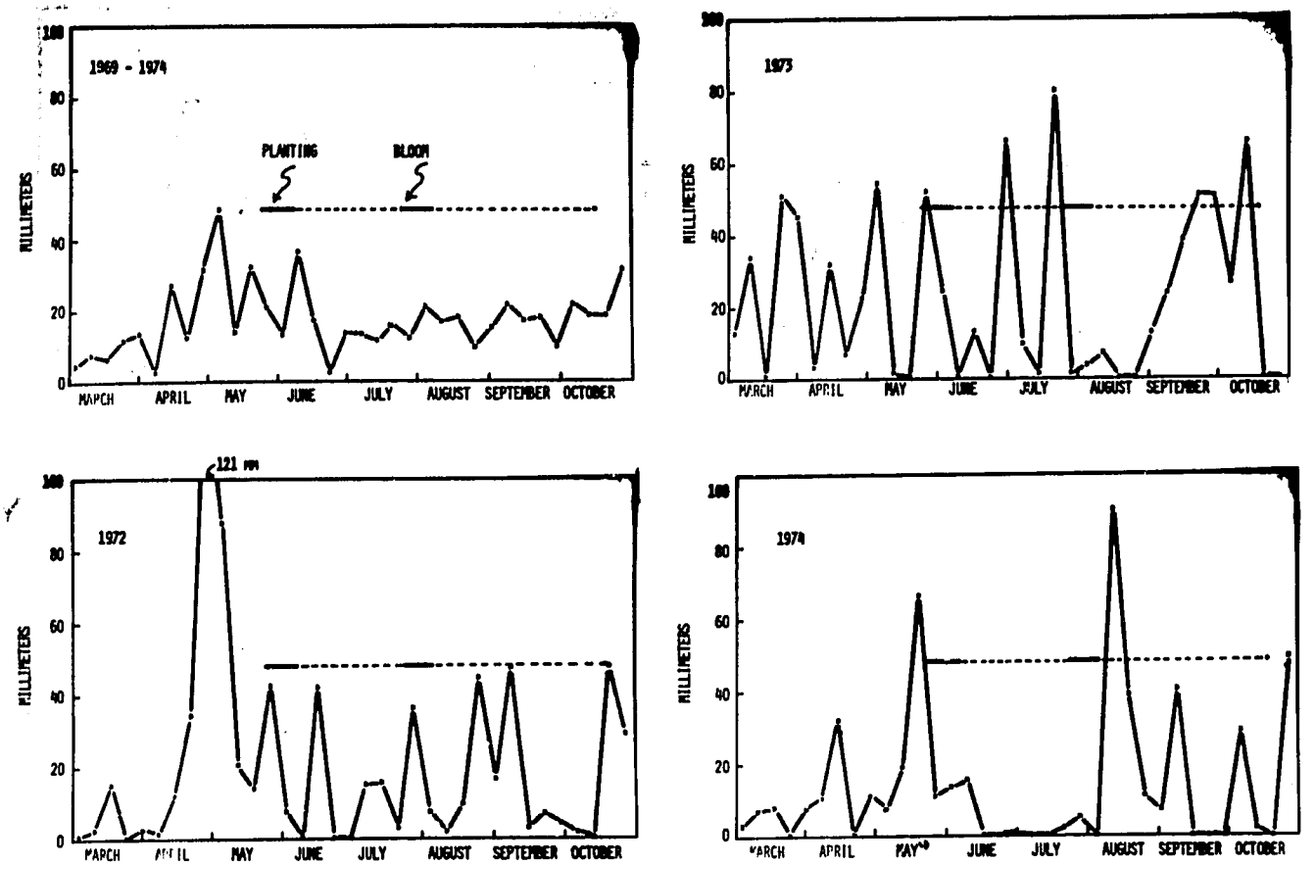

Figure 2. Precipitation received at Mead, Nebraska for the six year period 1969-1974 and 1972, 1973, 1974 seasons.

correlation exists between yield and maturity as reported by Dalton (1967).

In 1973 a high percentage of GDU's were received in June and early July (Figure 1). This resulted in early blooming as is shown in Table 3. Most of the remaining GDU's were received in August. Little were received in September. Precipitation was adequate until September, in which more than average amounts were received (Figure 2). Because of the low temperatures in September, the season was shortened and did not favor the long season hybrids. The yield for 1973 was therefore reduced. The extra precipitation in the fall resulted in other problems. One was that the seed in the grain sorghum heads began to germinate, causing losses in both yield and quality. It also interfered with harvesting.

For the 1974 season, approximately 82% of the GDU's were received from May through July (Figure 1). We would have predicted an early bloom date because of the relations of growth to GDU's. However, precipitation was lacking from June until mid-August (Figure 2), and the drought stress delayed blooming and again especially in the late hybrids. Adequate rainfall occurred August 9 and throughout the rest of the season. The crop should have responded to the moisture, and respectable yields should have been obtained. But, lack of high temperatures and an early frost ended the season. Consequently, the yields were low. Thus, we can see a combination of both drought, low temperatures in August, and length of season resulting in a yield loss.

Interestingly, over the three year period the average yield of the six hybrids was not too different. The medium early hybrid RS 626 was probably the most stable yielding hybrid with a high test weight and from a subsistence point of view, would be the desired maturity hybrid

to use.

The previous discussion does little to account for subtle climatic aberrations which account for unnoticeable yield losses. This is an area which needs exploring. For instance, what might happen if the temperature of an area could be reduced 1 C and rainfall to become less by 10%? Computer simulations for such a climatic change in the Midwest showed corn yields would be increased by 20% (Decker, 1974).

Radiation intercepted by a crop directly influences crop yield (Clegg, 1969). The radiation of an area is naturally varied by altitude and cloud cover. However, very little if any research has been done to assess the amount of yield reduction which could occur. This may be part of the explanation for the yield increase determined by computer simulation for the Midwest, since reduction in precipitation would reduce cloudiness.

There is essentially no way to controll the climate. But, it is possible to record various climatic factors and relate them to crop physiological processes. Thus, the climatic data can be used to implement field experiments. This is very important where climatic conditions change just by going a few miles to another location.

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SORGHUM DISEASE PROBLEMS AND PROGRAMS IN NORTH AMERICA

L. K. Edmunds [1]

Disease problems of sorghum in N. A. have been recognized in various ways, but usually they first were detected by persons with considerable knowledge of the crop and who spent considerable time in the field. Sometimes pathologists are first to detect a disease, but more often they identify diseases brought to their attention by public and industrial research agronomists, Cooperative Extension Service workers, and industrial sales personnel.

Sorghum is a relatively new plant species to North America. Most introductions of seed were made less than a century ago. Scientific selection and genetic manipulation are concentrated in the last half century. F_1 hybrids have been available for less than a quarter century. It seems logical, therefore, that very few sorghum diseases are unique to N. A. Only one of our sorghum diseases has not been found elsewhere, a root and crown rot of milo types that attacked and was defeated in the interim of the two World Wars. The most serious virus disease of sorghum probably evolved in N. A., but now that disease is known to occur on most other continents. Several other diseases were first described in N. A., but most of those probably were introduced with seed from elsewhere.

However, there are several aspects of sorghum culture in N. A.

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that could or did promote disease problems. Genetic vulnerability is one aspect that has received much attention recently, but in a broad sense it has played a role in sorghum diseases since the first seed introduction was made. Introduction of a new plant species, in itself, is an open invitation to attack by new enemies. Sorghum was subjected to rapid genetic change after introduction to N. A., and this may have extended an open invitation to attack by old enemies that also were introduced. Narrow margins of profit for farmers and a highly competitive hybrid seed industry have precipitated a greater degree of genetic uniformity among sorghums grown in N. A. than on any other continent.

Proximity and continuity of crop units often determine rate and extent a disease spreads. Cultivation of sorghum in N. A. is concentrated in relatively few States of Mexico and the U. S. For most of the crop, there are no natural barriers to hinder dissemination of air-borne pathogens by prevailing winds. Hybrid grain sorghum typically is grown in large fields, 50-250 hectares or more, and those fields usually are separated by little more than roads and rivers.

Ample opportunities have arisen for pathogens to bridge greater barriers than roads and rivers. Only recently, for example, have strict quarantines been enforced on seed importations from other continents. Commercial shipments of sorghum in N. A. are voluminous and extensive. One needs only to observe the amount of volunteer sorghum along our highways and railroads to confirm in transit loss of seed. Pathogens and their weed hosts also may be transported by harvest machinery. Much of the crop in N. A. is harvested by custom operators

who move their machines northward from farm to farm each season.

A unique environment that is conclusive to less transient pathogens, such as those attacking roots and stalks, appears to be evolving among our soils. Production efficiency demanded by narrow profit margins have resulted in use of progressively heavier equipment on intensively cropped lands. Soil organic content has decreased, soil bulk density has increased, and coincident activity of root-infecting fungi appears to be greater.

These aspects of sorghum production in N. A. may seem to suggest that our farmers face undue adversity because of plant diseases, but in reality, sorghum is a relatively healthy crop. There are two important reasons for this. First, most of the crop is produced in a climate generally unfavorable to most pathogens, particularly to those that require humid weather to attack foliage or inflorescences. Second, disease controls, developed through sound research programs and executed by an extremely well-informed agricultural industry, have been effective in minimizing disease losses. Lest we seem overly proud, however, we must acknowledge that disease losses are the consequences of our mistakes and misjudgements in some aspect of crop culture, and that disease controls represent our efforts to rectify those mistakes.

Rectifying or averting those mistakes affords the opportunity for input by plant pathologists, especially those having specific assignment on a commodity basis. Those inputs fit one or more of the following categories: 1) identification or authentication of existing or predictable disease phenomena; 2) estimation or prediction of

losses; 3) design or affirmation and implementation of the most feasible control strategy; 4) obtaining basic information that advances interdisciplinary programs for solving production problems.

The purpose of this paper is to review development of disease problems and programs related to sorghum in N. A., more or less chronologically, in hopes that our experiences might be of some value to those conducting similar programs on other continents.

Disease Control Through Seed Treatment

Seed treatment and seed quality are so routinely applied by our modern seed industry that their importance, both historically and currently, often is forgotten, overlooked or misunderstood. Seed treatment figured intimately in the discovery and confirmation during the last half of the 18th century, as observed in wheat bunt, that microorganisms cause plant diseases. Seed treatment was the method chosen to control kernel smut, the first major disease problem of sorghum in N. A. Like bunt of wheat, kernel smut of sorghum is seedborne. It first was described in 1825 (40) and because of its prevalence, logically accompanied early introductions of seed to N. A.

Seed treatment experiments on sorghum were initiated by W. A. Kellerman (19) in Kansas in 1890, the same year that they first found kernel smut in that State. At that time, chemical control of disease was a novel tool, panacea perhaps, that underpinned the relatively new science of plant pathology. Early experiments compared effectiveness of hot water with that of various inorganic salts of copper, iron, potassium and mercury. Those early chemical treatments generally were harmful to seed, while hot water treatment was laborious and time-con-

suming. In 1907, better and safer control of kernel smut by use of formaldehyde was reported by Roberts and Freeman (30). For several decades, that method became the standard by which following treatments were evaluated. An important additional benefit of seed treatment was reported by Finnell in 1926 (7). Using copper carbonate, he noted that not only was kernel smut controlled, but also that stands were greatly improved. Moreover, copper carbonate exhibited less toxicity to seed. Copper carbonate applied as a dust replaced the liquid formaldehyde treatment and was in general use during the late twenties and early thirties (17). Intensive programs conducted by the Cooperative Extension Service resulted in widespread use of seed treatment by our farmers until they were relieved of the task by the hybrid seed industry. Effectiveness of organic mercurials, mostly New Improved Ceresan, was implemented briefly before World War II (24). Then the era of non-mercurial organic fungicides finally emerged, with chloranil thiram and phygon leading the way (20). Dusts were replaced by slurries to reduce hazards in application, and the latter are used almost exclusively to date (15). Even safer treatments are foreseen in flowable formulations and new seed coating processes that currently are being evaluated (15).

The most obvious result of seed treatment was the essential elimination of kernel smut among sorghum crops in N. A. Less obvious, but perhaps just as important, is the added assurance of good stands that seed treatment gives. Seed rot and seedling blight are problems most generally associated with seed quality and seedbed environment (23). The most critical period for growth of a sorghum plant is the

first 3-4 weeks after planting. As compared to maize, sorghum characteristically has weak seedlings, especially if seedbed conditions are sub-optimum. Early arrival of favorable planting weather often tempts farmers to gamble that such weather will continue, and thereby increase chances of evading drought problems later in the season. Weather patterns in N. A. are fickle, however, and more often than not, such gambles are partially or wholly lost when a week or so of cold wet weather follows planting. Under those conditions, all sorts of seedborne and soilborne fungi may invade seed or seedlings. Rhizosphere environments that are adverse to root development may be expected to enhance root-infecting fungi. Those conditions include adverse temperature, low oxygen, high carbon dioxide, and excessive root exudates. Excessive root exudates in the rhizosphere may result accumulatively from retarded outward diffusion or directly from virus infection (5). Decomposition of young weeds that are incorporated to the soil less than two weeks before planting may release metabolites that are toxic to young sorghum roots. Except under the most adverse conditions, losses in stand from seed rot and damping off just before or after emergence have been minimized adequately by using high quality seed and seed treatment.

Disease Control through Host Resistance

Host resistance has been chosen more often than any other method to control sorghum diseases in N. A. Demonstrable host specificity among the pathogens, vast crop areas, and limited income per crop unit logically favor host resistance for control of sorghum diseases. Utilization of host resistance has been aided greatly by: 1) dis-

covery of cytoplasmic male sterility for development and production of F_1 hybrids; 2) establishment of the World Sorghum Collection and the Sorghum Conversion Program that proved to be sources of wide resistance; and 3) development of adequate disease screening tests.

Cytoplasmic Male Sterility and F_1 Hybrid Sorghums

The classic discovery of cytoplasmic male sterility reported in 1952 by workers at Chillicothe, Texas (38) has had incalculable impact on control of sorghum diseases. The immediately elevated socioeconomic status of sorghum prompted expansion of public research programs that included greater attention to pathological aspects of sorghum production. Opportunity for pathological input among breeding programs was particularly enhanced, not only because genetic possibilities expanded, but also because new diseases and races appeared. Cooperative investigations between plant breeders and pathologists are exemplified by those on anthracnose in Georgia and Mississippi, charcoal rot in Arizona, New Mexico and Texas, and downy mildew, head smut and maize dwarf mosaic (MDM) in Kansas and Texas.

Cytoplasmic male sterility made possible the development of a highly sophisticated hybrid sorghum seed industry. Cooperation and influential support of public research programs by that industry, both as individual companies and collectively as the American Seed Trade Association[2], have been significant. The voluminous task of evaluating

[2] The American Seed Trade Association, Executive Building, Suite 964, Washington, D.C. 20005.

parental lines for development of superior hybrids was taken over largely by commercial seed companies. Plant breeders at Agricultural Experiment Stations were able to shift emphases from development of varieties and hybrids to providing basic information and breeding materials that complement the efforts of the seed industry.

The seed industry also has directly eased implementation of sorghum disease control, not only by increasing availability of high quality, treated seed, but also by incorporating resistance to new diseases and races in the shortest time possible. They have the operational flexibility to establish strategically located disease screening nurseries and seed production fields, and to extensively test new hybrids at varied locations.

The World Sorghum Collection and the Sorghum Conversion Program

The problem of genetic vulnerability among major food crops was crystallized by the maize blight of 1970. It is no secret that hybrid sorghum is as vulnerable if not more so than maize. Sterility-inducing milo cytoplasm is common to all our hybrids, and pedigrees of those bybrids seldom include more than two or three parental lines (28). Without male sterility, we have the added complication of perfect flowers in hybrid seed production. Our hybrid seed industry would be in immediate jeopardy if a virulence, similarly specific for male sterile cytoplasm as was Helminthosporium maydis race in maize, were to evolve or be introduced among our sorghums in N. A.

The scramble of our plant breeders to reduce genetic vulnerability by broadening gene bases among major food crops has met with unique foresight and good fortune in the case of sorghum. Great diversity in

sorghums has survived among those in native habitats and has been preserved among those cultivated since ancient times by peoples in isolated villages throughout much of Africa and Asia. Consolidation, preservation and utilization of that genetic resource, both from breeders' collections and from recent plant explorations, became a continuing reality in 1963 with establishment of two monumental projects. One is the World Sorghum Collection, now containing over 16,000 entries (26). It is among such diversity that we are finding disease resistances which probably evolved more or less naturally to most known sorghum pathogens. Multigenic resistances to individual diseases and combined resistance to several diseases are of particular interest to us because they reduce opportunity for development of new virulences among sorghum pathogens. The second project, of course, is the Sorghum Conversion Program which facilitates transfer of those resistances in day-sensitive to day-neutral sorghums suitable for breeding objectives in N. A. (26). Promising resistances to most sorghum diseases already have been identified among converted World Collection entries (10). Germplasm in form of partially purified lines and bulks recently have been released (27). Through use of random-mating populations, consolidation of those resistances into wide-base germplasms is being attempted (33).

Disease Screening Tests

We have relied heavily on natural or induced infection by specific pathogens in strategically located screening tests to identify disease resistances among sorghums.

Probably the most concentrated screening efforts in recent years

have taken place in Texas where head smut attained unprecedented incidence and where sorghum downy mildew and MDM in sorghum first were found in N. A. (29). Screening tests for head smut and sorghum downy mildew have been maintained in the Coastal Bend Area by growing susceptible sorghums on sites with histories of unusually high incidences of those diseases. By that practice, production of overwintering soilborne inoculum sufficient to give high disease incidence among subsequently planted sorghums is possible. The first MDM field screening tests also were conducted in south Texas (42). In recent years, however, adequate evaluations have been possible in screening tests at home stations of several plant breeders located throughout the southern half of the United States.

Anthracnose screening tests also are conducted among field nurseries. Natural infection is used effectively by breeders in Georgia (16). Natural infection is supplemented by introducing pulverized diseased tissues into whorls of young plants in screening tests conducted at Meridian, Mississippi (3).

The most remarkable aspect of strategically located disease nurseries in N. A. is the extensive cooperation among the various federal and state research personnel, cooperation that permits any plant breeder with interests in disease resistance to utilize the strategic locations mentioned.

Although field tests have been of great value, they are not without limitations. They can be conducted only in the growing season; on a given test site, disease incidences vary from year to year and sometimes within a year; availability of land and personnel limit the scope of a test. Reliable seedling screening tests under controlled condi-

tions can eliminate those shortcomings. Thus far, however, very few such tests have been perfected. Host-specific toxins produced by Periconia circinata are effectively used to test young sorghum seedlings for resistance to milo disease under laboratory conditions (36). Conidia of Sclerospora sorghi are being used in a promising method for screening seedlings for resistance to sorghum downy mildew in the greenhouse (18). Histological assay of floral primordia in seedlings infected with Sphacelotheca reiliana has potential for development of a screening test for head smut (47). The principal obstacle in use of seedling tests has not been inability to obtain infection, but rather difficulty in obtaining close correlation with field reactions that plants exhibit in later stages of development when damage is most representative of the diseases controlled by host resistance.

The most notable diseases we have controlled by host resistance have been: 1) milo disease, caused by Periconia circinata; 2) anthracnose, caused by Colletotrichum graminicolum; 3) head smut, caused by Sphacelotheca reiliana; 4) maize dwarf mosaic, caused by maize dwarf mosaic virus; and 5) sorghum downy mildew, caused by Sclerospora sorghi.

Periconia Root Rot

Periconia root rot or milo disease, has historical significance because it was the first serious disease of sorghum in N. A. that was tactically controlled by development of resistant varieties. The disease was recognized in the heart of our sorghum region in the southern Great Plains, first at Chillicothe, Texas in 1924 (6), and then at Garden City, Kansas in 1926 (6). Affected plants first

showed slightly rolled leaves with yellowish margins and tips. Growth became retarded and plants gradually debilitated until they were valueless. The disease was slow moving within and among plants and in a given field or area, but once established, it essentially eliminated susceptible varieties from further productior. It was named milo disease because only milo types were susceptible, and perhaps also because the primary pathogen was not identified until 24 years after the disease first was detected (21).

In 1927, when it was apparent that a major disease problem was developing, the U. S. Department of Agriculture sent Ms. Charlotte Elliott to the scene to investigate. After a decade of intensive study, she and her co-workers mistakenly implicated Pythium arrhenomanes as the primary pathogen, even though they had not reproduced the disease with pure cultures of the implicated fungus (6). That shortcoming led R. W. Leukel, another USDA pathologist, to take up further studies of milo disease in 1942. After several years, he isolated a slow-growing dirty gray fungus named P. circinata, and reproduced the disease with pure cultures of that organism (21).

Most species of Periconia had been regarded as saprophytic, and none had been associated with root diseases. Unlike most root-infecting fungi of sorghum, P. circinata evolved a unique strain in the southern Great Plains that was pathogenic by virtue of producing a toxin specific for milo sorghums (34). Exceptions to that specificity were reported in 1936 by Wagner (46), who had detected the disease at Garden City, Kansas a decade earlier. By 1943, use of Garden City soil for large-scale seedling screening tests resulted in development of resistant milos (25). To serve plant breeders who wish to monitor

milo disease resistance in their sorghum lines or hybrids, a field nursery has been maintained continuously on the original Garden City site.

With few exceptions, resistance to milo disease has been maintained in this manner. Theoretically, however, P. circinata has the capability to develop strains specific for germplasms common to large portions of the crop, and therefore could jeopardize our best hybrids.

Anthracnose

Anthracnose in the humid South, caused by Colletotrichum graminicolum, represents the most destructive disease caused by deuteromycetous foliage pathogens of sorghum in N. A. Satisfactory resistance among sweet or forage sorghums to both leaf and stalk anthracnose has been available for many years (3). However, grain sorghum hybrids generally are susceptible to anthracnose. The phenomenal rise of poultry production in the humid South is based on grain sorghum rations. As a consequence of anthracnose problems, however, most sorghum grain needed for the poultry industry there has to be imported from the Great Plains.

The difficulty in developing anthracnose-resistant grain sorghums lies in the tendency of resistance to dissipate as the grain matures. Under warm, humid conditions during that stage of development, massive invasion of panicles and stalks occurs (16). Therefore, emphasis in current screening tests at selected Georgia and Mississippi locations is placed on mature plant reaction to the disease. Promising mature plant resistance has been noted in lines derived from crosses between grain and anthracnose-resistant sweet sorghums (49). Considerable

resistance also has been identified among converted World Collection entries (10).

Head Smut

By hybridizing all combinations of the three smut fungi that infect sorghum in N. A., close intrageneric relationship has been demonstrated among them (31,43,45). All three species infect floral primordia in seedlings. The two species that cause kernel smuts are easily controlled by seed treatment, but Sphacelotheca reiliana, the cause of head smut, can infect sorghum up to several weeks after planting and is not controlled by seed treatment (20). Even seed treatment with systemic fungicides such as benomyl do not protect seedlings long enough to prevent infection (8).

Head smut was known in N. A. as early as 1890, but apparently it did not cause serious losses until the 1950's when highly susceptible sorghums were grown extensively in the Coastal Bend Area in south Texas (29). Before new head smut races appeared, susceptibility to head smut probably originated most commonly from certain kafirs, e.g., the Martin selection Tx7078 used as the pollinator of the hybrid RS 610, a group noted to be affected frequently in the Texas Panhandle as early as 1920 (41). Concurrently, milos, feterita and hegari were generally resistant.

Losses in the Coastal Bend Area and potential losses elsewhere prompted the Texas Agricultural Experiment Station (TAES) to establish screening nurseries at two sites near Beeville, Texas before 1960 (29). Because of shifts in disease incidence and pathogen virulence after that, additional nurseries were established in the area

by the TAES to carry on their own breeding programs and to cooperate with those being conducted by the USDA-Agricultural Research Service and several state experiment stations. Commercial companies also established nurseries in the Coastal Bend Area.

The first head smut-resistant public hybrids were released in 1964 (32). Those hybrids utilized simply inherited dominant resistance obtained from Tx09 Combine White Feterita. The resistance was incorporated into Tx7078 and released as a pollinator, R Tx414 (32). That pollinator was used to develop hybrids such as RS 625 and RS 626 (32). Four years later, new race of head smut was reported to occur among those hybrids in south Texas (11). Several sources of resistance to that race, designated as race 3, were identified among converted World Collection entries (10). Resistance obtained from the entry, IS 12610c recently was released in form of a pollinator, R TAM 428 and two hybrids, TAM 670 and TAM 680. The hybrid TAM 670 also carries head smut resistance obtained from Spur Feterita, via KS3, and incorporated into the female parent, A TAM 618 (1). Reactions observed in 1974, however, indicate that head smut resistance to race 3, as derived from some of the multidisease-resistant converted World Collection entries, has been defeated by another new race (8). Obviously, S. reiliana is able to evolve new races to overcome simply inherited resistances about as quickly as those resistances are utilized.

Maize Dwarf Mosaic

It is somewhat difficult to imagine why sorghum escaped a major virus disease problem in N. A. as long as it did. Viruses were known

to infect sorghums in N. A. as early as 1919 (2), but serious losses did not occur until 1967 (42) when maize dwarf mosaic (MDM) caused extensive damage to grain sorghum in the southern Great Plains. The unprecedented virulence came from a virus strain that infects johnsongrass. Johnsongrass is a perennial host, suspected to have provided transition and strain development from sugarcane mosaic virus (35). Since being introduced to Georgia in 1830, johnsongrass steadily has gained territory in N. A. as a weed problem as far north as the Ohio and Platte River Valleys. Therefore, it serves to overwinter MDMV in proximity to most of the crop. The principal vectors are corn leaf aphids (Rhopalosiphum maydis) and greenbugs (Schizaphis graminum). They seldom fail, save isolated cases, to produce sufficient populations to spread the virus from johnsongrass directly or indirectly to every sorghum field south of the two rivers mentioned.

Although the disease is named partially after the chlorotic symptom produced, the most dramatic and destructive form of damage sustained by infected sorghum plants is necrotic. Extent of necrosis relates directly to sorghum genotype and to temperature. In varying degrees, virus-infected tissues of many sorghum genotypes are hypersensitive to temperatures of 18°C or lower (37). Although not exactly determined, sensitivity of infected tissues to low temperatures relates to their age and to the amount of time elapsed after becoming infected. In leaves, younger infected tissues are more sensitive to low temperature than all mature tissues. In panicles, greatest sensitivity of infected tissues to low temperature appears to follow the most active period of translocation to the seed (4).

Losses from MDM were reduced rather quickly after 1967 because seed companies sidelined their most sensitive hybrids and then promoted or developed other hybrids with considerable tolerance. However, the hypersensitive reaction has not been eliminated completely among our commercial hybrids. In some years damage to panicle parts is significant, especially when coincident or subsequent wet weather promotes invasion of seed by such airborne fungi as Alternaria, spp. and of panicle tissues by such fungi as Fusarium spp.(12).Affected seeds tend to have thin pericarps and chalky endosperms, and often they sprout before harvest when subjected to prolonged moist weather. Complete understanding of possible interrelationships between fungal and viral infections of seeds or panicle parts has not yet been reached, but apparently, the pathogens may act both in concert and independently of each other, depending on host genotype, host maturity, and environment. There is little question, however, that the problem of late-season seed deterioration has become a major disease hazard of grain sorghum in the Great Plains.

Sorghum Downy Mildew

Sorghum downy mildew probably represents our most recently introduced pathogen. It first was identified in material collected from experimental plots at Chillicothe and College Station, Texas in the fall of 1961 (14). The next spring the disease was found among experimental plots at Beeville. The disease gradually became more prevalent until it reached epidemic proportions in 1967 in the Coastal Bend Area. Sudangrass and Sudan-forage hybrids exhibited extreme susceptibility and served to build up primary inoculum (oospores).

Primary inoculum probably was introduced with seed to the other states where the disease now has been found (14).

Damage from downy mildew has not been extensive outside of south Texas, but potentially, the disease could become serious wherever highly susceptible sorghums are produced. We particularly are concerned about the potential damage in our maize belt where high frequency of nightly dews favor production of airborne conidia. Widespread use of susceptible sudangrasses in that region possibly could duplicate the disease history in south Texas. For that reason, intensive effort is underway to produce downy mildew-resistant sudangrass germplasms. Among grain sorghums, high susceptibility occurs among yellow endosperm hybrids. Although a few common open pedigree inbreds and hybrids are resistant to downy mildew, wide resistance has been found principally among converted World Collection entries (10). Resistance from several converted zerazera type selections now has been incorporated to yellow endosperm restorer line bulks (TAM Bk 45, 46, 47, and 48) that hopefully will prove useful in developing new yellow endosperm hybrids that are downy mildew-resistant (27). Another recent release is a R TAM 428, white seeded pollinator, and it contains downy mildew-resistance originally found in the World Collection entry, IS 62610. That entry also is a zerazera type that was collected in Ethiopia and utilized through the Sorghum Conversion Program (10).

Disease Control through Quarantine

Impetus for passage of the U. S. Plant Quarantine Act of 1912 included the threat of Philippine downy mildew of maize (*Sclerospora philippinensis*) to that crop in N. A. *S. philippinensis* also can in-

fect sorghum (44). It is a matter of speculation whether quarantine of maize seed from the Orient prevented introduction of that pathogen to N. A., because no resting stage of the fungus has been found in association with seed (44). Until recently, use of quarantines for sorghum seed was rare. That lack of enforcement probably accounts for introduction to N. A. of most sorghum pathogens that are economically important on other continents. Hopefully, current enforcement of quarantines on sorghum seed from Africa and southeast Asia will prevent introduction of potentially damaging sorghum pathogens such as Sphacelia sorghi (ergot) and Striga hermonthica (witchweed). Quarantines can be effective in sorghum disease control, but concurrent provisions must be made to import seed representing germplasms vital to breeding programs. Depending of the extent of needs and finances, those provisions could be effected by producing certified disease-free seed near its source, on offshore islands, or under approved containment facilities at destinations.

Disease Control through Cultural Practices

Success achieved with seed treatment and host resistance probably has upstaged any attention given to the effects of cultural practices on sorghum diseases in N. A. A notable exception is the work conducted by personnel at the Centro Investigacion Agricolas de Tamulipas Experiment Station near Rio Bravo, Tam., Mexico (13). They found that date of planting maize significantly affects downy mildew incidence, and that the disease could be minimized by relatively early planting dates. Escape mechanisms in maize revealed by those tests now is being evaluated among similar tests as far north as 39° N latitude in the

United States. Another method of cultural control is exemplified by the elimination of sudangrass-forage green crop and seed production in south Texas (9). By that elimination, primary inoculum in form of oospores was reduced significantly, and time was gained to develop additional control in form of host resistance.

Effect of tillage methods, crop sequences, plant populations and spacings, fertilizations, and irrigations on diseases have been investigated scantily. The only diseases seemingly relating to such practices, and for which little or no clear-cut resistance has been demonstrated, are the root and stalk rots caused by such non-specific pathogens as certain species of Fusarium, Pythium, Sclerotium, and possibly Rhizoctonia. Activity of those pathogens may involve a complex with environment, soil structure, soil phases, host maturity, crop residues and associated soil microflora (5). As compared to an undisturbed native prairie soil, our cultivated soils have lost up to 50% organic matter and have increased in bulk density at least 30%. Roots are subjected to increased physical resistance of the soil, reduced availability of oxygen and water, and reduced dispersion of toxic gaseous and liquid exudates from roots. Under those conditions sorghum plants become stressed faster and more severely until they are susceptible to attack by root-infecting fungi. Crop management systems are being evaluated at many locations throughout the Great Plains. Some evidence has been obtained that suggests we may be able to counterbalance the effects of crop production on rhizosphere environments by using one of several tillage procedures aimed at moisture conservation (5).

Conclusion

From a score or more of formal national and international sorghum meetings that have convened since hybrid sorghums went into production, we have heard many words of wisdom on the value of what has been done and needs to be done with that crop. I have none. For those desiring further inspiration for sorghum work, I refer you to the proceedings of meetings sponsored by the Grain Sorghum Producers Association[3] and the American Seed Trade Association. Personal contact with sorghum workers always is beneficial and can be made en masse at those meetings, as well as at those of the Sorghum Improvement Conference of North America[4], and at special meetings such as the one we currently are attending. Such communication is vital to the success of any sorghum program, and I certainly appreciate this opportunity for a unique encounter with new and old colleagues in the surroundings of Puerto Rico's unsurpassed beauty.

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[4] Sorghum Improvement Conference of North America, D. E. Weibel, chm. Agronomy Dept., Oklahoma State University, Stillwater, Oklahoma 74074.

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SORGHUM DISEASES IN BRASIL

Eric G. Sharvelle

An International program dedicated to the technology of sorghum production and concerned with limiting factors involved in efficient utilization of this crop is a notable landmark in International Agricultural cooperation. Agricultural science should not and must not be restricted to geographical areas endowed with the fortuitous advantages of a fortunate society. On the contrary, world progress in agricultural crops production can only meet the challenges of the twenty first century if agricultural scientists share their technical knowhow and work together without restrictions of geographical location.

Alexander Graham Bell, American scientist, pioneer of modern electronic communication by sound waves and sponsor of the Astrophysical Observatory of the Smithsonian Institute (1847-1922) once said "great discoveries and improvements invariably involve the cooperation of many minds. I may be given credit for having blazed the trail but when I look at the subsequent developments I feel the credit is due to others rather than to myself".

The philosophy of worldwide cooperation in agricultural progress is a commendable thesis for any international meeting.

In this modern era of rapid advancement of the natural and physical sciences it is somewhat unusual to consider the old when the new is usually thought to be the key to unlock the door of the future. Sorghum is not new - in fact sorghum is one of the oldest of man's cultivated crops. Sorghum to some people means a crop used for making molasses. This use for sorghum, however, accounts for only one percent

of domestic acreage in the United States and only 0.05 percent of world acreage in grain sorghum. The importance of grain and forage sorghums as sources of human and animal food, and for industrial usage has not been widely recognized in many agricultural areas.

It is of interest that a crop of such antiquity as sorghum should be considered of sufficient importance to merit international deliberation by scientists from the Americas - north, south and central. Deliberations of this type will undoubtedly have a major impact on future advancement of sorghum technology.

Sorghum must be designated as a crop of acknowledged antiquity since it has been known as an agricultural crop for two thousand years before Christ, and has served as a relatively unheralded source of human food for many centuries in areas of the world where other grain crops could not be grown.

S.A.J. Tarr, in his textbook on diseases of sorghum, refers to a realistic carving of what undoubtedly was a field of sorghum that was discovered in the archaelogical remains of one of the palaces of one of the Kings of Assyria on the Banks of the River Tigris dating cerca BC 704-681. It is also believed that sorghum was grown in Egypt during the days of the Pharaohs and there are records of sorghum production in India and China in the opening centuries of the Christian Era. Sorghum has also been used for human food consumption in Africa for several thousand years.

In spite of its antiquity it is only in relatively recent times that sorghum has received serious consideration as a potential commercial food crop in developing countries of the world. At the present time sorghum ranks fourth as a world grain crop being preceded in importance

only by wheat, rice and maize. The world production of the major grain crops is summarized below:

World Acreage in Grain Crops 1970

Crop	Acreage (hectares)
Wheat	210,300,000
Rice	135,500,000
Maize	110,800,000
Sorghum	103,000,000
Barley	78,100,000
Oats	32,000,000

The major sorghum producing countries are India, Mexico, Argentina, Nigeria, the Sudan and the United States. In Latin America, Argentina leads in sorghum production with an annual production of approximately 5,000,000 tons followed by Mexico producing 2,000,000 tons of sorghum annually.

In 1972-1973 Brasil was reported to have harvested 600,000 tons of sorghum, with additional acreage in the States of Sao Paulo, Parana, Minas Gerais, southern Mato Grosso and southern Goias with possibilities of production in the semi arid areas of the Northeast. Approximately 70% of the Brasilian sorghum acreage is grown in the State of Rio Grande do Sul.

Interest in sorghum improvement in Brasil is of relatively recent origin but it is now a major interest of the crop improvement programs of commercial seed producing companies such as Proagro Pioneer SA, Cargill, Sementes Agroceres SA, Companhia Continental de Cerais "Contibrasil" and others, as well as the Federal Department of Agriculture under the guidance of EMBRAPA (Empresa Brasiliera de

Pesquisa Agropecuaria). The Projeto Nacional de Milho e Sorgo is an International Loan Agreement between EMBRAPA/Purdue University and USAID. Under the terms of this agreement a team of six American specialists including an entomologist, plant pathologist, plant breeder, soil management specialist and soil fertility expert are working in cooperation with Brasilian investigators in the development of a sorghum improvement program. Recognition of plant diseases as important saboteurs of crops production is accepted by most agricultural scientists as an important consideration in any program of crop improvement. It is no longer progressive or broadminded to relegate plant pathology to a minor role as a subservient adjunct to reputed dominant areas of scientific endeavor. Plant pathology, the science of cause and control of plant diseases has graduated to the roster of featured players in the game of providing food for sufficiency for expanding world populations and the unborn millions of to-morrow. Dr. E.C. Stakman, distinguished senior citizen and Dean of Plant Pathology in the USA has defined the role of phytopathology as "for better or worse plant pathology has its genesis in fields and granaries rather than in Halls of ivy. The emphasis on the practical is nothing to be ashamed of, on the contrary plant pathology can be proud it is needed rather than merely tolerated by society."

A consideration of the identity, scope and significance of plant diseases in the several countries represented in this International Workshop is therefore an important aspect of the deliberations. In Brasil a survey of the extent and severity of plant diseases of sorghum was initiated in the major sorghum producing areas and will be continued during the coming growing season. The Projeto Nacional de Milho e Sorgo

in Brasil was fortunate in having the services o. Dr. Richard Frederiksen of Texas A & M University to assist in this initial plant disease survey.

At the present time sorghum anthracnose, Colletotrichum graminicola (Ces.) G & W Wils, is the most widely distributed sorghum disease in Brasil. With the possible exception of the Northeast semi-arid region, anthracnose occurs in every region wherever sorghum is grown in Brasil. The severity of anthracnose will vary from relatively insignificant foliage infections to severe foliage damage involving most of the leaves resulting in partial or complete crop failures. Later in the season, generally after flowering, susceptible sorghum varieties will develop peduncle infections and infection of the grain bearing heads. Several of the commercial and experimental sorghum varieties show excellent resistance to anthracnose but none of them appear to be immune. Preliminary field observations indicate the possibility of varietal differences in susceptibility to foliar, peduncle and grain head infections suggesting the possibility of biotypes or pathogenic strains of the causal pathogen. A summary outline of the research program with sorghum anthracnose in Brasil is attached in Appendix I.

Rust of sorghum (Puccinia purpurea) occurs widely in most sorghum producing areas of Brasil on both grain and forage sorghum. It appears to be of little economic importance since it generally appears late in the growing season after sorghum heads have developed. In areas where forage sorghum is of importance a consideration of methods of rust control might be worthy of some investigation.

Stalk rot of sorghum (charcoal rot), caused by Macrophomina phaseoli, has been observed in most of the sorghum producing areas and tne severity of this problem is related to population density, growth

stress and especially high temperature stress during periods of drought. In Brasil charcoal rot invades only the basal portion of sorghum stems.

Another disease problem of concern in Brasil is Sugarcane mosaic which has been observed in destructive degree in an experimental planting of sorghum following sugarcane at Sete Logoas. In 1973 severe necrosis and death of TX 2536 occurred from sugarcane mosaic. Apparently the Brasilian strain of this virus is different to the strain in the USA. Susceptibility of TX 2536 to sugarcane mosaic in Brasil is of significance since this and closely related lines are generally considered to be the most important parents of currently grown sorghum hybrids. The proximity of sugarcane plantings to many sorghum fields in Brasil would justify further observation of this virus problem.

Smuts of sorghum do occur in Brasil but at present do not seem to be of major importance in most sorghum producing areas. Other foliage diseases of sorghum that have been observed but at present do not seem to be of major significance are:

Cercospora leafspot - Cercospora sorghi

Helminthosporium leaf blight - Helminthosporium turcicum

Zonate leafspot - Gloeocercospora sorghi

Phoma leafspot - Phoma insidiosa (Phyllosticta sorghina)

Sooty stripe - Ramulispora sorghi

Downy mildew (Sclerospora sorghi) observed and identified in Brasil for the first time in 1974 by Dr. Richard Frederiksen, is currently a problem of concern. A summary of the sorghum downy mildew situation is presented in Appendix II.

While anthracnose at the present time appears to be the major disease of sorghum in Brasil it is to be expected that the occurrence and severity of sorghum diseases will change as the sorghum production industry expands and intensifies. Constant vigilance for the appearance of new sorghum diseases in Brasil and shifting emphasis on important present diseases will be an important consideration of the Brasilian program of plant pathology in the sorghum improvement program.

Diseases of sorghum have been recognized as factors for concern in many sorghum improvement programs and will constitute a phase of the Brasilian sorghum research program.

If we have learned anything in agricultural sciences during the past two decades it is that biological competition is no respector of the dogma of "the Balance of Nature". The "natural environment" of which agriculture is a part is in truth "an unnatural environment" which man has created to serve his needs - the provision of sufficient food for expanding world populations. The unnatural manmade environment of world agriculture contravenes the original purpose and intent of a beneficent creator and consequently man has been forced to develop science and technology to offset the consequences of an unbalanced environment. Plant disease control is now one of the essential needs in most world centers of agricultural development.

There is no one discipline or scientific specialty which can develop the modern wheel of sorghum production by mere application of the technology in one area of scientific specialty. Soil management and production practices are not the sole answer to control of sorghum diseases. Plant breeding independent of other areas of specialty cannot and has not succeeded in inhibiting the ability of phytopathogens to

assert their genetic variability enabling them to overcome artificial barriers of man induced resistance. Constant vigilance by plant pathologists will be necessary to erect the danger signs of new diseases, or new strains of phytopathogens, as they appear - as they will as sorghum production expands and intersifies.

No one country has by itself sufficient expertise to solve all of the problems of sorghum production, which differ from country to country and from region to region. In the world community of commercial sorghum production there is room for contribution from all countries with vested sorghum interests. Plant pathology, the science of plant disease etiology and control, is thus one of the spokes in the wheel of sorghum production. Together with the other spokes of agricultural science, entomology, nematology, physiology, virology, agronomy and plant breeding, plant pathology must be polished and fitted into the hub of progress to be bound with the rim of understanding to constitute the wheel of sorghum production as it encounters the practical vicissitudes of travel down the highway of human endeavor in the years that lie ahead.

APPENDIX 1

THE BRASILIAN RESEARCH PROGRAM ON THE EPIDEMIOLOGY AND CONTROL OF SORGHUM ANTHRACNOSE *COLLETOTRICHUM GRAMINICOLA*

1. Methods of Isolation and Laboratory Culture

Under the tropical conditions of Brasil collection and storage of anthracnose infected leaf, stem and peduncle specimens has not been the most effective method of obtaining and storing sorghum anthracnose inoculum for isolation purposes. The anthracnose pathogen in Brasil will not survive on infected material in common storage for more than three (3) months.

Since volunteer sorghum plants continue to grow throughout the year, field collections of infected peduncles as needed has been the best source of anthracnose inoculum.

Standard nutrient media such as potato-dextrose agar, malt agar, bean agar and corn meal agar and V-8 agar produce an abundance of mycelial growth but few spores of the pathogen.

Inoculated, sterilized corn and sorghum stem produced limited quantities of conidia in 14-21 days under normal laboratory conditions. Oatmeal agar was the best medium for artificial production of conidia of *Colletotrichum* which was greatly increased by placing sterilized Whatman filter paper aseptically on the surface of oatmeal agar and seeding the filter paper with a spore suspension.

Using this method abundant supplies of conidia have been produced in 5 days under laboratory conditions.

2. Methods of inoculation

The development of a simple and rapid method of inoculation was desired for extensive field experiments planned for the coming growing season. Several methods of inoculation were investigated. Sorghum plants in the 5-7 leaf stage were more susceptible to infection than plants in later stages of development. Applications of sprays of calibrated spore suspensions were unsatisfactory due to low humidity field conditions. Only slight foliar infections were obtained when spore suspensions were applied with a pressure sprayer.

Dusting of dry, powdered inoculum obtained from ground up infected peduncles into the plant whorl gave excellent infection within 7-10 days after inoculation and satisfactory uniform distribution of leaf infection within 21 days under natural field conditions.

Hypodermic inoculation was time consuming and required the use of special needles with lateral orifices and failed to result in later uniform foliar infection.

3. Evaluation of susceptibility of sorghum varieties and hybrids to anthracnose

Field plantings of 100 sorghum entries have been established in several locations for anthracnose susceptibility ratings. A standard disease infection scale of 1-5 will be used for foliar and peduncle infections and disease ratings will be made at three intervals during the growing season Viz:pre-flowering, post-flowering and in the early grain development stage.

Varietal susceptibility under conditions of natural infection will be compared with the disease reaction of the same varieties

artificially inoculated with dry, powdered anthracnose inoculum.

4. Influence of time of planting on anthracnose epidemiology and stalk rot susceptibility

5. Susceptibility of sorghum varieties to sugarcane mosaic.

6. Influence of population density on the development of anthracnose and other diseases.

7. The influence of Colletotrichum stalk rot on yield and seed quality of grain sorghum using two varieties and artificial inoculation technics. Pioneer 846 (susceptible) and NK 233 (Resistant).

8. Epidemiology or sorghum anthracnose. A study of the rate of spread from inoculum focal points and the susceptibility to anthracnose of native wild grasses.

APPENDIX

O MILDIO DO SORGO NO BRASIL

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E difícil estabelecer quando o mildio do sorgo (Sclerospora sorghi (Kulk) Weston & Uppal.) apareceu pela primeira vez no Brasil. Oficialmente ele foi constatado pelo Dr. Richard A. Frederiksen (Texas A & M University, College Station, Texas, USA), em março de 1974 em parcelas experimentais próximas a Ribeirão Preto, São Paulo, quando de sua visita a este país. A doença ocorreu em plantios tardios de introducões da Argentina e em linhagens sucetíveis, provenientes do Texas, e tidas como livres do patógeno. A percentagem de plantas atacadas variou de 1,3 a 88,7%. Considerando-se que este campo experimental já vinha sendo plantado com sorgo há dois anos e que os sintomas apresentados pelas plantas indicavam a ocorrencia de infecção sistemica, é provável que esta doença tenha sido introduzida antes de 1974. Neste mesmo ano ela foi constatada ocorrendo de uma maneira severa, em parcelas experimentais na Estação Experimental de Uruguaiana, Rio Grande do Sul.

Após sua constatação em 1974, verificou-se que esta doença já havia ocorrido anteriormente no Brasil no Estado do Rio Grande do Sul. Talavez pela pouca expressão economica do sorgo na época e/ou pelo desconhecimento de sua importancia para as culturas do sorgo e do milho, ela não tenha sido registrada. O professor Porfirio Costa Neto (Faculdade de Agronomia da Universidade Federal do Rio Grande do Sul) afirma te-la observado em 1971 na Estação Experimental de Guaiba e em 1973, na Estação Experimental de São Borja, ambas no Rio Grande do Sul, em híbridos forrageiros oriundos do cruzamento de sorgo com Capin Sudam.

Para o Dr. Alexander Grobman (comunicação pessoal), ela já havia ocorrido neste Estado em 1967.

No Brasil o milho mantem uma posição de destaque, sendo considerado atualmente, o maior de todos os produtos agrícolas em valor de produção. A área ocupada com esta cultura em 1970 foi estimada em 9,8 milhões de hectares enquanto que a produção o foi em 14,8 milhões de toneladas. Deste total, as regiões Centro Oeste, Sudeste e Sul produziram 87%. Quanto ao sorgo, embora tenha sido introduzido no Brasil há mais de 20 anos, a sua importância é relativamente recente. A área ocupada com esta cultura em 1973/74 foi estimada em 200.000 hectares, não havendo estimativas oficiais para a produção. A região Sul é a maior produtora seguida das regiões Centro Oeste e Sudeste.

A importancia do mildio do sorgo para o Brasil se resume no fato de ser o sorgo e o milho hospedeiros de S. sorghi e de não conhecermos a reação dos materiais de milho a esta doença. Assim, se a doença se espalhar pelo Brasil, poderá causar prejuizos incalculáveis principalmente á cultura do milho. Atualmente o mildio do sorgo se encontra restrito ao Estado do Rio Grande do Sul, na região Sul. Quanto ao foco localizado próximo a Ribeirão Preto, na região Sudeste, esse já está sob controle.

Com a finalidade de evitar a disseminação da doença para outras áreas e visando proteger principalmente a cultura do milho, a Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) convocou uma reunião de técnicos interessados no problema, para determinar medidas visando evitar a disseminação do mildio do sorgo. Essas medidas foram enviadas ao Departamento de Defesa Vegetal do Ministério da Agricultura que baixou uma Portaria regularmentando a importação, comercialização e

plantio de sementes de capim Sudam e de seus híbridos. Essa Portaria também dá enfase á necessidade da realização de levantamentos anuais para avaliar a ocorrencia do mildio nas várias regiões do país; á erradicação dos focos da doença e interdição dos campos para plantio de variedades de milho e sorgo sucetíveis ao mildio; e da realização de testes de resistencia nos materiais brasileiros de milho e sorgo que deverão ser conduzidos na Argentina e no Texas, USA.

As normas baixadas pelo Departamento de Defesa Vegetal não espelhavam aquilo que foi decidido na reunião realizada pela EMBRAPA. Da maneira como foram redigidas interferiam, a curto prazo, na produção e importação de sementes pelas Companhias particulares, limitando o desenvolvimento da cultura no país. Por esse motivo os pesquisadores de sorgo da EMBRAPA, juntamente com representantes de firmas particulares, elaboraram uma série de modificações a serem feitas na referida Portaria, que atualmente estão sendo avaliadas pelo Departamento de Defesa Vegetal.

APPENDIX III

ITEMS OF INTEREST IN INTERNATIONAL COOPERATION IN SORGHUM PHYTOPATHOLOGY

1. Diseases of Sorghum. Colored illustrations Titles and descriptions to be added in English, Spanish or Portuguese.
2. Exchange of black and white photographs of sorghum diseases.
3. International kodachrome slide sets of sorghum diseases.
4. Illustrations of spore forms and fruiting bodies of sorghum pathogens to aid in disease diagnosis.
5. Manual of laboratory methods for sorghum pathologists.
6. Growth stage chart for sorghum similar to the internationally accepted growth stages for rice, tobacco, smallgrains and corn published in the FAO manual on the Evaluation and Prevention of losses by pests, diseases and Weeds. Rome 1970.
7. Uniform disease severity rating scales for foliage diseases, stalk rots, peduncle infections and virus diseases.
8. Designated International Centers for advanced study in plant pathology for degree candidates from Latin American countries with proposed curricula for the degrees of MS and Ph.D.
9. International agreement on import and export restrictions as applicable to exchange of experimental sorghum seed.
10. International sorghum newsletter.

MANAGEMENT OF INSECT PESTS IN GRAIN SORGHUM

George L. Teetes

Grain sorghum is presently one of the most important cash crops in Texas, approaching $1 billion annually. The introduction of hybrid sorghum along with advancements in production and harvesting techniques, the expanding feed lot industry, and improved export markets has caused the crop to reach a new economic status. Most of the advances which have been witnessed relative to grain sorghum are a result of research. The hybridization process itself is a classic example.

Increases in production of a crop, especially when the crop is grown in large monocultures, inevitably results in increases in pest problems. In this respect, those of us who work in the segment of crop production referred to as pest control are obligated to keep in step with changes in attitudes, technology, demands and knowledge. In some respects we can already see advances that have resulted because of the need for change. The realization that total dependence on pesticides to combat pest problems is not a sound approach may not be an earthshaking discovery, but it is a start.

I am convinced that the solution to pest control problems in grain sorghum lies in the establishment and implementation of sound pest management strategies. Simply, this means the use of all applicable methods in a compatible manner to achieve pest suppression below levels causing economic injury. Biological, ecological, cultural and chemical means of pest regulation can be used in a program designed to allow profitable crop production without creating great imbalances in the agroecosystem. History has shown that insect control programs based on the unilateral use of insecticides are destined for failure. Integrated control

strategies provide a much sounder and longer lasting approach to pest control, for if properly implemented they can reduce the chance of concomitant problems of secondary pest outbreaks, insecticide-resistant pest strains and environmental pollution.

Formulating integrated pest management strategies revolves around the "key" pest or pests. Key pests are the more economic damaging, perennially occurring, persistent species for which most insecticidal control is applied. In the case of grain sorghum, the greenbug Schizaphis graminum (Rondani) and the sorghum midge Contarinia sorghicola (Coquillet) are the key pests. In contrast to key pests, "secondary" pests, though possibly present most of the time, cause economic damage only at certain restricted times and generally are not the focal point of an insect control program. A significant fact is that outbreaks of secondary pests are often triggered by unilateral insecticide treatment for a key pest. In the case of grain sorghum, spider mites, especially the Banks grass mite, Oligonychus pratensis (Banks) may be considered a secondary pest; however, once this mite is released from natural control it may cause more damage to the crop than the key pest. Other insect pests in grain sorghum such as the corn earworm, Heliothis spp.; fall armyworm, Laphygma frugiperda (J. E. Smith); false chinch bug, Nysius spp; white grubs, Phyllophaga spp.; sorghum webworm, Celama sorghiella (Riley); and several species of root and stalk borers only occasionally require insecticidal control. These species are clumped into the category of "occasional" pests. But, it is important to realize that an outbreak of these pests can destroy a management strategy that does not take them into account. Research-wise they are extremely important.

For the purpose of illustrating how pest management strategies can

be developed and implemented, and the different suppression techniques (components) available, I would like to concentrate my discussion on the pest situation in grain sorghum on the Texas High Plains. The principles of integrated control are sound for any crop in any location, but of course, the pests involved may be different. The basis for the management strategy is developed around the greenbug and the sorghum midge which are the key pests in Texas.

As I discuss each pest, I will attempt to describe their interrelationships, severity, biology, nature of damage, habits, natural control agents, economic injury levels and artificial control measures. It must not be forgotten that in spite of their adverse publicity and sometimes adverse side-effects, insecticides remain our most powerful tool for artificially regulating pest populations.

The sorghum midge may be the most cosmopolitan pest of grain sorghum. Damage to Texas grain sorghum by this insect pest has been estimated at more than $10 million annually. In many sections of the state where the sorghum midge is especially abundant, as much as one-fifth of the crop may be destroyed each year. Until about 1961, extensive sorghum midge damage in Texas was confined primarily to the more humid eastern portions of the state. Since then, however, the pest has appeared in damaging numbers on grain sorghum in the semi-arid southern High Plains. Hybrid grain sorghum introduced in the late 1950's apparently created a situation very favorable for seasonal development. In 1963, the sorghum midge caused an estimated four to seven million dollars damage to grain sorghum in the High Plains area.

When the midge first appeared in the High Plains, grain sorghum hybrids were planted at all intervals of the spring and summer between

April 15 and July 1. Thus, blooming heads were available for oviposition sites over a long period of time. Damaging infestations generally developed after two or three consecutive midge generations in grain sorghum. Most grain sorghum blooming after the development of these damaging infestations usually suffered heavy yield losses.

The sorghum midge adult is a small gnat-like fly, usually orange in color, that lays its eggs on the developing seed of blooming grain sorghum. Larvae feed on the developing seed and cause "blasting" of the heads. The life cycle is short, only about 18 days being required for a generation in the High Plains. Each adult may lay 50 to 250 eggs during her 24 to 48 hour life.

Since the development of damaging infestations of midge was dependent on progressive buildup late in the year, entomologists developed a very effective cultural recommendation to escape damage. Early, uniform planting of grain sorghum so that blooming occurred throughout the area during a relatively short period was encouraged. This restricted oviposition to blooming heads and forestalled the development of damaging infestations until late in the year after a critical date.

Relatively small acreages of grain sorghum are now planted late but these may require insecticidal treatment to prevent loss. For these situations, judgement decisions for control are based on economic injury levels. Recommendations are to carefully inspect fields daily for adult midge, beginning when heads first start to bloom at the tip. Apply treatments when 25 to 30 percent of the heads have begun to bloom if the average number of midge adults per head exceed one. If adults are still active three to five days later, immediately apply a second treatment. Three applications at three-day intervals may be justified if the yield

potential is high and midge are abundant.

Another management tool was recently discovered in Texas that could have far reaching implications in the management of sorghum pests - the discovery of sorghum from the conversion program that are resistant to the sorghum midge. Not only providing an escape from midge damage, resistant sorghums provide flexibility in time of planting. Sorghums could be planted later in the season, thus, allowing for more efficient use of natural rainfall. Equally as significant is the fact that freedom to plant later in the season without fear of the midge would permit sorghum to bloom and mature during the cooler, wetter part of the season. This is not only advantageous yield-wise, but reduces irrigation requirements because of seasonal rainfall patterns.

Possibly even more significant is the fact that sorghum midge resistant sorghums provide another approach to dealing with a serious potential threat to sorghum production, the Banks grass mite. The ability to plant grain sorghum later in the season allows maturation of sorghum during the cooler, wetter part of the season which is characteristically not conducive to buildup of the mite. This pest increases in abundance more rapidly after the boot stage of sorghum and during periods of hot, dry climatic conditions.

The greenbug is also a key pest of sorghum. An explosive outbreak occurred in 1968 in almost all areas where sorghum is produced. This greenbug was identified as biotype "C" and differed in several aspects from the previous biotypes "A" and "B" which attacked small grains.

The greenbug damages grain sorghum by feeding on the plant leaves. It sucks sap from the leaves and injects a toxin. The combined effects from the sap loss and toxin injection cause severe leaf damage under

heavy population attack. Extremely heavy infestations will kill most of the plant leaves.

The reproductive population of greenbugs on sorghum consists only of es that give birth to living offspring. A population may consist of both winged and wingless members. More winged forms are observed during mid-summer when the population is expanding rapidly on grain sorghum.

A buildup of a damaging population on grain sorghum often follows this course:

1) Winged greenbugs fly from early spring hosts to small grain sorghum. The pattern of seasonal host infestation is grain sorghum to johnsongrass to wheat - from wheat to johnsongrass to grain sorghum.
2) Reproduction begins immediately with the population sometimes increasing at a rate of 20 fold per week with a seasonal weekly fold increase of ca. 6.
3) In not controlled, the population will continue to increase until mid-July to early August; then, it usually declines rapidly.

Beneficial parasites and predators become abundant at that time and are very effective in destroying the greenbug population. Abundance of natural enemies has shown the characteristic lag time of about one-two weeks and natural aphid predators have not always held greenbug populations in check, but they do influence greenbug abundance. The major seasonal mortality factor in the greenbug population is parasitism. Certain abiotic components of the environment, especially rain and wind, can drastically reduce greenbug density early in the growing season. Thus, it is quite apparent that the greenbug is under the influence of natural control agents for a majority of the growing season. And, there is only about a two-week period in which greenbug numbers may exceed the economic injury level.

No integrated control strategy can function without an assessment of population densities of the key pest required to cause economic yield

loss. Damage tolerance levels, primarily the economic injury level, must be determined so an economic threshold (the density at which artificial control measures should be implemented to prevent an increasing pest population from reaching the economic injury level) can be established. Data accumulated since 1971 have shown in general that greenbug numbers in excess of 1300-1500 per plant and leaf kill in excess of three per plant at about the bloom stage is required to cause economic yield loss in grain sorghum.

Once an economic threshold was developed, a means of suppressing greenbug populations to prevent them from reaching the economic injury level was needed. Chemicals were necessary. But, nonselective insecticides could eliminate the biotic factors holding other pests in check. Selectivity was achieved by rate manipulation. It was found that extremely low dosage rates ($\leq$ .1 lb AI/acre) of several approved chemicals provided greenbug suppression, yet spared most of the naturally occurring beneficial species. Treatments with selective insecticide rates have the effect of throwing the balance back in favor of the natural control by preserving natural enemies. Such selective treatments are applied when the aphid population reaches the economic threshold. When properly timed, only one insecticide application is required and resurgence of the greenbug is prevented by the natural control afforded by parasites and predators.

Recent developments of insecticide resistance by the greenbug could greatly hamper the use of selective insecticide rates. In dosage-mortality tests a level of resistance of greenbug populations from some areas of Texas were 35-fold that of greenbug populations in areas where insecticidal treatments had been limited in the past.

Another component of the integrated control program soon will be the use of insect-resistant sorghum hybrids. Sources of greenbug resistant germ plasm were found soon after 1968 and releases of resistant breeding materials have been made to commercial seed companies by TAES sorghum breeders. Hybrid sorghums resistant to the greenbug should be on the market by 1976. Since the principle mechanism of resistance to the greenbug in these grain sorghums is tolerance, the economic injury level is raised with little or no disruption of the agroecosystem. This is because the greenbug can attain numbers sufficiently high on these varieties to maintain beneficial insect populations and the end result will be that the pest and its natural enemies will come into balance with pest numbers being kept below crop damaging levels. Insecticidal control for greenbug then will not be required.

I need to inject another thought at this point and it relates to the interrelationships among crops in an ecosystem. I have discussed briefly how some pests interrelate and we should also realize that there is an association among crops. In the High Plains of Texas, grain sorghum and cotton are the two major crops. Presently, insect pest problems in cotton on the High Plains are in direct contrast to that of the other major cotton producing regions of the country. There are no serious problems with key pests such as boll weevils and annual, widespread and damaging insect infestations in cotton have not occurred. As a result, insecticides have not been widely applied to cotton as other pests, such as bollworms, spider mites and aphids are kept in check by their natural enemies. In the High Plains area, grain sorghum is believed to serve as the major source of natural enemies which later are active in cotton. Therefore, indescriminate use of insecticides in grain sorghum may well

result in the necessity for increased insecticide usage in cotton due to the destruction of arthropod predators and parasites in grain sorghum before they disperse to cotton. Also, the drift of insecticide from sorghum to cotton can kill these beneficial insects, thus, allowing the bollworm to escape nautral control and increase to damaging numbers.

Even though the greenbug is currently responsible for most of the insecticidal control being executed in sorghum in Texas (up to $14 million annually), the Banks grass mite, has also spurred considerable usage of insecticide.

This spider mite is first found feeding on the underside of the lower functional leaves along the midrib. The infested areas of the leaves are pale yellow initially and later take on a reddish color on the top side of the leaves. As mite numbers increase on the lower leaves, the infestation spreads upward through the plant. The underside of heavily infested leaves will have a dense deposit of fine webbing spun by the mites. In the final stages of infestation the mites completely web up the sorghum heads.

Research-wise, our knowledge of the spider mite complex in sorghum is limited. There are at least four species of the spider mites infesting grain sorghum in Texas. The Banks grass mite is the most frequent species encountered.

Spider mite outbreaks are closely correlated with reproductive maturity of the plant. Rapid population increases generally begin after heading.

Infestations of mites appear to be separated temporarily and spatially from populations of effective natural enemies. Also, there is a close correlation between mite density and hot, dry climatic conditions.

In some areas the mite is extremely difficult to control with insecticides, especially in the Trans-Pecos Area of Texas. There is also evidence of resistance in other localized areas of Texas.

Some evidence exists to support the theory that some insecticidal treatments, especially parathion, applied for aphid control enhances the severity of the mite. A classic example of a secondary pest.

In general, the Banks grass mite is a serious potential threat and the species is a secondary pest being influenced by weather, plant maturity and previous insecticide treatment. Our greatest opportunity for dealing with this pest lies in the area of host-plant-resistance. Screening trials for a period of three years of sorghums from the conversion program, especially some "non-senessing" types look particularly promising.

Other insect pests attack grain sorghum which I previously categorized as occasional pests. If these are not considered in a total management scheme their outbreak can cause difficulty and weaken the control system because of the uncertainty involved. I will discuss only some of the more important occasional pests that occur in grain sorghum in Texas.

The sorghum webworm occurs primarily in the more humid eastern half of Texas. It frequently occurs in large numbers on grain sorghum heads where it gnaws circular holes in the grains and feeds upon the starchy contents. The mature larva, about one-half an inch long, is coverered densely with closely spaced spines and fine hairs. Its reddish-tan, dark brown body is marked with throe darker lines down the back.

For making judgment decisions for chemical control, heads should be inspected beginning in the bloom stage and continuing until hard dough. Control is suggested when 10 to 25 percent of the heads are infested with five or more small larvae per head. Planting sorghum early often

provides a means of escaping this pest.

White grubs are the larval stage of May or June beetles. Damage to grain sorghum may occur in several different ways. The most obvious damage and perhaps the most significant is death of seedling plants from larvae feeding on the roots. Seed germination occurs and a satisfactory stand is established. Within a short period, however, when plants are four to six inches tall, death of these seedlings begins to occur. In severely infested areas, stand loss can occur within one week to ten days One grub is able to destroy all plants within one-two feet of row. Plant which are not killed as seedlings are stunted severely and in many cases never produce seed. A third type of damage results from root pruning by larvae which had overwintered plus those produced during the growing season. Plants which are able to produce seedheads in many cases do not have sufficient roots to prevent lodging. In some cases, lodging is enhanced by secondary stalk rot organisms.

Seasonal field biology data would indicate the possibility of delayed planting as a means to escape seedling damage. However, the crop remains susceptible to attack later in the season. These data have also revealed the fact that some individuals have a life cycle longer than one year. Light trap data have shown only one major peak in adult abundance and activity.

Damage assessment studies have shown that the economic injury level is two grubs per square foot and the economic threshold has been set at one grub per square foot. Because of the nature of the grub infestations, A preplant broadcast incorporated application of insecticide is required for control when the economic threshold is exceeded.

Infestations of a lygaeid bug in grain sorghum are sporatic, but, they cause considerable concern to producers because of extremely high population levels. Populations of this false chinch bug are concentrated in small areas, and general infestations over an entire grains osrghum field are rare. Reproduction has not been observed on this host.

Damage results from bugs sucking juices from the immature developing seed. Commonly, the damaged seed are infected with a fungus (Alternera sp.) which causes the seed to be black in color and resulting in further deterioration of quality. Damaged seed rarely develop fully and are considerably smaller, softer and lighter in weight than the undamaged seed and are subject to loss in harvesting. This false chinch bug also feeds in clusters on the leaves of sorghum; however, little leaf damage results

Damage assessment studies by confining different populations in cages on sorghum heads have shown in general that for each additional ten false chinch bugs per head, there was a one percent increase in damaged seed. Actual yield loss, however, was evident only when 200 bugs per head damaged 23 percent of the seed. Increase in weight of undamaged seed apparently compensated for yield loss to a point because in most of the treatments percentage of damaged seed was less than the percentage in seed weight. Only when percentage of damaged seed was greater than percentage increase in seed weight was there evidence of reduced yields. The point of equal compensatory effect occurred at 14 percent damaged seed or approximately 140 bugs per head. Spot treatment with insecticides may be required to prevent yield loss.

Stalk borers, namely the southwestern corn borer, sugarcane borer and sugarcane rootstock weevil may cause damage from extensive tunneling and girdling of the stalk which often results in stalk lodging. Only

light infestations have in general been reported in grain sorghum. Although efforts at chemical control of stalk borers in grain sorghum have generally given sporatic results, insecticides may be justified in ratoon sorghum.

Various cultural control practices appear to afford the most effective means of controlling these pests. Area-wide stalk destruction through practices such as double discing and deep breaking, destroy the plant crown which affords overwintering larval destruction. Research and observational data indicate that early plantings may escape infestation and are less susceptible to plant lodging. A reasonable plant population to insure large healthy stalks along with proper fertilization and adequate irrigation help revent lodging of borer-infested stalks. Crop rotation, use of early maturing varieties, and early harvest with equipment designed to pick up lodged stalks aid in reducing yield losses.

Research results are of little value until they are implemented by producers. Entomologists of the Texas Agricultural Experiment Station and Extension Service have worked together to bring about the acceptance of integrated pest management by producers. Extension entomologists believe that the most rapid way to achieve adoption of integrated control strategies by producers is through large scale demonstrations. By this mechanism, many more producers are directly involved than possible through conventional extension techniques. These demonstrations, along with effective educational and communication programs have the potential of hastening the acceptance of scientifically sound pest control practices by producers.

In 1973, 68 producers farming 18, 346 acres of grain sorghum participated as members of a Pest Management Association. These members con-

tributed 50¢ per acre to help defray the cost of the program. Each producer farmed an average of 279 acres of sorghum while the sorghum acreage per farmer ranged from 850 acres to 28 acres. This total acreage included 290 fields with an average field size of 60 acres. The program covered a rectangular area of 35 square miles.

The working framework of the pest management program consisted of a field monitoring service to check participating producers' fields on a weekly basis. The field monitoring service consisted of 10 field scouts and one county entomologist as supervisor. The scouts monitored pest and beneficial populations and furnished each producer with a weekly report on the insect situation in each of their fields. The county entomologist was responsible for coordination of activities with the Pest Management Association, supervision of the field monitoring service, and consultation with producers on insect problems. The field monitoring service was operated for 14 weeks from June 4 through September 21.

The results of the first year of the program were dramatic. Producers reported that 100 percent of their acreage received one application of insecticide for greenbug control in 1972, with an additional 20 percent of the acreage receiving a second treatment. Conversely, in 1973, these producers reported that 92 percent of their acreage received only one treatment. None of the acreage received a second treatment. In addition to the number of applications required to give economic control, the pounds of insecticide applied per acre were reduced. Extension service recommendations encouraged producers to use minimum effective rates of insecticides. Research had shown these reduced rates to be as effective as the higher rates that were commonly being used by farmers. The low dosage spared beneficial insects allowing them to gain control of the

greenbug, thus eliminating the need for a second treatment. Treatments were recommended only when greenbugs reached the economic threshold.

Approximately 60 percent of the producers followed the recommendation for the minimum effective dosage of insecticide. This led to a substantial reduction in pounds of insecticide applied per acre. The producers responding to a survey reported that they applied 1.04 pounds of active ingredient per acre for greenbug control in 1972, while applying only 0.28 pounds of active ingredient per acre for the greenbug control in 1973 as a part of the program. This is a 73 percent reduction in the pounds of insecticide applied per acre from 1972 to 1973, and a substantial reduction in the amount of insecticide released into the agroecosystem of the High Plains.

With a reduction in the number of applications and pounds of insecticide required for the economic control, the cost per acre for greenbug control was greatly decreased. In 1972, the participating producers paid $4.35 per acre for greenbug control but only $2.66 in 1973. This is a net savings of $1.69 per acre or 39 percent reduction over what they paid in 1972. If this savings was experienced over the entire High Plains, it could mean a savings of $4.4 million. Ninety-six percent of the participating producers reported that these savings have been accomplished while maintaining yields. The monetary savings realized by the producers was important, but of equal importance was the substantial reduction in the amounts of insecticide released into the High Plains environment, the minimal disruption of the agroecosystem, conservation of the natural balance between insect pest and its natural enemies, the delay of the development of insecticide-resistant pest strains and minimization of problems caused by the drift of insecticides from sorghum onto other

crops and pastureland.

The key to the success of the use of integrated control systems depends on close supervision by qualified personnel trained in the integrated control concept. But, the principles of pest management have been demonstrated to be applicable to grain sorghum and can insure a system that yields increasing profits with minimum disruption to the agroecosystem.

I would like to reiterate the fact that my intentions to this point have not been solely to describe the sorghum pest situation in Texas. My intentions have been to illustrate that pest and crops interrelate and make up a complex ecosystem. Although it may be necessary to research a pest or a crop independently at times, it is mandatory that problems be considered as a whole not as a part. The pest situation in sorghum in Texas is probably different than in your area or country. But, the components needed to establish and implement management strategies are the same. There must be an integration of biological, ecological, cultural and chemical data into a wise and sound scheme for insect management. Remember, the ecosystems with which we work are not naturally balanced. We must insure that the control techniques we implement do not infact cause an even greater imbalance.

I hope that we will have the opportunity to discuss the pest situation in sorghum in your country. We need to exchange information on problems and opportunities for solution at this time when food supplies are the topic of discussion at coffee breaks.

Inoculation Techniques for Testing Resistance to Sorghum Downy Mildew

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Sorghum downy mildew caused by Sclerospora sorghi Weston and Uppal is a disease of international importance and concern in areas where sorghum and corn are major food crops. The most practical means of combating this disease is the development of resistant cultivars of sorghum and corn. Such development requires some method of identifying the resistant genotypes in the host population.

In the United States the common method for identification of downy mildew resistance has been to plant field nurseries in areas of high natural incidence of sorghum downy mildew. This method has been successful in the detection of resistance in several sorghum cultivars but has certain serious faults. As one fault, field plantings are more expensive than greenhouse production of seedlings. The time of testing is restricted to the growing season. Even in south Texas where downy mildew is endemic, the disease incidence is extremely erratic, varying widely from year to year and between different sections of the testing site. Moreover, rapid progress in improvement of resistance in segregating populations is hampered by the failure to detect susceptible genotypes when the disease incidence is low.

Dependence on field nurseries could be reduced or eliminated by a satisfactory method of artificial inoculation that would permit greenhouse tests for reactions to S. sorghi. The inoculation method should be simple, highly effective in the detection of susceptibility.

and suitable for rapid screening of large numbers of plants. It should give highly positive correlations with the reactions expressed under field conditions conducive to a high incidence of downy mildew.

That S. sorghi produces two types of spores, conidia and oospores, provides alternative approaches to artificial inoculation. The oospores are the resting spore stage of the pathogen. These spores are resistant to adverse conditions, retain viability for long periods of time, and are the usual cause of primary infection where growing seasons are separated by seasons of dormanc

The first successful artificial inoculation of sorghum with oospores of S. sorghi was reported in 1932 (10). Weston and Uppal produced infection by infesting soil and seeds of sorghum and corn with oospores in powdered leaf material. More recently, Cosper (2) and Kenneth (4) reported infection of sorghum planted in soil artificially infested with inoculum produced by grinding leaves containing oospores of S. sorghi. Cosper noted that grain sorghum was infected at soil temperatures from 18 to 29°C. In a similar study with forage sorghum, Kenneth found that the temperature of oospore-infested soil must be above 20°C to produce infection and that the optimum temperature range was 24 to 29°C. Kenneth secured infection with inoculum produced by macerating living leaves containing newly formed oospores and showed that no dormant period was needed by oospores before germination. Although Cosper and Kenneth secured high levels of infection with oospore inoculum, both noted a lack of uniformity in the reactions of susceptible sorghum cultivars in repeated trials of oospore inoculation

Frederiksen and Tuleen (personal communication) observed a similar variability in their oospore inoculation studies

One possible explanation for these inconsistent results is differences between oospore populations in germination during inoculation. Safeeulla (8) observed that germination of oospores of S. sorghi was improved by weathering, germination occurred when oospores were in contact with seed of susceptible sorghum and corn varieties, and optimum temperature for germination was 21 to 23°C.

Germination of 30% has been observed in some of the oospore populations studied at Texas A&M University (Vuhanavitch, Craig and Frederiksen, unpublished). These researchers produced oospore populations by growing infected sorghum plants in the greenhouse and collecting leaves when the chlorotic interveinal stripes, indicative of oospore formation, turned brown. These leaves were macerated with water in a Waring Blendor [1] and the resulting suspension filtered through cheesecloth. The filtrate was incubated at 23°C. Oospore germination by germ tubes was observed when cultures were examined after 24 hours.

Remnant leaf sections from samples that produced germinating oospores were mixed with soil in a Waring Blendor at the rate of 1 gm

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1 Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

leaves (fresh weight) to 50 cc dry soil. The infested soil was placed in pots, watered, and placed in a 26°C chamber for 48 hours. The pots were planted with TX412, a downy mildew-susceptible sorghum, and kept in the 26°C environment for 24 hours. The pots were placed in the greenhouse with temperatures from 17 to more than 39°C. Twentynine days after planting, 85% of the sorghum plants showed symptoms of downy mildew.

Collections of leaves from a second group of diseased plants grown in the greenhouse produced oospore populations with only a trace of germination. One cause of poor germination in oospores may have been parasitism by other fungi. Kenneth and Shahor (6) noted that a species of Phlyctochytrium attacked oospores of S. sorghi and probably reduced the infective potential of oospore inoculum. I have not seen Phlyctochytrium on oospores, but have observed an unidentified biflagellate phycomycete present as a parasite in oospore populations collected in Texas and Kentucky. When infected oospores are freed from leaf tissue by maceration and incubated in water, the exospore disintegrates, and oval zoospores ca two μ in diameter are released. The zoospores penetrate the walls of germ tubes of germinating spores. After penetration the zoospores increase in size to a maximum diameter of 8μ and form sporangia which produce more zoospores. This hyperparasite has been observed also in germinating conidia of S. sorghi, and attacks conidial germ tubes in the same manner as described for oospore germ tubes.

Consistent results from artificial inoculation with oospores

appear to depend on securing populations of oospores that exhibit a reasonable level of germination. Due to factors, known and unknown, we are unable to do this.

Conidia are the fragile, asexual spores produced by S. sorghi and require cool, moist conditions for production and plant infection. These spores are the means of rapid secondary spread of downy mildew from infected plants and provide another avenue to artificial inoculation.

The first successful method of conidial inoculation was reported in 1955 (7). In this procedure conidia from infected leaves were brushed on the leaves of sorghum and corn.

Jones (3) devised a method of conidial inoculation in which leaf sections were taken from plants infected with sorghum downy mildew and placed on the leaves of sorghum seedlings. He covered the seedlings with polythene sheeting to create a high relative humidity. When cool night temperatures occurred, the excised leaf sections produced conidia that were deposited on the leaves of the seedlings. He reported that levels of infection were high, and sorghum plants 1 to 5 days old were more susceptible to infection than older plants.

Kenneth and Shahor (5) recently reported an inoculation method with leaf sections from infected plants. The seedlings destined for inoculation were enclosed in containers, and the infected leaf sections were attached to the inside of the containers and above the seedlings. The containers were placed in chambers at 17 to 18°C. Conidia were produced on the infected leaf sections and deposited on the seedlings

under these leaf sections. This method produced 95 to 100% infection on 1-to3-day-old seedlings of a susceptible sorghum cultivar. The percentage of infection declined as the plants grew older. Kenneth and Shahor used this method to determine the effect of inoculation site on the percentage of infection resulting from inoculation. Their study showed that in sorghum plants at the three-leaf stage of growth, conidial inoculation of the coleoptile area gave higher levels of infection than inoculation of leaves above the Coleoptile.

Inoculation of corn with S. sorghi has been successfully used for identification of downy mildew resistant corn selections in Thailand (1). Schmitt and Freytag (9) recently reported a technique for artificial inoculation of sorghum and corn by spraying with a water suspension of conidia. By the proper timing of artificial light and controlled temperature and humidity conidia could be secured at any time, day or night. As the pathologists, in Thailand had noted earlier, Schmitt and Freytag found that conidial concentration in the inoculum is critical in determining the reaction of inoculated plants. They reported that a concentration of 100,000 conidia/ml gave high levels of infection of susceptible genotypes.

A conidial inoculation method with elements of the systems described by Jones (3) and Kenneth and Shahor (5) and certain original features was recently devised for use in greenhouse screening for downy mildew resistance at Texas A&M University. In this method, sorghum plants intended for inoculation were planted in 6.25 cm peat pots, 10 seed per pot. These pots were placed in a polystyrene tray

with dimensions of 37 X 32 X 8.7 cm. The plants were grown to the one- to two-leaf stage desired for inoculation. The potted plants were left in the tray, which served as the bottom half of the inoculation chamber. A second tray identical to the first, except for a rectangular hole 13.5 X 16 cm cut in the bottom, was turned upside down and placed over the tray which contained the peat pots, to form the inoculation chamber. A galvanized wire-mesh rectangular screen 18 X 19 cm with two holes 1 cm diameter and located midwidth the screen and 6 cm from each end. The screen was placed over the aperture in the tray with the 1 cm holes about equidistant from the sides and ends of the hole in the tray. The screen was covered with a piece of cheesecloth in which two holes were cut to match those in the screen. Leaves showing the chlorotic symptoms of the early stages of downy mildew infection were collected from sorghum plants and cut into sections about 2 cm long. These sections were placed, abaxial side down, on the cheesecloth. Twenty leaf sections were needed to give the desired coverage of the area above the hole in the tray. A pad of seed germination paper was soaked with distilled water, pressed to remove excess water, and placed over the leaf sections on the cheesecloth. Two holes were made in the paper pad in line with those in the cheesecloth and screen. A piece of plywood 0.6 cm thick with holes matching those in the preceding layers of material was placed on the paper pad.

The inoculation chamber was placed in an environment chamber with a temperature of 20°C and relative humidity near 100%. Two pieces of 0.6 cm rubber tubing were made airtight at one end by the insertion of

metal plugs. A ring of closely spaced holes was burned in each tube, slightly above the plugged sections, with a hot dissecting needle. The closed ends of the tubes were inserted through the holes in the layers of materials on the inoculation chamber until the rings of holes in the tubes were about 5 cm below the wire mesh. The tubes were secured at this level by stops resting on the plywood section. The free ends of the tubes were attached to a section of copper tubing, 0.6 cm in diameter and 10 m long, immersed in water kept at a temperature of 19°C.

The other end of the copper tubing was connected to the outlet of an air-pressure pump. The inlet of this pump was attached to a humid air chamber with a relative humidity of 100%. The pump was operated at a pressure of 0.23 kg/cm^2 for 5 hours starting 6 hours after the inoculation chamber was placed in the environment chamber. Conidial formation on the excised leaves started 6 to 8 hours after the inoculation chamber was placed in an environment of 20°C and high humidity and continued for 2 to 4 hours. The conidia formed on these leaves fell downward through the cheesecloth and the wire screen. The timing of the operation of the air pump ensured that these falling conidia were dispersed more or less uniformly over the seedlings in the bottom half of the inoculation chamber.

The plants were removed from the inoculation chamber after 24 hours and planted without removal of the peat pots in 10 cm clay pots in the greenhouse. The inoculated plants were grown in the greenhouse for 21 days and observed for reactions to inoculations. Inoculations of two susceptible sorghum cultivars, TX 412 and TX 414, produced

infection of 91 and 92%, respectively. In another test to determine the efficiency of the inoculation method in identification of downy mildew resistance, five commercial sorghum hybrids were inoculated that had been observed for incidence of downy mildew infection in field nurseries (Frederiksen, unpublished data).

Table 1. Downy mildew infection of 5 commercial sorghum hybrids in the field and the greenhouse.

Commercial hybrid	% Infection	
	Field	Greenhouse
1	2	3
2	25	47
3	17	18
4	2	13
5	30	81

As shown in Table 1, correlations between reactions of the resistant hybrids to conidial inoculation in the greenhouse and their field reactions were good, but the less resistant hybrids exhibited much higher levels of infection in response to artificial inoculation than those observed in the field.

Some cultivars of sorghum and corn that appear to have some resistance to downy mildew in the field are highly susceptible to artificial inoculation with conidia (5;Frederiksen, unpublished data). This might indicate that certain types of resistance to downy mildew were curcumvented by the artificial inoculation technique. Also the

factors conditioning resistance or escape from infection by oospores in the field might differ from those controlling reaction to conidial inoculation.

I have no information that genotypes resistant to conidial inoculation may be susceptible to oospore infection. In addition, conidial infection in the field is always a potential threat and in seasons with compatible weather conditions, conidial infection has caused epiphytotics. Therefore, conidial inoculation methods should be used more in screening for resistance to sorghum downy mildew.

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SORGHUM DOWNY MILDEW AND MIDGE IN ARGENTINA

R. A. Parodi, M. J. Frezzi & J. L. Scantamburlo [1]

The growing of sorghum is very important in Argentina. Since 1957, the acreage devoted to the cultivation of sorghum continuously increased. At that time 1,691,400 hectares were planted to sorghum for different purposes: 1,234,000 with forage sorghums (443,000 or sudangrass; 437,000 of Sorghum almum "Columbusgrass"; and 354,000 of Sweet sorghum); 418,000 of grain sorghum; and 39,400 of broomcorn. The largest acreage was that in 1970/71 which consisted of 4,952,570 hectares, of which 3,121,600 were grain sorghum; 1,047,200 of sweet sorghum; 638,000 of sudangrass, 113,500 of Columbusgrass and 32,370 of broomcorn.

In 1971/72 the sorghum acreage reached 4,666,800 hectares, of which 2,759,000 were in grain sorghum, 1,875,000 in forage sorghums (1,185,800 of sweet sorghum, 601,000 of sudangrass and 89,000 of columbusgrass) and 32,800 of broomcorn. The 1972/73 season may have been a little higher (1 or 2% higher) because the grain sorghum which is the main sorghum, reached an acreage of 2,890,000 hectares or 1.3% higher than the year before.

Sorghum ranks third among all crops and grain sorghum (2,890,000 ha. and 4,900,000 t) ranks in the same place, after corn (4,300,000 ha. and 9,800,000 t) and wheat (5,600,000 ha. and 8,100,000 t), among grain crops in acreage and production.

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Seed production and commerce, particularly hybrid seed, increased parallel to the increase in importance of the sorghum crop. Because domestic seed production was insufficient to satisfy local demand, at the beginning it was necessary to import seed every year. We admit that this was a good contribution, but we also think that it had some inconveniences, because some imported seed didn't have the required quality or because the sanitary control measures were not adequate. That way certain pests or diseases, were introduced along with imported seed. Examples of this are Contarinia sorghicola Coq., "sorghum midge" and Sclerospora sorghi Weston & Uppal, "downy mildew", and others.

We believe that the "sorghum midge" was introduced with seeds of the first grain sorghum hybrids or their parents, imported as experimental material or on a large scale.

The first report of sorghum midge in Argentina was made in 1958 on the sorghum crops of Oliveros, Pergamino and Manfredi, located at the provinces of Santa Fe, Buenos Aires and Cordoba, respectively, and other regions of the country. The sorghum midge then spread all over the sorghum region, and is now distributed over the humid and warm regions of the provinces of Formosa, Chaco, Santa Fe, Corrientes, Entre Rios, Cordoba and Buenos Aires.

On the other hand, downy mildew is probably the most recent sorghum disease in the country. The first report of its presence in the country was that of Fresa in March 196. (1) after studying grain and forage sorghum trials and samples received from different localities in the country such as Salto, Sastre and Las Brenas, located in the provinces of Buenos Aires, Santa Fe and Chaco, respectively.

The Plant Pathology Laboratory of the Manfredi Agricultural Experiment Station produced several reports during the seasons of 1968/69 and 1969/70. Most recently Frezzi (2) reported about its distribution and the economic importance of the downy mildew in Argentina.

Downy mildew was not reported in Argentina until the 1968/69 season when it appeared in different sorghum regions of the country. In some cases it damages up to 90% of the crop, according to Nider et al. 1969 (3).

Downy mildew is spread over most of the Argentine sorghum growing regions, but the greatest damage (up to 20%) is observed in the provinces of Formosa, Chaco, Entre Rios and Santa Fe, in the north where more favorable weather conditions (humidity and temperature) prevail. Downy mildew also causes about 15% losses in Eastern Tucuman, Central, Eastern and Northern Cordoba and Northern of Buenos Aires provinces.

We should mention that the damage observed was in crops of highly susceptible cultivars planted late in the season (which is not the best planting date), between the later half of December or the beginning of January.

As was the case with the 1969/70 season, downy mildew infections increased over different types, hybrids, varieties and strains of sorghum. The Manfredi Agricultural Experiment Station decided to work in the etiology, biology, taxonomy, pathogenicity and mechanism of infection of the causal agent of the disease. In addition, efforts were made to establish direct control measures and to search for resistant materials.

The following cultural practices and control measures were employed to reduce downy mildew damage:

1. Planting date. The disease appearance is directly correlated with favorable weather conditions, humidity and temperature, and the time of planting. We have seen few and some times no infected plants in crops planted early (November 1 to 20, in the Central part of the Cordoba province), which is the best planting season in our region.

The degree of infection on susceptible cultivars increases when the planting date is delayed.

2. Destruction of infected plant debries to eliminate the inoculum.

3. Eliminate the infected plants as soon as they present the first symptoms of the systemic infection.

4. Outline a rotation scheme in highly infected fields where by sorghum or corn are not planted for several years, because oospores are viable for long periods of time.

5. To prevent infection foci for future plantings avoid planting excessively low soils, where plant remains are accumulated.

6. Direct control measures: Seed Treatment. None of the publications reviewed on the direct or chemical control of downy mildew by means of seed treatment with current fungicides, reported positive results, except Weston (4), but his method is not considered practical by farmers. The method can be employed in small plots or experimental tests. However, we plan to evaluate seed desinfection by using fungicides with systemic action.

7. Indirect control measures: Search for resistant material. By using the abundant breeding material available in the sorghum nursery of the Manfredi Agricultural Experiment Station, we started testing at the Saenz Pena Agricultural Experiment Station (Chaco) since 1970/71. This

location was chosen because of the favorable weather conditions that allow a high degree of natural infection with the two forms (asexual or localized and sexual or systemic) of Sclerospora sorghi. Sorghum is planted early for high levels of infection.

The first year, we tested 707 strains and hybrids of grain and forage sorghums; a great number (352) of which were highly resistant. After three years of testing we can choose 4 hybrids and the corresponding parents with very high resistance to downy mildew and acceptable agronomic characteristics. There are also many other strains and hybrids with high resistance. All this material will be tested again by artificial inoculation.

At the same time, all the hybrids and varieties of grain and forage sorghums which are sold and sown in the country are tested under natural and artificial conditions; 75% of the 106 cultivars tested were resistant.

We are also cooperating with the International Downy Mildew Nursery, sponsored by the Rockefeller Foundation.

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RESOLUTIONS

1. Be it resolved that the International Sorghum Workshop express its appreciation to the host institution, the University of Puerto Rico and its authorities and personnel, the Mayaguez Institute of Tropical Agriculture and its official representatives, as well as the many individuals including bus drivers, and to the supporting agencies, Purdue University, University of Nebraska, Texas A & M University, and U. S. Agency for International Development for sponsoring this very successful event. Special thanks should go to the local ladies for hosting the visiting wives and making their stay so pleasant. Be it further resolved that the conference thank the proper persons for chicken barbecue, cheese, crackers, doughnuts, coffee, etc.
2. Be it resolved that the International Sorghum Workshop express its appreciation to the staff involved in language interpretation and the public address system for their efficient service of making the translations of the presentations for the full benefit of all participants.
3. Be it resolved that the Latin American countries be encouraged to develop their present informal organizing committee for Sorghum workers into formal organization of sorghum research workers, similar to SICNA in the USA, which could be designated as Sorghum Improvement Conference for Latin America. Its is also resolved that once the latter is formed, the chairmen and vice chairmen of these respective groups lead in the development of plans for future meetings, as well as the implementation of all resolutions herein, pertinent to their scope of action and capabilities. The Resolutions Committee

recommends that the joint next meeting of U.S. and Latin America members be tentatively scheduled for February or March 1977 in Argentina.

4. Its is proposed that public institutions of all countries, exchange, in full reciprocity among them, all sorts of sorghum bulk populations, lines, hybrids or varieties developed with their own national public funds, and make those same materials available to any and all bona-fide sorghum breeders, and/or seed producers, who should request them as a means of facilitating the use of improved sorghum germplasm in increasing sorghum productivity and production all over the world.

5. An important aspect of world wide cooperation in the improvement of seed is the movement of germplasm. It is recommended that serious consideration be given to expidite the movement of seed between the Eastern and Western Hemispheres.

6. Technology for increased sorghum production in the less-developed areas of the world is now available and could conceivably increase the capability of those countries for attaining self sufficiency in feed and human grain demand.

   An appeal is made to governments all around the world to create the conditions that would allow the transfer, development, and use of such technology and its applications with the aim of increasing total sorghum production within their territories by way of the political, economics, and social decisions, which within their own sovereign understanding would still allow the ultimate fullfilment of the increased sorghum grain and forage production.

7. That this workshop notes the existence of the new International

Association for Cereal Chemistry Study Group for the study of the non-industrial processing of sorghum and millets and encourages all present with an interest in post-harvest aspects of these grains to become members.

8. Be it resolved to establish working committees to consider preparation of the following tools in plant pathology for international sorghum workers.

   a) A pool of black and white photographs of sorghum diseases for publication use.

   b) An international series of Kodachrome slides of sorghum diseases.

   c) A colored sheet of sorghum disease illustrations with symptom descriptions in English, French, Spanish and Portugues.

   Prepare a uniform system of recording disease severity indices for:

   a) Foliage disease of sorghum

   b) Stalk rots of sorghum

   c) Various disease of sorghum

   Develop an international system of growth stages of sorghum similar to internationally accepted growth stages for smallgrains, cotton, tobacco, rice.

   A Laboratory manual of isolation, inoculation, artificial cultive technics and diagnosis of sorghum diseases.

   Prepare a listing of Universities and Institutions prepared to offer a graduate curriculum towards the degrees of MS and PhD for graduate students with financial sponsonship from their own governments institutions.

9. It is proposed that a pilot project for sorghum be initiated, which can later be integrated (if desirable) with an international information retrieval system sponsored by ICRISAT.

   Participants in the pilot project should be a small group of sorghum specialists representative of various programs, willing to share their data with the team of information specialists in the Taximetrics Laboratory, University of Colorado.

   The results of the pilot program should be widely distributed via news letter to workers in sorghum wherever the workers are located. The sorghum specialists involved in the project will criticize, and make recommendations for improvement in the system to members of the Taximetrics Laboratory.

   Further, funding agencies both national and international, private or public, are invited to observe the pilot project for sorghum.

10. There should be formed an international net work established and funded to make literature resources on sorghum easily available to workers in areas where library resources are minimal.

    The resources to be made available include not only literature published in recognized journals or published books, but also reports generated by more informal means (mimeographed or cyclostyle, xeroxed, or other copying devices).

    A central repository for the information mentioned above should be established to provide a permanent record of the literature on sorghum.

11. The bibliography "Sorghum", and its first supplement covering the years 1964 thru 1969 has been found useful and convenient. Five years, 1970 thru 1974 have now elapsed and it is recommended that

ICRISAT be encouraged to take leadership in organizing a second five year supplement.

12. Cooperation between research programs in the America's and ICRISAT should be strenghthened. It is recommended that ICRISAT explore with workers in the America's how this cooperation be expideted including the possible identification of one or more out research locations in the Western Hemisphire.

13. A current list of sorghum workers in the world should be maintained and kept up to date annually. This list would include name, address, and interest area. ICRISAT should serve as a coordinating agency for this service.

    Lists at present maintained by government agencies and other institutions should be turned over to ICRISAT. This list would be useful for such things as solicitated of items for the Sorghum Newsletter.

Respectively submitted by the resolutions committee:

1. F. Saura
2. A. Sotomayor
3. O. J. Webster
4. L. House
5. E. Sharvelle
6. D. E. Weibel
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Downy Mildew Diseases of Corn in Sorghum in Venezuela.

G. Malaguti, A. Fernandez and H. Nass

CENIAP, Maracay, Venezuela.

Corn is the most important and traditional cer[illegible] crop in Venezuela. It is commonly planted during the first weeks of May, at the beginning of the rainy season, to take advantage of the abundant rainfall (about 1.500 mm.) that lasts in September.

Grain sorghum is almost new in the Country, but with increasingly importance for animal consumption, due to its good yield and harvesting facility with combine. It is also planted during the rainy season, 4-6 weeks later than corn.

The growing area of both crops is the plain, at an elevation from 100-500 meters a.s.l.; with a temperature averaging 25-30° C.

The disease in corn.

It was first observed in 1973, in small areas of three Districts of Yaracuy State, affecting tassels of corn, with many variable symptoms (proliferation of the tassel, witches' broom formation, yellow striping of the leaves, etc.) that are very similar to those described in the literature for "Crazy top". When young, the diseased plant appears sometimes more vigorous, green, oversized; when mature the "Crazy top" symptoms are frequently associated with a number (3-6) of elongated ear shoots, with no grain and cob.

The leaves, specially those of the deformed tassels, are commonly yellow striped or striated. Sometimes, diseased plants fail to develop tassels and ears; they remain stunted, with the bud a little bounded.

Histological sections of deformed tissues, specially of leaves and floral structures, revealed abundant coenocytic, intercellular mycelium, variable in size. Only occasional oospores were found; sporangiophores and sporangia have never been observed.

Many infection experiments were done in moist chamber, inoculating young plants with infected matherials, using different methods; but the results were negative. Other experiments were done planting seeds (or seedlings) in soil taken from a field where the disease was severe, or in soil where diseased material had been incorporated; but no symptoms of the disease were observed.

During 1974 the disease was very severe in almost all the corn areas of the mentioned State (Yaracuy); with an incidence, in many cases, of more than 50-70% of the plants. Later, during the growing periods, when the rainfall and humidity had increased, the disease was observed in other, nearly adjacent States (Barinas, Portuguesa, Aragua), with the same "Crazy top" symptoms. In most cases the diseased tassels were severely affected by corn smut (Ustilago zeae). The commercial varieties and hybrids were almost equally infected; "Arichuna" hybrid and "Minita" variety were apparently more affected than "Obregon", "Baraure" and "Sicarigua" cultivars.

It is interesting to note that both 1973 and 1974 were very abnormal years regarding rain-fall. It was, indeed, very poor

during May and June (while the plant were at their early stage of development), and later abundant in July and August. Also temperatures were somewhat irregular, sometimes warmer (about 30° C.) during the day, and colder (about 18° C.) during the night, than normal. It might be that the dry condition at which the plant were submitted, made them more susceptible to the fungus infection. (probably Sclerospora macrospora).

It was ordered to burn corn residues in the affected areas after harvest and before plowing, in order to reduce the risk of incorporating inoculum to the soil. Crop rotation in the affected areas was also suggested.

The disease in sorghum.

The disease was first observed in small experimental areas, where different cultivars of grain sorghum were planted, at Yaracuy State. Later the disease was noted at Valencia (Carabobo State).

In 1974 the disease was noted, very severe, in experimental plots at Barinas State.

The symptoms in sorghum are typically of the systemic form of infection, with chlorotic areas in the leaves, parallel stripes of green and white tissues.

The chlorotic stripes turn brownish, necrotic streaks, and later the leaf shreds. Shredding of leaves is a very conspicous sympton. Affected leaves soon become necrotic and dry from the tip downwards to the base of the leaves.

Infected plants remain stunted, tiller; abundantly and fail to flower or produce grain.

The mycelium and oospores are easily observed in microscopic

preparations. Oospores are extremely abundant in shredded leaves, located in chains in the mesophyll cells parellel to the vascular tissue. Conidiophora and conidia (sporangia) were rarely observed. The characteristic of the fungus and the shape and size oospores suggest that it may be Sclerospora sorghi.

Among cultivars observed, "Dorado N" was the most susceptible.

Screening of Sorghum Lines for Resistance to the Sorghum Midge, *Contarinia sorghicola* (Coquillett)

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Research conducted by us during 1973 and 1974 was in cooperation with Agronomists located here and with Agronomists and Entomologists at the Texas A&M Research and Extension Center, Lubbock, Texas.

Testing areas during both years included College Station and Beeville, Texas and Rio Bravo, Tamps. Mexico. One hundred and 24 sorghum line entries were evaluated for midge resistance in 1973 and 1974, respectively. Approximately one-third of those in each test were known susceptible hybrids. Additionally, five highly susceptible types of grain sorghums were planted around borders of each test plots primarily as a source of midge in order to provide heavy infestation pressure to other entries subjected to tests. A randomized block-plot arrangement was used, including 4 replications of each sorghum line and spreader.

Two "late" plantings were made at each location to insure midge infestations. Yields were based on seed harvested from heads covered (pollinating bags) versus that obtained from heads left exposed to midge attack. Also visual ratings of damage caused by midge to each of 10 heads were based on a scale of 1-10; 0=no damage; 1=up to 10% head

damaged, etc., up to 10= 90%.

There are several lines with various degrees of resistance but the following were the most obvious or pronounced:

Disignation	Type	Source
SC 175-9	Zerazera	73 PR 903
SC 239-14	Zerazera	73 PR 912
SC 423-14	Zerazera	73 LADN 147 op BK

A new method for observation of midge activity was initiated this year (1974). The technique involved a count of the number of midge visitations (or landing) per hour on heads of certain sorghum lines and later, the removal and examination of spikelets to determine the number of eggs deposited. Specific results relative to this study have not been analyzed.

RESPUESTA DE 15 VARIEDADES DE SORGO AL ATAQUE DE LA MOSQUITA DE LA PANOJA Contarinia sorghicola (Coquillett), EN EL VALLE DEL FUERTE, SINALOA, MEXICO

Santiago Armenta C.*

INTRODUCCION

El sorgo para grano en México, ocupa un área aproximada de un millón de hectáreas de riego y temporal y en el Estado de Sinaloa se siembran alrededor de 150,000 hectáreas por año lo cual representa el 15% de la superficie a nivel nacional.

La plaga principal de este cultivo en el Estado es la mosquita del sorgo, Contarinia sorghicola (Coq.) y actualmente se cuenta con alguna información para su control como son: fechas de siembra, uso de variedades de floración uniforme, destrucción de hospederas, horas adecuadas de muestreo, conocimiento de su ciclo de vida, insecticidas efectivos, etc., desconociéndose a la fecha la tolerancia o susceptibilidad de las variedades usadas al ataque de este insecto.

Con la finalidad de obtener información sobre este último aspecto se condujo el presente trabajo con 15 de las variedades más comúnmente sembradas en la región.

MATERIALES Y METODOS

El experimento se llevó a cabo en terrenos del Campo Agrícola Experimental del Valle del Fuerte en el año de 1974.

Las variedades en estudio se enlistan en el Cuadro 1. La siembra se hizo fuera de la fecha recomendada para que la floración coincidiera

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Cuadro 1. Producción de 15 variedades de sorgo con y sin aplicación de insecticida contra mosquita de la panoja, Contarinia sorghicola (Coq.) y significancia estadística del porcentaje de rendimiento entre parcelas de la misma variedad.

VARIEDADES	PRODUCCION KG/HA APLICADA	PRODUCCION KG/HA SIN APLICAR	REN. EN[1] %	SIG. ESTAD.[2]
NK-Savanna	5446	3225	59.3	a
Dekalb C-42-a	5870	2622	44.8	b
NK-210	5223	2031	39.0	b c
Asgrow Doble-TX	4162	1651	38.4	b c
NK-280	4419	1361	31.1	c d
NK-275	3929	1138	29.4	c d
Asgrow X-4065	4710	1339	28.0	c d e
Dekalb DD-50	5290	1395	26.3	c d e
Dekalb C-44-c	4955	1205	24.0	d e f
Dekalb C-44-b	5144	1171	22.8	d e f
Dekalb D-50-a	5290	948	17.7	d e f g
Asgrow Rico	4375	736	15.3	e f g
Asgrow Amark-R12	4598	669	14.3	e f g
NK-227	4263	502	11.7	f g
Dekalb F-63	3862	256	6.6	g

[1]Porcentaje de rendimiento de la parcela no tratada con relación a la tratada de la misma variedad.

[2]Al nivel de 0.05 y de acuerdo con la prueba de Duncan. Valores con la misma letra son iguales estadísticamente.

con temperaturas más altas y asegurar con ello una población adecuada de la plaga.

Bajo un diseño de bloques al azar con cuatro repeticiones se sembraron seis variedades el día 16 de abril, y nueve el día 24 del mismo mes; estos días de diferencia de la siembra se debieron a que las primeras son más tardías que las segundas, lográndose de esta manera una floración uniforme en una misma época para todas las variedades. La parcela experimental fue de cuatro surcos de 8 m. de largo y 0.07 m. de distancia entre surcos (22.4 m^2) y la parcela útil de 11.2 m^2.

En este experimento se tuvieron dos parcelas de cada variedad por repetición, una de ellas recibió aplicaciones de Gusatión Etílico 375 gr. de ingrediente activo por hectárea los días 24, 26 y 28 de junio y el día 1ro. de julio. La otra parcela estuvo expuesta al ataque de la mosquita.

El grado de tolerancia al ataque de la plaga se cuantificó en base al porcentaje de rendimiento de las parcelas no aplicadas en relación con las aplicadas.

RESULTADOS Y DISCUSION

Al llevar a cabo el análisis de varianza se encontró diferencia altamente significativa entre variedades procediéndose a realizar la prueba de Duncan, con los porcentajes promedios cuyos resultados se indican en el Cuadro 1.

Debido al tamaño de las parcelas (22.4 m^2) y a la movilidad de la mosquita no se consideró conveniente llevar a cabo muestreos de poblaciones, pero al observar el Cuadro 1., encontramos a la variedad F-63 con 6.6% de producción que es equivalente a sólo 256 kg por hectárea.

Esto nos da una idea de la buena población de mosquita que había durante el tiempo que duró la floración.

CONCLUSIONES

Los resultados obtenidos bajo las condiciones en que se trabajó, nos permiten concluir que: existe diferente grado de respuesta entre las variedades de sorgo al ataque de la mosquita de la panoja. De las 15 variedades evaluadas se encontró que con la variedad NK-Savanna se obtuvo mayor porcentaje de rendimiento que fue de 59.3, equivalente a 3225 kg. por hectárea; la variedad Dekalb C-42-a rindió 44.8% equivalente a 2622 kg por hectárea y ocupó el segundo lugar.

Dekalb F-63 fue la variedad con la que se obtuvo el menor porcentaje de rendimiento y fue de 6.6 equivalente a 256 kg por hectárea.

A MOSCA - Contarinia sorghicola (Coquillet, 1898) DO SORGO NO NORDESTE DO BRASIL. SITUAÇÃO ATUAL E PERSPECTIVAS [1]

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INTRODUÇÃO

A mosca - C. sorghicola (Coq., 1898) do sorgo é a mais importante praga dessa cultura no Nordeste do Brasil. As suas larvas danificam os grãos de sorgo e causam "murcha" de panículas, constituindo-se como fator limitante à implantação e ao desenvolvimento do sorgo. Trabalhos de pesquisas relacionados a essa praga foram iniciados muito recentemente no Nordeste. No Estado de Pernambuco, especificamente, tiveram início em 1973, com o estabelecimento de bases físicas de operação experimental e de execução de projetos de pesquisas.

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(1) Apresentado no "International Sorghum Workshop", Mayaguez, Puerto Rico, 7-11 de Janeiro de 1975.

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Nas regiões fisiográficas do Agreste e do Sertão, onde o sorgo é mais intensamente cultivado, o seu plantio é feito no período das chuvas, a partir de fevereiro-março-abril. Existe no Nordeste condições climáticas adequadas às exigências da cultura do sorgo, que se desenvolve nas regiões de baixa pluviosidade e alta temperatura (Anônimo, 1971; Miranda et alii, 1972).

O conhecimento da etologia e bio-ecologia da mosca C. sorghicola em diferentes micro-regiões do Estado, o estabelecimento de métodos de controle, eficientes e práticos, bem como a identificação de fontes de germoplasmas resistentes para o melhoramento varietal, são algumas linhas de pesquisas em desenvolvimento nas diversas Estações Experimentais do IPA, em Pernambuco.

Constitui o escopo principal do presente trabalho o conhecimento da programação de pesquisa sobre a mosca - C. sorghicola, do sorgo em desenvolvimento no IPA, Pernambuco, a possibilidade da formação de um Centro de Avaliação de Germoplasma para resistência, bem como, a sugestão de um planejamento global de pesquisas regionais, principalmente nos Estados de Pernambuco, Ceará, Paraíba, Rio Grande do Norte, Piauí e Bahia (Norte).

OCORRÊNCIA E DISTRIBUIÇÃO DA MOSCA C. sorghicola (Coq.) NO BRASIL

Sendo uma espécie de inseto de fácil disseminação, expandiu-se com o sorgo para todas as partes do mundo onde o

mesmo é atualmente cultivado. A sua ocorrência no Brasil ainda não está bem definida, todavia, esse aspecto não se constitui, no momento de caracterizada importância, pois, é realmente difícil se estabelecer o ano e o local de ocorrência do primeiro foco da C. sorghicola.

Rossetto et alii (1967a, 1967b) registraram, pela primeira vez, em 1967, a sua ocorrência no Brasil nos municípios de Piracicaba, São Paulo. Admitiram, todavia, a possibilidade dessa praga já existir no País há vários anos. Sabendo-se que a mesma foi observada pela primeira vez na Argentina em 1958 (Parodi, 1966), julgaram aqueles pesquisadores a possibilidade de ter havido uma disseminação do inseto para o Norte, atingindo o Uruguai e, em seguida, os Estados do Sul do Brasil até São Paulo (Rossetto et alii, 1967b). Até então era desconhecida a sua ocorrência em outras regiões do Brasil.

Em 1970 a mesma foi assinalada, pela primeira vez, no município de Limoeiro, Pernambuco, atacando sorgo cultivado (Anônimo, 1970), sendo confirmado a sua presença em Recife em 1972 (Rossetto e Leão Veiga, 1973). Nessa mesma época, análise procedida em panícula antiga de sorgo, pertencente à coleção (material nº 13) da Seção de Fitossanidade e Microbiologia do IPA, em Recife, Pernambuco, indicou que a mosca-C. sorghicola já estava presente nesse Estado há mais de 15 anos, tendo aparecido, possivelmente, em Pernambuco, ao tempo ou antes de ser referida na Argentina (Rossetto e Leão Veiga, 1973).

É citada a sua ocorrência no Estado do Ceará, causando sérios danos à cultura do sorgo (Anônimo, 1973a).

Possivelmente, a mosca-C. sorghicola já se encontra em todos os Estados do Nordeste onde o sorgo existe ou tenha sido introduzido, sendo certa a sua presença no Rio Grande do Norte e na Paraíba (comunicação pessoal, 1973).

É evidente e inevitável a sua expansão e disseminação no Brasil, em face do incremento e desenvolvimento da cultura do sorgo, ensejando, portanto, sugestões a implantação de uma programação de pesquisa, indubitavelmente de caráter regional que possibilite o conhecimento e a solução do problema.

SITUAÇÃO ATUAL NO NORDESTE DO BRASIL

A importância e prioridade que deve ser dada às pesquisas relacionadas à mosca-C. sorghicola já foi comprovada em muitos outros paises do Mundo e também no Brasil, no Estado de São Paulo.

No Nordeste, especialmente nos Estados de Pernambuco e Ceará, os trabalhos programados de pesquisa com essa praga são bastante recentes e datam de 1973, todavia, já ficaram perfeitamente evidenciados os sérios danos e prejuizos causados à cultura do sorgo em várias micro-regiões desses Estados, sendo constatados índices de danos às panículas de até 100%, como é o caso da variedade IPA-1155 (comercial) em Serra Talhada (E. Experimental - IPA, Pernambuco), em 1973 e 1974 (Anônimo, 1973b).

No Ceará, a situação é semelhante, verificando-se

altos níveis de infestação e índices de danos às panículas que alcançam 80 a 100% em cultivares de sorgo (Anônimo,1973a

Em Cruz das Almas, na Bahia, também já foi assinalad alta incidência de mosca-C. sorghicola danificando a cultura do sorgo (comunicação pessoal).

Nos demais Estados do Nordeste, não existem dados precisos em face da inexistência de pesquisas regionais.

Verifica-se então, acentuada redução da produção de grãos, variável com os diferentes níveis de ataque da mosca, com as condições ecológicas locais, com a época de plantio e com a variedade de sorgo.

No momento torna-se necessário estabelecer às épocas de ocorrência da mosca-C. sorghicola nas diferentes regiões fisiográficas de Pernambuco e do Nordeste do Brasil, através do estudo de sua flutuação populacional. Esse aspecto é considerado como o primeiro passo para os trabalhos de melhoramento visando resistência à mosca, evitando-se, assim, a confusão de Resistência com Escape.

É da mais alta importância a identificação e a seleção de variedades resistentes à mosca-C. sorghicola, ecologicamente adaptáveis às condições semi-áridas das diferentes regiões promissoras para o sorgo no Nordeste.

O plantio do sorgo no NE é feito dentro das faixas de pluviosidade, não existindo época certa. Os dados climáticos regionais, bem como os estudos sobre flutuação populacional, biologia, diapausa, etc., permitirão a obtenção de informações sobre a ecologia da mosca e um embasamento para

as pesquisas sobre métodos de controle.

PLANEJAMENTO GLOBAL DE PESQUISAS REGIONAIS PARA O NORDESTE

Tem-se em vista naturalmente aqueles Estados do Nordeste, onde existe a cultura do sorgo e esta tem expressão economica ou que esteja sendo introduzida e incrementada a sua implantação e desenvolvimento, como é o caso atualmente, de Pernambuco, Ceará, Paraíba, Rio Grande do Norte, Piauí e Bahia.

Em face das condições ecológicas, nitidamente variáveis entre os Estados e inclusive, entre micro-regiões nos Estados, terem uma grande influência sobre a etologia da mosca-C. sorghicola, é proposto, a título de sugestão, o desenvolvimento de uma programação de pesquisas, de caráter regional, a ser executada, de preferência, por instituições de pesquisa e coordenada por pessoal especializado-entomologista(s) e fitotecnista(s). Torna-se necessário, para a obtenção de resultados satisfatórios, que os trabalhos iniciados não sofram solução de continuidade, para que possam, após alguns anos, fornecer os subsídios necessários ao conhecimento e solução do problema.

Cada linha de pesquisa possibilita o delineamento de inúmeros planos ou sub-projetos de pesquisas, a serem desenvolvidos em espaço de tempo variável.

Seria, talvez, mais proveitoso e prático que cada linha de pesquisa fosse desenvolvida por etapas. Todavia, em

função de circunstâncias locais, poderão ser executadas mais de uma linha, simultâneamente. Nesse caso, há necessidade de uma dedicação maior às atividades.

Linhas de pesquisas em relação à mosca-*C. sorghicola* (*Coq.*) que podem ser utilizadas para uma programação regional no Nordeste, Brasil.

1 - Estudos de campo, sobre ecologia da mosca-*C. sorghicola*, visando sobretudo a flutuação populacional anual, em micro-regiões selecionadas e promissoras para a cultura do sorgo.

Objetivos gerais: visa o conhecimento da época de maior ocorrência populacional em relação aos fatores climáticos locais, às épocas de plantio, de início (50%) da floração, etc.

2 - Pesquisas sobre aspectos bio-ecológicos, no campo e em laboratório:

- ciclo de vida
- inimigos naturais
- plantas hospedeiras
- diapausa x época do ano
- hábitos da mosca em relação ao hospedeiro
- levantamento agro-climático
- danos e índices de prejuizos, etc.

3 - Métodos de controle:

- controle químico: experimentos com inseticidas, eficiência, dosagens, época de apli-

cação, fitotoxidade, etc.

- controle biológico: inimigos naturais, espécies, índices de controle.
- controle cultural: época adequada de plantio, etc.

4 - Identificação de fontes de resistência para o melhoramento:

- identificação e avaliação de resistência entre germoplasmas de sorgo
- causas da resistência
- correlações diversas com índices de danos, população de mosca, época de maior incidência, floração, etc.
- seleção de germoplasmas promissores
- seleção e formação de variedades resistentes, etc.

PROGRAMA DE PESQUISAS NO INSTITUTO DE PESQUISAS AGRONÔMICAS (IPA), PERNAMBUCO, BRASIL

A programação de pesquisas sobre a mosca-C. sorghicola (Coq.) do sorgo em Pernambuco, segue, de modo geral, as linhas estruturais sugeridas neste trabalho. Foi iniciada em 1973, continuada com maior ênfase no ano de 1974, estando dentro das previsões uma continuidade por mais 3 ou 4 anos, até o conhecimento geral do problema e a identificação de métodos de controle racionais, econômicos e/ou permanentes.

A programação abaixo, é definida por projetos gerais.

ANO DE 1973

1 - avaliação da suscetibilidade de variedades de sorgo forrageiro ao ataque da mosca-C. sorghicola, na Estação Experimental de Serra Talhada (IPA).
Projeto: I-SOR-162/1973.

2 - Avaliação da suscetibilidade de variedades de sorgo granífero ao ataque da mosca-C. sorghicola (Coq.) na Estação Experimental de Serra Talhada (IPA).
Projeto: I-SOR-161.

3 - Avaliação da suscetibilidade ao ataque da mosca-C. sorghicola (Coq.), em 69 linhas puras da Coleção Mundial,na Estação Experimental de Serra Talhada (IPA).
Projeto: I-SOR-168.

4 - Ecologia da mosca-C. sorghicola, do sorgo: flutuação populacional em Serra Talhada e Caruaru, Pernambuco.

ANO DE 1974

1 - Ecologia da mosca-C. sorghicola (Coq.)

1.1. - Estimativas de prejuizos à produção e população absoluta de mosca do sorgo na Estação Experimental de Serra Talhada, Pernambuco.
Projeto: I-SOR-185.

1.2. - Estudos biológicos da mosca: ciclo da vida, plantas hospedeiras, restos de culturas e diapausa.
Projeto: I-SOR-187.

1.3. - Ocorrência, flutuação populacional e inimigos naturais da mosca em diferentes regiões fisiográfi-

cas de Pernambuco.

Projeto: I-SOR-184.

2 - Efeito da aplicação de inseticidas no controle da mosca-C. sorghicola do sorgo, em Serra Talhada, Pernambuco. Projeto: I-SOR-186.

3 - Identificação de fontes de resistência em germoplasmas de sorgo (1.400 linhas da Coleção Mundial), em relação ao ataque da mosca-C. sorghicola (Coq.), em Serra Talhada, Pernambuco.

PERSPECTIVAS

A mosca-C. sorghicola (Coq.) é considerada como a mais séria praga da cultura do sorgo no Nordeste do Brasil, ensejando, por isso, a necessidade de se desenvolver amplos estudos de caráter regional, sobre a mesma.

A sua distribuição é generalizada nos Estados de Pernambuco e do Ceará. Atualmente, as pesquisas sobre entomologia do sorgo no Nordeste estão concentradas nesses dois Estados, sendo desenvolvidas através do Instituto de Pesquisas Agronômicas (IPA) (nas suas diversas Estações Experimentais) e do Centro de Ciências Agrárias, Universidade Federal do Ceará, respectivamente.

Inexistem dados de pesquisas sobre a mosca do sorgo em outros Estados, todavia, acredita-se que a mesma ocorra em todo o Nordeste onde haja cultivo de sorgo.

Enfatiza-se a necessidade de pesquisas regionais sobre: flutuação populacional da mosca e correlacionamento com

fatores climáticos locais, como prioritário para o conhecimento de épocas de maior incidência; estudos bio-ecológicos diversos, visando ao conhecimento da etologia da mosca em micro-regiões de cultivo do sorgo, inclusive, diapausa e hospedeiros intermediários; inimigos naturais - parasitos, e sua contribuição para a redução populacional; pesquisas sobre métodos de controle, destacando-se o de resistência de variedades, o químico e o biológico e a identificação de fontes de resistência à mosca para o melhoramento e seleção de variedades resistentes. Essas linhas de pesquisas gerais sobre a mosca-C. sorghicola possibilitarão importantes e indispensáveis subsídios para o conhecimento e solução do problema. No Nordeste, essas linhas de pesquisas devem, indubitavelmente, visar a obtenção e distribuição de variedades de sorgo resistentes com caracteres agronômicos favoráveis e ecologicamente adaptadas às diversas micro-regiões de cultivo.

As linhas de pesquisas relatadas poderão servir de base para a sua execução em outras regiões do Nordeste.

O Programa de Melhoramento do Sorgo para o NE, que tem como sede o IPA, contribuirá com instituições congêneres, empresas particulares, etc. no fornecimento de informações, de dados técnicos, de sementes (genótipos) para experimentação, de orientação e assessoria, etc., de modo a incrementar a implantação do sorgo no Nordeste.

A programação de pesquisas do IPA, Pernambuco, e do Centro de Ciências Agrárias, Ceará, dentro de 3 a 4 anos terá formado aportes científicos suficientes para o conhecimen-

to regional e para a redução e/ou solução do problema da mosca-C. sorghicola do sorgo, considerada, atualmente, como fator limitante dessa cultura nessas regiões.

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THE GENERAL BIRD PROBLEM IN GRAIN SORGHUM

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I - INTRODUCTION

Many species of birds feed on developing or mature grains of sorghum. For example, English sparrows feed on grains at the milk stage while black birds and starlings eat mature grains. Profitable harvest of grain sorghum in many areas of the world depends in part, on the ability of the crop to withstand the ravages of several species of birds.

Each area has its own bird problem. In Africa the Quellea, small-red billed weavers, are the most serious problem. In addition to the Quellea, Africa has many other birds which eat sorghum grain. Sparrows, yellow weavers, bishop birds, and other members of the ploceidae are persistent grain theives (Doggett, 1970).

Among the most destructive bird pests of sorghum, in Asia, are: sparrows, parakeets, crows, mynas and other species (Wall and Ross, 1970). In North America, black birds are the most serious problem of all. The term black bird is frequently used to include grackles, cowbirds, yellow headed,

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(1) Presented to the International Sorghum Workshop.

aguez, Puerto Rico, U.S.A. January 7-11, 1975.

and red-winged, all of which are species of the New World black bird family (Icteridae). The term is also used to refer to some other species which are not true black birds as in the starling case. In addition to those species, town sparrows, crows and many other species cause crop depredation.

Ryan (1968) estimated the annual crop losses to black birds and starlings in the United States at $ 50 to $ 100 million. Doggett (1970) estimated the annual amount of grain losses to Quellea in Africa at one million tons. He stated that the Quellea problem in Africa is more akin to the locust situation than to "bird damage".

Bird damage to sorghum cultivars can reach as high as 100 percent. Voight (1966a, 1966b) reported losses in yield ranging from 48 to 72% as a result of damage to non-resistant sorghum hybrids in Arizona. Harris (1969) estimated 50% losses in Georgia sorghum fields and received reports of the total destruction of sizable plantings. Tipton et al. (1970) stated that bird damage to grain sorghum in Louisiana fields was more a concern to growers than were losses inflicted by insects.

The introduction of sorghum, as a new grain crop to the semi-arid Brazilian Northeast, has a good chance of achieving success. However, bird attack is the most limiting factor. In the Northeast, bird losses up to 100% were recorded in experimental plots and in seed multiplication fields. In some cases the attack was so severe that the birds tore pollination bags to get through to the sorghum

grains of selfed heads and crosses. Grain losses were severe when other food sources were not available and during the off season (dry-season) plantings.

II - BIRD CONTROL

Control measures of limited success used in problem areas include; scaring with noisemakers and other frightening devices, reduction of local bird population, eliminating nesting, roosting and hiding places, spraying or dusting of standing crops with repellents, planting buffer or diversionary crops to attract attention away from important cultivars, and timing the crop maturity to coincide with those of the surrounding areas.

Reduction of local bird population and the use of bird repellents are discussed in more detail.

A - Reduction of Local Birds

The most effective control measures involve attacking the birds in their nesting and roosting sites. Initially flame throwers and explosives were used, but because of high costs, aerial spraying with chemicals such as parathion, phosdine and Queletox was adopted in uninhabited areas (Doggett, 1970). The Kenya and Tanzania control units killed 331 million birds during the period 1956 to 1960. In West Africa, the numbers of birds destroyed in 1960 and 1961, were 247 million and 305 million respectively. In South Africa, over 100 million birds were destroyed each year from 1953 to

1960 before any noticeable reduction was made in the Quellea population.

In the U.S., black bird species are given federal protection and can only be killed when commiting or about to commit crop depredation. One can argue that it is very essential to attack the birds, reduce their population to a tolerable level, and to prevent them from building up their numbers again, i.e., to try, in some cases, to restore the situation to what it must have been years back. However, conservationists and government agencies are very much opposed against killing birds as a means of solving these problems.

B - Bird Repellents

Chemical repellents have been used on crops to protect them from birds for more than 150 years. There are at least three kinds of repellency action: 1) true repellency, based on distastefulness; 2) physiological repellency, which happens when the birds are not repelled by its distastefulness but take in enough chemical to show sub-lethal effects and are not physically able to consume more treated seed, and 3) area or behavioral repellency: the behavioral response by unaffected members of a population to actions of affected members. An analog would be psychological repellency or chemical frightening. The effect is especially pronounced on the more social bird species.

Only a few results have been published for repel-

lents used on ripening grain. Griffin and Baumgartner (1959) gave several coded compounds good ratings as repellents from "pan" tests and from spraying reipening sorghum. They stated that a thiram formulation (Arisan 42-S) repelled birds exceptionally well. Metzer and Royal (1961) found thiram to be the most effective of three chemicals sprayed on mature grain sorghum for repelling English sparrows in Texas. Thiram is known to act as a behavioral repellent. Doggett (1970) indicated that two other valuable substances for this purpose are: 4-nitropyridine-N-oxide (Avitrol 100) and 4-amino-pyridine (Avitrol 200).

In Colorado and Oklahoma, J. Guarino (1971) reported that a new chemical called "Methiocarp" was effective for reducing damage caused by red-winged black birds and common grackles. Methiocarp seems to be an effective repellent for preventing bird damage to sprouting corn and sorghum, to ripening rice and sorghum, and ripening cherries and grapes. It has been stated that Methiocarp is a broad-spectrum compound with high repellent activity for numerous species of birds including pheasants, common and boat-tailed grackles, red-winged black birds, starlings, robins, house finchs and crows (Guarino, 1971). However, this chemical was tried on mature grain sorghum under field conditions in the Northeast of Brazil and it gave poor results on grain sorghum against cowbirds, parakeets, red-head black birds (Parvaria larvata), golinha (Sperophila plumblea) and sabiá (Turdus albicollis).

III - BIRD RESISTANCE IN SORGHUM

A. Characteristics of Bird-Resistant Sorghum

Harris (1969) defined bird-resistance in grain sorghum as that mechanism or characteristic of a variety which, when birds are given a choice of feeding material, will normally cause them not to depredate. It is obvious that bird-resistance, as defined herein, is relative to bird populations, other feeding sources, and probably many other factors.

Large glumes have been suggested as giving some protection and this may be true for some birds. However, yellow weavers in East Africa squeeze the glumes so that the soft green grain pops out, which they then devour (Doggett, 1970). Other possibilities include; awned lemma types, lax panicles, and pendent heads (goose-neck) where only the upper part of the grain is taken and some 50% remains on the plant.

The bitter grain characteristic is a basis for developing resistance in sorghum because birds do not take bitter grain in most seasons unless there are not sufficient alternative food resources. In other words, it is not an absolute resistance as hungry birds will eat the bitter types if they do not have another choice.

Harris (1969) tested 20 sorghum hybrids classified by seed color and found that the brown-seeded hybrids were approximately 3% higher in tannin than the red- or yellow-

seeded hybrids. The astringent grains containing tannin are not taken readily by the birds. This is the basis for the bird resistant varieties or hybrids (bird-proof sorghums).

Tannins are high molecular weight polymers composed of phenolic compounds. The principal tannin in grain sorghum has been identified as a Leuco-anthocyanin, which upon heating with mineral acid yields leuteoforal (leucohiteolinidin) 3', 4, 4', 5, 7 - pentahydrozyflavan (Bate-Smith and Rasper, 1969).

The phenolic pigments were found mainly in the epicarp, the hypocarp (outer layers of the pericarp) and the testa (inner layer separated from the pericarp by a colorless mesocarp). Any one of these layers may be completely absent and their presence or absence is controlled genetically (Quinby and Martin, 1954; Wanjari and York, 1972).

Many data have been presented to support the association between bird-resistance and the brown,high tannin sorghums (Harris, 1969; Tipton et al.,1970; McMillian et al., 1972).

More recently, McMillian et al (1972) studied the relative amount of bird resistance in a broad spectrum of sorghum lines (142 sorghum lines). The amount of tannin and the seed color showed a positive correlation (r = 0.520) and bird damage was negatively associated with tannin content of seed (r =-0.622). Neverthless, several sorghum lines appeared to be resistant although they contained a relatively low amount of tannin.

High tannin sorghum seems to be less affected by weathering, i.e., deterioration of seed quality due to weather conditions, including pre-harvest germination (Harris, 1969; Harris and Burns, 1970). Little is known about the nature of weathering resistance, but Harris and Burns have suggested possible ways in which tannins may contribute to retard pre-harvest seed germination.

B. Nutritional Aspects Associated with Bird Resistance in Grain Sorghum.

Tannins of sorghum affect quality of the grain for animal and human consumption. Considerable data have been generated to support the theory that the brown-seeded, but resistant varieties or hybrids have reduced digestability and consequently nutritional performance (Chang and Fuller, 1964; Harris, 1969; Harris et al., 1970). Probably the most nearly complete digestion study conducted with sorghum was reported by McGinty in 1969. He used sorghum seed of various colors produced in the same environment to determine the relative feeding value. Brown-seeded varieties showed significantly lower <u>in vitro</u> dry matter digestability (IVDMD), percent protein, and protein digestability than white-, red- or yellow-seeded varieties. Hard, corneous endosperm types were lower in feed efficiency than soft, starchy varieties. McGinty removed the pericarps (including the brown nucellar layer, when present) from "Tx-09" (white, soft, starchy), "DARSET 28" (brown, soft, starchy), and "KAOLIANG" (brown,

soft, starchy) by tangential abrasion and added the pericarps of each variety to the endosperms of all varieties in all possible combinations. When the pericaprs were removed there was no difference in digestability of the various endosperms. When "DARSET 28" or "KAOLIANG" pericarps were added to any endosperm there was a significant decrease in digestability.

Schaffert (1972) studied the role of polyphenols in the digestion of sorghum grains. He reported that a significantly larger amount of nitrogen was left in the residue of the high tannin grains. He concluded that the polyphenol somehow reduces the digestability of the protein more than it reduces the digestability of the carbohydrates. Jambunathan and Mertz (1973) have shown that high and low tannin sorghums exhibit different protein fractionation patterns consistent with the idea of protein-tannin complex.

Considerable data support the theory that tannin and tannic acid reduce the digestability of sorghum and other plant materials (McGinty, 1969; Vohra et al., 1966; Tami and Alumont, 1970; Glick and Joslyn, 1970).

The work at Purdue University revealed that no threshold level of tannin is required for growth depression. Any amount of tannin in sub-optimal protein diets would be expected to result in reduced nutritional quality (Cummings and Axtell, 1973).

One can conclude that tannin in grain sorghum reduces the nutritional quality by at least two mechanisms: a. lower digestability due to reduced protein availability,

and b., toxic effects. However, the actual mechanisms involved are not known yet.

Sorghum tannins may be associated with growth retardation (Chang and Fuller, 1964; Fuller et al., 1966) and may increase leg abnormalities in chickens (Rostagno et al., 1973). Tannin can cause gastrointestinal inflamation and may be tumorigenic. A high incidence of esophageal cancer in certain areas of the world has been hypothetically linked with consumption of dark brown, bird resistant sorghum grains (Morton, 1970).

Some reports indicate complete or partial elimination of the toxic effects of tannin and tannic acid by dietary supplementation with compounds such as choline, or methionine (Chang and Fuller, 1964; Conner et al., 1969; Rayudu et al., 1970).

There exists some information which indicates that specific methods of processing grain sorghum, such as steam-flaking, reconstitution before grinding, or rolling and dry-heat treatment (micronizing) enhance the feeding value of the grain (Anonymous, 1971). However, limited data are available to explain the benefits of processing sorghum grain. Knowledge of the changes in physical and/or chemical characteristics which are necessary to bring about required utilization of the grain should permit development of the most efficient and economical processing method.

IV - OUTLOOK

It seems that there is a widespread confusion regarding tannins and bird resistance in sorghum. We cannot ignore the evidence that the presence of tannin in sorghum grain reduces the nutritional quality of the grain. Neither can we overlook the need for developing bird resistance varieties and hybrids in areas with large bird populations.

It appears important to stimulate close cooperation between breeders and nutritionists. The need for defining nutritional quality in sorghum is clear. Such a definition should incorporate protein, factors of digestability, tannin effects, etc. The actual mechanism by which tannin reduces the nutritional quality in grain sorghum should be elucidated. This is an important step towards finding ways to counterbalance this obvious drawback in bird-resistant sorghum grain.

It is evident that there is a great deal of further research opportunity for studying the world sorghum collection to detect other variations of bird resistance. Recent work from Purdue (Oswalt, 1974) indicates that some grain sorghum lines with partial or complete testa do not contain levels of tannin which significantly reduce biological estimates of protein quality. McMillian et al. (1972) found that several bird resistance sorghum lines contained low amount of tannin while other lines which contained high amounts of tannin in the seed appeared susceptible to birds.

These results indicate that both quality and quantity of tannin are influencing factors. In other cases, it may prove useful to look for grain which possesses tannin when green but whose tannin is absorbed or disintegrated when the grain ripens.

There are other possibilities which have to be looked at, such as: (a) supplementation of high-tannin sorghum with additional sources of dietary protein to meet the nutritional requirement. This may prove to be an unfeasable approach if one considers the economic aspect, (b) use of processing techniques to improve the nutritional quality of grain sorghum. The impact of this approach in Asia and Africa is not likely to be great for a long time to come because of present utilization patterns, to mention nothing of processing costs, and (c) use of additives that could preferentially bind with the tannins and free the protein to be utilized.

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MILDEW OF SORGHUM IN BRASIL

Fernando Tavares Fernandes

It is difficult to establish when sorghum downy mildew appeared for the first time in Brasil. Officially it was reported by Dr. Richard A. Frederiksen of Texas A & M University, College Station, Texas in March 1974 in experimental plots near Riberão Preto, São Paulo, when he visited Brasil in 1974. The disease occurred in the late plantings of Argentina introductions and in susceptible lines from Texas considered to be free of the pathogen. The percentage of plants attacked varied from 1.3 - 88.7%. Considering that this experimental field had already been planted to sorghum for two years symptoms presented by affected plants indicated the occurrence of systemic infections, it is probable that the disease had been introduced before 1974.

In this same year it (downy mildew) was reported as occurring in severe form in experimental plots of the Experiment Station of Uruguiana, Rio Grande do Sul.

After Frederiksen's report in 1974 it was verified that the disease had already occurred previously in Brasil in the State of Rio Grande do Sul. Perhaps because of the low economic importance of sorghum at that time or because of failure to recognize its importance for corn and sorghum, it had not been recorded. Professor Perfire Costa Neto (Faculty of Agronomy of the Federal University of Rio Grande do Sul) affirms that it had been observed in 1971 at the Experiment Station of Guaiba, and in 1973 in the Experiment Station of São Sorja, both in Rio Grande do Sul, on forage hybrids derived from crosses of sorghum with sudamgrass.

In personal communication from Dr. Alexander Grobman he indicated that it had already occurred in that state in 1967.

In Brasil corn occupies a position of distinction being actually considered the most important of all agricultural products in value of production. The area occupied by this crop in 1970 was estimated to be 9.8 million hectares with a production of 14.8 million tons. Of this total, the regions of the Central West, Southeast and South produced 87%. As for sorghum, although it has been introduced in Brasil for more than twenty years its importance is relatively recent. The area occupied by this crop in 1973/74 was estimated at 200,000 hectares but there is no official production estimate. The southern region is the major production region followed by the Central West and Southeast regions.

The importance of sorghum mildew for Brasil can be summarized by the fact that sorghum and corn are hosts of S. sorghi and we do not know the reaction of corn material to this disease. Thus, if the disease spreads in Brasil it could cause incalculable losses principally to corn. Actually, sorghum mildew is restricted to the state of Rio Grande do Sul in the southern region. As for the local focus close to Riberao Preto in the Southeast region this has already been placed under control.

With the end purpose of avoiding dissemination of the disease to other areas and aiming principally at protecting corn Empresa Brasiliera de Pesquisa Agropecuaria (EMBRAPA) called a meeting of technologists interested in the problem to determine methods aimed at avoiding dissemination of sorghum mildew. These methods were sent to the Department of Plant Protection of the Ministry which issued a

directive regulating the importation, distribution and planting of seed of sudamgrass and its hybrids. This directive also emphasized the necessity for undertaking annual surveys to evaluate the occurrence of sorghum mildew in various regions of the country; to eradicate foci of the disease and to prohibit the planting of corn varieties susceptible to mildew, and directed resistance tests of Brasilian corn and sorghum varieties which should be conducted in Argentina or the USA.

The regulations issued by the Department of Plant Protection do not reflect that which was decided at the meeting called by EMBRAPA.

The manner in which the directive was drawn up interfered, at short notice, with the production and importation of seeds by private companies, limiting the development of corn in the country. For this reason EMBRAPA workers with sorghum, jointly with representatives of private companies, prepared a series of modifications to be made in the aforementioned directive which are being evaluated by the Department of Plant Protection.

THE ACTIVITY AND CONTROL OF SORGHUM MIDGE, CONTARINIA SORGHICOLA (COQ.) (DIPTERA: CECIDOMYIIDAE) IN TRINIDAD

Ronald M. Barrow

INTRODUCTION:

The sorghum midge, Contarinia sorghicola (Coquillet) is established throughout most of the sorghum-growing regions of the World (Callan, 1945; Harris, 1969). Although there are no records of the actual entry of the midge into Trinidad it seems reasonable to assume that the pest was introduced several years ago into the Caribbean areas in importations of seed from the USA and southern Asia (Callan, 1941). Patterson (1912) reported that the midge was introduced into the West Indies from the USA sometime prior to 1910.

Considerable grain crop loss due to the midge was recorded in a survey taken of crops grown at St. Augustine, Trinidad by Callan (1941). Subsequent to that survey the importance of sorghum as a grain crop in Trinidad has steadily declined. It was not until the early 1970s when an attempt was made to augment locally grown animal feeds that sorghum assumed any importance and so did C. sorghicola.

Huddleston et al (1972) gave a fairly complete review of literature pertaining to the biology and control of C. sorghicola. They reported that in many areas chemical control is considered to be impractical and cultural control techniques have been recommended. The date of planting seems to have some effect on midge populations since, as Passlow (1965) pointed out the percentage of population emerging after diapause is probably regulated by weather conditions. To combat major midge damage in sorghum, Huddleston et al (1972) hold that chemical control is occasionally necessary but as Harris (1969) postulated, economic

chemical control measures still need to be evolved.

This study here reported was undertaken in north Trinidad from mid-February 1973 and continues to the present date. Observations were made to obtain behaviour data aimed at establishing the economic status of the sorghum midge over a range of flowering dates, to define the relationship of the stage of bloom and the oviposition rate of the midge and also to investigate the incidence of diapause in the midge. Trials were conducted to determine whether several compounds related to those found effective for midge control in other countries could prove valuable under Trinidad conditions.

Materials and Methods

Sorghum plots planted at Chaguaramas, El Carmen, CES, St. Augustine nurseries and El Reposo were selected for sorghum midge studies. The seeds used throughout these experiments were obtained from the Pioneer Seed Company. Of the two head types grown - compact and open, all the findings here expressed were based on the compact head varieties unless otherwise stated. Records of rainfall throughout the experiment were duly noted.

Time of flowering and midge damage

According to Callan (1941) sorghum should be sown in Trinidad between October and December. Bowden (1965) reported that the ideal time for the planting of sorghum in Ghana is in May-June just after the start of the main rainy season in that country. Since it has been shown that an important relationship exists between midge infestation and the time of the main flowering of the crop (Harris, 1961) it was decided to determine the economic status of the sorghum midge over various flowering dates in Trinidad. In so doing the seasonal biology of the midge could

be determined, the periodicity of emergence and oviposition and the incidence of diapause. No detailed life cycle studies were undertaken since there was no evidence (gleaned from the preliminary survey) to suggest that the life history differed significantly from that described by Harris (1961) for the midge in Nigeria.

A preliminary survey was conducted at CADP from mid-February to the end of May 1973. Once an estimate of the extent of the midge problem was learnt and realistic sampling techniques devised, an on-going survey was instituted starting June 5, 1973. This survey was conducted in untreated sorghum plots.

The following are the two sampling techniques used:

1) Bagging flowering sorghum heads

To determine adult population levels in the field at varying times of the day and on flowering dates throughout the year hourly samples were taken of flowering heads in the mid-bloom stage. Five heads selected at random were sampled hourly. Samples were taken from sunrise to sunset (when possible) by bagging over the heads using transparent polythene bags (45 x 22.5 mm) and removing the head by cutting the stalk off beneath level of the bag. The heads were shaken and the number and species of insects in the bag were recorded. The bags with the heads were sealed, labelled and taken to the laboratory where checks were made for the time of emergence of the pest.

This was done monthly from June 5, 1973 onwards to the present date as indicated in Fig. I.

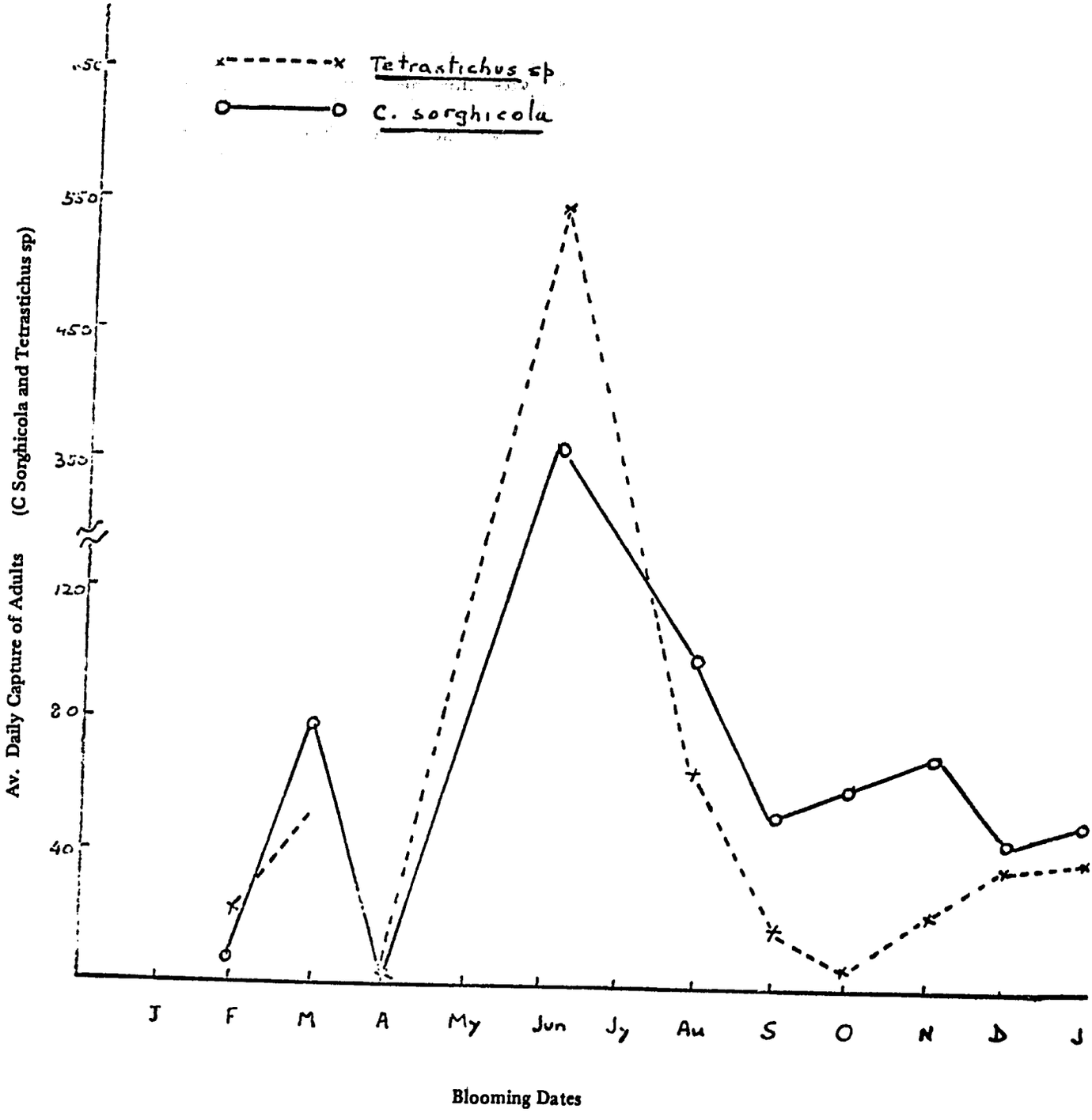

Fig. I Average daily capture of C. Sorghicola and Tetrastichus sp on grain sorghum at different blooming dates in 1973 & 74 throughout North Trinidad. (Sample Technique - bagging sorghum heads in mid-bloom stage).

2) Sampling of mature spikelets

To assess the incidence of damage caused by the midge, the sampling technique used was the one devised by Bowden (1965). A sprig of spikelets was selected from the head of every 10th plant in which flowering had ceased. Selection was made along rows chosen at random. As large a selection of spikelets were taken as man-hours permitted. The sprigs were taken to the laboratory and spikelets removed. By a process of repeated halving, 100 spikelets were finally selected from the bulk dissected under binocular microscope and the contents recorded in 3 categories, namely - a) healthy b) damaged by midge c) damaged (cause unknown).

Records were made of midge damage from July 1973 onwards throughout north Trinidad.

Stage of Bloom Experiments

To evaluate the stage at which a grain sorghum head is most susceptible to midge damage bagging experiments similar to those reported by Stanford et al (1972) were conducted at Chaguaramas and St. Augustine. No chemicals were used on these heads. At Chaguaramas one hundred sorghum plants selected at random were bagged on August 11, 1973 before head emergence from the boot. Those bagged heads were then labelled and divided into four separate groups of 25 heads each and exposed for 24 hours during a particular bloom period. They were then rebagged until the heads were matured when they were harvested and the spikelets examined for midge damage.

The following 4 periods of bloom stages were selected for exposure:

a) Heads fully exserted from the boot with no blooms evident

b) Approximately 20% of each head in yellow blooms, with no red blooms present c) Yellow and red blooms covering entire head in a ratio of approximately 1 : 1 d) No yellow blooms present and about 30% of the head in the red bloom stage.

To bag a sorghum head, use was made of a wire frame over which a muslin bag was placed. The frame was supported by a stake so that the head was free within the cage. This test was repeated on 5 February and March 1, 1974, at Chaguaramas and November 15, 1974 at St. Augustine.

Insecticide Evaluation

A series of tests were conducted using Trichlorphon, metamidophos and Carbaryl to evaluate the effectiveness of these insecticides and to determine the time (i.e. stage of flowering) of application that affords the best control of the sorghum midge. Chemicals were applied at 0.8 ozs A. 1/acre using knapsack sprayers calibrated to deliver a fixed amount of chemical per plot. A randomized complete block design was used. Each plot was 40' x 10' and each treatment was replicated 4X.

The following were the tests conducted:

1) A single spray application was made when the sorghum heads were in the mid-bloom stage.
2) A single spray application when majority of the heads were 20% yellow.
3) Two spray applications were made six days apart, the first when the majority of the heads had just emerged from the boot and the second when the heads were in the red bloom stage.

Control was based on the average weight of the threshed grain from each plot taken at dry harvest and the incidence of midge damage from

plot samples. The screening test (#2) was repeated at St. Augustine.

Results and Discussion

Time of flowering and midge damage.

The preliminary survey conducted from February 12, 1973 on cultivated and ratoon plants in the plant breeder's plot at CADP revealed a high infestation of midge. More than 65% of spikelets examined were damaged by C. sorghicola with 54% infested with one larva or pupa, and the rest containing two or more immature stages.

The biology of the midge in Trinidad does not differ significantly from that described elsewhere. Adult emergence occurs in the early morning and the peak period of oviposition occurs between 0800-1200 hours. From the bagged samples taken, there seems to be no clear cut pattern in the seasonality of the adult midge in Trinidad as indicated in Fig. I. The incidence of the midge was highest during June when ratoon plants were sampled. Sorghum planted in August is no less susceptible to attack by the midge than a crop planted in December. However, there is some indication that the incidence of the midge increases as adjacent crops flower in sequence. No adult midges were taken at El Carmen sampled in late March and early April, September, October. No evidence of diapause was found in Trinidad although it might be expected to occur on occasion in the dry season between December - March. Of the other insects collected in the samples the endoparasite, Tetrastichus diplosidis (Crawford) occurred with the highest frequency. The influence this parasite exerts on population levels of the midge has not been determined and as Simmonds (1974) suggests T. diplosidis should be investigated as a means of biocontrol.

The results obtained in Table 1 would indicate that some relationship may exist between midge infestation and the time of the year the crop flowers. As the season progresses, the incidence of midge attack increases, as evidenced by the crops planted in June and in December. The ratoon crop occurred at the end of a very severe dry season and the high incidence of damage maybe attributed to a break in larval diapause (if diapause does occur in Trinidad). Loss from other agents is not significant. An unidentified Tettigoniid was seen infesting the sorghum heads at St. Augustine. The grass - birds, Sporophila grisea Gmel and Sporophila minuta minuta L. caused some seed loss at CADP. There was an outbreak of Mocis repanda (F.) at El Carmen in 1974. Aphids, Aphis maidis Fitch and Spodoptera frugiperda (Smith & Abbott) are found on sorghum before the crop heads. From these results reported here it is felt that severe loss of grain due to midge attack could be expected in the crops planted late and adequate precautions should be taken to prevent this.

Stage of Bloom Experiments

There is significant difference at the 0.05 level (Duncan's multiple range test) between the various bloom stages with regard to susceptibility to midge damage. The heads exposed in the 2nd and 3rd stage i.e. 20% yellow and 50% : 50% yellow to red had a significantly higher incidence of attack than the 1st and 4th stages. Based on these findings if midge populations reach economically damaging levels, farmers should be advised to start spray applications for midge control just as the majority of the sorghum heads begin to bloom. Since as Wiseman and McMillian (1973) reported oviposition on a sorghum spikelet does no reoccur, that is, once the sorghum passes through the

Table 1. Average number of sorghum spikelets per head damaged by the sorghum midge and other agents at various flowering dates throughout the year.

Variety	Date		Av. No. of grains damaged (%)	
	Planted	Harvested	by midge	by other agents
	Ratoon	July 1973	65.0	no figures available
XB 925	June 1973	October 1973	2.5	2.1
8202 TX 321	Dec. 12 1973	April 1974	11.9	2.4
XB 925 (Tall, open)	Dec. 31 1973	April 1974	24.0	2.1
8202 TX 321	Jan. 25, 1974	April, May 1974	0.0	8.0

Table 2. Average number of midge-damaged grains per sorghum head (Var. XB 925) during each of 4 exposure stages. (Stage of Bloom exp.)

Date Exp. Started	Bloom Stage			
	1	2	3	4
	No Blooms	20% Yellow only	50% Yellow 50% Red	30% red only
August 1973	3.3	7.0	10.0	10.0
February 1974	0.0	2.1	5.3	1.0
March 1974	0.0	0.0	0.1	0.1
December 1974	0.0	18.2	13.3	4.8
Means	0.8a	6.8b	7.2b	3.9a

Means not followed by the same letter are significantly different at the 0.05 level (Duncan's multiple range test.)

susceptible stage the midge does not attack it again.

INSECTICIDE EVALUATION:

The results obtained with the three insecticides (Trichlorphon, Carbaryl and metamidophos) tested to determine their effect in controlling the sorghum midge are inconclusive. Although the yield of threshed grain taken at dry harvest was higher in the treated plots than in the control, there was no significant difference between the treated plots and the control or amongst the treated plots. A single spray application to sorghum in the mid-bloom stage gave a consistently higher yield of grain than when the heads were sprayed in the early bloom stage, where two spray applications were made six days apart the control provided was not significantly better than when single spray applications were made. The results of tests carried out in December 1974 are not available as yet.

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SORGHUM MIDGE AND BANKS GRASS MITE CONTROL STUDIES

Charles R. Ward

The sorghum midge, Contarinia sorghicola (Coquillett), has been a key pest of grain sorghum in most areas of Texas and other parts of the world for many years. The first major outbreak on the High Plains occurred in 1961 following several years of expanded sorghum plantings in the area. Subsequently, numerous studies have determined that early uniform planting which assured blooming prior to August fifteenth greatly reduced the chances of damage from this pest. However, various factors such as loss of initial plantings to weather and outbreaks of occasional pests (for example white grubs, Phyllophaga spp.), frequently result in a disruption of this cultural technique and production losses of ninety percent may be encountered in these areas. Insecticidal control studies have been continued to assure an effective chemical arsenal to control these sporadic appearances.

Early studies proved DDT to be one of the most effective treatments with other chlorinated hydrocarbons showing little promise. Higher rates with two applications of organophosphates such as disulfoton, carbophenothion, diazinon, parathion and ethion, and a carbamate, carbaryl, are the currently recommended treatments. Studies in Argentina suggested that the same treatments would work in that country.

More recent work has indicated that aerial ULV applications of disulfoton and malathion may be as effective as conventional sprays and the latter is now currently recommended. Ground applications of methidathion, oxydemetonmethyl, azinphosmethyl, and leptophos have

indicated good control capabilities and warrant further evaluation.

The Banks grass mite, Oligonychus pratensis (Banks), has recently become a major threat to grain sorghum production. Although several compounds are currently registered for use in control, variable results are obtained from their application. One of the main reasons for this is acaracidal resistance as indicated both in field and laboratory studies. Seven, eight and fourteen fold resistance levels to carbophenothion, parathion and disulfoton respectively, have been indicated among mites collected from locations in the Trans-Pecos, Texas area.

At Texas Tech, studies are also conducted on the greenbug, corn leaf aphid, white grub, and sugarcane rootstock weevil to aid in the development of a complete sorghum pest management program.

SOME PERSPECTIVES ON INSECT PROBLEMS OF SORGHUM IN BRAZIL

James L. Overman

Brazilian agriculture is in a state of flux in many geographic areas, with the traditional crops such as coffee being supplanted by row crops such as soybeans and non-traditional crops. Sorghum, Sorghum bicolor (L.) Moench, is one of the "new" crops receiving considerable attention from farmers looking for crops that can fit into their new rotational, double cropping and minimum tillage systems. Sorghum also has the potential of being a major crop for marginal land areas, especially where rainfall is a limiting factor.

Insect problems are currently considered as major limiting factors in sorghum production in Brazil. Unfortunately, many cropping systems into which sorghum must fit can be expected to intensify the existing insect problems and/or create new ones. Sound pest management practices need to be developed to enable sorghum to achieve its potential in Brazil.

Insects Associated with Sorghum

The identification of insects associated with sorghum, their geographical and seasonal distribution and their biotic and climatic controls are the basis from which sound pest management systems are developed. However, only in the past few years has sorghum received much attention from entomologists in Brazil. As late as 1967, the IV Catálogo (Silva et al., 1967) listed only 16 insect species attacking sorghum in Brazil. Contarinia sorghicola (Coq.) the most damaging pest of sorghum in Brazil, was not reported in Brazil until 1967 (Rossetto et al., 1967), although a later examination of herbarium specimens

indicated the presence of the midge in Brazil prior to 1958 (Rossetto *et al.*, 1973).

Studies of spittle bugs in the North East of Brazil by Guagliumi *et al.* (1972) have added eight species of Cercopidae to the list of sorghum insects. The green bug, *Schizaphis graminum*, a major pest of sorghum and small grains in the U.S. and Europe, was found infesting sorghum in Brazil for the first time in 1973. It seems quite probable that more intensive survey work, especially in marginal land areas, would reveal several other regionally important insect species.

Table I reflects the current listing of insect species found on sorghum in Brazil. This listing is by no means complete, but only indicates species that have been identified. Current surveys by our group at Sete Lagoas have revealed a variety of species that are unidentified. Many of these are commonly collected in sorghum and probably play an important role as primary feeders, or as parasites or predators. Much more work is required to identify the interrelationships of these insects.

Sorghum Resistance to Insects

If sorghum production is to increase in Brazil, it will depend on the margin of profit realized in relation to alternative crop choices. Control measures for sorghum pests that are expensive to the farmer will inhibit the use of sorghum. The use of chemical controls, although necessary for the moment, are often prohibitively expensive. This is especially true in areas where sorghum only has a marginal advantage over alternate crops or where sorghum is a subsistence crop.

Plant resistance to insects is one promising area of research

Table 1. Records of insect species attacking sorghum in Brazil

Order	Family	Species
Hemiptera	Cynidae	Scaptocoris castanea Perty
Homoptera	Adhididae	Rhopalosiphum maidis (Fitch)
		Schizaphis graminum (Rondani)[b]
	Araeopidae	Peregrinus maidis (Ashm)
	Cercopidae[c]	Aeneolamia selecta (Wlk.)
		Mahanarva fimbriolata Stal.
		" posticata Stal.
		" rubicunda indentata Wlk.
		Zulia entreriana (Berg)
		Deois schach' (F.)
		" flavopicta Stal.
		" incompleta (Wlk.)
Lepidoptera	Noctuidae	Spodoptera frugiperda J.E. Smith
		Mocis latipes Guenée
	Nolidae	Celama sorghiella Riley
	Crambidae	Diatraea saccharalis (F.)
	Galleridae	Corcyra cephalonica (Stainton)
	Phycitidae	Cryptoblabes gnidiella (Milliere)
		Elasmopalpus lignosellus (Zeller)
	Pyralidae	Pyralis farinalis (L.)
	Gelechiidae	Sitotrogo cerealella (Olivier)
Coleoptera	Curculionidae	Sitophilus oryzae (L.)
		" zeamais (Motschulsky)
	Chrysomelidae	Chaetocnema spp.[d]
	Nitidulidae	Carpophilus spp.[d]
	Tenebrionidae	Gnathocerus curvicornia Champion
		Tribolium castaneum Herbst
Diptera	Cecidomyiidae	Contarinia sorghicola (Coquillet)

a. List in accord with that of Rossetto et al. (1972) except where otherwise noted.

b. Specimens collected by Overman, Rossetto, Frederiksen, Schaffert, and Gonçalves.

c. All Cercopidae from the list of Guagliumi et al. (1972).

d. Collected by Overman at Sete Lagoas, M. G.

where pest management can be achieved with little or no additional cost to the farmer. Several research groups or individuals are actively involved in the search for resistance to insects in sorghum. Much of the credit for this interest must go to Rossetto (IAC), a former student of the late Dr. Painter of Kansas. Rossetto has provided guidance and collaboration to many colleagues throughout Brazil.

Most sorghum entomology groups in Brazil have centered their studies on resistance to the sorghum midge. Gonçalves and Rossetto have initiated work on sorghum resistance to the greenbug, Schizaphis graminum, and the stalkborer, Diatraea saccharalis. Preliminary screening of varieties from the world collection is currently being conducted by Faris (Ford Foundation) and Veiga (IPA) in Recife, Martins and Santos from UFC in Fortaleza, Rossetto and Gonçalves (IAC) at Campinas and our group at Sete Lagoas.

Rossetto et al. (1972) have already reported high levels of resistance in the sorghum variety AF-28. These observations have subsequently been reconfirmed by personnel at Recife and Sete Lagoas, and by Lara at Jaboticabal, S.P. Research is also underway to define the inheritance of this resistance and to determine the type of resistance: antibiosis, non-preference, and/or tolerance. Field studies at Sete Lagoas indicate that the resistance is due, at least in part, to non-preference for ovipositioning (Table 2). These conclusions were supported in laboratory studies by Rossetto and Gonçalves at Campinas (personal communication).

Biology of Sorghum Pests

Biological studies of the sorghum midge have been conducted by most of the entomology research groups working with sorghum. Other pest

Table 2. Resistance to the sorghum midge in the sorghum variety AF-28.

Variety	Ave. Number of Visitations[a]	% Infestation[b]	% Damage[c]
SGIRL - MR	48.0	94	80.8
Granador	69.3	93	82.3
IS8361	68.0	56	99.7
TX2536	114.2	96	98.6
BRP3R	104.3	88	99.5
BRP4B	73.9	84	97.5
AF-28	186.0	46	43.0
Leoti	96.0	100	100.0

a. The number of adults found per panicle at 0900 hours during flowering.

b. The percent of flowers containing midge eggs.

c. The percent of florets that failed to develop seed.

problems have received less attention, although Goncalves has initiated studies to determine the biotypes of greenbug in Brazil. Becker (Curitiba) is active in the area of biology and taxonomy of stalkborers.

In 1973 we began field observations at Sete Lagoas trying to identify changes in cultural practices that could reduce the incidence of the midge. The sorghum midge is widely distributed in Brazil, having been observed in all regions where sorghum is produced. The midge has also been observed in initial plantings of sorghum where sorghum was not previously grown. The adult midge seldom lives more than 24 hours and migrates only a short distance from the site of eclosion. These facts suggest the occurrence and importance of alternate sylvatic host plants in the maintenance of an endemic reservior population.

There is general agreement that the midge is relatively host specific, with plant species distantly related to Sorghum bicolor probably not being suitable host plants (Harris, 1963, 1970).

A collection of panicles of "wild" sorghums was initiated in 1974 to evaluate the importance of these host plants in the "epidemiology" of the midge. These sorghums were commonly found along roadsides, lowland areas, fence rows, sorghum plots and abandoned cultivated land. In general these plants conformed to Snowden's 1955 description of Sorghum verticilliflorum. This species is characterized by an open panicle, awns 10-16 mm in length, a fragile raceme that readily disarticulates at maturity and sessile spikelets (Doggett, 1970). Intermediate types are commonly found around the margins of sorghum fields in Africa, where they apparently result from crosses of S. bicolor and S. verticilliflorum (Doggett, 1970) Harlan and de Witt (1972) are currently classifying S. verticilliflorum as a race of S. bicolor rather than a separate species.

The wild sorghum, intermediate types and volunteer cultivated sorghums were collected in July, 1974 during the dry season at Sete Lagoas. They were examined for C. sorghicola larvae. A random sample of panicles from five locations near Sete Lagoas revealed a high incidence of diapausing larvae. An average of 76 diapausing larvae were observed for every 100 florets. The level of aborted florets in S. bicolor var. verticilliflorum was greater than 90 percent. A high incidence of diapausing larvae (170 per 100 florets) was observed in florets that had empty pupal exuviae. A random sample of fallen sessile spikelets had an average of 20 diapausing larvae per 100 spikelets.

The above evidence confirms the importance of wild sorghums, intermediate types, volunteer sorghums and residue of sorghum fields in the maintenance of a reservior of the midge during the dry season.

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THE SORGHUM MIDGE IN MISSISSIPPI - PEST MANAGEMENT

H. N. Pitre, J. P. Roth, and L. M. Gourley

The sorghum midge, Contarina sorghicola (Coquillett) is the principal insect pest on sorghum grain heads in Mississippi. This abstract presents MAFES research findings during 1971-1973 on this pest of grain sorghum in Mississippi and the application of this information in management practices to reduce seed yield losses.

Tillage practices did not appreciably affect winter survival of the midge. Nevertheless, good seed bed preparation for establishment of uniform stands and good cultivation practices to eliminate volunteer sorghum within fields helped to reduce midge population and minimize seed losses. Adults emerged in low numbers from overwintering in johnsongrass and sorghum residue during the first week in April, peaked in mid-May when johnsongrass was in full bloom, and completed emergence by the third week in June. Wheat planted in the fall after sorghum harvest provided a favorable overwintering microclimate for the midge. Adults dispersed from overwintering sites to johnsongrass which serves as a reservoir host for this insect until sorghum is in bloom. The distance that midge dispersed to johnsongrass depended on the availability of this host in bloom. Midge emergence from johnsongrass was highest during July, and the adults completed emergence from this host in October. Peak adult emergence from johnsongrass coincided with first widespread bloom of volunteer and early planted sorghum. Management of johnsongrass along field borders by clipping after peak emergence of midge from overwintering (mid-May) and shortly before first sorghum bloom should destroy the insect, break the cycle of reproduction,

and minimize seed losses if this practice is critically timed.

The number of adult midge infesting the grain head and damaging the crop increased with each delay in planting dates; damage increased from 1% on sorghum planted early (April 28) to 98% on sorghum planted late (July 13). Sorghum in bloom after mid-July was infested by large numbers of midge. Although midge initiate population buildup on johnsongrass, economically damaging populations develop within staggered plantings or plantings that do not bloom uniformly. Midge can reproduce through 9 to 11 generations on johnsongrass and 11 to 14 generations on both johnsongrass and sorghum during the season. Midge were active on blooming sorghum tillers until first frost in November.

Early planting without regard fro midge population on johnsongrass and sorghum bloom date can result in serious seed losses, particularly in small fields. Bloom date should not coincide with peak emergence of adults from johnsongrass in early to mid-July.

When 2 to 3 adult midge per head are observed on sorghum, insecticide should be recommended. The first application should be made when 10% of the crop is in early bloom. Additional applications should be made at 3 to 4 day intervals after the first application if midge are present on blooming heads. Proper timing and rates of insecticide application are critical. Low dosages of effective, recommended insecticides can be used effectively in a good pest management program to minimize the harmful effect of insecticide on naturally occurring beneficial arthropods in the field.

SORGHUM BREEDING AND IMPROVEMENT IN BRAZIL - PROBLEMS AND POTENTIALS*

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Sorghum is a relatively new crop, commercially, in Brazil that appears to have much potential in the future development of agriculture both as a grain crop and as a forage crop. The impact that sorghum will have in the future on Brazilian agriculture is difficult to predict, but is expected to be significant. Experimental yields during the past agricultural year, 1973-1974, in Minas Gerais and São Paulo have been between six and seven tons per hectare of dry grain and greater than thirty tons of forage dry matter per hectare. Although sorghum is not native to Brazil, its center of origin is in the tropics with conditions similar to those of Brazil. The grain hybrids that have yielded well in Brazil are not hybrids that have been developed for the tropical conditions of Brazil, but were developed for the temperate zones of the U.S.A. and Argentina. Even though production has been good, it is logical to assume that yields would be much better if genetic material adapted and developed for conditions of Brazil were used.

The principal regions of Brazil that offer the greatest potential for sorghum production are the semi-arid Northeast, the "cerrado" located principally in the States of Goiás, Minas Gerais, Mato Grosso

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and the Federal District, and the fronteir region with Argentina in Rio Grande do Sul. These regions vary greatly from each other and require separate breeding programs. The semi-arid Northeast has many similarities with parts of Africa and Asia where breeding programs such as ICRISAT already exist. The State of Rio Grande do Sul has many similarities to the temperate regions of Argentina and the U.S.A. where several sorghum research programs exist. The "cerrado", however is unique from any other region in the world that produces sorghum commercially. The soils of these "cerrado" regions are frequently very acid, high in exchangable aluminum, low in exchangable phosphorus and generally have a low water holding capacity. The rainfall in these regions vary from 800 mm to 1,500 mm per year, generally occurring between November and March. In December or January there frequently occurs a "veranico", a period of 20 or more days without rain. These soils frequently have a topography which makes them suitable for mechanized agricultural production and are located in geographical areas with reasonable infrastructure for intensive agricultural development.

Considering these characteristics of the "cerrado" it becomes obvious that sorghum should be a culture that can be adapted to this area. However, two negative factors must also be considered. These are the existence of "native" sorghums, Sorghum verticilliflorum, S. helapense, and possibly other closely related species that are generally distributed in the region that serve as alternate - hosts for diseases and insects and the frequent occurrance of excess rain after maturity and before harvest.

Our research center, IPEACO (Agriculture Research Institute of the Central-West), is located in this "cerrado" region and this discussion

will be primarily limited to the problems in this area and the areas of São Paulo and the Minas Triangle that have red latisols.

The most serious problems encountered to date have been intestations of sorghum midge (Contarinia sorghicola), anthracnose (Colletotrichum graminicola) attacks, and drought stress associated with poor root development in acid soils with high levels of aluminum. Other serious problems have been the greenbug (Schizaphis graminum) and severe weathering. Recently, sorghum downy mildew (Sclerospora sorghi) has been observed and is a potential problem. Several other insects and diseases have been observed and will probably become more serious problems as the area of sorghum production increases.

Sorghum midge has been observed in nearly all the locations of Brazil where sorghum has been produced or research conducted. In many cases midge has been observed in areas where sorghum was planted for the first time indicating a native alternate - host for this insect. In the Northeast and the Central, losses have been up to 100% due to damage caused by this insect.

In 1967 Rossetto and Banzatto reported that the sorghum variety AF-28 was resistant to the sorghum midge in São Paulo. AF-28 is a tall late maturing variety that was introduced into Brazil from Africa many years ago. We have verified this resistance in trials during the agricultural years 1973-1974 and 1974-1975 at IPEACO and it has been verified by others in Brazil. In our trials approximately five percent damage occurred in AF-28 when 100 to 200 midge were observed per panicle at anthesis last year. In contrast, TX2536 and IS8361 B were nearly 100% damaged and SGIRLMR-1 and Granador were approximately 75% damaged when they all flowered at the same time. We are currently studying the

genetic inheritance of this resistance and are attempting to transfer it to more adapted material. Preliminary observations indicate that the resistance is not completely dominant. This is the most promising resistance we have found to date, however, valid comparisons are not available with some of the material recently reported to be resistance from the U.S.A. We hope to have more detailed information by the end of this growing season.

Preliminary results of testing sorghum material for tolerance to high levels of exchangable aluminum in the soil indicate that a wide range of variability exists for this trait. This has been reported in another section of this meeting. We are currently studying the genetics of this trait and are attempting to transfer it to more adapted material. There is also interest in the possibility of more efficient phosphorus utilization associated with tolerance to toxic aluminum. This has been reported in corn by Clark and Brown (1974). We are initiating a program to screen a large number of entries from the world collection and the commercial material available in Brazil for this trait. Preliminary observations indicate that this trait is dominant and that hybrid vigor is present.

Anthracnose is by far the most serious disease encountered in the Central region of Brazil. Studies utilizing the All Sorghum Disease Nursery from Texas A and M University and the Brazilian National Grain Hybrid Trials, indicate that the anthracnose causing serious problems in Brazil is somewhat different from that which occurs in the U.S.A. Some of the material, both commercial and experimental, that has been resistant in the U.S.A. has broken down under our conditions and some material that showns little resistance in the U.S.A. has been at least

partially resistant. We are currently studying the inheritance of this resistance that has been observed in some of the lines from the Texas Disease Nursery and are transferring this trait to more adapted material.

In 1974 the occurrence of sorghum downy mildew (Sclerospora sorghi) was verified in one isolated field in the State of São Paulo. This was the first official report of this disease in Brazil, but further investigations indicated that it has been present in Rio Grande do Sul, the State that borders Argentina, for several years. We are interested in incorporating resistance to this disease in our most adapted material, but due to the low frequency of the disease in Brazil and not wishing to further disseminate the pathogen, this work must be carried on by cooperative projects between Brazil and Argentina and the U.S.A.

Sources of resistances to stalk rots, weathering, Cercospora, sugar cane mosaic virus, foliage diseases, greenbug, stem borer and stored grain insects are being sought to incorporate into our most adapted populations and lines.

In addition to the traits mentioned in the preceding discussion, there exists several other areas of research in which the plant breeder can improve sorghum in Brazil. These include the use of population improvement techniques for improving production utilizing the tropical environment to conduct several generations per year for selection and recombination, improving the nutritional quality by utilizing the high lysine gene recently discovered at Purdue University, developing a sorghum to mix with wheat flour, and utilizing genotypes capable of fixing nitrogen. We have also initiated studies on resistance to stored

grain insects that is a serious problem throughout the tropics. The goal in the work is to increase the resistance of sorghum to the various insects involved using population improvement techniques.

Currently we are testing one intra-population and one inter-population selection technique adapted to the tropical conditions of Sete Lagoas, Minas Gerais. These are briefly described in Tables 1 and 2. We currently have replicated progeny trials in the field. Early indications are that adequate progress can be made and that the techniques are viable.

The high lysine material, IS11167 and IS11758, are being converted to short early lines adapted to the tropical conditions of Central Brazil. Advanced testing will be conducted during the agricultural year, 1975-1976. Adapted high protein, high lysine varieties and hybrids could fill an important gap in the feed industry for swine and poultry. Various methods to improve forage quality are being studied as forage sorghums have a great potential to provide animal feed in the winter (dry) season.

We are cooperating with a private research group to study the fleasability of diluting wheat flour with sorghum flour.

Interest has recently developed for identifying sources of sorghum and millet that fix N_2 since the reports of N_2 fixation in some tropical grasses with C-4 pathways by Dobereiner and Day (1974). We are currently developing a cooperative program with Drs. Dobereiner and Day to screen several sorghum and millet lines for potential ability to fix N_2. Preliminary observations by this group indicate that this trait does exist in sorghum and millet.

The problems and potentials in sorghum breeding in Brazil cover

TABLE 1 - An intra-population improvement model for the Central region of Brazil.

Generation	Season	Operations
1	October-January	Select 1000 to 2000 unbagged panicles from male-fertile plants in a random-mating population practicing visual mass selection.
2	February-May	Plant one row plots of these S_1 selections.
		Self-pollinate three or four fertile plants in each row. Select 200 to 400 S_1 rows using visual selection or panicle weight.
3	October-January	Plant replicated yield trial using seed from self-pollinated plants in selected S_1 rows. Select the best 20 to 80 S_2 entries to form the recombination generation.
4	February-May	Plant an isolated recombination block using remnant seed from selected S_1 entries. 1/6 of the plants will be male-sterile which should be tagged and used to plant the first generation of the next cycle.

TABLE 2 - A model for full-sib reciprocal recurrent selection in random-mating B and R populations of sorghum (Inter-population improvement).

Generation	Season	
1	October-January	Select approximately 500 unbagged panicles from fertile plants in each of a random-mating B and R population practicing visual mass selection (panicles from male-sterile plants could also be used).
2	February-May	Plant one row plots of these S_1 selections from the B and R populations in paired rows at a low plant density to insure tillering. Select a male-sterile plant in one row and cross it with a male-fertile plant in the other row of the pair*. A tiller of the male-sterile plant should be sib-mated using pollen from several fertile panicles within the row. If this is not possible a composite of self-pollinated seed of full-sib plants can be used in the recombination cycle. The male-fertile plants used in the cross should be selfed.
3	October-January	Plant replicated yield trials of the F_1 hybrids, selecting the best 10 to 20% of the hybrids. (Note that the parents of selected hybrids can be used to form B and R-lines for potential use in commercial hybrid production).
4	February-May	Plant an isolated recombination block using selfed and sibbed seed of the parents of selected hybrids for each of the B and R populations. A small proportion of the plants will be male-sterile and should be tagged and the seed composited to plant the first generation of the next cycle.

*In order to avoid unpredictable height variation in the hybrid trials, one parent should be a four dwarf and one parent should be a three dwarf.

a wide area. We are giving top priority to solve the problems directly associated with production and as our program expands we will be able to give more attention to the areas that will give the crop more value.

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PROBLEMS AND LIMITATIONS OF SORGHUM INTERNATIONALLY

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I have assumed that the title given to me for this paper is intended to cover those problems and limitations of the sorghum crops which are of general concern to several countries, if not all countries which grow this crop..

The requirements of any good sorghum are high yield, and good grain quality. In the semi-arid tropics, stability of yield is even more important than high yield, because storage and transport are limiting factors. The problems of moving food into an area when production has fallen short may be great - conversely, marketing an unusually large surplus can lead to similar difficulties. At ICRISAT, we regard our basic objectives as good, stable yield, combined with good grain quality

Yield

Yield limiting factors are numerous and widespread. Inadequate or maldistributed moisture supply and low soil fertility levels are major factors limiting yield internationally. Neither of these problems can be tackled by improved plant types alone. Farming systems which make the best use of the available moisture, and which maintain and increase soil fertility using inputs which are within the economic reach of the small farmer, are a fundamental requirement if the problems and limitations of sorghum are to be met. This is the reason that ICRISAT has a strong farming systems component in its program. For this work to have value

internationally, it must link in very closely with similar research being carried out in other parts of the semi-arid world. Hence, the need for a network of research activity, which we prefer not to regard as outreach. We hope to be cooperating with research scientists through the semi-arid tropics in solving common problems. There will be a lot of inreach as well as outreach, and it seems preferable to emphasize cooperation, rather than to imply the handing out of wisdom from the central institute.

It will be necessary to strengthen the research work in Africa, with both scientists and money, and the most acceptable way of doing this in an efficient manner is being explored in each are now. The availability of agricultural scientists is not a limiting factor in India, but more money needs to be spent on the improvement of the sorghum crop and on the farming systems in which it is involved, if progress is to be made swiftly. The Central and South American situation is probably intermediate, and there is a great need for the creation of a cooperative international network of scientists through the sorghum growing areas of the world.

Farming systems research at ICRISAT involves a study of the most efficient way of utilising as much of the rainfall as possible falling on the land within individual catchment areas, without using water from external sources. Secondly, we are looking at cropping systems which conserve water, and which use fertility well. Intercropping, especially of cereals with legumes, is receiving special attention. A research area needing more exploration is that of the nitrogen fixing bacteria occurring in the sorghum root zone; there may be cultural methods which encourage their activity, and sorghum varietal differences in

suitability as hosts for these bacteria.

We need more work on the utilization of mineral nutrients by sorghums. Some varieties seem to take up nitrogen more efficiently than others, and the great frame of the tall, late, tropical sorghums may accumulate minerals which are mobilized and used by the developing grain after flowering. Little is known about this. Where moisture use is concerned, there are large varietal differences in drought endurance, and more study of root systems and of the capacity of the vegetative tissue to endure stress, are required. Perhaps most progress can be made by adjusting length of maturity to match critical stage of crop development (growth stage 2) to the most reliable rainfall period in the distribution. This may require very early varieties, and types which ratoon well. Often short term varieties would best be planted late in the season, and here we run into the complex problems of fertility, and insect pests. Also, short term types will often ripen in wet conditions, so resistance to grain moulds, or protection from them by large glumes, becomes essential. Such short term sorghums must evidently be photoperiod insensitive. A whole series of problems require solution as soon as we try to fit short term sorghums into longer term rainy seasons in order to make best use of the moisture, and to give increased reliability of yield.

The second international problem on sorghum is insect pests. Those who live in the developed world can have little realization of how serious pests are to the sorghum farmers in the developing world. Stem-borers are most damaging when the growing conditions for the plants are poorest, so the greater the drought stress, or the lower the fertility level, the more devastating the stem-borers become. Pests such as

shoot-fly, which are serious on delayed plantings, can be controlled by using carbofuran, but this chemical is both poisonous and expensive. Here, plant resistance must be the main defence, and fortunately, prospects are good; there is a primary resistance discovered and developed in India, and a recovery resistance discovered and developed in Africa. It looks as though the combination of the two may be sufficient to withstand shoot-fly attack, except under the most unfavourable conditions. Midge can be another problem, particularly when short term improved types are being introduced into areas where the indigenous sorghums are long term. There must be many cases in which the additional yield from the improved varieties has been much more than offset by the loss in yield from the indigenous varieties, through the midge build-up on the new short term types. Fortunately, good resistance to midge seems to be available, and at ICRISAT it looks as though the combination of shoot-fly resistance and midge resistance may already be present in some of our material.

Chemical protection undoubtedly has a part to play in defending the farmer against insect pests, but it is the larger farmer who can best use such inputs. There seem to be two possible ways in which to attempt to help all farmers, including the small farmer. The first is by better agricultural practices, restricting the build-up of the pests. Intercropping, without the use of chemicals, may help a little in this direction. Suitable rotations and plant sanitation are obvious measures. A second approach is the use of viruses pathogenic to the pests. There is evidence that these can be very effective against Lepidoptera, which take a serious toll of the crop, mainly as stem-borers, and ear-head caterpillars, notably the omniverous Heliothis.

The Agoumis grain moth Sitotroga is a serious storage pest, and there are other moths such as Ephestia which can also be damaging to stored grain. The potential for using pathogenic viruses in the developing world seems to be great; the production of the virus inoculant is a labour intensive process, and so can be done far more cheaply in the developing world than in countries such as the U.S.A., without the expenditure of foreign exchange. The use of these viruses is also unlikely to pose a threat to those predators which already have some contribution to make towards pest control. In this great problem area of insect pests, the highest obtainable level of resistance must be sort in the sorghum cultivars, but improved farming methods and control by insect viruses or similar means are quite essential if the problem is to be overcome.

Another international problem which inhabitants of the New World seldom appreciate is the devastating damage done by the witchweeds, Striga, spp. These parasitic weeds, indigenous to Africa and India, build up in vast numbers as soon as sorghum is grown too frequently on the same land, without suitable rotation. It is far from certain that any rotation suited to intensive cropping could keep the level of infestation by this parasite down to an acceptable level, without supplementary measures. Very extensive areas of arable land of Africa, and some in India, have been rendered unfit for cereal cultivation, and certainly for sorghum cultivation, through the build-up of witchweed. These parasites have minute seeds which can remain viable in the soil for more than 10 years, and which can only be germinated after an appropriate pretreatment with moisture at certain termperatures, followed by the action of a stimulant solution produced by the root of the host plant. The

attack on this problem includes host plant resistances, and much useful screening work has been done in Nigeria under Project 26. However, resistance is insufficient to prevent large numbers of the parasites emerging above ground, flowering, and distributing millions of seed. Other important control methods under study include artificial stimulants to germinate the seed in the soil in the absence of their host. Strigol has been identified as the agent involved in nature, but research indicates that ethylene, and various synthetic compounds containing a small segment of the strigol formula, will also germinate pre-treated Striga seeds. Kinetins seem able to germinate all Striga seed, whether pre-treated or not. The use of measures of this kind will be essential to bring Striga infested land back into production. Trap cropping, the growing of a susceptible crop and ploughing it in before the Striga has flowered, is an additional, or an alternative procedure. Weeding to remove all Striga before it has flowered is essential to prevent build up, and in Nigeria spot spraying with herbicides is being used for this purpose. Undoubtedly, crop rotation can play some part in keeping down the level of infestation, some crops produce strigol and so germinate the Striga seed, but are unsuitable as hosts for the full development of the parasite. The natural stimulant strigol was extracted from cotton roots.

Sorghum diseases are fortunately less of a problem and limitation in the developing world, than factors already mentioned. We cannot be complacent about this, downy mildew is proving troublesome in the U.S.A. and may yet become much more serious in the semi-arid tropics, but generally in the semi-arid tropics this disease takes only a modest toll of the crop, which may relate to the temperature requirements of the

pathogen. The seed borne diseases, such as the smuts, and Helminthosporium, which are among the greatest causes of yield loss through disease, can fortunately be controlled economically by dressing the seed. Once the regular provision of fresh seed becomes a characteristic of the agricultural pattern, as it one day must, this particular set of problems will disappear.

The second aspect of yield, which is the development of genotypes having an inherently high yielding capacity, will also become important, although it should be noted that known technology could increase yield from existing cultivars by a factor of two or three times without recourse to types with a higher yield potential. Thus, Dr. N.G.P. Rao, Co-ordinator of the All India Sorghum Improvement Program, has pointed out that the average yield of sorghum in India is 3 grams per plant, and no very complex technology is required to increase that yield to 6 grams, or even 9 grams per plant. The benefits of hybrids, with their capacity to yield better than varieties even under adverse conditions, are too well known to require comment. We think that recurrent selection methods applied to composite sorghum populations hold out great hope of producing both better varieties, and better hybrid parents. With the aid of an international network, and selection under a wide range of environmental conditions, we believe that it will prove possible to get broad adaptation in varieties. These are certainly important initially, until seed production facilities for hybrids are much more widely available in the developed world than is now the case. Evidently we shall be trying hybrids also, and the existence of wide adaptation in hybrids is clearly attested by the performance of NK300 in so many parts of the world.

Our Plant Physiologist is looking at more efficient plant types, picking up some of the approaches pioneered by the Plant Physiologists at Lincoln, Nebraska. A large seed with a large germ may give better establishment, and perhaps a larger bud when floral initiation occurs; the time from initiation to flowering involves much competition between the developing panicle and the unfolding of a large number of leaves in the sorghum plant, and is therefore very susceptible to stress. There are types which unfold few leaves during this period, so there is scope for the plant breeder here. Once the plant has endured all the vicissitudes of the growing season, and set seed, we may be able to lengthen both the rate and duration of the filling of those seeds, thus somewhat increasing yield. All these aspects will no doubt be dealt with much more clearly and thoroughly by other speakers at this conference.

Quality

Quality is an area of neglect, because research workers in the countries where most sorghum research has been done have been concerned more with live weight gains in ruminants, poultry, or swine than with food for people. I believe that the fundamental question has never been asked, or at least made a matter for investigation, "why is sorghum a coarse grain?" That it is a coarse grain is beyond doubt, everyone chooses rice and wheat first, maize is often third on the list, although by no means always so, while sorghums and millets have a much lower rating. The glib explanation of this ranking is to say that rice and wheat are prestige grains, which are eaten by the wealthier classes, and are therefore symbols of success. Sorghum is eaten by the poor. However, these taste preferences are so widespread, that we ought to

enquire whether this is an adequate explanation. It may be significant that rice, the most highly prized grain, has virtually no prolamine; wheat, which comes next on the list, has a moderate prolamine content. The coarse grains, including maize, are generally characterized by a substantial prolamine content. Dr. Lloyd Rooney's results indicate that some of the digestibility problems in sorghum are due to the protein matrix in which the starch grains are held, especially towards the outer layers of the endosperm. I suggest that it might be valuable to breed sorghums with a low prolamine content, and to investigate the effect on quality. In purely practical terms, a high protein content may be important for an operator making his profits from feeding valuable grains to ruminants, but in terms of the developing world, the situation deserves another look. The evidence suggests that adults require only some eight percent of protein in their diet, provided that the protein is biologically well balanced. It may be much more logical to breed cereal grains adapted to the needs of the adult population, and to supplement for infants and growing children with other foods, rather than trying to produce high protein, high lysine types. The evidence from the Purdue trials last year suggests that NK300, which does not have a particularly high protein percentage in the grain, in fact produces the most protein per acre. The current grandiose phrase "protein-calory-malnutrition" is surely only another way of saying that people are hungry because they are short of food.

Quite a lot of the segregates from crosses made by Dr. John Axtell and his colleagues at Purdue between the Ethiopian high lysine sorghums and Purdue populations, sent to us at ICRISAT, are segregating for high lysine, with protein levels around eight percent. There are some

sorghums in the World Collection which have similar characteristics. I suggest that we should look much more carefully at the factors which distinguish a coarse grain from a quality grain, we may well be able to produce a sorghum type which is not despised, but which is valued in its own right for its quality and flavour. Certainly there is a most interesting range of material in Ethiopia, where people have depended on sorghum for several thousands years and have selected some very good culinary types. Much collecting needs to be done there still, but one interesting cultivar which came to us recently, has a name in the local language which means "If you have this sorghum, why bother about wheat?" and it has a distinctly wheat-like flavour. These people in the Ethiopian highlands are also wheat eaters. There is an area here requiring a lot more investigation. I have not mentioned all the obvious characteristics of sorghum grain quality, because they are already very well known to the delegates at this conference.

Birds

I have left bird damage until last, because it involves an interaction between yield and quality. There is no reason to believe that sorghum is unusually susceptible to bird damage, when compared with rice, wheat, or other small grains, grown on a wide scale. All countries have had to come to terms with the ravages of the local grass-seed eating birds on their grain crops. Extensive areas of cereals, relative to bush, scrub, hedge row, and other places where the grass-seed feeders can lurk, have led to a balanced situation, in which losses from birds may be annoying, but are no longer crippling. There is no reason to believe that sorghum would be any different in relation to the

normal indigenous grass-seed eating bird population. Better organized agriculture will solve much of this problem in most places. However, there is one situation in Africa which is in a different category. Quelea, the Sudan Dioch, or red-billed weaver bird, does devastating damage in the savannah areas of Africa, moving in great swarms like locusts. I am sure that this particular species must be dealt with like locusts. We need thorough studies of its life-cycle, and the bird must be attacked wherever possible by appropriate techniques to kill it. There is no other solution, it is a hard choice between birds and people. In the areas where these quelea occur, the only worthwhile resistance is given by the bitter polyphenols which occur in types with a persistent integument under the seed coat. This is an effective mechanism as long as these quelea have enough grass seed and other food to eat; only when the alternative food has been exhausted do they move in and destroy the so called "bird resistant" types. The use of these sorghums, necessary for the present, cannot be regarded as a long term solution. The grains that are unpalatable to the birds are unpalatable to the people also; various methods of food preparation, involving soaking, or malting, are used to make these grains more palatable, but they are never going to be competitive with maize, which is ready wrapped to protect it against the birds, and so a crop which is more susceptible to drought stress, and more demanding in fertility requirements is being and will be grown where sorghum should be the main cereal. Dr. John Axtell has demonstrated that many of the types containing these polyphenols have less available protein, because of the complexes formed between the polyphenols and the protein molecules. I see no long term answer here, other than physical control of the

quelea populations and better agricultural landscaping permitting the growing of sorghum varieties and hybrids of high grain quality, palatable and desirable for human food.

Gentlemen, I much regret my inability to present this paper to you in person.

THE GENETICS OF TEMPERATE AND TROPICAL ADAPTATION IN SORGHUM

J. R. Quinby[1]

It became apparent more than 30 years ago as the study of the inheritance of maturity in sorghum was well under way (Quinby and Karper, 1945) that a recessive at the first maturity locus produced temperate adaptation. Farmers in the United States had selected several recessive mutations from a single tropical variety and Early White Milo and Double Dwarf Yellow Milo were being grown extensively on farms. When these two varieties were crossed, the resulting F_1 plants were tall and late. It was apparent that the phenotype of the tropical variety that had been introduced more than fifty years earlier had been recovered. The conclusion drawn from this information was that the difference between tropical and temperate varieties is simple genetically and is nothing but a difference in maturity. Later, when Hegari, Early Hegari, and Fargo were identified for maturity (Quinby, 1967), it was realized that a recessive at any one of the four maturity loci results in temperate adaptation.

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The idea that a tropical variety could be converted into a temperate variety simply by substituting a recessive maturity allele for a dominant one was the basis of starting a program to convert tropical varieties to temperate adaptation. Several hundred tropical varieties have now been converted to temperate adaptation and short stature by the U. S. Department of Agriculture and the Texas Agricultural Experiment Station, and by at least one seed company. The idea was to make tropical germplasm easily available to plant breeders in the temperate zones. The conversion program has been described several times. (Stephens *et al*. 1967, Rosenow. 1967; Quinby. 1968; Johnson *et al*. 1971)

It has become apparent that some tropical varieties are resistant to many of the diseases and insects that plague sorghum in the temperate zones including anthracnose (*Colletotrichum gramimcolum* (Ces.) G. W. Wils), downy mildew (*Scerspora sorghi* Weston and Uppal), and maize dwarf mosaic virus (MDMV). Resistance to the sorghum midge (*Contarina sorghi-cola* Cog.) has been recognized in several of the converted tropicals (Johnson, Rosenow, and Teetes, 1973). This resistance seems to be inherited as a dominant character and will undoubtedly prove to be useful. A biotype of the aphid (*Schezaphis graminum* Rond.), a pest of wheat that we call the greenbug, attacked sorghum in the Great Plains in 1968 and is apparently becoming resistant to the insecticides commonly used to control it. Resistance to this aphid is present in a few of the sixty tropical conversions distributed originally. The resistance is more apparent in hybrids made with the resistant varieties than in the varieties themselves. This seems to indicate that hybrid vigor contributes to resistance or that there are complementary factors for resistance.

Even though the most obvious contribution of converted tropicals to temperate plant breeding is in resistance to diseases, at least two of the originally distributed converted tropical varieties, both from Ethiopia, make agronomically suitable hybrids. Because of their resistance to diseases and insects, as well as their vigor, these hybrids will undoubtedly soon be in commercial production.

It is obvious by now that tropical germplasm will be useful in the temperate zones, but tropical plant breeders may not be aware of the possibility that the conversion program in the United States may be useful to them. Because the difference between temperate and tropical adaptation is only one of maturity, at least two possibilities for tropical plant breeders to use the converted varieties are obvious.

Firstly, if sorghum breeders working in the tropics are interested in short stature, short parental lines with tropical maturities could be selected from the last backcross F_2 populations. I am sure arrangements could be made to get the needed seed from the USDA and the Texas Station.

The second possibility is to produce female parents that are dominant $\underline{Ma}_1$ so that hybrids of tropical maturities could be produced using the converted tropical varieties or the many temperate parents presently being used to make commercial hybrids for the temperate zones. The genetic constitution of some of the possible parental lines is shown in Table 1.

Table 1. THE MATURITY GENOTYPES OF TEMPERATE PARENTS THAT PRODUCE TROPICAL HYBRIDS

Parents	Genotype
Female	$\underline{Ma}_1\underline{ma}_2\underline{ma}_3\underline{ma}_4$
Male	$\underline{ma}_1\underline{Ma}_2\underline{Ma}_3\underline{Ma}_4$
Female	$\underline{Ma}_1\underline{ma}_2\underline{Ma}_3\underline{ma}_4$
Male	$\underline{ma}_1\underline{Ma}_2\underline{ma}_3\underline{Ma}_4$

Female parents of the genotypes $\underline{Ma}_1\underline{ma}_2\underline{ma}_3\underline{ma}_4$ and $\underline{Ma}_1\underline{ma}_2\underline{Ma}_3\underline{ma}_4$ are early in maturity in the temperate zone. Most parental male parents are of the genotypes $\underline{ma}_1\underline{Ma}_2\underline{Ma}_3\underline{Ma}_4$ or $\underline{ma}_1\underline{Ma}_2\underline{ma}_3\underline{Ma}_4$. This being true, a commercial seed company in one of the temperate zones could produce tropical hybrids using two temperate parents because the hybrids would be heterozygous dominant at all maturity loci and would be tropical in adaptation. Thus, only an evaluation program of hybrids in the tropics would be needed. This might be particularly useful in Australia where the seed producing area is in the more temperate area, but hybrids of different maturities are needed in the more tropical area. At least one tropical hybrid with two temperate parents is already in production.

The converted tropical varieties, when grown in the temperate zones, vary in time of flowering from 60 to 85 days after planting. The early flowering temperate lines make early maturing tropical hybrids. The late flowering temperate lines make late flowering tropical hybrids. For these reasons, it is thought that the tropical conversion program in the United States will result in hybrids adapted to any area of the tropics from which converted varieties came originally, provided the dominant tropical alleles at maturity loci 2, 3, and 4 are in the converted lines.

It has become apparent rather recently that there is a problem in the conversion of tropical varieties to temperate adaptation that was not anticipated at the inception of the conversion program. There appear to be linkages between maturity and height genes and the linkages are a problem because of the need to have the converted varieties recessive at three or four height loci. If the linkages are not broken, the converted tropicals will have the same maturity genotype as the short, temperate, non-recurrent parent. Information on the linkage relationship is just now being accumulated; and, before long, the amount of work needed to break the linkages should become apparent. However, the linkages appear to be broken with some frequenc; otherwise, all of the converted varieties started on the same 4-dwarf non-recurrent parent would have the same duration of growth. Since this is not true, it is apparent that the linkages break during the conversion process even when no great effort is made to recognize the crossovers.

The conversion of tropical varieties to temperate zone adaptation continues. The sixty tropical varieties converted originally represent many of the botanical working groups of the world collection. More recently, the effort has been to convert the best tropical varieties in use throughout the tropics. A proper evaluation of varieties in the world collection is a monumental task. It would be helpful if you in this audience would point out the best varieties known to you so that they could be put into the conversion program if they are not there already. We need more information about agronomic traits and insect resistance like that presented by Sundaram (1972) on resistance to diseases in the world collection of sorghum varieties.

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USE AND POTENTIALS OF THE SORGHUM CONVERSION PROGRAM TO REDUCE GENETIC VULNERABILITY IN SORGHUM[1]

K. F. Schertz[2]

INTRODUCTION

Consumers, farmers, seed producers, and breeders all desire that the best and highest-yielding varieties be grown. This unanimity of purpose results in the near uniform planting of the same or similar varieties throughout extensive regions. One undesired result of this unity is a near uniform response of a crop to biological or environmental hazards. Such is genetic vulnerability.

Genetic vulnerability brings to mind the corn leaf blight problem in 1970. But we have had many previous reminders. The Irish potato famine in the 1840's and the coffee rust epidemic in the 1870's in Ceylon and again in 1969 in Brazil are all reminders of genetic vulnerability. Bananas have been hit by Panama disease and Sigatoka disease. Wheat rust epidemics, dating back to at least 700 BC, all attest to this problem.

Contribution from the Agricultural Research Service, USDA, and the Texas Agricultural Experiment Station, Soil and Crop Sciences Department, Texas A&M University, College Station, Texas.

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What about sorghum (Sorghum bicolor (L.) Moench); is it vulnerable? It surely is. Many hybrids have similar parentage, and all have milo cytoplasm. The remedy, of course, is the introduction and use of diversity. Fortunately, individuals working on sorghum have had the vision to develop programs to reduce sorghum vulnerability. The Conversion Program is one part of the total effort in this area. I will describe what the Conversion Program is and point out ways in which it does or could provide diversity. Among these I will provide details on a program with which I am particularly concerned, that of finding new sources of cytoplasmic-genic sterility.

WORLD COLLECTION

A major program to collect and classify sorghum lines was begun in 1957. Many organizations and people have participated in this work centered in India with Rockefeller Foundation coordination and PL 480 support. Sixteen thousand entries have been gathered. Seed of these have been increased in the western hemisphere, and most of them have been made available to private and public breeders. Most lines are of tropical origin, and many will not mature in the temperate zone because of their short-day-photoperiod requirement.

CONVERSION PROGRAM

To be of use in the temperate zones, sorghum must not

have a requirement for short days to induce flowering, as do most tropical lines. Instead, the plants must be relatively day neutral for flowering control. Fortunately, Quinby (3, 4) had determined the genetic control of flowering, and a breeding program for changing varieties from short day to temperate zone adaptation was plausible. R. D. Lewis, then director of the Texas Agricultural Experiment Station, asked for a proposal to accomplish the purpose. J. C. Stephens developed a plan (7) using backcrossing cycles. The Texas Agricultural Experiment Station and ARS, USDA cooperated in the project which has come to be known as the Conversion Program, for the conversion of tropical types to temperate adaptation. Genes for temperate adaptation and for shortness are transferred. The Conversion Program involves backcrossing cycles. Each cycle includes a crossing generation in Puerto Rico, an F_1 generation in Puerto Rico, and an F_2 generation in Texas, in which short early plants are selected Cycles are repeated until the desired number of backcrosses, currently four, are obtained.

The Conversion Program was started in 1963. To date, 183 fully converted lines have been released. In addition, temperate bulks and tropical bulks were released from each final conversion progeny. During the conversion of the first group of lines, many desirable types were observed, and 40 bulks of partially converted materials were released, so the

newly available diversity could be used rapidly. None of these releases was intended to be an improved variety, but was made available for breeding.

Another 120 converted lines and their temperate bulks have just been released, and tropical bulks will be ready soon. About 1,000 other lines are in various stages of conversion, and it is anticipated that some of these will be ready for release within one year.

USE

Many of the released lines represent types that have not been readily available in temperate zones, and some of them posess characteristics difficult to obtain by other means. Released jointly by the Texas Agricultural Experiment Station and the USDA, they are available to public and private employees. Some companies have their own conversion programs and therefore additional sources of diversity.

Use of the converted materials varies among the breeding programs. In some programs, little or no direct use of the materials has been made for reasons of program objectives, availability of other materials, and staffing situations. Others use converted lines directly, cross onto elite lines, select specific characters from them, or develop populations from them. Considerable progress in selecting for yield improvement has been reported for some of these populations, and we expect even more progress. There are some miscon-

ceptions about the roles of population breeding and the Conversion Program. Some speak of them as competing systems, whereas they are and need to be complementary. In fact, converted lines are the main sources of diversity on which progress depends in many of the populations. Tropical bulks have been sent to several breeding programs in the tropics and provide excellent opportunities for selection of higher-yielding materials adapted there.

From the Conversion Program have come specific desirable characters, sometimes the best or only available source of such characteristics. Notable among those observed are resistance to downy mildew, Fusarium head blight, anthracnose, charcoal rot, Helminthosporium leaf blight, gray leaf spot, lodging, and grain weathering. Also significant are resistance to midge, Banks grass mite, and greenbug.

Some of these characteristics have contributed to newly released parents and hybrids. For example, 'TAM 428' is an improved pollinator with high levels of disease resistance to downy mildew, head smut, anthracnose, and maize dwarf mosaic. Midge resistance of 'TAM 2566' makes it a particularly valuable release that traces back to the Conversion Program.

POTENTIALS

Let us consider the characteristics for which breeders are looking and which may be available in converted materials, especially, but not limited to, those characteristics which

have an effect on vulnerability.

1. Greater nuclear diversity. At present parents of hybrids, particularly the females, are quite similar. By estimation, one pollinator is used to produce more than 50% of the hybrids. Greater diversity would be desirable.
2. Cytoplasmic diversity among females and hence among hybrids. I will discuss this in more detail later.
3. Improved combining ability. Types with improved combining ability may be found among the converted lines, or from the populations or progenies derived from those lines.
4. Insect resistance. Any advance in this area could help reduce vulnerability to insects, which are an increasing problem with intensive sorghum culture.
5. Disease resistance. Converted lines have provided resistance to some diseases and hold promise for others. Perhaps proper recognition and manipulation of sources of resistance will not only solve present, but avert potential problems.
6. Improved water-use efficiency. In many areas water is becoming increasingly scarce. Water-use efficiency might vary among the sorghum lines in the world collection.

7. Moisture stress. We have a recent example of what drought can do to food supply worldwide. Sorghum is considered to be relatively drought tolerant, but research indicates diversity within the species for this characteristic. Some converted lines seem promising.

8. Fertilizer-use efficiency. Lack of sufficient fertilizer affected grain production this past year. Lines of sorghum that could more efficiently use fertilizer could reduce vulnerability to this environmental hazard.

9. Solar-energy-conversion efficiency. Converted sorghum lines have diversity for leaf size, shape, and orientation. Perhaps these characteristics, interacting with cultural practices would affect productivity. Photosynthetic efficiency per se also needs to be considered.

10. Improved digestibility. Any improvement in digestibility is 100% effective, so even a slight improvement is worth seeking.

11. Improved protein quantity and quality. Already the Conversion Program has provided a line with higher lysine, and another high lysine line is being converted.

12. Diversity should be sought for other traits such as

root characteristics, cold tolerance, night respiration rate, tolerance to herbicides used on grassy weeds, improved threshing, and resistance to grain weathering.

CYTOPLASMS

There are, therefore, many ways in which the Sorghum Conversion Program can reduce genetic vulnerability and contribute to improved characteristics. Of these, I will describe in detail diversity of cytoplasms. Before 1970 not many would have considered this topic important. But we all now understand what we earlier learned, that plants differ in cytoplasmic as well as nuclear hereditary determiners. Maize with T cytoplasm was severely affected by corn leaf blights in 1970.

In grain sorghum, all hybrids have milo cytoplasm, because all are made with the same cytoplasmic-genic male sterility system. If susceptibility associated with milo cytoplasm should develop, hybrid production might be jeopardized. We do not have another system of producing hybrids in sorghum.

Some work has been devoted to this problem, and some encouraging findings have been reported. W. M. Ross (5) developed and released 'Combine Kafir 60' lines in a series of different cytoplasms (Table 1). The sterility reactions are the same as that of Combine Kafir 60 in milo cytoplasm, but

since the cytoplasms are from different sources they may differ in reaction to biological or environmental hazards and should be used in breeding programs.

Webster and Singh (8) have reported a male sterile in variety '9E' from Ghana. It is maintained by kafirs, but also by milo (Table 2). Thus, it is apparently a new cytoplasmic-genic sterility system. Indian workers, Nagur and others (1, 2), have reported on male sterilities which they feel are different from the milo-kafir system now in use (Table 3). Also others, including private breeders, have been looking for new sources of sterility.

In our studies (6) seeking new cytoplasmic-genic sterility systems we have depended heavily on the Conversion Program. Converted lines in their original cytoplasms have been reciprocally intercrossed, each line has been crossed onto 'A3197' and as the female in a cross with 'B3197'.

The intercrosses have produced many steriles in F_1s and F_2s (Table 4). Nearly all the F_1 steriles and many of the F_2 steriles probably have nuclear control. Some, however, are controlled by cytoplasmic-nuclear interaction, as indicated by differences between reciprocal crosses. Steriles have been backcrossed to the male parent of the original cross, bc_1 progenies have been observed, and bc_2 seed have been produced on some. Among these, three lines appear to be sources of cytoplasm for male sterility (Table 5).

But this appearance does not mean that they are different from our present system. The crosses with A3197 and B3197 indicate about the similarities of sterility systems. To determine if any of the female parents of the F_2 progenies with sterile plants had a cytoplasm different from that of milo, each was used as a female in a cross with B3197. Lack of sterile plants in the F_2 of this cross would indicate that the cytoplasm of the female parent differed from that of milo.

We are quite confident that we have new cytoplasmic-genic sterility systems, but they still need to be made useful. Promising lines need to be backcrossed, and reliable steriles will need to be developed. Not all steriles remain such during backcrossing.

Assuming that we do develop a new useful cytoplasmic-genic sterility system, what happens then? To increase diversity we must use the new sterility system. Just having such a system does nothing to reduce vulnerability. There are several ways in which breeders might use new systems. (1) Presently used lines could be sterilized and held until a need for their use arises. (2) Some present hybrids might be produced in the new cytoplasms. (3) Hybrids could be produced with a mixture of cytoplasms. (4) Entirely different hybrids with different cytoplasms might be possible. Whatever method is used there will be extra cost involved, but hybrids might be assured against a uniform

catastrophe.

As spin-off from this work on cytoplasms is the possibility for greater nuclear diversity among female parents. Such diversity may prove to be even more important than new sterility systems. At present, because of the necessity for the milo-kafir interaction to cause sterility, diversity among female parents is limited. The use of new cytoplasmic-genic sterility systems could allow the use of entirely new types of females and thus dramatically broaden the base of nuclear diversity.

SUMMARY

The Sorghum Conversion Program is the source through which tropical types in the World Collection are made available to breeding programs in the temperate climate. It provides material for breeding programs to improve such characteristics as disease resistance, insect resistance, drought tolerance, sterility, yield, and grain quality. It even provides superior material for breeding programs in the tropics.

We need to fully use this diversity, both nuclear and cytoplasmic, in breeding programs. By such use, genetic vulnerability can be reduced.

Table 1. Cytoplasmic-genic male sterile lines of CK 60 in different cytoplasms developed by Ross.*

Line	Cytoplasm source
KS34	*Sorghum arundinaceum* (Willd) Stapf
KS35	S. *arundinaceum*
KS36	S. *verticilliflorum* (Steud.) Stapf
KS37	S. *sudanense* (Piper) Stapf
KS38	S. *conspicuum* Snowden
KS39	S. *niloticum* (Stapf ex Piper) Snowden

* Adapted from Ross and Hacherott (5).

Table 2. Sterility reaction of 9E cytoplasm of sorghum.*

Cross	Reaction
9E x Leoti	Sterile
Leoti x 9E	Fertile
9E Sterile x milo	Sterile
9E Sterile x durra	Sterile
9E Sterile x broomcorn	Sterile
9E Sterile x sorgo	Sterile
9E Sterile x feterita	Fertile

* Adapted from Webster and Singh (8) and personal communication.

Table 3. Sterility reaction of Nagur cytoplasms of sorghum.*

Sterile	Varietal source	Sterile x B CK 60	A CK 60 x maintainer
ms G1	durra	Sterile	Fertile
ms VZM1	durra	Sterile	Fertile
ms VZM2	durra	Sterile	Fertile
ms M35-1	dochna	Sterile	Fertile
ms M31-2	cernuum	Sterile	Fertile

*Adapted from Nagur (1).

Table 4. Sterility reaction in F_2 progenies of sorghum, 1974.

Female parent		No. of F_2 progenies with steriles
IS	SC	
5322C	250	1
1116C	195	5
6705C	265	1
7274C	272	4
7909C	282	1
7920C	299	3
7534C	289	1
7007C	268	4
7502C	374	9
1598C	214	3
2482C	311	3
2483C	309	3
2266C	93	7
2403C	103	1
3063C	333	1
7382C	344	1
7248C	366	1
7720C	380	1
7506C	407	5

Female parent		No. of F_2 progenies with steriles
IS	SC	
2573C	64	2
12662C	171	8
2549C	228	1
2816C	120	4
12609C	109	1
12666C	175	1
12677C	186	3
12678C	187	1
12679C	189	2
7498C	353	3
12565C	50	1
1022	105	9
1056	233	3
12683	221	3
1112C	193	9
12617C	126	5
12645C	154	4
12622C	131	1
12567C	53	3

Table 5. BC_1 progenies that were uniformly sterile, 1974.

IS 7920C (SC 299)	x	IS 12565C (SC 50)
IS 7248C (SC 366)	x	IS 2483C (SC 309)
IS 12662C (SC 171)	x	IS 5322C (SC 250)

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NON-RECURRENT PARENT CONTRIBUTION TO CONVERTED SORGHUM LINES

J. D. Smith

The practice of backcrossing, the crossing of F_1's and/or successive generations with one of the original parents, is well established as a procedure for transferring genes from one genotype into another genotype. Ware (1) credits John Griffin of Greenville, Mississippi, with using this procedure in 1867, although Harlan and Pope (2) are probably responsible for the systematic development and widespread use of backcrossing as a breeding procedure. Some insight into the extent to which the method has been used to transfer a multiplicity of diverse characteristics from genotype to genotype can be gleaned from Thomas' (3) review.

The theory of backcrossing is predicated upon the knowledge that the probability that a single heterozygous pair of alleles will remain heterozygous through n successive generations of backcrossing to a homozygous genotype diminishes as a function of $(1/2)^n$. Unfortunately, Thomas (3) and many other practicioners of the art have construed this to mean that only $(1/2)^n$ of the genes of an nth generation backcross hybrid originated with the non-recurrent parent. Such an interpretation ignores two features inherent to the method: (1) backcrossing has no meaning without selection and selection forces heterozygosis for those chromosome segments containing the selected genes; and (2) non-selected segregational units will converge binomially upon the recurrent parent genotype. The obvious effect of these events will be to slow the rate of recovery of the recurrent parent genotype. Thus, we should ask the question "What proportion of the total genotype originated with the

non-recurrent parent?"

Although we cannot find an exact answer to this question, it is possible, by making certain assumptions, to obtain approximations to the answer. In the process we also gain greater appreciation of our need for additional information concerning sorghum genetics.

We can partition the total probability of residual heterozygosity following n generations of backcrossing into two components. One of these is a direct result of selection for specific genes contributed by the non-recurrent parent, while the other is a function of the random distribution of the unselected segregational units. The size of the initial linkage block associated with a selected gene and the rate of breakup of these chromosomal segments in successive generations determine the extent to which selection contributes to the heterozygosity which persists following n generations of backcrossing. The random component of residual heterozygosity is primarily determined by the number of non-selected chromosomal segments after the first two or three generations of backcrossing. In both cases, then, the frequency of crossing over per chromosome and the length of the chromosome segment that is transmitted intact must be known before an estimate can be obtained for the non-recurrent parent contribution to the genotype of an nth generation backcross.

If we consider the chromosomes of sorghum to have an average length L measured with reference to their true recombinational scale (4) and assume that crossovers occur independently, then the probability that a chromosome will undergo x crossovers is defined by the Poisson distribution, $Px = (e^{-L}L^{x}/x!)$. By assuming that the probability density for the x breaks within a chromosome was uniform, Hanson (5) derived the

expected lengths of chromosomal segments, S, containing a selected gene which were transmitted intact through a single meiosis for chromosomes of specified genetic lengths. A portion of his data have been reproduced in Table 1, where E(S) is the expected length of the selected segment in genetic map units/100, E(S/L) is the proportion of the total chromosome represented by the selected segment, and P(S=L) is the probability that the chromosome will be transmitted intact without recombination. L, of course, represents recombinational length of the chromosome. The points of particular interest in this table are the high probability that the selected segment represents the entire chromosome, or most of it, for "short" chromosomes and the fact that the selected segment actually represents a greater recombinational length as the "length" of the chromosome increases.

Table 1 - Characteristics of recombinational segments (S) of chromosomes of arbitrary recombinational length (L=centimorgans/100). (Data from Hanson, 1959).

	Length of Chromosome (L)				
	.5	.7	1.0	2.0	3.0
E(S)	.393	.503	.632	.865	.950
E(S/L)	.786	.719	.632	.432	.317
P(S=L)	.606	.497	.368	.135	.050

Although we have no actual knowledge of the true recombinational length of any of the sorghum chromosomes, it seems reasonable to assume from knowledge of other species that the average recombinational length

(centimorgans/100) will fall in the range $0.5 \leq L \leq 2.0$. Thus, we can use Hanson's derivations (6) to estimate the proportion of the non-recurrent chromosome that will be transmitted intact along with the selected gene through various generations of backcrossing (Table 2).

Table 2 - Expected proportion of original chromosome associated with a locus held heterozygous by backcrossing for chromosomes of arbitrary recombination lengths (centimorgans/100).

Chromosome Length (L)	Stat.*	Generation					
		BC_1	BC_2	BC_3	BC_4	BC_5	BC_{20}
.5	E(P)	.884	.788	.704	.632	.572	.200
	E(S)	.442	.394	.352	.316	.286	.100
1.0	E(P)	.786	.632	.518	.432	.368	.100
	E(S)	.786	.632	.518	.432	.368	.100
2.0	E(P)	.632	.432	.317	.245	.199	.050
	E(S)	1.264	.864	.634	.490	.398	.100

* E(P) = E(S)/L = proportion of chromosome

$E(S) = \frac{2}{n}(1-e^{-Ln/2})$ (cm/100) from Hanson, 1959 = expected segment length

By extrapolation from 1 to m independent loci which are being held heterozygous by selection, we can estimate the proportion of the entire sorghum genome which is held heterozygous concomitantly. Table 3 shows these expectations following five generations of backcrossing for a species with 10 chromosomes such as sorghum. Five generations was chosen deliberately since this number is frequently used in the derivation of "near isogenic" lines. Similarly, the range of three to seven

selected loci was chosen because it represents the range of selected chromosomes for most of the exotic materials being used in the Sorghum Conversion Program.

Table 3 - Expected proportion* of the sorghum genome held heterozygous by selection for m independent loci following five generations of backcrossing assuming chromosomes of arbitrary average recombinational length (centimorgans/100).

Average Chromosome Length (L)	No. of Loci Held Heterozygous by Selection (m)				
	3	4	5	6	7
.5	.172	.229	.286	.343	.400
1.0	.110	.147	.184	.221	.258
2.0	.060	.080	.100	.119	.139

$* \; E(G) = \frac{m}{L} (E[S]) = \frac{2m}{nL} (1-e^{-Ln/2})$

The random contribution to heterozygosity must be added to these values in estimating the total contribution of the non-recurrent parent to the population following five generations of backcrossing. This contribution results from the chance segregation of unselected chromosomal segments at successive meiotic divisions. The expected number of crossovers per chromosome will vary slightly with chromosomal length, but a constant value of $\bar{x}=2$ was used in all computations because the total random contribution is rather modest after five backcross generations. For similar reasons, these unselected segments were considered

to follow the binomial distribution rather than the more precise hypergeometric distribution. Although these simplifying assumptions reduce the precision of the estimates, these errors are insignificant when compared to our lack of knowledge concerning true recombinational length of the sorghum chromosomes.

Table 4, then, shows these estimates of the total proportion of the sorghum genome which can be expected to remain heterozygous after five generations of backcrossing when from three to seven independent genes are held heterozygous by selection. The random contribution to this persistent heterozygosity falls in the range of 1-2% of the total genome, although its contribution is appreciably greater in earlier generations.

Table 4 - Approximate proportion of the total sorghum genome remaining heterozygous as a function of chance* and selection for m independent loci following five generations of backcrossing assuming chromosomes of arbitrary average recombinational length (centimorgans/100).

Average Chromosome Length (L)	No. of Loci Held Heterozygous by Selection (m)				
	3	4	5	6	7
.5	.194	.248	.302	.356	.410
1.0	.132	.166	.200	.233	.267
2.0	.082	.098	.115	.132	.149

$Px = \left(\frac{e^{-L_L x}}{x!}\right)$ = Probability of x recombination points/chromosome

$E(x) = \Sigma\, xPx$; Approximation assumed $\bar{x} = 2$

Zea mays has an average chromosome length of about 100 centimorgans (L=1.0), and this might well be our best guess for the length of the chromosomes of sorghum. If we accept this guess, then it becomes obvious that 13-27% of the genome of fifth generation backcross plants comes from the non-recurrent parent, and most of this contribution will be retained when these lines are selfed to fixation for the selected genes.

Although the exact figures presented here are certainly debatable, the implications with reference to the sorghum conversion program are clear. The use of a single non-recurrent parent for the entire conversion program obviously will lead to the fixation of a large proportion of all converted lines for identical genes. Similar results can be expected to result from the use of different non-recurrent parents which are genetically similar for most or all of the chromosomal regions surrounding the dwarf and maturity genes which receive primary attention in the selection cycles of the program. It seems apparent that a real effort should be made to synthesize new non-recurrent parent sources from diverse forms of the exotic sorghum materials *per se*.

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TECHNIQUES IN BREEDING FOR INSECT RESISTANCE*

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Plant breeders, especially those working in the tropics, are increasingly concerned with insect problems in the initial planning of their breeding programs. Because the release of an insect susceptible, but otherwise superior variety may achieve little, breeding nurseries are now being established where no insecticides are used, thus providing early evaluation of breeding lines for insect susceptibility.

Several excellent reviews of sorghum insects, insect resistance in sorghum and its role in insect control have been published (1, 2, 3, 5, 6, 15, 27).

I will not attempt to discuss the many merits of resistance except to say that its proper utilization will be as one of several tools in a pest management program.

Breeding for insect resistance differs in no fundamental way from breeding for other characters. Consequently, any of the various methods of breeding appropriate for sorghum can be used in developing insect resistant varieties once resistance has been found and efficient evaluation techniques have been developed. We are concerned with a minimum of three objectives: (1) to develop agronomically suitable varieties resistant to insects of economic importance as rapidly as possible, (2) to continue to find new sources of resistance, and (3) improve the level of resistance over that presently available.

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This paper is intended to provide information on resistant sources and techniques to best accomplish these goals.

GREENBUG

In the United States the greenbug [Schizaphis graminum (Rondani)] has been recognized as a major pest of sorghum since 1968 and has been reported on sorghum in Brazil (R.A. Frederiksen, personal communication 1974). Resistance to this pest has been reported in the seedling stage (7, 10, 18, 19, 20, 21, 23) and in the adult plant stage (8, 9, 10, 11, 22). Cultivars reported as resistant were not suitable for commercial use and considerable breeding work has been required to incorporate this resistance into commercially acceptable material. Lines that have been reported as resistant are given in Table 1a and 1b. Agronomically improved lines can be obtained from the Agricultural Experiment Stations in Kansas, Oklahoma or Texas.

The inheritance of greenbug resistance in lines that have been studied is dominant or incompletely dominant. The resistance of several breeding lines with resistance derived from Sorghum virgatum was reported to be conferred by dominant genes at more than one locus (7). Studies by Johnson (10, 13) indicate that resistance in PI 264453 is simply inherited and incompletely dominant and that resistance in IS 809, SA 7536-1, PI 220248, and PI 302236 is incompletely dominant. Studies by Weibel, et al. (23) of F_1 and F_2 populations from susceptible varieties and SA 7536-1, IS 809 and PI 264453 indicate the inheritance of resistance from three lines to be incompletely dominant and simply inherited.

Since it has been established that greenbug resistance is not complexly inherited and can be retained through several backcrosses,

the primary need is an effective evaluation technique to identify resistant material in segregating populations.

SEEDLING EVALUATION

The technique described by Wood (26) for evaluating small grains has been modified to be used on sorghum. This technique consists of culturing greenbug biotype C on a susceptible sorghum hybrid grown in one-gallon cans. From 30 to 50 seeds are planted per can in soil and covered with sand to a depth of one inch. Before plant emergence, they are covered with a cage inserted into the sand in each can to protect them from premature greenbug infestation and to prevent infestation by parasitic wasps. Cages are constructed of clear vinyl plastic 0.015 inches thick, 13 inches high and 5.5 inches in diameter. Ventilation is aided by cutting holes 2.5 inches in diameter in two sides of the cage. The ventilation holes and the cage top are covered with fine mesh nylon cloth. After the culture plants have reached a height of 6 to 8 inches, each can is infested with about 200 greenbugs. After about two weeks these cultures are ready to use.

Breeding lines that are to be evaluated for resistance are planted in galvanized metal flats 14 x 20 x 3.75 inches. This flat will accomodate 10 entries in rows 14 inches long. A resistant and susceptible check is planted in each flat. Approximately 20 seeds of each entry is planted per row and thinned to 15 plants per row one week after emergence. These plants are infested from the culture plants by brushing approximately 1,500 greenbugs on each flat.

Rating for resistances began when the susceptible variety is near death. The 1 to 9 rating system is used where 1 equals no damage and 9 equals dead plants. Rows segregating for resistance are recorded as

such and a rating given on the most resistant plant in the row. This procedure permits evaluation to begin on seed from plants selected from F_2 populations.

ADULT PLANT RESISTANCE

Resistance of most lines are easily detected in the field if natural greenbug populations are at an adequate level. Natural populations averaging over 200 per plant are required to obtain reliable data on adult plants. The rating system given in Table 2 is useful in evaluating nursery material. When susceptible checks are rated as 6, resistant selections should have a rating no higher than 3. When susceptible checks are rated 3 or 4, resistant selections should have a rating no higher than 1. Evaluations should be made when greenbugs are present. If too much time elapses between maximum greenbug infestation and the time evaluations are made it is difficult to distinguish natural leaf death of the lower leaves and death caused by greenbug feeding.

Because of the low number of greenbugs occurring in the late planted sorghum at Lubbock, a technique has been developed to artificially infest selected adult plants in the field. Materials needed in this procedure are clip-on cages described by Cate, Bottrell and Teetes (4) and a small artist paint brush. The cages are a clip-on type constructed of one-inch cube plastic boxes. Screen-covered holes, 3/4 inches in diameter in opposite sides of the boxes allow ventilation within the cages. Five adult greenbugs are transferred from culture cans into each cage with a small artist brush. Two cages are attached to a leaf of each plant to be evaluated. We normally use the third leaf from the top of the plant. Cages are inspected the day following

attachment to the leaves to insure that five greenbugs are alive and feeding on the plant. Additional greenbugs are added as needed to bring the total to five. Resistant and susceptible checks are included in the test.

Snap cages can be used at any time even on mature plants. This provides flexibility to the evaluation program and permits the breeder to determine when evaluations will be made.

Ratings of the leaf area under the cage begins about one week after infestation and are taken every two days if the greenbugs are reproducing well on the susceptible check. The rating system used with this technique is as follows: 0 equals no necrotic plant tissue in the caged area, 1 equals 10 percent necrosis, 2 equals 20 percent, 3 equals 30 percent, 4 equals 40 percent, 5 equals 50 percent, 6 equals 60 percent, 7 equals 70 percent, 8 equals 80 percent, 9 equals 90 percent, and 10 equals 100 percent. Plants that receive a mean rating of five or less on the same date the susceptible check receives an eight or more, are considered to be resistant.

MIDGE

The sorghum midge [*Contarinia sorghicola* (Coquillett)] is a pest of sorghum in almost all regions of the world where the crop is grown. Varieties resistant to the insect have been reported from several countries (12, 14, 16, 17, 24, 25).

Identification of varieties resistant in the United States breeding programs in the past have been relatively fruitless, primarily due to the limited amount of germ plasm available in lines adapted to temperate regions. In addition, breeding nurseries were planted at a time designed to escape midge damage or were sprayed with insecticide

to control the midge if it became a problem, thus eliminating the opportunity to observe resistance if it were present.

Interest among breeders and entomologists at the Texas Agricultural Experiment Station was renewed in 1969 by independent observations by Dr. D. T. Rosenow at Lubbock, Texas and Dr. F. R. Miller at the Federal Experiment Station in Mayaguez, Puerto Rico. They reported that partially converted selections from IS 12610 had less midge damage than other lines in their nurseries. Since then, we have eliminated, or greatly reduced, insecticide application for midge control in our nurseries at Lubbock.

The absence of midge control provides the opportunity to select lines that have resistance. Using this approach, lines are identified for entrance in midge evaluation tests. Converted and partially converted exotic lines from the sorghum conversion program and their progenies from hybridization with elite U. S. material have been evaluated since 1971.

Resistant sources adapted to temperate area of sorghum production are listed in Table 3. These lines were shown to be resistant by evaluation of replicated tests at several locations during 1972, 1973, and 1974. During this time, several rating systems have been tried, but we have now chosen the rating system shown in Table 4, and encourage others to utilize the same system to aid in compiling data from international nurseries or tests.

In order to provide a uniform infestation of midge over the test area, "spreader rows" should be planted throughout the nursery with not over 50 feet between rows. These rows should consist of a mixture of hybrids classed as early, medium and late in the location that the test

or nursery will be grown.

The use of a large number of susceptible varieties as checks is required. Every effort should be made to include check varieties that overlap in their maturity and include the earliest and latest varieties adapted to the area. This is especially important in areas that have a large fluctuation in midge numbers throughout the blooming period. At Lubbock, the midge population generally reaches adequate levels by mid August and stays high until frost. However, in other areas populations may be large one week and very low the next.

In our present program, varieties reported as resistant are grown at Lubbock to evaluate them for resistance to the midge and for their maturity in the U. S. Most midge resistant introductions are too late in blooming for proper evaluation of resistance and are entered into the conversion program. Partially converted selections from these lines are evaluated for midge resistance as they progress through the conversion program.

BANKS GRASS MITE

The Banks grass mite is normally a damaging pest only on adult plants. Evaluation of lines for resistance is difficult because of a maturity plant susceptibility interaction. Rarely does this pest damage sorghum until after bloom and damage generally occurs during the seed filling period.

Because the mite is normally a problem after the plants have bloomed, yield losses should be restricted to decreased seed size and losses due to lodging. We have evaluated lines first for their ability to maintain green leaves in the presence of large mite populations. Lines that are above average in this respect are evaluated for their

ability to maintain live stalks and normal seed size with mites present.

In general, grassy sorghum such as 'Sweet Sudan' and 'KS 30' do not receive much mite damage. However, observations indicate that the grassy types are not preferred by mites. Possibly because each plant usually has many tillers that have not reached the bloom stage. It is doubtful if this apparent non-preference can be transferred to grain types.

Two lines, SC 599-6 — a partially converted 'Rio' — and a partially converted IS 12568 selection, have shown resistance to the Banks grass mite in preliminary tests. We are evaluating SC 599-6, its F_1 hybrid and progeny from crosses with resistant sources in field planting We are attempting to establish methods for evaluating material in the greenhouse.

SHOOT FLY

The sorghum shoot fly (Atherigona soccata Rond.) is not a pest of sorghum in the Americas. However, because of the importance of this insect in many sorghum producing areas, and the demonstrated international usefulness of lines released by the Texas Agricultural Experiment Station, we are conducting work in the area.

Lines that are identified as resistant to the shoot fly or other important insects such as the stem borer (Chilo zonellus Swin) are being entered into the sorghum conversion program. Selections will be made of partially converted lines from the segregating F_2 populations that are adapted to temperate areas and evaluated for resistance by cooperators in the area that the insect is a problem. Lines that are resistant will be combined in a population with elite lines from the Texas program. Distribution of the population will be made to all

interested breeders.

BREEDING METHODS

The breeding methods that seem appropriate for the arthropod pests discussed in this paper are outlined below:

Midge

Pedigree Method:

(1) The highest level of resistance should be transferred to agronomically acceptable types by hybridization and selection.

(2) Agronomically acceptable lines with the least susceptibility to midge should be used as the nonresistant parent, e.g., TAM 428..

(3) Grow a large F_2 population, at least 4,000 plants. Selection can be accomplished here without midge being present. Our limited experience has shown that selection for small-glummed types should increase the frequency of midge resistant types from the F_2 populations.

(4) Evaluate F_3 rows under large midge populations. To increase the probability of large midge populations during blooming of this material, it should be planted at more than one date or location.

(5) Evaluate F_4 selections in replicated progeny rows and back-cross superior plants if necessary.

Population Breeding:

(1) Selection of the proper genetic male sterile may be critical in establishing the population. We have found ms3 to be satisfactory. Populations containing genetic male sterility can be obtained from the Agricultural Experiment Stations in Kansas,

Nebraska or Texas. Antherless has not always been successful for use in the tropics.

(2) Four types of populations should be established:

a. For 'rapid' progress, B and R populations should be established combining acceptable agronomic types and high levels of resistance,

b. for long range improvement, establish B and R populations using elite varieties from the area the material will be utilized and all resistant sources available.

(3) Utilize the appropriate selection scheme best suited to the area, i.e., mass selection, reciprocal recurrent selection,etc.

Greenbug

Pedigree Method:

(1) Select lines with the highest level of resistance but suited agronomically to the area of intended use to be hybridized with elite adapted varieties.

(2) Backcross F_1 plant of cross between resistant and susceptible line.

(3) Evaluate large F_2 populations of cross between F_1 and elite susceptible variety. Use either seedling evaluation, transplanting resistant types to the field or evaluate F_2 populations in the field.

(4) Backcross resistant F_2 plants or select for evaluation in F_3 rows depending on agronomic desirability of the plant.

Population Breeding:

The same basic plan outlined above for midge resistance breeding should be used for greenbugs.

Shoot Fly and Banks Grass Mite

The same basic procedure outlined for midge resistance should be an appropriate approach to use for these pests.

SUMMARY

A coordinated international effort to improve the insect resistance of sorghum is imperative. Interest in this endeavor is high and increasing especially for midge resistance. We plan to increase our efforts in this area and request suggestions from participants in this program for ways that cooperation and information exchange can be improved.

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TABLE 1a

Sources of resistance to the greenbug

Designation	Species	Type
IS 809	*S. bicolor*	Grain
PI 264453	*S. bicolor*	Forage
KS 30	*S. virgatum*	Grassy
SA 7536-1	*S. nigricans*	Grassy
PI 302236	*S. hewisonii*	Grassy
PI 220248	*S. sudanense*	Grassy
PI 308976	*S. sudanense*	Grassy
PI 38108 (T.S. 1636)	*S. virgatum*	Grassy

TABLE 1b

Agronomically Improved Sources of Resistance to the Greenbug

Designation	B or R reaction	Source of Resistance
TAM BK-41	R	SA 7536-1
TAM BK-42	R	PI 264453
TAM BK-43	B	KS 30
TAM BK-44	B	KS 30
TAM 2567	R	SA 7536-1
TAM 2568	R	SA 7536-1
KS 41	R	T.S. 1636
KS 42	R	T.S. 1636
KS 43	R	T.S. 1636
KS 44	R	T.S. 1636
KS 56	B	T.S. 1636
KS 57	B	T.S. 1636
OK GP-1	-	SA 7536-1
OK GP-2	-	SA 7536-1
OK GP-3	-	SA 7536-1
OK GP-4	-	SA 7536-1
OK GP-5	-	SA 7536-1
OK GP-6	-	IS 809
OK GP-7	-	IS 809
OK GP-8	-	IS 809

TABLE 2

Proposed rating scheme for rating resistance of sorghum to greenbugs

Score	Description of Damage*
1	No red spotting on leaves
2	Red spotting on leaves
3	Portion of a leaf killed by greenbugs
4	One entire leaf killed by greenbugs
5	Two entire leaves killed by greenbugs
6	Four entire leaves killed by greenbugs
7	Six entire leaves killed by greenbugs
8	Eight entire leaves killed by greenbugs
9	Plant killed by greenbugs

*Data may be taken at any plant growth stage when greenbugs are present. It is suggested that estimates of greenbug numbers be taken if possible.

TABLE 37

Midge damage rating of selected sorghum lines, 1973 and 1974

Line	SC No.	Group Name	Midge Damage Score[1/] 1973	Midge Damage Score[1/] 1974	Days to Bloom 1973	Days to Bloom 1974
IS 2501C	52	Nigricans-Feterita	1.8	2.6	63	60
IS 12608C	108	Zerazera	3.8	4.8	65	65
IS 12612C	112	Zerazera	3.4	6.3	65	63
IS 2816C	120	Zerazera	3.9	6.1	64	63
TAM 2566	175-9	Zerazera	1.8	3.6	69	67
IS 12666C	175	Zerazera	1.2	4.2	67	65
IS 2549C	228	Zerazera	3.2	3.1	59	60
IS 7007C	268	Caudatum-Nigricans	4.0	8.4	63	57
IS 1309C	322	Nigricans	3.2	4.7	70	66
IS 2508C	414	Caudatum-Kafir	4.3	5.8	70	63
IS 2579C	423	Zerazera	2.1	4.6	69	62
IS 8100C	424	Caudatum-Nigricans	3.4	6.2	57	60
TAM 428	-	Zerazera	-	8.0	-	67
SGIRL-MR-1**	-	-	4.5	6.7	66	63
Tx 2536*	-	-	8.2	9.7	67	64
Tx 7000*	-	-	8.7	10.0	69	66
B Tx 378*	-	-	7.8	9.1	69	66
Tx 7078*	-	-	6.9	9.7	63	62
B Tx 3042*	-	-	6.2	9.6	64	57
B Tx 3197*	-	-	7.6	9.6	67	63
Tx 415*	-	-	8.6	9.5	76	67

[1/] The 1974 mean score of six 4-replication tests at 4 locations, Georgia, Mississippi, Lubbock, Texas and Beeville, Texas. 1973 mean score of three 4-replication tests at Experiment, Georgia and Beeville, Texas. 1 = <10% seed loss, 2 = >10 <20, 3 = >20 <30, 4 = >30 <40, 5 = >40 <50, 6 = >50 <60, 7 = >60 <70, 8 = >78 <80, 9 = >80.

** Resistant check.

* Susceptible check.

TABLE 4

Proposed rating scheme for rating resistance of sorghum to the sorghum midge

Score	Description of damage
1	No damaged seed
2	1-10% damaged seed
3	11-20% damaged seed
4	21-30% damaged seed
5	31-40% damaged seed
6	41-60% damaged seed
7	61-80% damaged seed
8	81-90% damaged seed
9	91-100% damaged seed

FIELD TESTING FOR STRESS TOLERANCE IN *SORGHUM BICOLOR* (L.) MOENCH

PAUL MENGE[1] DICK CRILL[2]

The major environmental variables with which sorghum breeders are faced are the mean and extreme temperatures, day length, length of growing season, annual rainfall, elevation, soil variables such as saline, sodic, acidic or alkaline soils, disease, birds and insect pests. Variations of these environmental factors will regulate the adaptability of breeding materials. This in turn will limit the adaptability of the possible derived hybrid combinations that can be made in a hybrid development program.

Perhaps Clausen, Keck and Hiesey[3] in 1940 were among the first to significantly contribute to the understanding of plant adaptation. From their paper entitled "Experimental Studies on the Nature of Species. I. Effect of Varied Environments on Western North American Plants" came the

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[2]Sorghum Breeder for Northrup, King & Co., Lubbock, TX.

[3]Clausen, J., D.D. Keck, and Wm. M. Hiesey. 1940. Experimental studies on the nature of species. I. Effect of varied environments on western North American plants. Carnegie Inst. Wash. Publ. No. 520.

concept of phenotypic plasticity. This concept is of major evolutionary importance in accounting for the selective advantage that higher plants have achieved for survival in the Plant Kingdom. Roughly stated, this concept is that the same genotype grown in different environments can give rise to a variety of phenotypes that are individually adapted in each different environment in which they are grown.

Stress tolerance in flowering plants can probably best be understood in terms of phenotypic plasticity. When some particular stress condition occurrs such as excessive moisture or drought or reduced sunlight or whatever, a major change in growth response occurrs. The processes of cell division and cell expansion take on a modified growth response so that a different phenotype results. This new phenotype is now adapted for the particular environment in which it was grown. Our research work along these lines has tested the hypothesis that adaptation to various environmental stress conditions is in fact regulated by phenotypic plasticity. This type of work can only be consistently studied by planting identical inbred ovservation nurseries and trials in various stress environments.

The term environmental extreme as used in this study refers to the environments that restrict cropping practices of sorghums in the United States. Sorghum nurseries were established in locations that delineate limiting environ-

mental conditions for adaptation of the sorghums. Adaptation of breeding materials is an important aspect of plant breeding. The limits of plant adaptation in a particular environment will affect the success of developing a crop for that environment.

The original plans were to use environmental extreme nurseries in conjuction with a hybrid breeding program. This would constitute an effort to select genotypes that could be used to expand the phenotypic plasticity of sorghum hybrids. It was thought that the result would be very widely adapted hybrids. The environmental extreme nurseries, would through natural selection, expose germplasm adapted in widely varied environments.

USE AND LOCATION OF ENVIRONMENTAL EXTREME NURSERIES

The sorghum inbred-line development nurseries for this study includes Eden Prairie, Minnesota; Lubbock, Texas; Pecos, Texas and Cloudcroft, New Mexico. Pecos and Cloudcroft are opposite environmental extreme locations. Pecos is located in the Permian Basin area of the Sonora Desert in southwest Texas. Cloudcroft is in the Lincoln National Forest of the Rocky Mountains of southern New Mexico. The Pecos location is extremely hot and dry with very alkaline, sodic soils. The Cloudcroft location is at 7,000 feet elevation above sea level with very cool temperatures, high rainfall, high humidity and acid soils. Eden Prairie and

Lubbock are more or less optimum type environments for most temperate adapted sorghum genotypes.

The use of environmental extreme locations were twofold. The first was to find the genotypes of maximum adaptation for marginal or extreme environments. This would locate the germplasm that could be most effectively utilized in developing a crop for the marginal agricultural areas which are similar to the environmental extreme nursery locations. A second observation has been that inbred lines adapted in opposite and extreme environments, when crossed together, produce hybrids with considerable vigor.

The data collected for these studies were observational scores from 1 to 5. A 1 rating was the best adapted materials. Such things as seed yield, leaf color and size, stunted appearance, etc. were used to make subjective ratings. A 5 rating was restricted to those plants that did not complete their life cycle due to stress conditions.

Adaptation to environments that normally restrict crop production has been of considerable interest. The possibility of increasing crop production in marginal farming areas have interested plant breeders for many years. The interest in marginal farming areas seems to be expanding. Increased food production in the U.S., as in other parts of the world, will require increased utilization of marginal farm-

ing areas. The areas where farming is marginal are areas of light rainfall or limited irrigation or extreme temperatures or undesirable unique soil conditions such as extreme pH levels, salt accumulations, etc. It has been long observed that centers of human populations correspond well with centers of intensive crop production. As the world population increases our crop production areas must be expanded. This means of course an increased effort will be made to farm the marginal agricultural areas of the world. This becomes a challenge to plant breeders to develop crops for these areas. The concept of environmental extreme nurseries is one suggestion for a breeding program to meet this challenge.

It has been observed in this study that adapted inbreds from opposite and extreme environments when crossed together usually exhibit considerable hybrid vigor. It is therefore probably important to mention some of the basic concepts of what is thought to cause hybrid vigor. In so doing it becomes necessary to formulate a hypothesis involving genetics, hybrid vigor, physiology or biochemistry and adaptation. This hypothesis stems from the general relationship between these interdisciplinary sciences. The entire science of physiology and biochemistry is in the interim between genetics and adaptation.

The expression of genetics results in the intricate and com-

plex facets of physiology and biochemistry. The sum total of an individual plants biochemistry is responsible for that plants limit of adaptability. Therefore, crosses involving inbred lines adapted in widely different environments must be wide genetic crosses for at least a portion of the genes in the separate genotypes involved. If this is sound reasoning, the classification of inbred lines for adaptability in opposite and extreme environments could provide a basis for locating genetic materials that represent wide crosses.

Hybrid vigor is a subject which has captured the imagination of botanists and plant breeders for over 200 years. The early papers on this subject concluded that the vigor of a hybrid was related to the degree of genetic dissimilarity of its parents. Several attempts to explain hybrid vigor or heterosis have withstood the test of time and are still with us today. However, it is not the intent of this paper to discuss these concepts of hybrid vigor. Rather it is an attempt to suggest a relationship between inbred adaptation for opposite and extreme environments with the heterosis of hybrids derived from these inbreds.

Plant breeding programs have in general been restricted to rather limited areas. Quite often actual breeding nurseries on many breeding projects have been restricted to one or two locations. This limits the observable adaptations to

environmental variables which plant breeders have been able to recognize in source materials.

MATERIALS AND METHODS

The sorghum materials tested at these locations includes most, if not all, of the released sorghum lines from the various state and federal agencies in the U.S. Also included were selected portions of the World Collection of Sorghum, the Damon Collection, the high elevation cool tolerant sorghums obtained from Elmer Johnson with CIMMYT, and numerous genetic recombinations derived from emasculated crosses between these various sources of germplasm.

Numerous research publications have dealt with the physiological limitations of plant adaptation and crop production due to various stress conditions. However, this type of information has probably not been extensively utilized by very many plant breeding projects. A simple 4 line diallel analysis was conducted at the Pecos location to estimate the genetic situation that regulates stress tolerance for sorghums at this location.

Four sorghum lines and the six possible single crosses were rated visually for adaptation at the Pecos location. The lines used were KS4 (red kafir), redbine 60, martin and Oklahoma dwarf redlan. The single crosses were scored on a 1 to 5 basis. A 1 rating was for the best adapted materials. A 5

rating was restricted to those entries that did not complete their life cycle due to stress conditions.

Combining ability estimates were made for stress tolerance using model 1, method 4 of the Griffing diallel analysis.[4] The four sorghum lines represent a rather narrow segment of sorghum germplasm. Due to the procedure used inferences can be drawn only about the four lines used in this study. Nevertheless, this simple study gave some rather interesting results. Below is the visual data recorded on this study[5]:

	dwarf redlan x redbine 60	dwarf redlan x martin	dwarf redlan x red kafir	redbine 60 x martin	redbine 60 x red kafir	martin x red kafir
R1	3.0	2.0	2.0	2.0	3.0	3.0
R2	3.0	2.0	3.0	4.0	4.0	5.0
R3	3.0	2.0	3.0	3.0	3.0	3.0

ANALYSIS OF VARIANCE

Source		DF	SS	MS	F
Total		17	10.94		
Reps		2	3.11	1.56	5.38*
Entry		5	4.94	.98	3.42*
	GCA	3	1.14	.38	1.46
	SCA	2	.52	.26	.90
Error		10	2.89	.29	

*significant at .05

After following through the Griffing procedure and comparing the magnitude of the GCA variance effects with the SCA variance effects the following inferences could be made about the sorghum materials in this study. The visual scores given the dwarf redlan single crosses were due mostly to specific combining ability. The scores for redbine 60 crosses were due mostly to general combining ability. Scores for martin were due to specific combining ability. Scores for red kafir were due to general combining ability.

CONCLUSIONS

The conclusions of this study are fairly simple. Additive genetic effects reflected in terms of general combining ability can be fixed through selection in segregating populations in stress nurseries. Then hybrids must be evaluated in stress nurseries to exploit the specific combining ability effects. This means, of course, that if stress tolerance is an objective in breeding programs both selection nurseries and yield trials must be conducted under stress conditions. It would be more convenient if only yield tests were necessary in stress locations. However, the genetic situation is such that maximum progress would probably not be achieved unless selection nurseries were conducted under

[4]Griffing, B. Concept of General and Specific Combining Ability in Relation to Diallel Crossing Systems. 1956. J. Biol. Sci. 9:463-493.

[5]Visual data recorded by Gayland Anderson and Dick Crill at Pecos, Texas in 1971.

stress conditions.

A procedure that has proven practical for the authors of this study has been inbred observation nurseries in diverse environments. This provides information on line adaptability, tolerance to various stress conditions as well as locates germplasm resistant to crop pests and diseases. The breeding work presently being conducted by these authors rely on inbred observations and hybrid evaluation in numerous diverse environments. Inbred line extraction and hybrid synthesis based on line observation stress nurseries has proven practical for these breeders.

The Genetic and Breeding Potential of Kernel and Endosperm Structure[1]

by

R. D. Sullins and L. W. Rooney[2]

The world collection and the conversion program have made available sorghums that vary considerably in kernel characteristics such as size, shape, density, gross morphology, and in detailed structure. Many of these kernel characteristics play important roles in determining the relative usefulness of the sorghum for food, feed or industrial purposes. Many of the characteristics can be controlled genetically. Therefore, we have attempted to study the gross kernel morphology of sorghums as well as the detailed infrastructure of the endosperm by a combination of light and scanning electron microscopy.

The objectives of this paper are to present a detailed, comprehensive overview of the structure of a typical sorghum kernel and to document how the structure is affected by various genetically controlled factors.

1/ Contribution from the Cereal Quality Lab, Soil & Crop Sciences Department, Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas 77843.

2/ Research Associate and Associate Professor, respectively.

Kernel Structure

Sorghum grain from the World Collection varies considerably in size (5-65g/1,000 kernels), shape, pigmentation, germ size, pericarp thickness, endosperm texture (floury, intermediate, corneous), endosperm type (waxy, sugary, yellow) and other properties. This diversity in structure is also equalled by diversity in chemical and processing properties. The typical sorghum kernel is a flattened shpere approximately 3.5mm wide by 4.0mm long and 2.5mm thick. The average kernel weight is approximately 28mg with 12 to 16 thousand seed per pound. The kernel or caryopsis is composed of three main parts, the outer covering (pericarp), the storage tissue (endosperm), and the embryo (germ). Through genetic manipulation, many of the structural components may be altered for a specific use.

Pericarp

The pericarp can be subdivided into the epicarp, mesocarp, and endocarp as illustrated in Figure 1. The first or outermost portion is the epicarp which usually consists of two to three cell layers in thickness. These cells are long and rectangular in shape and contain wax and sometime pigments. The presence or absence of pigments in the epicarp are controlled by the spreader gene S- (1)[a]. However, if the kernel is enclosed in highly pigmented glumes, some of the pigments may leach into the epicarp and through into the endosperm tissue. During dry milling of sorghum into flour, it is difficult to prevent small pieces of pericarp from being collected with the flour. If the

[a] All subsequent gene symbols will be cited from Reference 1 unless otherwise noted.

pericarp is colored either from the S- gene or leaching from the glumes, the flour will then contain enough pieces of colored pericarp to yield a non-white flour.

The middle layer is the mesocarp which may contain small starch granules that can be seen under polarized light (Fig. 4). This layer may vary in thickness from a thick, starchy, chalky appearance to a thin, transparent mesocarp. The mesocarp is usually the thickest opposite the embryo. Mesocarp thickness is controlled by the Z- gene where thin is dominant to thick mesocarps. Mesocarp thickness is thought to have an effect on weatherability. Thin mesocarp sorghums appear to withstand weathering better than those with thick mesocarps. Sorghums with thin mesocarp exhibit improved milling yield over those with thick mesocarps.

The innermost layer of the pericarp is the endocarp consisting of cross and tube cells. The cross cells are long and narrow and are at right angles to the long axis of the kernel. The tube cells are 5μ wide and up to 200μ long and the long axis of each cell parallels the long axis of the kernel. One of the main functions of cross and tube cells is the transport of moisture. These cells are also the point of breakage when the bran is removed during milling of the grain.

Testa

Just beneath the pericarp, some lines have a highly pigmented layer called the testa or subcoat (Fig. 5). The presence or absence of the testa is controlled by the B_1 and B_2 gene. Testa is present when genes are B_1-B_2-, while testa is absent with all other gene combinations. Some lines contain a partial testa that is intermittent

around the kernel. The testa also varies in thickness from one line to another and from one area of the kernel to another. It is usually thickest at the crown of the kernel and thinnest over the embryo. Some sorghums have remnant of a testa which is usually very thin and non-pigmented. The testa was originally the inner integument which had a definite structure. However, as the kernel matures and the endosperm expands, the cellular configuration gives way to a continuous layer. Pigmentation is due to a high concentration of polyphenols or tannins. High tannin content appears to improve weatherability which includes retarding preharvest seed germination and reducing seed molding. It also appears to serve as a deterrent where birds are a problem. Studies have indicated tannins may reduce dry matter digestibility by binding protein and possibly complexing with digestive enzymes. Some polyphenolic precursors also appear to be located in the endosperm. When sorghum flours are treated with dilute alkali, these precursors react to give an off-white color to the food product. There are several combinations of presence or absence of testa plus pericarp color. The overall color of the seed is regulated by the R-Y-I- genes.

Endosperm Structure

The endosperm of sorghum consists of the aleurone layer, peripheral, corneous, and floury portions. The aleurone cell layer located beneath the pericarp (Fig. 3) or testa if present is usually a single layer of small rectangular cells distinguished by high concentrations of protein and oil (3). It is also thought to contain large amounts of minerals and autolytic enzymes. When the aleurone

cells are hydrated, they furnish the necessary mechanisms for autolysis. The aleurone protein is good quality and a multiple aleurone sorghum would be an asset nutritionally.

The peripheral endosperm is just beneath the aleurone layer and consists of the first two to six endosperm cells. These cells are small and blocky containing small starch granules (Fig. 3) embedded in a dense proteinaceous matrix. The matrix or amorphous protein is comprised mainly of glutelins or alkali soluble proteins. This matrix also contains small shperical protein bodies. The amorphous matrix protein can be preferentially removed by pronase enzyme to expose the protein bodies. The kernel in Figure 6 however, has only been treated with alpha-amylase enzyme to remove the starch which also expose some of the protein bodies. The protein bodies are storage proteins comprised of the alcohol soluble prolamines (Kafirin). The endosperm contains both free protein bodies and those located in the matrix protein. When the active cell cytoplasm, which is in greatest concentration around the periphery of the endosperm, dries during maturation of the kernel, it encases the protein bodies and then become the cementing protein matrix of the peripheral and corneous endosperm. The protein bodies in the peripheral and corneous endosperm range in size from 0.3-3.0μ in diameter and decrease in size and number toward the center of the kernel. The protein bodies in the floury endosperm range from 0.3-1.5μ in diameter. Figure 6 illustrates how the starch granules are embedded in a nest of protein bodies and matrix. Therefore, the starch granules are very tenaciously held in the peripheral endosperm and difficult to remove. Enzyme treatment of various

kernels have indicated only preferential digestion by amylases because the matrix and protein bodies are so dense in the peripheral area, the enzyme cannot penetrate beyond the surface to digest subsequent layers of starch. This renders much of the starch in the peripheral area unavailable for utilization. Processing methods have helped to breakdown this area mechanically but much of the starch still remains unavailable. The peripheral endosperm may vary in thickness and is influenced by environment (3) and genetics. A modification in structure or thickness of the peripheral endosperm will yield more efficient utilization of the starch.

The corneous endosperm (hard, flinty, horny) is located beneath the peripheral endosperm (Fig. 7A) and appears dense and translucent (Fig. 7B). Its appearance and hardness is due to the continuous interface between the starch and protein. The starch granules are very angular or polyhedral in shape with depressions where protein bodies were trapped between expanding starch granules. The starch protein bond is strong enough that some starch granules break rather than pull from the matrix. When corneous endosperm is treated with starch digesting enzymes, the starch is removed more readily than in the peripheral endosperm. This is because of a more uniform distribution of protein matrix and protein bodies between the starch granules as compared to the large concentration of protein surrounding each starch granule in the peripheral endosperm cells.

At some area in the endosperm, there is a transition from corneous to floury endosperm toward the center of the kernel. Figure 7C is a photomicrograph of this transition zone. Some cells in the floury

portion contain starch granules that appear well meshed together while other cells are loosely packed and contain large voids between the granules. The floury or opaque endosperm can be explained by the reduced concentration of cytoplasm in the center of the kernel and as drying occurred, the cytoplasm or protein matrix pulled away from the starch granules and left air voids. These air spaces alternating with cell constituents diffuse light as it passes through the endosperm yielding the chalky or opaque appearance. However, there are protein bodies and matrix in the floury endosperm (Fig. 7D) as illustrated in the photomicrograph. Within a kernel, the concentration of protein is low in the floury area as evidenced by decreasing protein matrix and bodies from the outside of the kernel toward its center.

Endosperm Texture

The relative proportion of corneous endosperm to floury endosperm dictates the texture of the endosperm as a whole (i.e., floury, intermediate, corneous). Endosperm texture varies from all floury to all corneous as illustrated in Figure 8. The floury endosperm is very chalky or soft and as one might expect imposes many agronomic problems in terms of weathering, germination, yield, handling, and processing. Most floury endosperm also have a void area in the center of the endosperm. They also have the peripheral endosperm that provides a hard outer cortex but is usually thin and does not help improve the kernel properties. The intermediate textured endosperms contain approximately equal proportions of floury to corneous material. Most commercial sorghums are intermediate in texture with some variation (Fig. 8). Corneous sorghums contain high percentages of the more organized cells

and appear flinty or translucent. The corneous endosperm sorghums to have good agronomic traits and desirable dry milling characteristics. The floury endosperms will break more easily yielding fine particles, but, will not yield as much flour as corneous lines. When both textured sorghums are treated with alpha-amylase enzymes, the corneous will be digested similar to the peripheral endosperm previously discussed whereas, the floury endosperm will be almost totally digested. The ratio of peripheral and corneous endosperm to floury endosperm in sorghum or corn influences the processing properties of the grain (4). Starch is obviously more difficult to separate from the protein in grains with high proportions of peripheral and corneous endosperm (5).

Endosperm Type

Waxy Endosperm. There are two types of starch in the sorghum kernel, one is amylose and the other is amylopectin. Amylose is a straight chain of α1-4 linked glucan units where the amylopectin is a branched chain with α1-4 and α1-6 linkage of glucan units. Normal sorghums contain 20 to 30% amylose and 70 to 80% amylopectin. Waxy cereals consist essentially of 100% amylopectin.

The endosperm tissue being triploid (3N), the waxy recessive allele wx must be homozygous at all three loci for an all waxy endosperm. The all waxy endosperm has a dull sheen or waxy appearance when compared to nonwaxy sorghum as in Figure 9.

Besides a difference in starch type, waxy sorghums appear to have a modification in endosperm structure. Normal sorghum usually has a dense peripheral endosperm with small starch granules well embedded in a dense proteinaceous matrix (Fig. 13). This arrangement

of protein and starch makes it rather difficult to remove the starch, either during digestion or by milling.

On the other hand, when the endosperm is homozygous for waxy (wxwxwx), there appears to be a modification of endosperm structure associated with the change in starch type. The waxy sorghums have a reduced peripheral endosperm with a much less concentration of protein bodies just beneath the aleurone cell layer (6). The protein is more evenly distributed in the corneous area and larger starch granules develop near the periphery of the endosperm (Fig. 10). The larger granules and smaller ones, for that matter, are more readily available for utilization than those in the nonwaxy lines. The waxy starch itself is also more readily degradated than the nonwaxy starch. The combination of waxy starch plus the modification in structure both account for the improvement in digestibility of waxy sorghum over nonwaxy sorghums (7).

Heterowaxy Endosperm. Crosses were made between homozygous Kafir waxy and nonwaxy lines to produce four endosperm genotypes containing 0 to 1, 2, and 3 doses (WxWxWx, WxWxwx, Wxwxwx, and wxwxwx) of the waxy recessive allele. Amylose content decreased from 24.0%, 23.1%, 17.3%, to a trace with 0, 1, 2, 3 doses of the waxy allele respectively. The peripheral endosperm was also modified. The two extremes or homozygous lines had the same structural difference as the waxy - nonwaxy comparison mentioned earlier in this paper. The heterowaxy containing one waxy allele decreased slightly in % amylose and the structure of the peripheral endosperm closely resembled that of the homozygous nonwaxy line. The heterowaxy line containing 2

doses of the waxy allele had 17.3% amylose and the peripheral endosperm was modified to approach that of the homozygous waxy line. The significance of this information is that waxy sorghum exhibits improved digestibility over nonwaxy but still has inherent problems with germination and yield. In Vitro digestibility data of the two heterowaxy lines, indicate improved digestibility over the nonwaxy sorghum. The heterowaxy also had better agronomic characteristics than the waxy sorghum. Therefore, it is conceivable that heterowaxys could exhibit improved feed efficiency over the nonwaxy sorghum and still retain good agronomic characteristics.

Yellow Endosperm. Yellow and heteroyellow sorghum lines have been reported to have improved feed efficiency over that of normal sorghum (8). These lines contain carotenoid pigments in the endosperm. Their structure is similar to the normal sorghum with some variation in concentration of protein in the peripheral endosperm. Examination of many different lines indicated differences in structure among the yellows but not of the magnitude of the waxy - nonwaxy lines. These differences in endosperm structure may or may not be genetically controlled.

Sugary Endosperm. Sugary sorghums are another area of interest. Karper and Quinby (9) found sugary to be a simple recessive to normal with possible linkage between su and one of the height genes. The sugary sorghums exhibit a dented or wrinkled seed. The upper portion of the kernel is where the dent is located. The overall structure of the endosperm appears different from that of normal sorghum. The top one-third of the kernel has a dense layer just beneath the aleurone layer that may be an extremely dense peripheral endosperm (Fig. 11),

This is not continuous around the periphery of the endosperm as in normal sorghum. Also, the endosperm shows little sign of organization in terms of endosperm cells, corneous and floury portions. The starch granules are irregular in shape and size. These differences in structure may be accounted for when some of the sugars are not converted to starch to fill the endosperm and develop other structural components. When moisture is lost approaching maturity, the kernel shrivels or dents at the tip. Normal sorghums contain about 1.5% total sugar where sugary sorghums contain twice that amount. This difference can easily be detected organoleptically when the kernels are in the milk or early dough stage. The sugary kernels have a distinct sweet flavor compared to normal sorghum. This particular type of grain is not grown in large quantities. In India, the "dimpled" grains are treasured for the sweet seeds that are eaten in the dough stage. The sugary grains are parched by placing green heads on a bed of coals. The grain is then knocked from the heads and eaten.

High Lysine Sorghum. Singh and Axtell (11) found two Ethiopian sorghum lines (IS 11167 and IS 11758) that were higher than normal in lysine content. The kernels were also floury and partially dented or shrunken. The high lysine appears to be controlled by the recessive hl gene. Rosenow (personal communication) found a similar shrunken, floury kernel (SC 1030-5-4 a BC_1 selection from IS 11790) in the sorghum conversion material at Chillicothe, Texas (Fig. 12). The shrunken or dented kernels have a soft, floury endosperm and weigh about 60% that of normal kernels. Amino acid analysis indicated the lysine content of the shrunken kernels were about twice that of normal sorghums.

However, the shrunken nature of these kernels causes a greater weight ratio of germ to endosperm which may account for part of the increase in protein and lysine content.

Normal sorghum has a plump or full endosperm with dense concentration of protein bodies in the peripheral area (Fig. 13). In comparison, the shrunken kernels have smaller and fewer protein bodies (Fig. 14) and appears to contain little protein matrix except around the periphery of the endosperm. These observations suggest that an actual alteration in protein synthesis does occur in the endosperm of these kernels (12). The shrunken or dented characteristic is a result of less starch being synthesized and as water is lost at maturity, the kernel shrivels or dents. Those sorghums with partially dented or shrunken endosperm are not practical for U.S. sorghum production until the gene has been suscessfully transferred to a plump kernel with acceptable agronomic characteristics.

A segregating population of SC 1030 was examined over an opaque light. The population was segregating shrunken high lysine and normal kernels. Several plump opaque kernels were also found in the population. Microscopic examination of the plump opaque kernels revealed endosperm tissue that contained relatively few protein bodies and more amorphous protein matrix than the shrunken high lysine or all floury endosperm sorghum (NSA 740) previously identified in Figure 8. This may serve as one means of screening for plump opaque kernels that are higher in lysine than normal sorghums. The Purdue workers (12) have found a plump opaque sorghum that is approximately 50% higher in lysine than normal sorghum. Preliminary examination of the endosperm structure indicates there is more amorphorous protein matrix than

shrunken high lysine kernels and smaller protein bodies. However, the endosperm is generally well organized and filled with starch.

Conclusion

The continuation of the World Collection of Sorghum will and has provided a tremendous source of genetic diversity. The conversion and use of this genetic diversity into useful breeding lines is a lengthy process. After conversion, analytical testing of genetic expression is laborious and time consuming. We feel that microscopy has a definite place in screening new lines for improved quality whether it be for food, feed, or agronomic cahrateristics.

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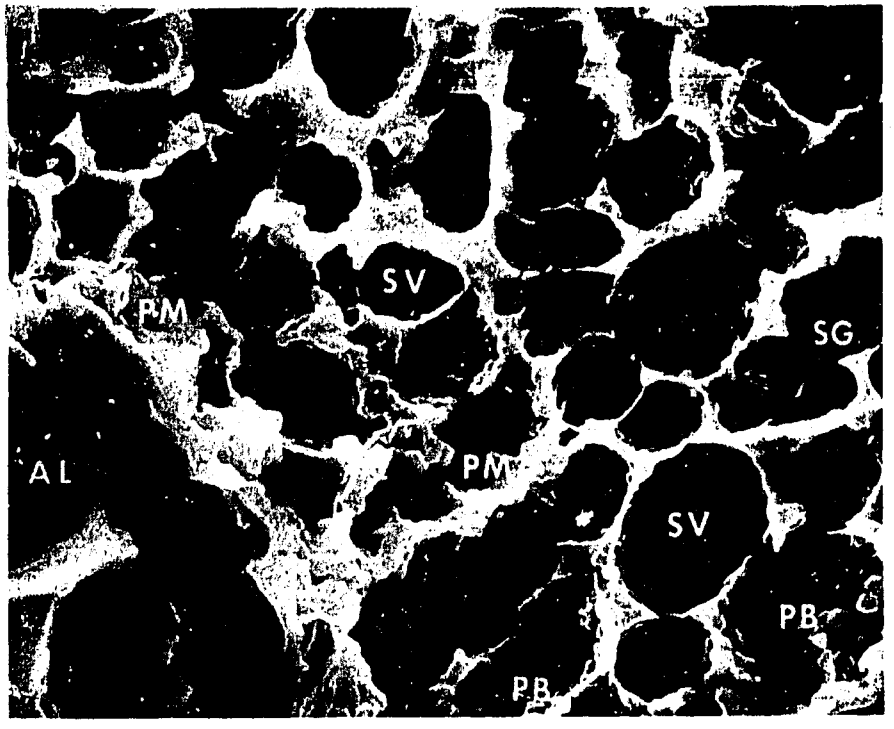

Figure 1 - Diagram of sorghum kernel.

Figure 2 - Longitudinal section of sorghum kernel (40X).

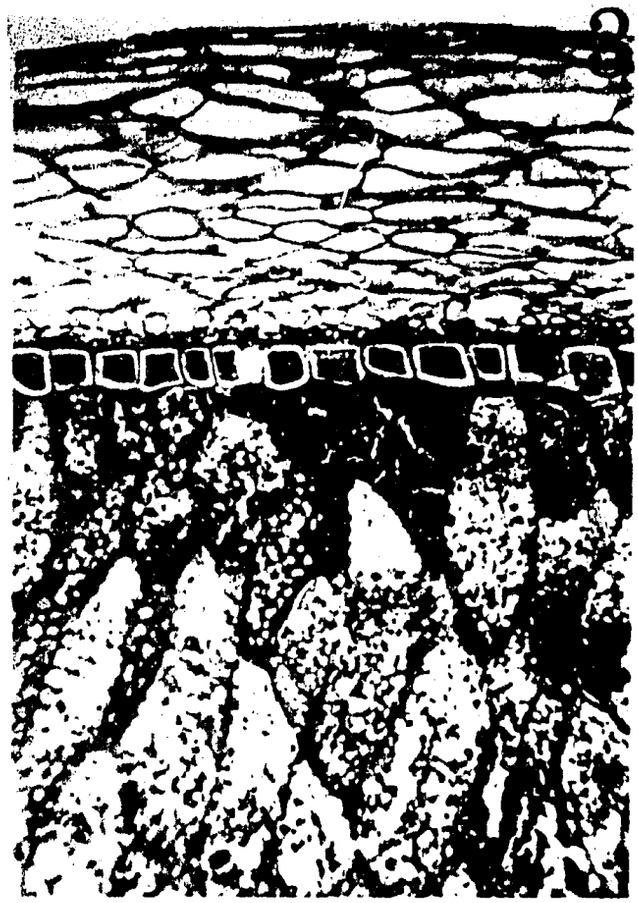

Figure 3 - Structure of typical sorghum pericarp and peripheral endosperm area under normal light (300X).

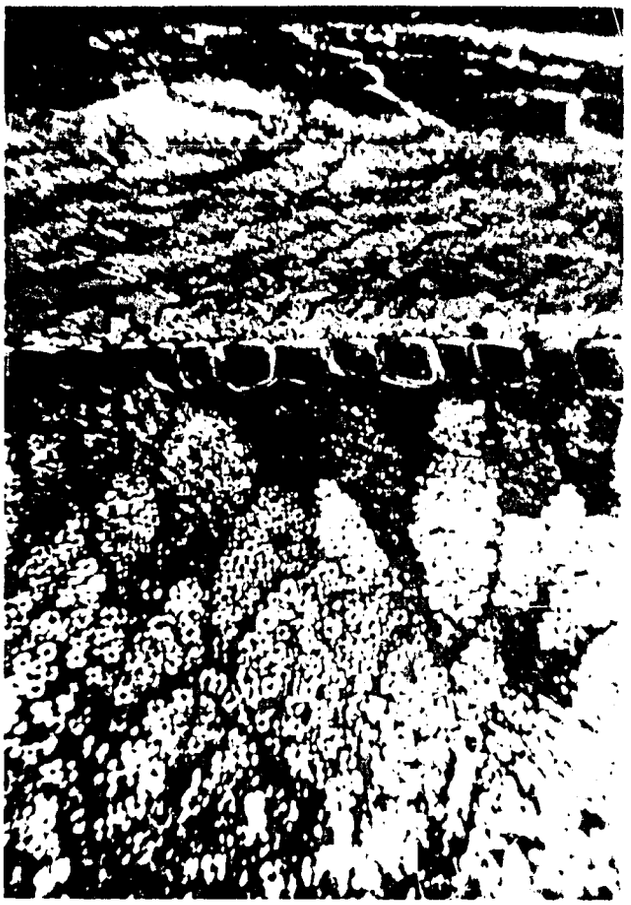

Figure 4 - Structure of typical sorghum pericarp and peripheral endosperm area under polarized light (300X).

Figure 5 - Longitudinal section of sorghum kernel with pigmented testa. P = pericarp, T = testa, AL = aleurone cells; (300X).

Figure 6 - Longitudinal section of peripheral endosperm of normal sorghum treated with alpha-amylase for 2 hours at 39°C. AL = aleurone cells, PM = protein matrix, PB = protein bodies, SV = starch void, SG = starch granule.

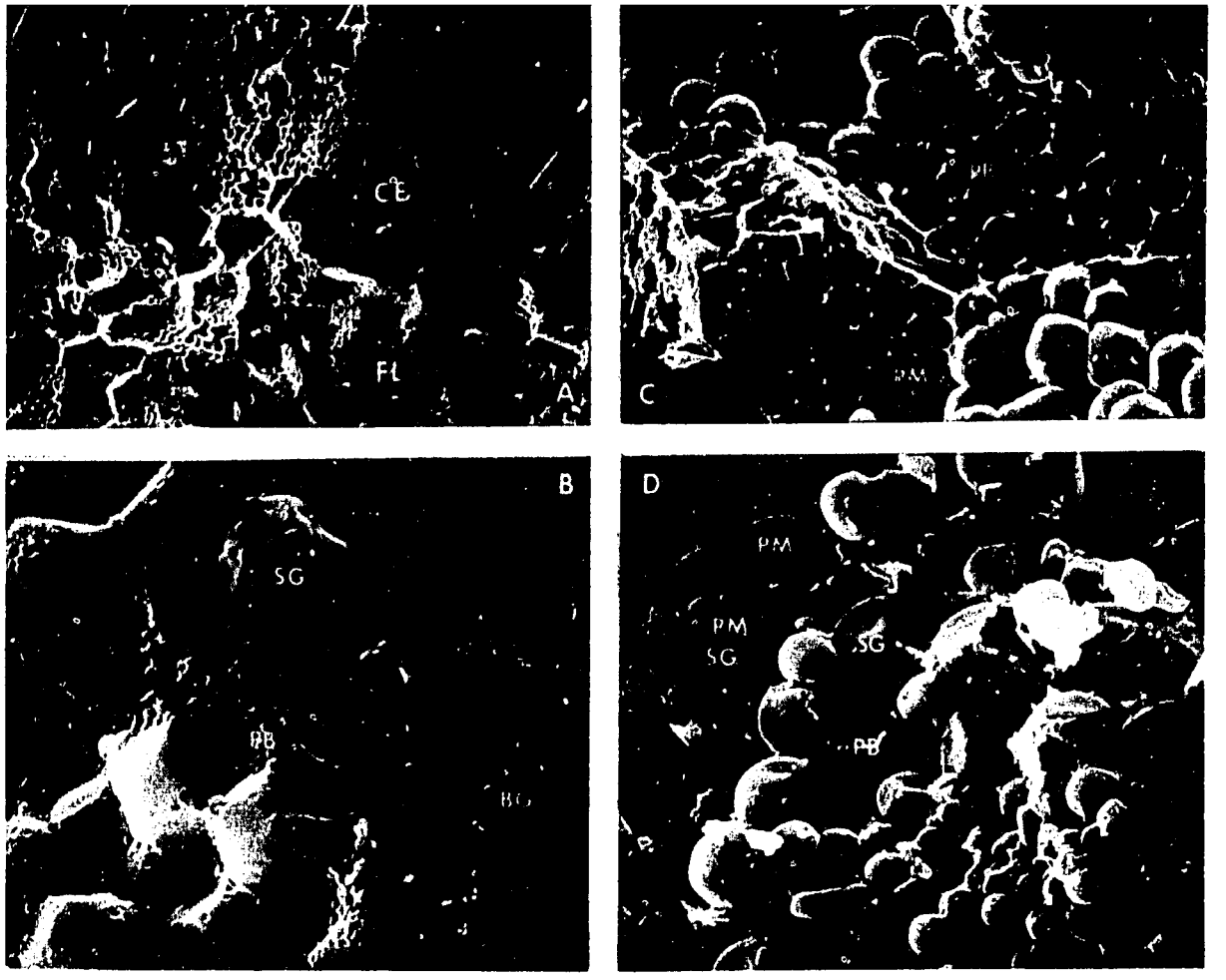

Figure 7 - Longitudinal section of normal sorghum endosperm.
Photograph: A = Peripheral, corneous and floury endosperm (100X)
B = Corneous endosperm (1600X)
C = Transition from corneous to floury endosperm (600X)
D = Floury endosperm (1000X)
PE = peripheral endosperm, C = corneous, FL = floury, SG = starch granule, PM = protein matrix, PB = protein bodies, BG = broken granule.

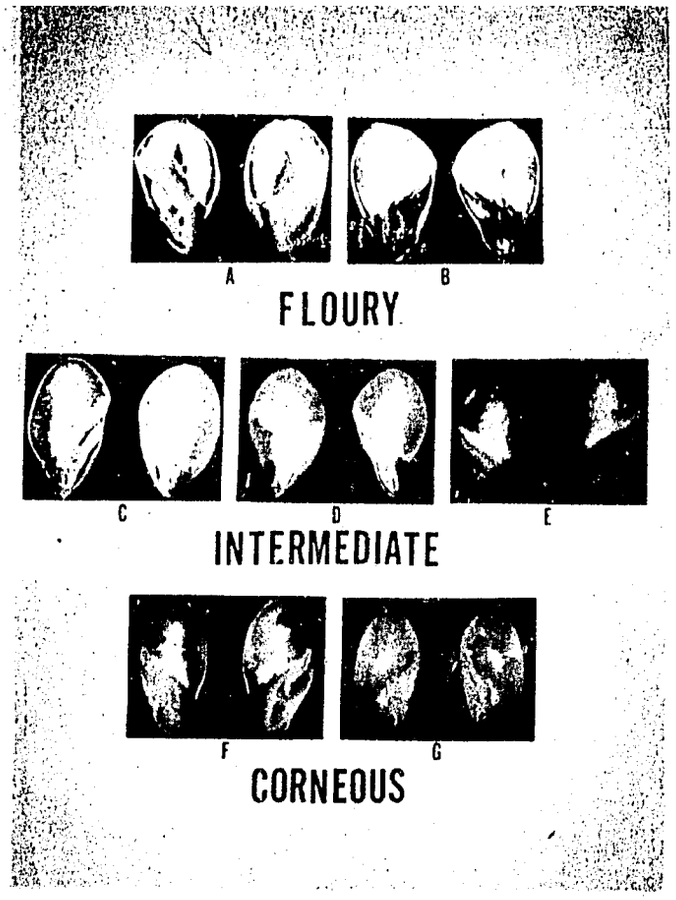

Figure 8 - Mean longitudinal sections of seven varieties of grain sorghum illustrating variation in endosperm texture. A = NSA 740, B = Tx 09, C = B 3197, D = Dekalb C 42Y, E = SC 110, F = SC 170, and G = SC 283. (6X)

NONWAXY

WAXY

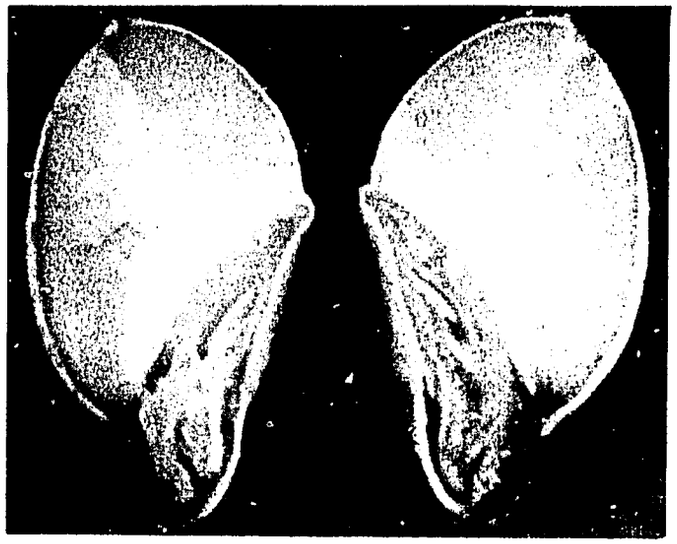

Figure 9 - Mean longitudinal section of normal and waxy endosperm sorghum. Nonwaxy = B 3197; Waxy = Tx 615 (12X).

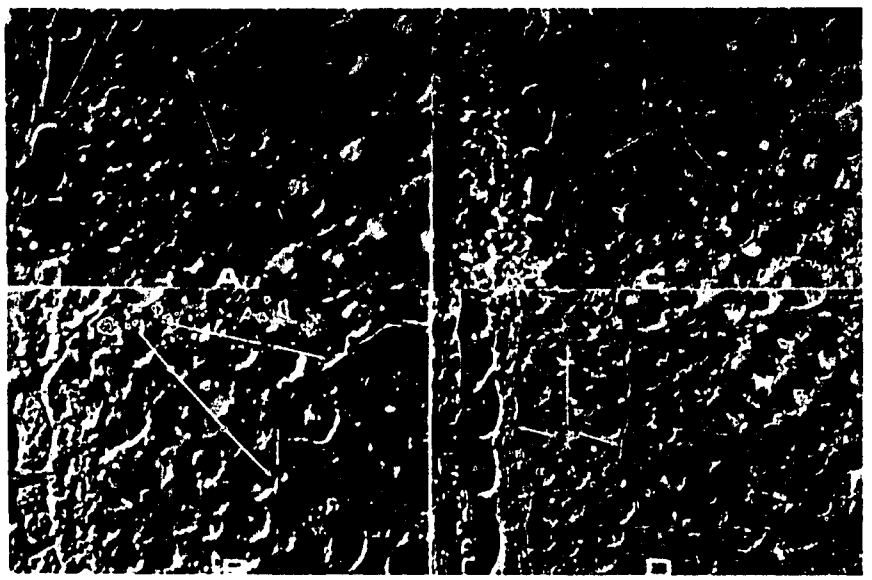

Figure 10 - Sections of untreated nonwaxy and waxy sorghum endosperm viewed with the light microscope by differential interference contrast optics. A, B, C, and D = 320X; AL = aleurone cells, CW = cell walls, PB = protein bodies, and SG = starch granules.
Photographs: A = nonwaxy Kafir
B = waxy Kafir
C = nonwaxy Redlan
D = waxy Redlan

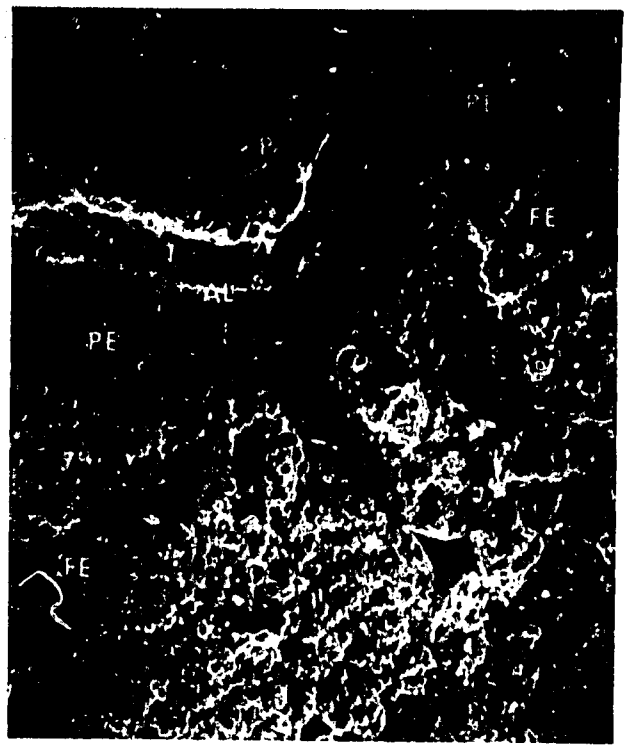

Figure 11 - Longitudinal section of sugary endosperm sorghum. P = pericarp, PE = peripheral endosperm, T = testa, AL = aleurone, FL = floury endosperm (100X).

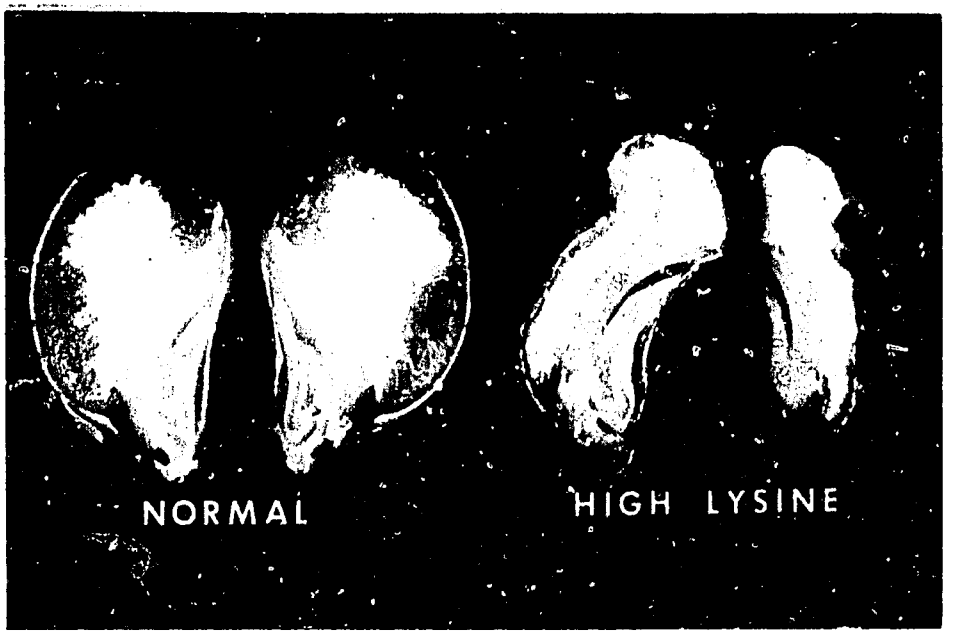

Figure 12 - Longitudinal sections of normal and high lysine sorghum kernels segregating on the same head; (10X).

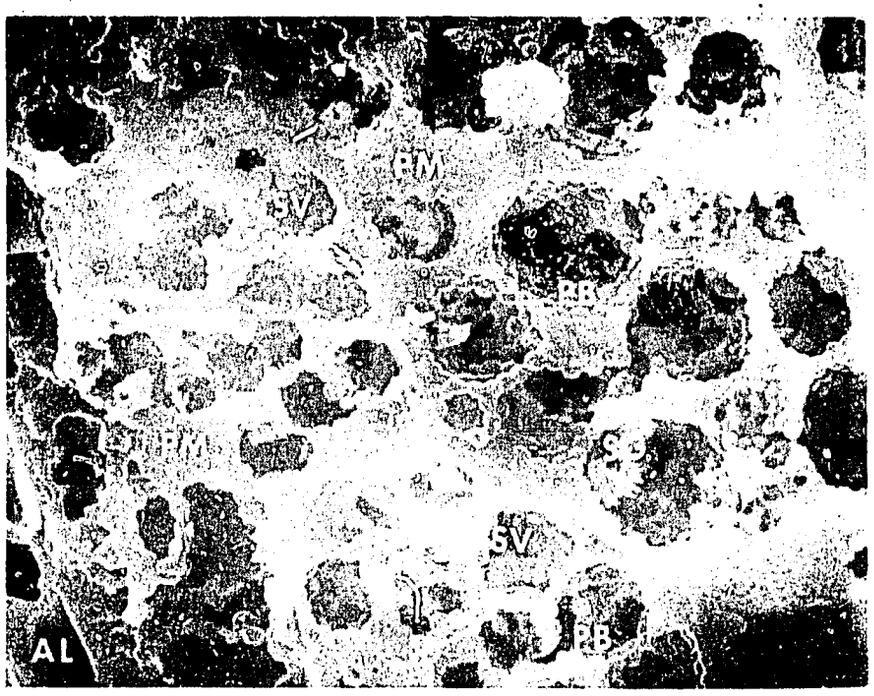

Figure 13 - Longitudinal section of normal sorghum treated with alpha-amylase enzyme for 2 hours at 39°C; AL = aleurone cell, PM = protein matrix, PB = protein bodies, SV = starch voids, SG = starch granules; (1000X).

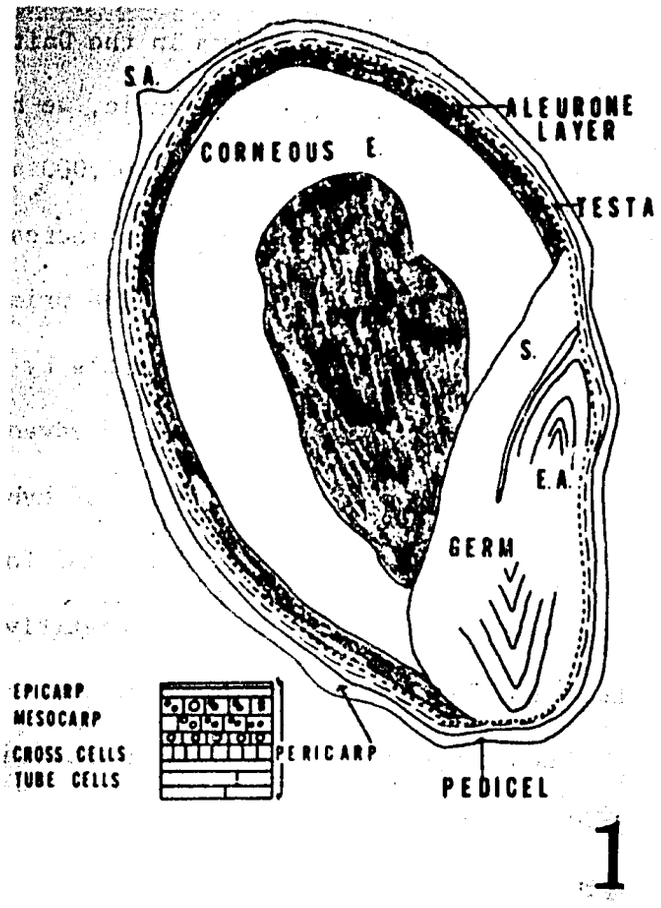

Figure 14 - Longitudinal section of high lysine sorghum treated with alpha-amylase for 2 hours at 39°C; AL = aleurone cells, PM = protein matrix, PB = protein bodies, SV = starch void, SG = starch granule; (1000X).

SUMMARY OF PROBLEMS AND POTENTIALS FOR SORGHUM IMPROVEMENT

Paul T. Nordquist

With the introduction of hybrid sorghum approximately 20 years ago we saw a substantial increase in research activity and increased utilization of sorghum in the United States and around the world. In Nebraska, for example, we had a tenfold increase in acreage from 200,000 to 2,000,000 acres per year after the introduction of hybrids. This increase in acreage resulted from a number of factors. The primary factor, of course, was the increased yield made possible by the utilization of hybrids. In addition to the yield advantage under our Nebraska environment the earlier maturity of hybrids has also been of substantial benefit. One additional factor, but difficult to measure, has been the better competitive ability against drouth, weeds, diseases, and insects.

Since hybrids were introduced we have maintained the variety Martin in our yield trials as an indicator of relative performance. Martin was one of the best varieties available at the time hybrids were introduced. I transformed the average performance of all hybrids in the tests to a percent of Martin for yield, plant height, and days from planting to bloom. In eastern Nebraska as you can see from Figure 1, from about 1958 to 1965 there was not a great deal of change in the relative grain yield of the hybrids compared to Martin. They fluctuated somewhere around 118% of Martin. In 1966, we see an increase in relative performance and this has been carried on into the later years. Presently our average performance

of all hybrids in the trials relative to Martin is about 130% or an increase since 1966 of about 10 to 12 percent. This is satisfactory improvement and we hope it will continue as more germplasm from the conversion program enters breeding programs. The increase in yield has not been at the expense of additional plant height which could cause problems of increased lodging. There has been some slight change toward later maturity. The average maturity of the hybrids in recent years is about equal to that of the variety Martin, while in earlier years the hybrids averaged about 2% earlier than Martin.

In central and southwest Nebraska we see about the same trend from the introduction of hybrids through about 1965 (Figure 2). We see the relative yield of the hybrids averaging about 118% of the variety Martin. After 1965 the average of hybrids shifted upward until they are averaging about 130% of Martin. The only exception was in 1969 where the hybrids averaged slightly over 110% of the variety Martin. In several of the other years, 1968 and 1973 for example, the hybrids averaged well over 140% of the variety. Plant height in central and southwest Nebraska has been slightly shortened in the hybrids relative to Martin. The shorter stature can be a real advantage from the standpoint of better standability of the crop. There seems to be little change in maturity with the hybrids continuing to be somewhat earlier than the variety Martin.

These data indicate that we have made substantial improvement in yield of the hybrids over the years since they were introduced. By making a comparison from the point of introduction of hybrids we have had a average increase of about 1% per year in the yield of the hybrids relative to Martin. If we start from 1966 or about the time a broader base of germplasm became available, our average yield increase has been slightly under 2% per year. Now that materials are becoming available from the conversion program we can hope that the rate of increase would be greater than 2% per year. Two percent is lower than theoritically predicted and less than breeders would hope to achieve. As we begin to utilize materials from the conversion program and implement new breeding techniques any improvement over this 2% will be helpful, but even that modest gain projected over several years amounts to a substantial increase in the amount of sorghum that can be produced from a unit area of land.

Although high performance hybrids are available to our producers their impact is no greater than their level of utilization. In order to get some measure of the utilization I compared the average county yield with the average performance of all hybrids in the variety trials we conducted in those counties. In Lancaster County for example in 1958, the producer average was only 50 bushels per acre while test plot average was 101 bushels per acre. Producers averaged only 49% of our test plot average that year. The best producers were able to accomplish was in 1968 when they averaged 90% of

test plot average. Over 15 years the producers have averaged only 64% of our test plot average. In southwest Nebraska we see the trend even more pronounced. The sorghum producer averaged 31% county wide compared to our varietal test in 1970 and the best they were able to accomplish was in 1958 and 1959 when they averaged 86% of our test averages. Over 15 years producers averaged only 55% of varietal test average. This seems then to be only a fraction of the potential being realized and there are indications that even our yield trials were probably not 100% of potential in most years.

Many factors contribute to the lower producer yields. One factor might be the use of improper hybrids. I think this is a major problem when the producers are delayed in planting. They have obtained their seed for a full season hybrid and then moisture conditions or other factors do not permit them to plant when they should. When they finally are able to plant they use the full season hybrid they had originally purchased rather than changing to an earlier hybrid and are caught by frost or bad weather before harvest. In some cases they have almost guaranteed a crop failure the day they plant.

Without question one of the most important factors in limiting yields is moisture management. We generally encounter some moisture stress with sorghum on non-irrigated conditions in most areas of the United States. If we do not properly manage the moisture that is available this stress becomes a severe limiting factor to yield. We lose this moisture all too frequently by means other than the crop.

Weeds of course are one of the most critical areas of moisture loss. Weeds can consume moisture at any time from harvest of the previous crop, through planting time and then as a competitor in the growing crop. In Nebraska we have found that weeds growing in stubble following wheat harvest may waste as much as two inches of available moisture in as little as 30 days. Volunteer winter wheat can become a heavy consumer of moisture and if left through the winter months may waste 2 to 3 inches of moisture. Weeds in the crop, of course, are heavy consumers of water. Some weed species consume several times more moisture per pound of dry matter produced than does the sorghum crop. As a rule of thumb, for each pound of dry weeds produced, yield of grain is reduced by a pound. It takes suprisingly few weeds to make several hundred pounds per acre.

Another area of moisture loss is tillage operations. Whenever we till the soil we generally lose moisture to the depth of the tillage operation. This can be a substantial amount if several tillage operations are conducted in the fall and spring. Runoff can also be a problem where we have destroyed the crop residue and then heavy rains occur. Losses from surface evaporation on bare soil are somewhat heavier than where the residues have been left to act as a mulch. Each component of moisture loss by itself may not seem too great but when all are combined they are the most important factor limiting sorghum yields.

Studies in Nebraska have shown that under our environmental conditions about 9" of moisture are needed to produce any grain at all. Available moisture above the 9 inches is what makes our grain crop. From May 1, 1974, when some of our early plantings were made, through September we received 7.56 inches of moisture. We were still able to obtain yields up to 80 bushels per acre. This good yield despite the low rainfall was the result of 5 inches of rain in September 1973 and 3 inches in April 1974 plus smaller amounts in several other months. The moisture was stored in the soil and utilized by the crop rather than lost to weeds or surface evaporation from excess tillage. Contributing to the good yields was the fact that temperatures were cool enough after blooming and through grain development to keep stalk rot development to a minimum. Although the plants were under drouth stress for nearly 3 months, plant growth was fairly normal and grain development was excellent, with seed size normal or somewhat larger than usual.

Planting rate is another factor that frequently contributes to reduced yields, primarily when the plantings are too thick. Frequently we see fields with about an optimum planting rate that will be disked up because they think it is too thin and then proceed to plant at populations twice or three times as heavy as they should. The additional plants, in a year for optimum moisture may yield slightly more, but when moisture becomes limiting the additional plants will utilize too much of the available moisture and the yield is sharpely

reduced. Plant population should be no higher than the minimum stand needed to give a good crop in average years. Sorghums have the capacity to sucker and increase seed size to utilize the additional moisture when conditions are above average. When moisture conditions are less than normal the lower population can frequently maintain itself until rains arrive when it can go ahead to make a good crop, or at least produce some crop if rains fail to come. I have seen yields of 100 bushels per acre from plant populations of 15,000 plants. I have also seen yield spread of only three bushels per acre between 20,000 and 90,000 plants per acre. Had rains failed, the heavier rate would have been seriously damaged by over population. With adequate rains that came the lower population nearly fully compensated by increasing panicle number, panicle size, and seed size.

Losses due to lodging also contribute to lowered yields. Lodging is frequently associated with the stalk rot complex and these tie back to drought stress. Insect damage certainly contributes to lowered yields, particularily when the problem is not taken care of before it sharpely reduces yield. In the past producers have been taught that sorghum is a crop that does well with less fertilization. This is partially true, but we must remember that no crop can perform to its maximum without having adequate fertilization and care.

Many factors can contribute to reduced yields. Each by themselves may be small, but when all are combined the magnitude of reduction can certainly be substantial.

Stalk strength is a problem that has been with us since well before hybrids were introduced. Plant breeders have attempted to improve the strength by breeding for shorter stature. Shortening the plants has given some improvement, but usually at a sacrifice of yield.

Healthy sorghum plants frequently have good stalk strength. Stalk rots are the primary factor that predispose the plants to lodging. As the stalk rot develops the vascular system, parenchyma tissue and rind die and begin to decompose. The correlation between rotting and lodging is very high. The stalk rot also contributes to lower yield by destroying the capacity of the plants to translocate water and nutrients into the developing seed. The combination of premature cessation of seed growth and high incidence of lodging results in sharpely reduced yields.

Pathologists, physiologists and plant breeders are all engaged in the search to improve stalk strength. If germplasm can be developed that tolerates stalk rot well enough to avoid premature death and lodging the potential for substantial increase in both grain and forage yield is possible. With the strength problem solved the higher yield potential of taller plant height can be used. The use of screening nurseries where high temperature and drouth stress following pollination can be achieved is of great value in selecting stalk rot tolerant germplasm. Pathologists and physiologists are trying to determine what change takes place in the plant after blooming that transforms them from completely resistant

to invasion of the stalk rot pathogenes to susceptible. We also need to know more about what the critical temperature is for stalk rot development. The drouth conditions at North Platte in 1974 were ideal for stalk rot, but the temperatures were slightly cooler than normal through the blooming and seed filling period which resulted in very little stalk rot development. In the absence of stalk rot the sorghum crop, though in severe drouth stress through the entire grain filling period, was able to develop larger than normal seed size and gave excellent grain yields of up to 80 bushels per acre. Rind thickness, vascular construction and configuration, cell size and number are all important factors in stalk strenth, but the importance of stalk rot resistance in relation to stalk strength cannot be overemphasized.

A crop of sorghum itself is of no more value than the use that can be made of it. Sorghum is used both as human food and as feed for livestock. A wide range of difference in digestability exists within the sorghums. Unfortunately many of the characteristics that contribute to improved digestability when used as food or feed also contribute to susceptibility to weathering and bird damage in the fields prior to harvest. We need to combine, insofar as possible, the better digestibility and satisfactory agronomic traits. There also is a great deal of difference in the chemical balance within the sorghums. Selecting and interbreeding strains with improved amino acid balance and more digestable starch components is possible. Incorporation of these into

agronomically acceptable strains is an integral part of the improvement program. The final product must combine the improved nutritional value with acceptable agronomic characteristics or it will have little more than academic value.

Several processing techniques are available for improving the nutritional value of the grains we currently have. All of the techniques require some outlay of money both in equipment and in actual costs of processing. The improvement must be greater than the costs or they are of no value and will not be used.

The research team at Purdue University is doing excellent work in locating and eveloping germplasm with improved nutritional value. We need additional information though, on how the environmental factors infleunce the nutritional value. What is the effect on nutritional value of well developed grain compared to the same genotype when the grain has been damaged by stalk rot infection killing the plants prior to full development? Why do we see cases in which the same genotype has been the top performer in one feeding trial while being near the bottom in another? How does the processing technique used affect the nutritional value of the improved strains? Until we get some of these questions answered we are in a blind alley as far as breeding for improvement is concerned.

The germplasm becoming available from the sorghum conversion program may well hold the potential for solving the problem of the narrow genetic base we are currently using

We must be cautious to avoid the pitfall of everyone using the same few selections from the program that seem to hold the most immediate promise and neglect any use of the remainder. This could have the same consequence as using the narrow base we now have. Human nature dictates the tendency to work with germplasm that appears to have the most promise. Continuing to work with that, which at first seems less than the best, may prove highly valuable in the long run. This could prove to be true regardless of the specific traits we may wish to improve.

Continuing the search for other cytoplasmic sterility systems must be a top priority item. Using other sterility systems may open other opportunities for improvement. Maybe we can overcome the problem of shedders in our female rows reducing or eliminating the roguing problem in seed fields. Unfortunately with shedders by the time you find them they have already done some damage.

We have seed production problems that require the attention of everyone. Ranking high as a problem is outcrossing to shattercane forage types. Many farmers are very reluctant to grow sorghum when they see the problems that have been created in many fields. It is easy to say the problem could have been solved in a few minutes of roughing of the first patch or two when they appeared. It is quite another matter when large areas are infested with thousands of plants per acre before they attempt to handle the problem. The outcross problem is made more difficult by the fact that most if not

all of the primary seed production areas of the United States have shatter cane problems making isolation completely free of shatter cane pollen difficult to find.

I'm not sure how far sorghum seed can be economically transported, but maybe there are a few areas in the country that could be developed primarily as grain sorghum seed production areas. As little as 15 to 25,000 acres of seed production would be sufficient to produce 50-75 million pounds or more of seed depending on the yielding ability of the seed parents used. An endeavor of this nature would require close cooperation of seed companies involved. Some may be reluctant fearing loss of their parental stock. Female stocks could be increased at other locations by each company while the male lines would probably be less subject to theft and use by other companies in such close proximity than they are now. Some attempts have been made to move some seed production. Problems were encountered although I'm not sure how serious. If we want to whip the outcross problem we will have to be prepared for some challenges.

Cold tolerance is a problem for many areas of the United States as well as other areas of the world. The problem is not the same in all areas, however. In Nebraska we frequently plant in colder than optimum soil and we need sorghums that can be germinated and produce vigorous plants under those conditions. In addition we need plants that can continue to develop grain if conditons turn cool after pollination. The nights are usually cool normally ranging from 35°F to 55°F as

we move past pollination while the days may be cool or reach temperatures as high as 100°F. It also must be mature in 40 to 50 days following pollination or it will be subject to frost damage. The combination of germplasm to tolerate all these conditions is not easy to find.

The ability of the grain to tolerate a light frost would have been worth many millions of dollars to producers in Nebraska and surrounding states in 1974. After observing the damage our nurseries sustained by frosts in early September, I am convinced differences in frost tolerance exist. I have a few selections that tolerated a low temperature of 22°F without all of the grain being killed. In some cases I could attribute this to protection by the leaf canopy, but in others the panicles were fully exposed and the grains were not well protected within the panicles. I am sure that stage of development, when subjected to the frost, influences their tolerance to freezing temperatures. I will attempt to check the selections I made under environmentally controlled freezing conditions to see if the differences are real.

I have touched on a number of problems and potentials, particularily those most prominent to our area. I have touched only briefly or not at all many other areas that I'm sure other speakers will discuss. The potential of sorghum is great. It is our challenge to make the crop perform to its potential.

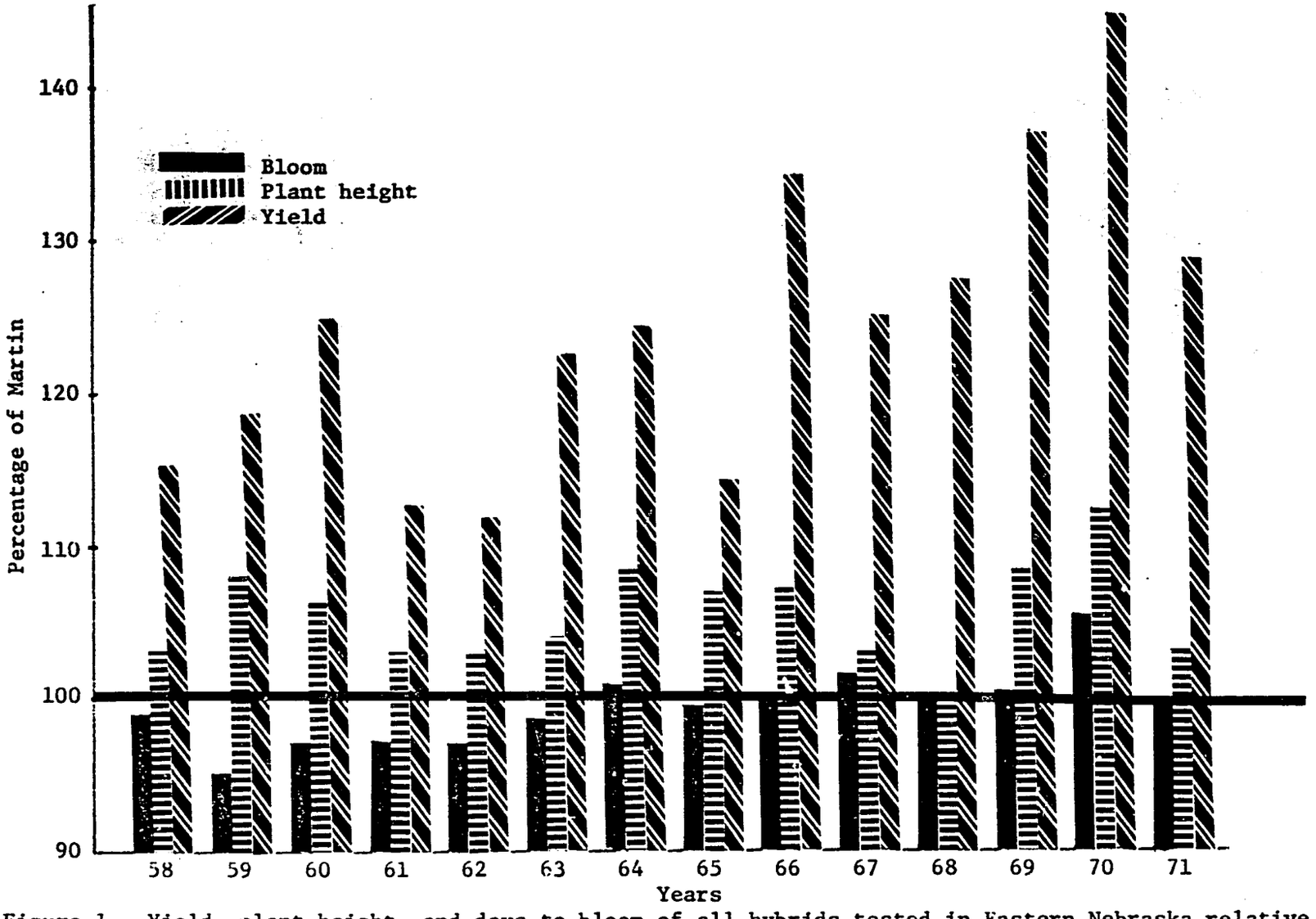

Figure 1. Yield, plant height, and days to bloom of all hybrids tested in Eastern Nebraska relative to the variety Martin.

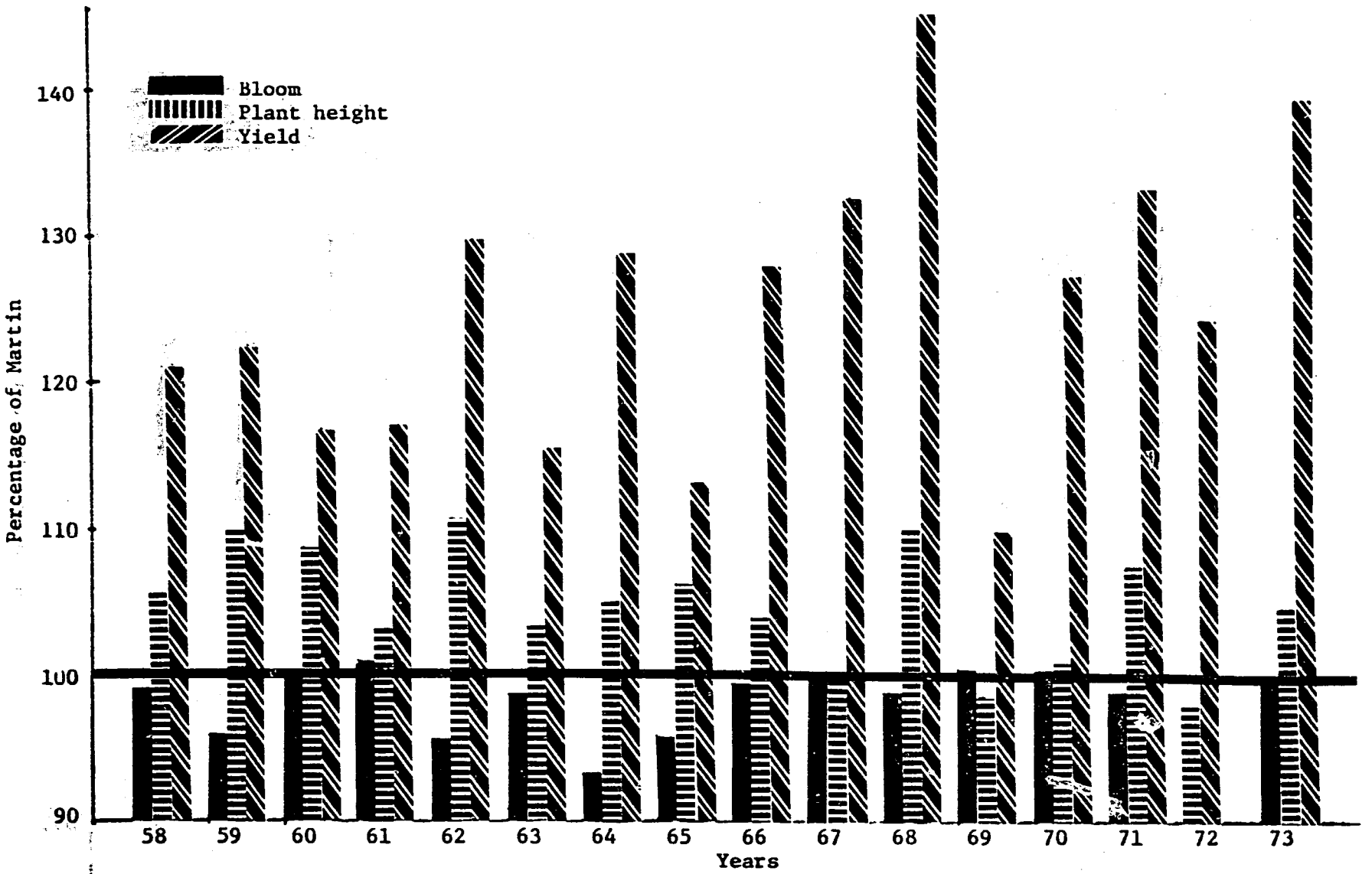

Figure 2. Yield, plant height, and days to bloom of all hybrids tested in Central Nebraska relative to the variety Martin.

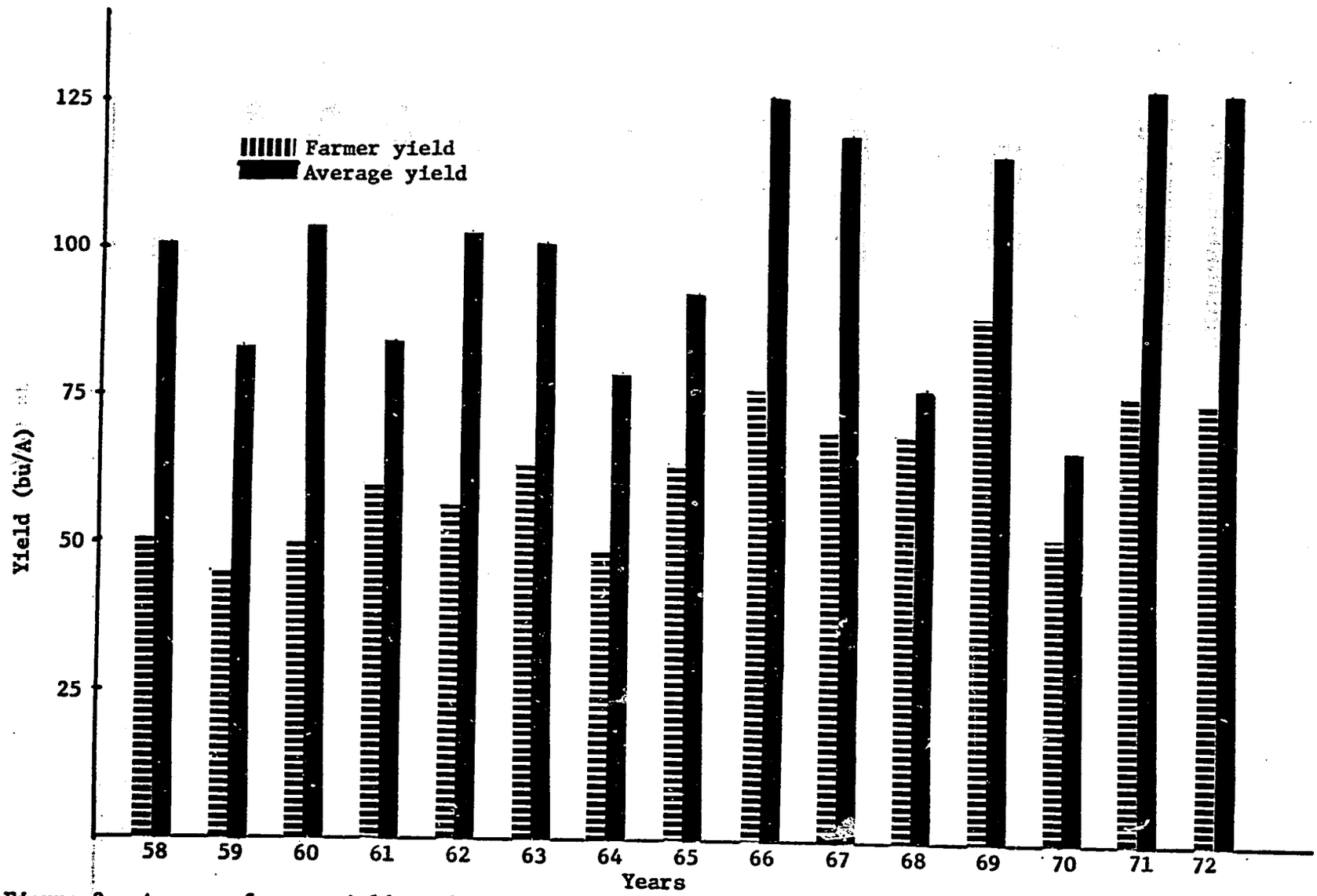

Figure 3. Average farmer yields and average yields of all hybrids tested in the same county in Eastern Nebraska from 1958 to 1972.

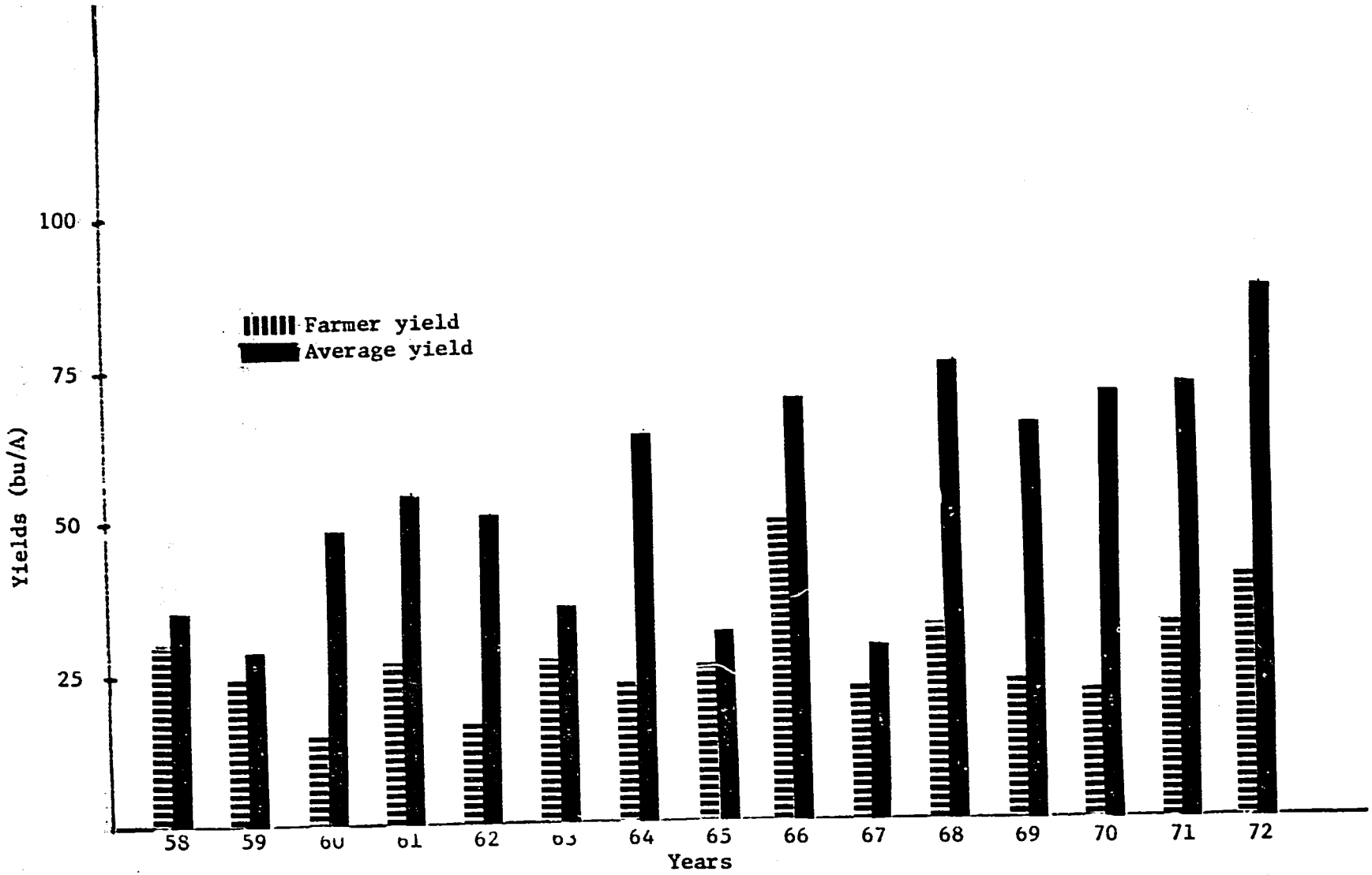

Figure 4. Average farmer yields and average yields of all hybrids tested in the same county in Central Nebraska from 1958 to 1972.

PROGRESS IN SORGHUM BREEDING AND IMPROVEMENT IN THE AMERICAS AND POTENTIAL FOR FUTURE IMPROVEMENT

D. T. Rosenow[1/]

EARLY HISTORY--INTRODUCTIONS

Sorghum is not a native of the Americas. Introductions apparently began in the early 1800's during the period of slave trade with Africa when grain was brought along as food. The Caribbean area was the site of introduction for several varieties. The Milo group of varieties was carried to Colombia and from there to the United States. Important introductions into the United States began in the 1850's and by 1909, most of the distinct types now used for both grain and forage were present.

Since the time of these early introductions, many more introduced types have been observed, but only a few have made contributions. The tall height and lateness of most tropical sorghums make them unadapted to temperate zone areas. The early introductions of some forage types, such as the ambers, orange, sourless, sumac, and sudangrass, along with early introductions of typical milo, kafir, feterita, and hegari formed the basis of sorghum improvement in the Americas. Only in the past few years have new introductions begun to contribute and change the basic germ plasm being used.

EARLY HISTORY--IMPROVEMENT

Early activities with sorghum were confined largely to introduction

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However, this system was discarded and the milo-kafir cytoplasmic-genic sterility system found at the Experiment Station at Chillicothe, Texas, was used. Hybrid seed using this cytoplasmic system was available in quantities in 1957, and farmers planted all available seed. By 1959, essentially all grain sorghum planted in the United States was from hybrid seed.

The development of hybrid sorghums not only increased yield potential, but was the catalyst for many other dramatic changes in the sorghum industry in the Americas and world-wide. Private seed companies developed rapidly and built extensive breeding programs. The higher yielding and widely adapted hybrids expanded the areas of sorghum production both within countries and to new countries. Cultural work on fertilization, irrigation, weed control, etc. was stimulated. A large portion of the fantastic yield per acre increases from pre-hybrid to the 1960's in the United States was due to improved culture. Also significant was the use of sorghums of proper maturity to utilize improved cultural techniques.

POST-HYBRID ERA

For several years after hybrids were developed, breeding work consisted of testing previously developed lines as parents and developing hybrids of specific maturity to fit into certain environments. Many old standard varieties proved to be outstanding parents, and disease and insect problems were relatively minor.

About 1960, head smut became serious in South Texas, but breeders had resistant hybrids on the market by 1964. Sorghum downy mildew was first recognized in the Western Hemisphere in Texas in the early 1960's. It became a serious threat to production in certain areas by 1965.

have been available for many years, their tallness and lateness in temperate zones have precluded their use to any large extent. To eliminate their height and maturity problems, a conversion program was conceived. This program involves changing a few major dominant height and maturity genes with a crossing and backcrossing program under short days in Puerto Rico with selection for short, early genotypes under long days in Texas. The results are converted lines essentially like the tropical exotic, but which are short and mature normally during long days. These essentially photoperiod insensitive converted lines are then usable under any day length.

The Texas Agricultural Experiment Station--United States Department of Agriculture cooperative conversion project as well as smaller conversion projects by private seed companies are now providing much new germ plasm in a usable form.

The assembly, cataloging, and distribution of the World Sorghum Collection in the 1960's also contributed greatly to availability of new germ plasm. It is from this collection of over 14,000 different varieties that new entries are selected for entry into the TAES-USDA conversion program.

NEW GERMPLASM--POTENTIAL

The availability of this new diverse germ plasm, the first of which was released in 1969, opens a new era in sorghum improvement and production in the Americas and world wide. The finding in conversion materials of superior sources of desirable characteristics along with the great obvious diversity indicates that the potential for future improvement is very bright.

Examples of outstanding source materials of insect and disease

resistance identified to date in this new germ plasm are resistance to downy mildew, head smut, anthracnose, maize dwarf mosaic, charcoal rot, rust, Fusarium head blight, and other foliage diseases, as well as resistance to midge, greenbug, Banks grass mite, shootfly, and witchweed. Grain quality improvement for feed, food, and industrial use appears likely with the finding of grain weathering resistance, high lysine grain, differences in digestibility, and white seeded types with little color and low in tannins. Other useful characteristics found are lodging resistance, easy threshing types, and a wide range of head, plant, and grain types potentially useful in physiology and breeding research. Non-senescing types could be useful in drought, insect, and disease resistance. The finding of B-lines in diverse types never before used in hybrids and evidence for new cytoplasmic systems offer exciting possibilities.

The recent interest and success in breeding for insect resistance in sorghum is especially noteworthy. Such research should contribute greatly to future improvement and expansion of sorghum into new areas, particularly tropical and sub-tropical areas where insects are often limiting factors.

My comments in this paper are based largely on knowledge of past and present sorghum research in the United States. I did not attempt to comment on past progress in other countries since my knowledge is very incomplete. However, I feel that significant improvements to date in other countries in the Western Hemisphere have largely mirrored those in the United States. The development of hybrids with wide adaptation along with research and expansion by private companies in many new countries were largely responsible for the sorghum industry as it is

known today in countries such as Argentina and Mexico.

Except for the areas of Africa and Asia where sorghum is native and used largely as a human food, sorghums used throughout the world are largely identical or very similar to those developed and used in the United States. In many cases in the past, United States varieties and hybrids have proven unadapted to tropical humid conditions when tried in other parts of the world. A major reason for this has been that germ plasm primarily used until very recently has been limited and unfortunately did not contain the necessary insect and/or disease resistance. The extensive use of new germ plasm of tropical origin in both public and private breeding programs should be very significant to sorghum improvement and expansion in countries of Central and South America where sorghum is not presently used or is a minor crop. The higher levels of insect and disease resistance, along with insensitivity to photoperiod, and greater inherent adaptation to tropical or sub-tropical conditions makes the future of sorghum in these areas very bright.

Although my comments have been primarily limited to grain sorghum, the past history and development of forage types is very similar. Also, the potential for future improvement in forage types is equally encouraging.

Cooperation and exchange of sorghum breeding materials and information are essential if the wealth of new germ plasm now available is to be efficiently utilized.

Resistance was not easy to find, and sometimes difficult to use, and only in the past two years have acceptable downy mildew resistant hybrids become commercially available. Maize dwarf mosaic was first recognized on sorghum in Texas in 1966, and it significantly damaged sorghum in Texas in 1967. In 1968, the greenbug suddenly became a serious pest of sorghum throughout most of the sorghum producing areas of the United States. Greenbug resistant hybrids should be commercially available on a limited scale in 1976. Other diseases and insects recognized in recent years as serious threats to sorghum in certain areas are anthracnose, rust, zonate leaf spot, Helminthosporium leaf blight, gray leaf spot, pythium root rot, Fusarium head blight, Banks grass mite, and white grub. Much breeding effort has been expended in the past 5 to 10 years to develop hybrids resistant to the above mentioned pests.

In the late 1960's, yellow endosperm parental lines came into use. Heteroyellow hybrids have dominated the United States market since then, with many hybrids using genetically similar male parents. The hybrids are widely adapted over a tremendous environmental range. They have also been reported to be somewhat superior in digestability to non-yellow types although data is not always consistent. The yellow endosperm exotic brought from Nigeria in the early 1950's has been the most significant introduction in providing different germ plasm used in the Americas since 1909.

NEW GERMPLASM--AVAILABILITY

The lack of diversity in the sorghums in common use in the Americas through the late 1960's was of concern to researchers several years ago. The recent outbreak of serious diseases and insect pests has added to this concern. Although introductions of diverse types

of new varieties and selection within existing strains. Many introductions were tall and late maturing. A major factor in their adaptation and use was selection for shorter and earlier mutant strains within the introductions. Many of these selections were made and preserved by farmers.

Plant breeding research to improve sorghum using hybridization and selection began about 1915 in the United States. The first varieties resulting from artificial hybridization were released to farmers in 1923. A root and stalk rot called milo disease threatened the sorghum industry in the United States in the early 1930's. However, selection for resistance was simple and resistant varieties were developed very rapidly.

MECHANIZATION

The first combine height variety was released in the United States in 1928. Another combine height variety, Wheatland, was released about 1930, and it marked the beginning of the combine sorghum era and was a significant step in grain sorghum improvement. A farm manpower shortage during World War II along with the release in the early 1940's of stiff-stalked varieties like Martin, Westland, Midland, Plainsman, and Caprock stimulated the shift to combine height sorghums and mechanical harvest. By 1945, combine type sorghums accounted for about 90% of all grain types grown.

HYBRIDS

The desirability of F_1 hybrids was long recognized, but their utilization awaited a usable male-sterile system to economically produce seed. The first commercial hybrid seed was available in the early 1950's and was a three-way cross using Day genetic male-sterility.

TAMAÑO Y FORMA OPTIMOS DE PARCELA EXPERIMENTAL DE SORGO PARA GRANO EN EL BAJIO DE MEXICO

Arturo Estrada G. y Hermilo H. Angeles A.*

Con el objeto de determinar el tamaño y forma óptimos de parcela experimental en el cultivo de sorgo para grano en la región de El Bajío en el ciclo de riego de 1972, se establecieron 3 experimentos de sorgos comerciales y experimentales, uno de ciclo tardío, otro de ciclo intermedio y otro de ciclo precoz. El diseño usado fue un Bloques al Azar de 4 repeticiones y parcelas usuales de 2 surcos de 10 m. de largo separadas a 76 cm. Antes de la cosecha cada parcela se subdividió en 8 secciones de 2.5 m de largo y cada sección se consideró como una unidad básica (U.B.) para obtener diferentes arreglos en tamaño y forma de parcelas agrupando unidades básicas. Se obtuvieron 6 tipos de parcela a los que se les determinó la varianza entre parcelas adyacentes de un mismo tipo y su coeficiente de variación considerando cada tamaño como un ensayo uniforme simulado para evitar el efecto de repeticiones y variedades (de acuerdo con Koch y Rigney 1951; Lessman y Atkins 1963b). Se determinaron coeficientes "b" de heterogeneidad del suelo (Federer 1955) y se aplicó la fórmula de Hateway (1961) para determinar el tamaño adecuado de parcela experimental en base a múltiples o submúltiples de la (U.B.) considerada con un número constante de repeticiones y diferencias "d" predichas. Los resultados obtenidos para detectar diferencias "d" de 20 y 25% entre los materiales de sorgo con respecto a su media fueron los siguientes:

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3. La parcela experimental utilizada actualmente en los trabajos de investigación en México se puede reducir a una de 2 surcos de 5 m. y así aumentar el número de experimentos en la misma superficie y costo.

A) Parcelas unitarias de 1 U.B. con 4 y 8 repeticiones tardíos quieren 4 y 2 U.B. y 1 y 0.50 U.B. respectivamente; intermedios 3 a 4 U.B. (7.5-10m. y 1.5 U.B. (3.75 m) ó 0.8 y 0.2 U.B. respectivamente y en los precoces se precisan 8 U.B. (1 Surco de 20 m. y de 2 U.B. (5m.) ó 0.8 (aprox. 1 U.B.) y 0.2 U.B. respectivamente para detectar diferencias de 20 y 25% respectivamente.

B) Parcelas unitarias de 2 surcos de 1 U.B. Tardíos parcelas de 1 a 2 U.B. (2 surcos de 5m.) y de 0.7 U.B. y de 0.4 y 0.2 U.B; intermedios parcelas de 1 y 0.3 U.B. ó 0.3 y 0.1 U.B. respectivamente y en sorgos precoces se requieren 1.6 y 2 U.B. con 4 repeticiones para detectar diferencias de 20 y 25% y con 8 repeticiones se necesitan parcelas de 0.2 y 0.04 U.B. respectivamente.

De acuerdo con los resultados anteriores se puede concluir lo siguiente:

1. En las pruebas experimentales de sorgo para grano se pueden utilizar parcelas del tamaño y forma indicados en los resultados mencionados anteriormente, si se desea utilizar diferencias entre materiales con respecto a la media de 20 y 25%.

   En caso contrario es conveniente utilizar parcelas de tamaño mayor y mayor número de repeticiones, que las encontradas en el presente trabajo, para lograr mayor precisión de las diferencias entre materiales.

THE BROWN MIDRIB GENE (brm*) IN SORGHUM AND ITS AFFECT ON FORAGE QUALITY

K. S. Porter, J. D. Axtell, V. L. Lechtenberg, V. F. Colenbrander

The brown midrib character has been known in maize for some time. Jorgensen (1931) described the character and subsequent to that time at least four separate genes have been identified and designated bm_1, bm_2, bm_3 and bm_4. Any of these genes results in the brown pigmentation characteristic of brown midrib plants. These genes have been used primarily as genetic markers.

Kuć and Nelson (1964) and Gee, Nelson and Kuć (1968) showed that the bm_1 gene in maize caused a change in the percent lignin in the plant. Other workers have also assessed the effect of the various bm genes on structural composition and digestibility of corn plant forage.

Lechtenberg *et al.*, (1972) analyzed the four mutant genotypes bm_1, bm_2, bm_3, bm_4 and the normal inbred Tr, for fiber content and for *in vitro* dry matter digestibility (IVDMD). Lignin and IVDMD percentages are presented in Table 1. They showed that the bm_3 gene caused the greatest decrease in percent lignin and the resulting largest increase in percent IVDMD when compared to normal, whereas the other bm genes caused smaller changes in percent lignin and IVDMD.

Muller *et al.*, (1971) and Barnes *et al.*, (1971) analyzed stem and leaf tissue for fiber content and IVDMD, as percent of dry matter, in bm_1, bm_3 and normal genotypes. They also found that the bm_3 gene significantly decreased percent lignin and increased IVDMD percentage

* brm is tentative gene symbol.

Table 1. Percent lignin and *in vitro* dry matter digestibility (IVDMD) of stover from mutant inbred corn plants harvested 55 days after silking.

Genotype	Lignin	IVDMD
	% of dry matter	
bm_1	7.05 bc	47.0 b
bm_2	6.76 c	51.8 ab
bm_3	5.32 d	54.8 a
bm_4	7.34 ab	51.3 ab
Normal (Tr)	7.76 a	46.4 b
S.E. of mean	0.23	1.44

a, b, c, d Means in the same column bearing a common letter are not significantly different at .05 level of probability

when compared to bm_1 and normal. Lignin and IVDMD percentages for stems and leaf blades are shown in Table 2.

Colenbrander et al., (1973) fed bm_3 and normal stover silage to yearling heifers to determine how mutant material might affect animal performance. Data from a six week feeding trial is shown in Table 3. They found significant increases in average daily gain, feed efficiency and daily dry matter intake with the bm_3 stover silage when compared to a normal commercial hybrid.

It has now been concluded that the bm_3 gene offers the greatest potential for use in improving maize forage quality by altering fiber composition. In summary, the bm_3 gene in maize has the following effects:

1. Brown pigmentation in leaf midrib, stem, root, tassel and cob.
2. A decrease in percent lignin of approximately 40%.
3. An increase in percent IVDMD of approximately 10%.
4. Increased daily dry matter intake by ruminants.
5. Increased weight gain and feed efficiency by ruminants.

In 1972 we treated seed of two different sorghum lines with diethyl sulfate (DES) to induce mutations. A short line (954114) and a tall line (945104) were treated with 1 ml. of 2 ml. DES/1000 ml. water for three hours.

M_3 plants showing the brown midrib character were identified in head rows in 1973. Nineteen different mutants were identified and designated brm-1 through brm-19. These are not gene symbols, but temporary identification numbers assigned pending completion of allelism tests. The corresponding normal segregates were designated N-1 through N-19. The source of each line by treatment is shown in Table 4. Since

Table 2. Percent lignin and *in vitro* dry matter digestibility (IVDMD) of stem and leaf blade from mutant inbred corn plants harvested 35 days post-silking.

Genotype	Stem		Leaf blade	
	Lignin	IVDMD	Lignin	IVDMD
	% of dry matter			
bm_1	7.16 ab	58.2	4.84 b	63.0
bm_3	5.25 b	66.7	4.58 b	68.9
Normal	8.54 a	56.3	6.28 a	60.9
S.E. of Mean	0.38		0.44	

a, b Means in some column bearing a common letter are not significantly different at the .05 level of probability.

Table 3. Daily gain, feed efficiency and intake of corn stover silage fed to cattle.

	Silage	
	bm_3	comm. hybrid
Average daily gain, kg.	1.09	0.53
Feed/gain, kgDM/kg gain	5.36	7.43
Daily dry matter intake, % BW*	2.06	1.47

*BW = body weight

Table 4. Brown midrib mutants induced by diethyl sulfate (DES) in two sorghum lines. Treatments shown are ml DES/1000 ml water.

954114-(short line)		954104-(tall line)	
1 ml DES/3 hrs	2 ml DES/3 hrs	1 ml DES/3 hrs	2 ml DES/3 hrs
brm-1	brm-8*	brm-12	brm-18
brm-2	brm-9*	brm-13*	brm-19
brm-3	brm-10*	brm-14	
brm-4	brm-11	brm-15	
brm-5		brm-16	
brm-6		brm-17	
brm-7			

* Deleted from study because of sterility.

the initial identification, four brm mutants have been deleted from our study because of sterility.

In 1974 we planted 16 of the brm mutants and corresponding normal segregates in adjacent plots in a randomized block design with three replications. Plots were sampled by selecting 4-6 plants at random and separating leaf blades and sheaths from the stems. The leaves and stems were then shredded, dried, ground and analyzed for fiber content and *in vitro* dry matter digestibility (IVDMD). Fiber concentration was determined using techniques developed by Van Soest. The modified Tilley and Terry technique was used to determine IVDMD.

The most distinguishing characteristic of the gene is the brown pigmentation present in the midrib on the back side of the leaf. In addition to the leaf midrib, the stem is also brown (particularly behind the leaf sheath), as is the culm, the immature panicle branches and the stem pith. The pigmentation is quite obvious at the 4-6 leaf stage and persists in the plant through maturity. Some fading may occur (particularly on the top side of the leaf) as tissue matures but even at full maturity the pigmentation is still quite obvious in the midrib on the back side of the leaf, in the stem behind the leaf sheath, and in the stem pith. The brown pigmentation in the pith may be difficult to distinguish in young plants. The mutant is quite distinct from orange or yellow midrib plants and is easily distinguishable from normal plants.

The intensity of the brown color may vary from line to line and may not be correlated with compositional difference in the forage.

The data presented here are only preliminary results and were obtained from samples analyzed up to this point. A more complete analysis of results including fiber digestibility will be forthcoming in

the near future. Some conclusions may be drawn and trends noted from the available data.

Table 5 contains preliminary lignin and IVDMD data on two of the short lines. Values shown represent percent of dry matter. Several points can be made from the data presented. An apparent correlation exists between percent lignin and IVDMD. In each case a decrease in percent lignin results in an increase in IVDMD. The magnitude of the change in percent lignin is reflected by a corresponding change in IVDMD. In Table 5, brm-4 shows less of a decrease in percent lignin than brm-6 and has a correspondingly smaller increase in percent IVDMD. This apparent relationship holds in both leaves and stems.

A second point to be made is that a marked difference exists among brm mutants in their apparent ability to decrease the percent lignin in the plant. Some mutants show only a small decrease while others show a very definite drop in percent lignin. We would hypothesize that there are probably several different brm genes, each of which may affect fiber composition to varying degrees. This has been shown to be true in maize and appears to be true in sorghum as well.

It should be noted that in both mutants, the brm gene is associated with an improvement in forage quality as measured by decreases in lignin and higher IVDMD in comparison with the normal plants.

Similar data from two of the tall lines is shown in Table 6. Again our preliminary data shows a striking difference between the brm mutants, the apparent correlation of percent lignin with IVDMD and the improvement in fiber composition and percent IVDMD of the mutant over the normal plants. The difference appears to be even more pronounced in the tall line. The brm-18 mutant shows an almost two-fold increase

Table 5. Percent lignin and *in vitro* dry matter digestibility (IVDMD) of stems and leaves from mutant and normal plants (956114 - short line).

Genotype	Stems		Leaves	
	Lignin	IVDMD	Lignin	IVDMD
brm-4	4.20	67.63	5.63	60.54
N-4	5.31	67.03	6.81	59.49
brm-6	4.57	68.24	5.70	61.39
N-6	7.96	64.49	6.98	56.70

Table 6. Percent lignin and *in vitro* dry matter digestibility (IVDMD) of stems and leaves from mutant and normal plants (954104 - tall lines).

Genotyp	Stems		Leaves	
	Lignin	IVDMD	Lignin	IVDMD
brm-16	5.07	66.60	5.95	63.68
N-16	6.38	60.72	6.66	59.90
brm-18	3.34	76.61	5.83	69.16
N-18	6.56	63.96	7.26	60.23

in percent IVDMD over brm-16 when both lines are compared to their normal counter parts. This increase is again probably due to the larger decrease in percent lignin in brm-18. Leaves again show a similar response to decreases in lignin.

Our data indicate differences among brm mutants, possibly due to the presence of different genes, a consistent correlation between decreases in percent lignin and increase in percent IVDMD and finally an improvement in some brm mutant lines in fiber concentration and IVDMD over normal lines.

In summary we have observed the following characteristics in brown midrib mutants we have worked with:

1. Brown pigmentation
   a. Leaf midrib (particularly back side of leaf)
   b. stem (particularly behind leaf sheath)
   c. culm
   d. immature panicle branches
   e. pith
2. Pigmentation most distinct in newest tissue
3. Decrease in percent lignin
4. Increase in percent IVDMD
5. Differences among mutants possibly resulting from the existence of different brown midrib genes.

Although our results are only preliminary, we feel confident that the brm gene can be a powerful tool in a sorghum breeding program for improving forage quality with the resulting improvement in animal performance.

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THE DEVELOPMENT OF COOL TEMPERATURE TOLERANT GRAIN SORGHUM

E. C. Johnson and Shree P. Singh

The cooperative agricultural research program of the Mexican Ministry of Agriculture and The Rockefeller Foundation[1] made repeated efforts to grow grain sorghums in the high cool plateau areas of Central Mexico between 1943 and 1961. Large regions of the country are chronically deficient in rainfall so that substituting sorghum for corn in such areas appeared to be a desirable shift in terms of the recognized agronomic characteristics of the two crops. The hope was that the drouth tolerance of the sorghum plant might also permit more land to be brought under cultivation.

Practically all of the varieties and strains available at the time were planted at 2,250 meters elevation near Chapingo, Mexico, over a period of several years. Results were discouraging since only occasionally did measurable grain formation take place. From one or two seeds up to 20 or 30 per panicle was the usual production level. Plants grew normally, although slowly, during the vegetative period. The reproductive process somehow failed to function normally. Seed harvested from plants that did produce seed resulted in no apparent improvement in grain production when planted in the following season, so the attempt was not pursued long enough to evaluate possible progress over a period

[1]Oficina de Estudios Especiales (Office of Special Studies).

of years. Pollen was apparently produced by most varieties, but the stigmas remained exposed and open for an abnormally long period before gradually shrivelling and no seed formed. The idea became accepted that night temperature minimums were simply too low to enable sorghum to set seed. Night temperature minimums during the sorghum growing season frequently range from 5° to 12°C (40° to 50°F) in the region. Subsequent observations of sorghum plantings in many areas have confirmed this as a limiting factor in seed production.

The rainy season around chapingo normally begins about mid-May and continues through September. Temperatures are highest at the onset of the rainy season, and frost does not often occur before October 1. When planted in mid-May many sorghum varieties flower during August and early September. It was noted that in years when the weather was warmer than usual during the flowering period of the sorghum more seed was produced.

Sources of cool tolerance

Efforts were made to obtain seed from the cool areas at high elevations in the presumed center of origin of sorghum in Africa. From the numerous samples obtained for trial in Mexico, three were selected initially as having potential since they produced seed at Chapingo. These three samples carried labels of origin as "Nyundo, Mabere, and Magune" and were stated to be from Ethiopia although they may actually be from Uganda. All three were tall and required a long growing cycle and appeared to be photoperiod sensitive. Varieties that have a long growing cycle would be of little use under the short rainy season conditions of the Mexican uplands, so a program of breeding was

initiated.

Development of the cool temperature tolerant pool

The three varieties, Nyundo, Mabere, and Magune, were used as sources of tolerance to low night temperatures. Genetic stocks of 38 Milo and 40 Kafir from Texas were chosen as sources of early maturity. In 1960 the three African materials were crossed with the early stocks at Progreso experimental station near Cuernavaca, Mexico which is at 1,500 meters elevation and with warmer temperatures than Chapingo. The crosses obtained were then grown for several generations in bulk at Cuernavaca before beginning selection at the higher elevation near Chapingo. A few plants were backcrossed to the three African parents and the resulting seed mixed into the bulk pool. No effort was made to keep pedigree records.

Bulk seed was then planted at the 2,250 meter elevation location after the several generations of mixing. Wide variations in plant type, height, maturity, etc. existed in the material. Approximately 1% of the plants in the bulk population produced enough seed to justify selection for further work. Seed set on the material as a whole varied from the extremes of no seed at all to a few heads with completely normal fill.

With the demonstration that it was possible to recover relatively short, early maturing genotypes from the crosses that had been made, additional variability was gradually fed into the pool. A procedure was established to allow introgression of other materials and to limit the height and number of days to flowering of the plants in the population. Individual plants were the initial basis of selection and were planted head-to-row. Two or three generations of this procedure quickly resulte

in uniform progeny rows in which mixtures or outcrosses could be readily detected by their dissimilarity to other plants in the row. Arbitrarily about 25% of the plants saved were from the shortest families in the field. Another 25% were from the earliest materials to flower, regardless of height. The remaining 50% consisted of families that appeared to be the heaviest seed producers and those that appeared to be mixtures or natural outcrosses that occurred in the field. To encourage such crosses to take place, other materials of diverse origin were randomly interplanted in rows throughout the nursery. These materials included a wide range of commercial hybrids, additional materials from high altitude areas, etc. The potential outcrosses occurring in the uniform progeny rows were in turn planted in progeny rows, and selection was done in the segregating rows on individual plant basis. As these recombinations were in turn successively selected in head rows, the 25% "genetic understory" each of short plants and of early plants was gradually changed to recombinant genotypes and the entire pool pushed in desired direction of selection.

In the initial selection of recombinants that was made after the bulk mixing generations, many of the plants were phenotypically quite similar to Ryer Milo, but with the important difference that seed was produced. The parents, Ryer Milo and Kafir, did not set seed, and the African parents were killed by frost before flowering. A complete range of types occurred in the segregating materials. No attempt was made to correlate parental morphological characters specifically with the formation of grain.

Circumstantial support for the belief that low morning minimum temperatures are responsible for the failure to set seed was provided by

the range of intermediate genotypes with partial seed set. These plants regularly formed noticeably more seeds on the side exposed to the first rays of the sun in the morning. Minimum temperatures usually occur just prior to sunrise, so differential warming of one side of the head at a critical temperature apparently resulted in greater seed production on that side. This phenomenon was so pronounced in certain families that viewing the row from one side gave the impression of a very good seed set while from the opposite side they seemed to have almost no seed. Similar effects are frequent in commercial materials, although to a less pronounced degree.

As advanced cycles of the mixing process were obtained, percentages of poorly filled heads have declined to the point that only those resulting from crosses to newly introduced germplasm appear to segregate for poor seed set. The continuous range of complete fill to non-fill with all degrees of intermediate types suggests that probably several genes are involved in the tolerance to low temperatures. However, the relative rapidity with which conversion was achieved and the few plants used to represent the original African sources of tolerance would suggest that the number of genes is not very large. Thus far no effort has been made to estimate the number involved. Possibly more extensive screening of sorghums from cool areas of the world would turn up additional genes conditioning tolerance to low night temperatures. Systematic recombination of such materials could very well develop substantially better performance under cool conditions than is now available.

The contrast between the selected pool of cool temperature tolerant material and the hybrids and varieties usually found in commercial

channels is striking: the difference is essentially one of complete seed failure compared with completely normal production. Detailed investigation of where the seed development process breaks down remains to be done. Interplanting commercial materials with the selected cool temperature tolerant pool so that ample pollen is available does not increase seed set that appears to rule out the possibility that pollen sterility is the cause. The breakdown evidently occurs on the female side - even pouring excess pollen on exposed stigmas produces no seed increase. Many of the plants that produce no seed do produce pollen, however. One plant of each of five different hybrids was dug out of the ground, put in large pots, and moved to lower elevation on the day that the anothers began to bloom out on the panicles. All five plants produced normal seed sets.

That a pool of material capable of producing normal seed has been developed under conditions quite different from those where the commercial hybrids have been developed is potentially of use in several ways. Fringe areas of sorghum production now limited by low night temperatures might well be made less hazardous. And new areas might be considered for production.

Selections from the pool have been also planted at 2,450 meters in Tlaxcala, Mexico, at 2,650 meters in the Toluca valley, Mexico, at 50 meters in Poza Rica, Mexico, as well as in Jamaica, U.S.A., Canada, France, Lebanon, Turkey, Yemen, U.S.S.R., South Africa, and India, with the idea of selecting the best genotypes at each locations. The selections obtained have been reassembled for recombination. Observations made at these widely differing locations bring out a number of significant behavior patterns that should be useful in further

development of the pool germplasm:

1) At least part of the genotypes survived and reproduced in all the environments.

2) Symptoms of what is probably damage from light quality became evident at the 2,450 meter elevation with even more severe damage at 2,650 meters elevation. Yellowing and bronzing discolorations of leaves with necrotic areas in extreme cases was common in many family progenies at the higher elevations, but with a wide range of differences. None of this tendency was noted at the 2,250 meter elevation.

3) Less sprouting of mature grain in the head was noted at Poza Rica under hot, humid conditions than was the case with the commercial hybrids used as checks. Also the cool tolerant selections appear to be free from headmolds.

4) Selections grown under higher temperature regimes (such as at Poza Rica) tend to have less robust plants and smaller heads. Head size reduction is much less noticeable in certain families than in others. Associated with this appears to be a decidedly strong tendency for the weaker plants to lodge under the higher temperatures and to initiate regrowth from the crown very rapidly.

5) Parallel to the relatively weaker plant appearance under high temperatures is a drastic reduction in tillering with many plants showing only single stems. At the cooler higher locations, tillering is pronounced and vigorous in a high percentage of the plants.

6) Variation in strength of perennial habit is broad in the population. At the lowland stations, most genotypes grow continuously even though repeatedly cut down during two complete years. At the 2,450 meter elevation, 75 out of 100 family rows survived the dry season (winter) and reinitiated growth and produced seed in the second season. The same families planted at the 2,650 meter location produced a series of progressively weaker sprouts which were successively frozen back, and all plants died by spring. Soil moisture was high at the 2,650 meter location and prompted the growth, while soil became very dry and induced near dormancy at the 2,450 meter location where survival was good.

7) Out of 4,000 progeny rows grown at Lethbridge, Canada nearly 1,000 flowered and produced seed. Photoperiod differences in response at the latitude of Lethbridge, approximately 50°N, indicated a relatively high frequency of genotypes suited to that latitude. These photoperiod differences cannot be distinguished at the 19°N. Latitude of Chapingo. Successive selection under northerly latitudes should quickly result in material that is nearly insensitive to daylength.

8) The frequency of desirable genotypes that survived under such widely different environments suggests the need for systematic recombination and selection over a series of environments to develop populations with a really broad range of adaptation.

9) The population under development was not protected from bird damage. Birds generally preferred white and lighter colored seed types. These types have been materially reduced in

frequency in the population. Seed colors have shifted largely to brown, red, and tan types.

10) Frequency of non-restorers ("B") to Milo Sterile Cytoplasm was about 5%.

The initial success in developing early maturing sorghum genotypes that produced normal seed formation under the cool night conditions of the valley of Mexico (2,250 meters elevation) and their potential usefulness in similar areas of the world which are characterized by scarce and erratic rainfall, has led to an expansion of the effort. This expansion has included the introduction of new sources of genetic variability for wider adaptation, different plant-types, seed color, seed size, disease and insect resistance, higher protein quantity and quality, etc. This addition of genetic variability for such desirable characters simultaneously reintroduces the lack of tolerance to cool temperatures, and therefore, selection under appropriate conditions to recover the desired recombinant types must be continued.

To achieve the desired crosses requires work under higher temperature conditions such as occur at Poza Rica and Tlaltizapan, where both cool tolerant and non-cool tolerant materials can be grown together. Use of six stations in Mexico (Table 1) provides environments for selection under widely differing conditions of soil types, temperature, moisture, solar radiation, diseases and insect pests, etc. Proper selection of superior genotypes at each of these stations permits identification of genotypes which do well at two or more of these locations and is a means of gradually building genotypes with increasingly wide adaptation. Observation in higher latitudes (U.S.A., Canada, Europe, etc.) is also contemplated to identify photoperiod insensitive

Table 1. Experiment Stations where CIMMYT Sorghum Research is conducted in Mexico

	Name of Station	Altitude (meters)	Nature of work	crops/ year
1.	El Batan, State of Mexico	2,250	Screening for Cool tolerance and yield trial	1
2.	Atizapán, State of Mexico	2,650	-do-	1
3.	Obregón, State of Sonora	60	-do-	1
4.	Huamantla, State of Tlaxcala	2,450	Screening for drought and cool tolerance	1
5.	Tlaltizapan, State of Morelos	1,000	Yield trial and seed increase	2
6.	Poza Rica, Veracruz	50	Breeding nursery, yield trial, and selection for resistance to diseases and insect pests	2-3

genotypes.

The major breeding objectives for continuing this work are: To develop cool temperature tolerant cultivars and populations with higher yield, wide adaptation, giving stability of yield, different agronomic and grain color types, field resistance to important diseases and insect pests, early maturity, higher protein quantity and quality, tolerance to bird damage, and a continued search for and use of new sources of cool tolerance.

Until 1973, natural crossing was the chief means for achieving recombination. But at present 1,000 to 1,500 controlled crosses are made every season and alternative breeding methods have been devised for a more directed use of available genetic variability. Breeding procedures currently adopted are the following:

1) Modified pedigree system with selective matings within and among families in early segregating generations:

   This procedure is followed for handling of single, double, and multiple crosses that appear to be agronomically desirable and free from at least certain diseases or insect pests. Grain yield and its components are the main criteria of selection along with the required degree of cool temperature tolerance.

2) Population development using genetic male sterility:

   Nebraska population "NP10BR" and Purdue population "PP23" are being used as sources of genetic male sterility. The major objective of this approach is to incorporate a wide range of germplasm with different sources of resistance to diseases and insect pests, wide adaptation, and cool temperature tolerance into a large intermating gene pool. After several cycles of

recombination, half-sib, full-sib, and S_1-testing procedures will be used to improve the base population and to generate elite lines. Work is also under way to develop a "Cold Tolerant High Protein" Pool with use of genetic male sterility.

3) Backcross method

his method is currently being used only to improve protein quality and quantity in agronomically desirable families. Pathologists and entomologists have been assisting in the identification of diseases and insect pests. There are regular arrangements for artificial inoculations and creation of epiphytotics to screen parents and breeding populations for resistance and/or tolerance to prevalent diseases and pests. As such agronomically desirable cool temperature tolerant recombinants are developed and identified, simple backcross subpopulations will be carried to simultaneously convert them to high protein and high lysine types.

Diseases and insect pests identified thus far, are listed below:

i) Helminthosporium leaf blight

H. turcicum, and

H. maydis

ii) Leaf rust (*Puccinia purpurea*)

iii) Zonate leaf spot (*Gloeocercospora sorghi*)

iv) Sorghum downy mildew (*Sclerospora sorghi*)

v) Maize dwarf mosaic virus (MDMV), and

vi) Head molds

Insect pests:

i) Sorghum midge (*Cantarinia sorghicola*)

ii) Corn leaf aphid (*Rhopalosiphum maydis*)

iii) Green bug (*Schizaphis graminum*)

iv) Fall armyworm (Spodoptera frugiperda)

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We would like to take this opportunity to express our gratitude to all persons who have kindly supplied us seed and have cooperated with us in evaluating our material. At the same time, it is appropriate to mention that the materials that we have are also available to others who may be interested.

BREEDING OBJECTIVES FOR HIGH QUALITY SORGHUM SILAGE

Lynn M. Gourley, John W. Lusk

In the past, forage varieties were considered improved if they yielded more than the common variety. Animal utilization and performance were not considered in varietal improvement. However, increasing costs and alternate high income usages for land make both high yield potential and improved quality important objectives for the forage breeder. Most of the silage sorghums on the market today were released on the basis of higher total yield without regard for the animal that was to utilize the product.

In many cases, permanent pastures and hays produced throughout the southern United States are not of the quality necessary to maintain the level of milk production required by present day dairy operations. Estimates from the 1971 Mississippi Dairy Herd Improvement Association (DHIA) records indicate that approximately 40% of the forage nutrient intake of dairy cows is from ensiled crops. (Carpenter, 1972).

To support the present animal industry, the state of Mississippi imports 1.27 million metric tons of feed grain annually. High costs prohibit the feeding of high grain rations to either dairy animals or beef in finishing operations in Mississippi. The dairy industry and an infant beef finishing industry in the southeastern United States have need of high quality sorghum silages to provide the bulk of the energy in the ration.

A number of Mississippi dairymen producing both corn and sorghum silages have experienced serious drops in milk production when switching from corn to sorghum silage in the feeding program. The lowered milk

yield from the cows fed sorghum silages appears to be due to both lower intake and digestibility.

Ramsey, et al. 1961 a have shown that the combine-type and silage-type sorghums excel sweet sorghums in both digestibility and consumption. The high dry matter fermentation losses in sweet sorghum silage many range from 22 to 32% at all stages of maturity at harvest, and may account for poor animal performance when compared with other sorghums or corn silage. The silage-type sorghums, even though superior to sweet sorghums for silage, do not equal the quality of corn or combine-type grain sorghum silage for high producing dairy cows. (Browning and Lusk, 1966, Nordquist and Rumley, 1967). Lusk (1968) has shown that the stover portion of the silage-type sorghums is 10% higher in cell wall components than combine-type sorghums, an indication of inherent differences in the fiber structure of the two types of hybrids.

Cummins and Dobson (1972) found that the waxy bloom on the surface of the fresh sorghum leaves caused a 20% reduction in in vitro dry matter digestibility (IVDMD). In earlier work, Cummins (1971) had reported that sorghum plant components, both ensiled and nonensiled, contained significant quantities of tannin. Ensiling resulted in a reduction in tannin content of the grain of a high tannin hybrid; however, the tannin in leaves, stalks, and chaff did not dissipate upon ensiling.

In our studies, the technique used to examine the different sorghum silage varieties was to collect four uniform 1000 g samples in plastic bags, 1 duplicate set of each treatment was frozen fresh and the other set ensiled. Air was evacuated from each sample to be ensiled using a vacuum pump, the bags securely tied, and placed in a 32°C oven

for 25 days. Fermentation losses were accurately determined and the samples were frozen until analyzed.

The Van Soest procedure was used to compare changes in neutral detergent fiber (NDF) due to the fermentation process on five grain sorghum and five sweet sorghum varieties (Table 1). The first apparent change due to the fermentation process was the loss of dry matter, or increase of metabolic water, with an average of 1.8% for the grain sorghums and 7.2% for the sweet sorghums, respectively. A more serious change due to the fermentation process was the 26.1% loss of dry matter recovered for the sweet sorghums while only a 6.4% loss for the grain types. The biological value of the remaining dry matter after ensiling was also reduced, as indicated by the increase in the percent NDF. Again the greatest change was in the sweet sorghums with a 16.18% increase compared with only a 2.72% increase in NDF for the grain sorghums. Lowered dry matter recovery with a concomitant increase in metabolic water indicates excessive utilization of readily available energy sources by fermentation organisms during the ensiling process.

A key factor believed to have been responsible for the dry matter loss and the increase in cell wall components (Table 2) was the rapid and adverse fermentation caused by the large quantity of soluble carbohydrates in the sweet sorghum silage. Sugar an starch analyzes are in progress at this time for verification of this hypothesis.

Indications are that with fresh forages of high sugar content one could expect high fermentation losses with marked increases in fiber during ensiling. Any cell wall value (% NDF) above 60% generally implies one should expect reduced intake of the forage by cattle because of a fill factor.

Table 1. Percent dry matter and neutral detergent fiber (NDF) of 10 sorghum varieties before and after ensiling, and the percent dry matter recovered after ensiling. 1/

Variety	% dry matter		% dry matter		% neutral detergent fiber	
	fresh	ensiled	recovered	lost	fresh	ensiled
Grain sorghum B-lines:						
CK 60	34.1	31.8	91.4	8.6	51.98	53.08
OK 11	39.3	36.0	89.6	10.4	45.82	51.63
Wheatland	44.6	43.0	95.2	4.8	45.57	48.09
Redland	35.1	34.1	97.3	2.7	48.92	50.74
Redlan	37.5	36.2	94.6	5.4	51.34	53.71
Mean	38.1	36.3	93.6	6.4	48.73	51.45
Change		-1.8	-6.4			+2.72
Sweet sorghum R-lines:						
Rio	35.4	27.3	73.4	26.6	50.41	67.01
Wiley	33.8	25.0	70.3	29.7	48.96	67.89
Brandes	30.9	24.7	76.7	23.3	47.87	58.41
Dale	27.4	19.2	66.0	34.0	47.70	71.63
Mn 752	39.6	34.7	83.3	16.7	63.41	74.31
Mean	33.4	26.2	73.9	26.1	51.67	67.85
Change		-7.2	-26.1			+16.18

1/ NDF = lignin, cellulose, and hemicellulose.

Table 2. Percent cell wall components of 10 sorghum varieties before and after ensiling.

Variety	% lignin		% cellulose		% hemicellulose	
	fresh	ensiled	fresh	ensiled	fresh	ensiled
Grain sorghum B-lines:						
CK 60	4.43	4.77	27.0	27.1	20.5	21.2
OK 11	3.33	4.08	22.1	22.9	20.4	24.7
Wheatland	4.12	4.51	20.0	20.0	21.4	23.6
Redland	4.08	4.38	23.6	23.8	21.2	22.6
Redlan	4.95	4.89	25.2	24.0	21.2	24.8
Mean	41.8	4.53	23.6	23.6	20.9	23.4
Change		+.35		+0.0		+2.5
Sweet sorghum R-lines:						
Rio	3.93	5.30	24.7	33.6	21.8	28.1
Wiley	4.64	6.86	25.3	35.4	19.0	25.6
Brandes	3.43	4.30	25.7	31.9	18.7	22.2
Dale	3.38	5.28	26.2	40.4	18.2	25.9
Mn 752	5.38	6.62	35.9	40.3	24.1	27.4
Mean	3.08	5.67	27.2	36.3	20.4	25.8
Change		+2.59		+9.1		+5.4

In developing breeding objectives for high quality sorghum silage the following additional factors are being studied:

Juicy versus dry stalk. A frequent complaint of farmers is the large quantity of runoff or seepage from sorghum silage. If the digestibility of dry-stalked sorghum varieties is equivalent to near isogenic juicy types at physiological maturity, this problem would be reduced. Low sugar lines would also reduce excess water in sorghum silage by reducing the amount of water and CO_2 formed during fermentation.

High grain to stover ratio. For high quality silage, a grain to stover ratio of 1 to 1 is desirable. Sorghum frequently has half of its dry weight made up of stalks and the other half fairly equally divided between heads and leaves. A two dwarf hybrid with high grain yield would better approach the desired high grain to stover ratio.

Bloom versus bloomless. Studies by Cummins *et al*. (1972) indicate that the waxy bloom of sorghum reduces its digestibility. Fermentation studies of near isogenic lines of bloom and bloomless varieties are currently being evaluated in our laboratory.

Tannin versus tanninless. All components of the sorghum plant contain tannins, including the non-bird-resistant varieties. As a minimum, high quality sorghum silage must be from a non-bird-resistant type. Tannin interference in digestion has been conclusively demonstrated. The World Collection of Sorghum should be screened for a tanninless type.

High digestibility of grain and stover. The improvements of grain quality made in the grain sorghum industry readily can be adopted for silage sorghums. Morphological-digestibility studies of limber versus stiff-stalked genotypes currently being evaluated, will give an insight

into the formers apparent higher digestibility. The brown midrib factor will be discussed at this workshop by Mr. Porter and this is another important character to be incorporated into high quality sorghum silage breeding lines.

These are but a few of the quality factors that need to be investigated. Inexpensive techniques will need to be developed for rapid yet precise measurement of differences. In conclusion, it is felt that recent significant advances in the breeding of sorghum silages suggest that once the quality objectives have been established the synthesis of a high quality product can become a reality.

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FACTORES QUE AFECTAN EL RENDIMIENTO DEL SORGO EN LAS CONDICIONES DE CENTROAMERICA Y PANAMA[1]

Ing. Angel Salazar B.[2]

En el Istmo centroamericano, que comprende los países de Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica y Panamá, se cultiva el sorgo (Sorghum bicolor (Linn.) Moench tanto para grano, como para forraje, en dos formas considerablemente diferentes por el grado de tecnología que se aplica: el cultivo tradicional y el cultivo moderno. Como ambas formas de cultivo son importantes en el área y como los problemas y factores que influyen en los rendimientos son distintos, en el presente trabajo presentaremos comentarios separados para las dos formas de cultivo.

Cultivo Tradicional

Esta forma de cultivo se practica en aproximadamente el 75% del área dedicada al sorgo en Centroamérica y Panamá, según puede verse en el cuadro 1. La característica principal de esta forma de cultivo es el uso de variedades de polinización abierta, sensibles al fotoperiodismo, tardías (4 a 6 meses), de plantas altas (6 a 12 pies), de cabezas compactas o abiertas y grano cristalino, apropiado para la alimentación humana o animal. El rendimiento promedio de estas variedades llamadas "ciollas", varía según el país, entre 700 y 1,700 K/Ha, alcanzando en

[1]Contribución presentada en el "International Sorghum Workshop", realizado en la Universidad de Puerto Rico, Enero 1975.

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Cuadro 1 - Area sembrada con sorgo granero y forrajero en Centroamérica y Panamá usando semillas mejoradas y criollas[1]

País	Hectáreas sembradas en 1974						
	Total	Híbridos	% del total	Varied. Mejor.	% del total	Varied. Criol1.	% del total
Guatemala	55,000	9,800	17.8	1,000	1.8	44,200	80.4
El Salvador	115,000	2,750	2.4	7,000	6.1	105,250	91.5
Honduras	35,000	3,750	10.7	1,380	3.9	29,870	85.4
Nicaragua	72,000	29,000	40.2	2,500	3.5	40,500	56.3
Costa Rica	7,000	7,000	100.0	--	0.0	--	0.0
Panamá	6,000	6,000	100.0	--	0.0	--	0.0
	290,000	58,300	20.1	11,880	4.1	219,820	75.8

[1]Los datos son estimaciones del autor.

casos excepcionales hasta 2,000 K/Ha. Los países que cultivan estas variedades son: Guatemala, El Salvador, Honduras y Nicaragua.

El terreno que se siembra con estas variedades es generalmente pobre y escarpado, donde no se puede a veces ni usar el arado de bueyes para su preparación. La gran mayoría de estas siembras no reciben fertilizantes, ni aplicación de insecticidas; las malezas se controlan tardía e ineficazmente con arado de bueyes, o con instrumentos manuales. Alrededor del 50% de las siembras con variedades criollas, se realiza en asociación con maíz u otros cultivos, como arroz, ajonjolí, yuca, etc.

La cosecha de estas variedades se realiza también a mano, así como su desgrane, secado, limpiado y almacenaje. El forraje que dejan estas variedades, aunque abundante, es de muy baja calidad.

Los agricultores que siembran estas variedades y practican el cultivo tradicional del sorgo, son los más pequeños y con menos recursos de tierra, insumos y educación agrícola. Estos agricultores practican la siembra del sorgo más que todo para la subsistencia y en pequeña escala para el comercio. El número de agricultores que practican este tipo de cultivo es grande, raya en el orden de los 10,000 y el principal mérito que encuentran en él, es su relativa mayor tolerancia a la escasez de humedad o irregularidad de las lluvias en la Costa del Pacífico del Istmo Centroamericano.

Problemas del cultivo tradicional del sorgo

Dentro del marco de prácticas que conforma el cultivo tradicional del sorgo en Centroamérica, prácticamente cada operación es susceptible de mejoramiento, comenzando desde la variedad hasta la cosecha y el almacenamiento. Sin embargo, conseguir un mejoramiento real y signifi-

cativo del rendimiento de este tipo de cultivo, no radica solamente en la acción del mejorador de cultivos, ni del agrónomo o el extensionista. Exigiría la acción coordinada de ellos más la de los financiadores, educadores, ingenieros civiles, sociólogos, médicos y políticos para mencionar algunos. Podría distribuirse una variedad mejorada entre pequeños agricultores, pero esto implica venderles también fertilizantes e insecticidas; luego sería necesario proveerles de mejores maquinarias que las manuales actualmente en uso para la siembra, cultivo y cosecha. Luego habría que financiar, a quienes no tienen más que lo necesario para subsistir, todos los anteriores insumos. Desde luego que lo anterior resultaría un verdadero beneficio para el pequeño agricultor si puede vender su producto en el lugar adecuado, a un precio justo y en su oportunidad; esto implica, caminos, almacenes, precios favorables.

Dada la naturaleza compleja del cultivo tradicional del sorgo, en el presente trabajo nos ocuparemos solamente del cultivo moderno de este cereal, donde sí se puede mejorar varios de los factores que afectan el rendimiento y obtener resultados notables a un plazo aceptable.

Cultivo Moderno

Llamamos cultivo moderno del sorgo en el área centroamericana, a aquel grupo de prácticas que implica el uso de semillas mejoradas, suelos agrícolas mecanizables, abonos, insecticidas, herbicidas y maquinaria para todas las operaciones desde la siembra a la cosecha, secado y almacenaje del grano. Este tipo de cultivo abarca cerca del 25% del área sembrada con sorgo en 1974 en esta parte de las américas (ver cuadro 1). Los agricultores que la practican, son aquellos de empresa, que siembran el sorgo como negocio y para su venta a las fábricas de

productos de alimentos animales. El rendimiento promedio de los híbridos es de alrededor de 2,000 K/Ha., pero los campos más productivos rinden 2,500 a 5,000 K/Ha.

Los comentarios y sugerencias expuestos aquí son el resultado de una encuesta realizada por el autor, a cada uno de los técnicos encargados del trabajo de investigación con sorgo, que funcionaron en 1974 en cada uno de los seis países del Istmo Centroamericano.

Entre los factores que con mayor frecuencia afectan el rendimiento de grano en las siembras modernas del sorgo, se mencionan los problemas de fertilidad, densidad de siembra y variedad.

Fertilidad - Gran número de campos de sorgo, sembrados en las condiciones de clima y suelo de la Costa del Pacífico de Centroamérica y Panamá, son afectados desfavorablemente en su rendimiento de grano por la pobre fertilidad de suelo, o por la inadecuada fertilización de los mismos. La deficiencia de nitrógeno es general en los suelos propios de los trópicos semi-húmedos y semi-secos de esta área. El sorgo se siembra en los suelos menos productivos y la fertilización que se realiza no es posiblemente la óptima ni en cantidad de elementos fertilizantes, ni en su análisis y oportunidad de aplicación. Cuando los fertilizantes químicos no habían subido aún a los altos precios actuales, el promedio de aplicación de nitrógeno, fósforo y potasio era de 50, 32.5 y 16.8 K/Ha. respectivamente. Las altas poblaciones de plantas, que frecuentemente consiguen los agricultores en los trópicos, requieren mayores cantidades de elementos fertilizantes que las anotadas. Este debiera ser un proyecto de investigación a realizarse para determinar las cantidades óptimas, económicamente aceptables actualmente en el sorgo.

También los agricultores suelen aplicar fertilizantes cuyo análisis está basado frecuentemente en recomendaciones de vendedores de fertilizantes o en resultados de pocos ensayos de fertilización, realizadas en pocas zonas de cultivo. Así mismo la forma y oportunidad de aplicación de nitrógeno en las variedades mejoradas en uso y en las condiciones de clima y suelo de esta área, debe ser distinto del que se practica en climas distintos de los trópicos de Centroamérica. Es necesario pues, investigar en forma sistemática y exhaustiva la práctica de la fertilización de los suelos tropicales de esta área, a fin de realizar al máximo posible el potencial de rendimiento de las variedades mejoradas en uso.

Densidad de siembra - Con mucha frecuencia se encuentran campos de sorgo granero con una alta población de plantas: 300 a 400 mil plantas por hectárea. Para esto los agricultores suelen usar entre 20 a 25 K/Ha de semilla. Estas altas poblaciones con similar frecuencia no están acompañadas de la correspondiente alta fertilización ni la suficiente humedad, como para resultar en altos rendimientos de grano. La práctica de usar altas cantidades de semilla de sorgo en esta área, se debe más que todo a la mala preparación de los terrenos, en los que un alto porcentaje de semilla se pierde. Los agricultores en lugar de preparar mejor los terrenos para propiciar la mayor germinación de la semilla y emergencia de las plantulas, triturando bien el terreno, eliminando las malezas y controlando los insectos, solo recurren al expediente de sembrar más semilla por hectárea. Cuando la humedad del terreno a la siembra es favorable, gran parte de esta semilla germina y resulta en una población alta, a la que no siempre se le aplica la cantidad de fertilizantes adecuada a estas poblaciones de plantas. El resultado

final es frecuentemente rendimientos mediocres. Este problema puede solucionarse en gran medida, mediante la divulgación de las ventajas de la apropiada preparación del terreno, control de insectos, determinación del porcentaje de germinación y uso adecuado de fertilizantes por parte de los agricultores que están localizados en áreas sin limitaciones de humedad durante el ciclo de desarrollo del sorgo.

Variedad - Como puede verse en cuadro 2, cerca del 25% del área con sorgo en el Istmo Centroamericano, se sembró con híbridos y variedades mejoradas. Esta área se consiguió después de cerca de 14 años de haberse introducido el uso de semillas mejoradas. Al presente se siembran alrededor de 15 diferentes híbridos graneros y 12 variedades mejoradas de sorgo granero en Centroamérica y Panamá. Toda la semilla de los híbridos es importada anualmente de los EEUU, mientras que la semilla de las variedades mejoradas es producida localmente. También se siembran 6 híbridos y una variedad mejorada de sorgo forrajero (ver cuadro 3).

Los híbridos graneros completan su ciclo de desarrollo entre los 90 y 110 días en las condiciones de clima de esta área. Esto significa que el ciclo de desarrollo de los híbridos procedentes de EEUU, se reduce en 10 a 15 días en los trópicos de la Costa del Pacífico de América Central, donde el promedio de horas-luz diario es de 12, sin variaciones mayores a una hora durante el año. En consecuencia todos los híbridos actualmente sembrados en esta área, tienen un límite de rendimiento inferior al de los EEUU, por contar con menor número de horas-luz por día durante su desarrollo. Sin embargo, en las condiciones de constantemente altas temperaturas, 24 a 28 grados centígrados, y con la humedad disponible en 5 a 6 meses de lluvias (Mayo-Diciembre),

Cuadro 2 - Evolución del área cosechada con sorgo granero y forrajero en Centroamérica y Panamá usando semillas criollas y mejoradas+

	1960 Ha.	% del total	1969 Ha.	% del total	1974 Ha.	% del total
Total	210,200	100.0	259,200	100.0	290,000	100.0
Semillas Mejoradas	3,000	1.4	34,900	13.5	70,180	24.2
Variedades Criollas	207,200	98.6	224,300	86.5	219,820	75.8

Los datos de área total para 1960 y 1969 fueron obtenidos de "Estadísticas sobre la alimentación y la agricultura en Centroamérica", SIECA 1972 p. 295.

Los datos para 1974 son estimaciones del autor.

Los datos sobre área sembrada con semillas mejoradas son estimaciones del autor

Cuadro 3 - Híbridos y variedades mejoradas de sorgo granero y forrajero sembrados en Centroamérica y Panamá

HIBRIDOS GRANEROS	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panamá
DeKalb E-57	+	+	+	+	+	+
DeKalb C-42-y			+	+		
DeKalb C-42-a			+	+	+	
DeKalb BR-64			+	+	+	+
DeKalb BR-54				+	+	+
DeKalb E-59				+	+	
N. King 133-a		+	+	+		+
N. King 222-a	+	+		+	+	
Pioneer 8417	+		+	+		+
Pioneer 8202				+		
Asgrow Dorado-M	+	+	+	+	+	+
Asgrow Bravis				+	+	
Mc Nair 546	+					
Mc Nair 652	+					
AKS-614				+		
Advance 14				+		
R-1023				+		

Cuadro 3 (Cont.)

VARIEDADES GRANERAS	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panamá
Guatecau	+			+		
Guatex Rojo	+					
Guatex Blanco	+					
Guatex Enano	+					
Xau-Kaura		+				
CaudaTum		+				
Kaf-Darso		+				
Centa S-1		+				
Centa S-2		+				
Tempranero 1			+			

Cuadro 3 (Cont.)

HIBRIDOS FORRAJEROS	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panamá
Sudax SX-16	+	+	+	+	+	+
Sudax ST-6				+		
Sordan	+	+	+	+	+	+
Trudan				+		
Grazer-A	+	+	+	+	+	+
Hy Grazer				+		
FS-4				+	+	
p-828				+		+
NK-300				+		
Beef Builder					+	
VARIEDADES FORRAJERAS						
Sart			+	+		

estos híbridos son capaces de permitir dos cortes de grano. Agricultores que cuentan con riego podrían obtener hasta tres cortes por siembra o ealizar 3 siembras por año.

Las siembras de sorgo granero realizadas al principio de la época de lluvias (Mayo-Junio en general son más favorables al rendimiento, que las realizadas en la parte final - Agosto-Septiembre) porque los suelos tienen mayor fertilidad y hay menos problemas con malezas, insectos y enfermedades. Sin embargo, la mayor parte de las siembras se efectúan en Agosto y Septiembre, porque a pesar de ser menos productoras, ofrecen mayor seguridad en la cosecha. Las siembras de Mayo y Junio con frecuencia ven disminuídos los rendimientos, debido al desgrane espontáneo, enmohecimiento y aún germinación en la planta de los granos, esto porque con frecuencia la cosecha coincide con alta humedad ambiental. Una alternativa para producir más sorgo sin sembrar 2 ó 3 veces, o en lugar de sembrar una vez y cortar el grano 1 a 2 veces, sería el introducir o desarrollar localmente, variedades de 4 a 5 meses de ciclo vegetativo, a fin de usar al máximo la época de lluvias y cosechar al final de ella.

Los caracteres deseables en una o varias variedades de sorgo granero para las condiciones climatéricas y en atención a la forma de consumo de este cereal en el Istmo Centroamericano, serían:

- Resistencia o tolerancia al desgrane espontáneo y al deterioro de la calidad del grano.
- Variedades de grano de endosperma y cutícula blanca y amarilla, además de los granos de cutícula roja y café actualmente usados. Las primeras tanto para consumo animal como humano. Para este último propósito debiera seleccionarse variedades del mayor contenido posible de proteína.

- Resistencia o tolerancia a las enfermedades conocidas como Pudricion Seca del Tallo (Charcoal Rot), Antracnosis, Carbón del grano (Smuts) y a varias enfermedades foliares causadas por Helminthosporium, Gleocercospora, Puccinia y otras enfermedades.
- Cabezas abiertas que toleren mejor la alta humedad a la cosecha y permitan control de insectos que atacan el grano al fin del desarrollo del cultivo.
- Tolerancia a los pájaros.
- Altos rendimientos promedios en condiciones de trópico semi-seco y semi-húmedo.

Otro grupo de factores que afectan el rendimiento del sorgo en Centro América y Panamá son: Malezas, Insectos, Enfermedades y Pájaros.

Malezas - Este factor desfavorable al rendimiento es especialmente importante en los trópicos de Centroamérica, donde las malezas cuentan con humedad y temperatura favorables durante gran parte del año. Posiblemente este factor por sí sólo es uno de los más importantes para limitar el rendimiento de las variedades de sorgo.

Muchos agricultores de esta área comparten aún la creencia de que el cultivo del sorgo en sí, controla las malezas sin mayor necesidad de prácticas del uso de herbicidas o cultivadoras mecánicas. Otro sector grande de agricultores, si bien practican el control de malezas, lo hacen en forma deficiente y/o inoportuna. Aún cuando los técnicos agrícolas recomiendan el control temprano de las malezas, muchos campos de sorgo sufren la competencia por parte de las malezas durante las 2 a 4 primeras semanas de desarrollo, cuando el rendimiento final es más afectado.

Ayudaría sensiblemente a disminuir el daño de las malezas al rendimiento del sorgo, trabajos experimentales para cuantificar la reducción del rendimiento que causan las malezas. Así mismo sería beneficioso conocer los hábitos de crecimiento y daños que causan cada una de las principales especies de malezas prevalentes en los campos de cultivo de la Costa del Pacífico de Centroamérica y Panamá.

Insectos - Numerosas especies de insectos atacan los cultivos de sorgo, dañando las raíces, tallos, hojas, flores y grano. El uso de insecticidas para controlar estos insectos, se hace en muchos casos indiscriminadamente, sin sopesar los beneficios que tal uso puede reportar en rendimiento de grano. Es necesario determinar hasta que punto es económico, por ejemplo, el control de los gusanos cortadores de hojas, Ya que el sorgo es un cultivo de relativamente menor ganancia que el arroz o maíz, se debe determinar con precisión el número y costo de las aplicaciones de insecticidas aplicados contra los cortadores de hojas.

La "Mosquita del Sorgo" (Contarinia sorghicola Coquillet) es posiblemente el insecto que más daños causa al rendimiento. Aún cuando se sabe cómo controlar esta plaga, su daño a veces pasa inadvertido por los agricultores, ya que no presenta daños aparentes en la planta, como lo hacen los insectos cortadores, o los taladradores del tallo. Los daños causados por los taladradores del maíz y la caña de azúcar, son importantes en los campos de sorgo cercanos a campos con estos cultivos. Sería de beneficio encontrar la forma más económica de controlar este insecto en las condiciones de Centroamérica.

Enfermedades - La "Pudrición Seca del Tallo" (Charcoal Rot) es posiblemente la enfermedad que más daño causa al rendimiento de sorgo en esta área. Cuando ocurren las condiciones que esta enfermedad

requiere para presentarse, causa serias pérdidas de rendimiento por reducción del peso del grano, o pérdida de él, debido al acame de plantas. Los agricultores de esta zona ya conocen esta enfermedad y aprecian variedades que poseen algún tipo de tolerancia a ella.

La Antracnosis, los carbones del grano y las manchas foliares, son también en ciertos casos causa de mermas de rendimiento. Afortunadamente algunas variedades híbridas, son resistentes a una o varias de estas enfermedades.

Hay necesidad en el área, de mucho trabajo para estudiar las enfermedades del sorgo, su identificación y forma más económica de control. Para esto se necesitan patólogos debidamente preparados y las facilidades de trabajo correspondientes.

Pájaros - Varias especies de pájaros migratorios y locales causan grandes pérdidas de grano de sorgo. Se han probado en el área, varias clases de espantapájaros con resultados muy relativos. También se siembran variedades con alto contenido de Tanino que resultan repelentes a los pájaros, con éxito aceptable, pero la aceptación de estas variedades está teniendo cada vez más resistencia por parte de los formuladores de alimentos animales.

Disponibilidad de agua en el suelo - Aún cuando en la Costa del Pacífico de Centroamérica y Panamá, llueve entre 30 a 60 pulgadas durante la época de cultivos, con frecuencia el sorgo sufre pérdidas de rendimiento por deficiencia de humedad. En esta área el problema más importante es pues la distribución de las lluvias, la que es irregular y desfavorable al rendimiento del sorgo. Desde luego, la determinación de las mejores épocas de siembra, de modo que se pueda evitar en lo posible deficiencias de humedad en los periodos críticos del sorgo, es

un problema que debe investigarse en cada área importante del cultivo del sorgo. Además, tienen un lugar en esta área las variedades que exhiban la mayor tolerancia posible a la escasez de humedad, como es el caso con algunas variedades de endosperma amarillo.

En Costa Rica se dan los extremos de escasez y exceso de humedad para el cultivo del sorgo. En la zona conocida como Pacífico seco (Guanacaste) se siembra la mayor parte del sorgo con solo la humedad residual que queda en el campo después de cosechar arroz. En estas condiciones se necesitan variedades de la mayor eficiencia en el aprovechamiento del agua del suelo. Por otro lado, en la zona conocida como Pacífico Sur, con mucha mayor precipitación, el problema es exceso de humedad durante el desarrollo del sorgo y al momento de la cosecha. Aquí se necesitan variedades tolerantes al exceso de humedad y al deterioro de la calidad del grano por la humedad ambiental a la cosecha.

Finalmente, mucho grano de sorgo se pierde en los campos debido a la ineficiencia de operación de las máquinas cosechadoras y debido al retraso en efectuarla. Si en los países con mayor experiencia en el cultivo del sorgo y con operarios mejor entrenados, es frecuente 5 a 10% de pérdidas de campo durante la cosecha, en Centroamérica y Panamá estas pérdidas pueden aumentar considerablemente. Un proyecto de divulgación sobre la magnitud de estas pérdidas y de entrenamiento de operadores de cosechadoras, así como de escogencia o adaptación de cosechadoras o partes de ellas, a las condiciones y variedades del área; ayudarían a reducir sensiblemente estas pérdidas.

EL CULTIVO DEL SORGO PARA GRANO; SUS PROBLEMAS Y SU FUTURO EN MEXICO Y AMERICA LATINA

Joaquín Ortíz Cereceres*

El cultivo del sorgo para grano, es el cultivo introducido que en los últimos 20 años ha alcanzado una gran importancia en varios países de Latinoamérica. Como evidencia de lo anterior se pueden mencionar los ejemplos siguientes: En México (2), país en el cual durante el período de 1951 a 1960 sólo se sembraron con sorgo para grano un promedio anual de 114,400 hectáreas con un rendimiento unitario de 1.5 ton/ha (Cuadro 1), se observó un gran incremento en el área dedicada a este cultivo. Durante la década de 1961 a 1970, cuando se generalizó el uso de híbridos introducidos principalmente de Estados Unidos de Norteamérica, la producción creció a un ritmo promedio de incremento anual de 29.0%, las superficies se extendieron a una tasa de 23.8% y los rendimientos unitarios se elevaron a un ritmo promedio anual de 4.2%. En el 1970 se sembró una superficie de un millón de hectáreas con una producción de 2.672,405 toneladas métricas y con un rendimiento unitario promedio de 2,672 kg/ha, y en el 1974 se sobrepasó el millón de hectáreas sembradas con sorgo manteniéndose los rendimientos promedio similares a los logrados en 1970.

El caso de Argentina (5) es muy similar, en ese país durante el período de 1955 a 1959, el área sembrada con sorgo creció de 138,700 a

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Cuadro 1. Superficie Sembrada, Producción y Rendimiento por Ha. de Sorgo para Grano en México (Período 1951-1972)

Período	Superficie cultivada Ha.	Producción Total Ton.	Rendimiento Kg/Ha
1951/60	114,406	177,444	1,551
1960/61	116,432	209,228	1,797
1961/62	116,000	291,250	2,500
1962/63	117,637	299,974	2,550
1963/64	262,786	538,711	2,050
1964/65	314,300	597,170	1,900
1965/66	554,000	1,315,750	2,375
1966/67	556,000	1,251,000	2,250
1967/68	846,000	2,140,380	2,530
1968/69	270,000	2,444,400	2,520
1969/70	1,000,000	2,500,000	2,500
1970/71	1,000,000	2,600,000	2,600
1971/72	1,100,000	2,860,000	2,600

Tomado de: Plan Nacional Agrícola Ganadero

936,800 hectáreas (Cuadro 2), teniéndose en ese lapso un rendimiento promedio de 1,775 kg/ha. Este incremento tan considerable en el área sembrada con sorgo fue posible gracias al uso de una serie de variedades 3dw, que permitió la casi completa mecanización de este cultivo. Sin embargo fue a partir de 1960, cuando se introducen los híbridos de sorgo, que este cultivo se extiende todavía más y se logran mayores rendimientos por unidad de superficie. Esto es, de aproximadamente un millón de hectáreas sembradas en 1960, se alcanza una superficie de más de dos millones y medio de hectáreas en 1972, con un rendimiento promedio unitario de aproximadamente dos toneladas por hectárea.

En Colombia (4) de 3,800 hectáreas sembradas con sorgo en 1962, se amplía una superficie de 30 mil hectáreas en 1969, con una producción de 75,000 toneladas, estimándose que para 1975 será necesaria una producción de 354,000 toneladas de grano para abastecer las necesidades de este cereal en dicho país (Cuadro 3).

En Brasil (3), país en que durante el período de 1969-1970 se plantaron 14,956 hectáreas de sorgo para grano que produjeron aproximadamente 57,000 toneladas. A partir de 1970, con la colaboración de varias agencias internacionales se intensificaron los trabajos de investigación con el objetivo fundamental de incrementar las áreas sembradas con este cultivo y aumentar la producción. Para el 1972 se vislumbraba la posibilidad de sembrar más de 100,000 hectáreas de sorgo y lograr una producción de más de 300,000 toneladas en base a los resultados de las investigaciones fundamentalmente sobre las prácticas de producción en áreas específicas en ese país.

Por todo lo anterior, puede concluirse que aunque el cultivo del sorgo era conocido en algunos países de América Latina, desde hace más

Cuadro 2. Superficie Sembrada, Producción y Rendimiento de Sorgo para Grano en Argentina (Período 1955-1972).

Período	Superficie cultivada Ha.	Superficie cultivada c/híbridos %	Producción total Ton.	Rendimiento Kg/Ha
1955/56	138,700		82,900	1,400
1959/60	730,000		609,000	1,673
1960/61	936,800	4.3	1,252,000	2,265
1961/62	1,074,500	13.0	1,394,000	2,159
1962/63	1,071,500	25.0	952,200	1,660
1963/64	1,218,400	30.0	1,267,000	1,751
1964/65	1,246,000	35.0	857,000	1,458
1965/66	1,345,500	40.0	2,130,000	2,524
1966/67	1,453,700	45.0	1,380,000	1,805
1967/68	1,841,300	50.0	1,897,000	1,752
1968/69	2,251,200	55.0	2,484,000	1,900
1969/70	2,567,500	60.0	3,820,000	2,040
1970/71	3,121,600	70.0	4,660,000	2,085
1971/72	2,597,600	85.0	2,350,000	2,085

Tomado de: Anais do 1º Simpósio Interamericano de Sorgo, 273-285, 1972.

Cuadro 3. Superficie y Producción de Sorgo de Grano (Período 1962-1969) y Estimación de las Necesidades de Este Cereal (Período 1970-1975) en Colombia.

Años	Superficie miles Has.	Producción miles Has.	Rendimiento Tons./Has.	Necesidades Sorgo de Grano - Tons.
1962	3.8	8	2.1	
1963	5.8	12	2.0	
1964	24	56	2.3	
1965	30	70	2.3	
1966	40	96	2.4	
1967	30	75	2.5	
1968	25	62	2.5	
1969	30	75	2.5	
1970				220,000
1971				242,000
1972				266,000
1973				293,000
1974				322,000
1975				354,000

de 20 años, empieza a adquirir una gran importancia aproximadamente a partir de 1960, cuando se inicia el uso de híbridos, introducidos de Estados Unidos de Norteamérica.

La información proporcionada anteriormente, podría indicar que el cultivo del sorgo para grano tiene asegurada su permanencia y que todavía puede extenderse más en áreas agrícolas de Latino América, y que s incremento se ha debido al éxito que los agricultores han tenido con este cultivo. Sin embargo, puede señalarse una serie de problemas de este cultivo, que en muchas ocaciones han propiciado grandes fracasos y pérdidas a los agricultores de algunas zonas de Latino América.

PROBLEMAS DEL CULTIVO

Variedades. La disponibilidad de variedades se restringe a aquellas desarrolladas en regiones de Estados Unidos de Norteamérica y que después de algunas pruebas, se determina que tienen mejor comportamiento en relación a otras en una región determinada. En algunos países como México, existe un Comité Calificador de Variedades de Plantas dependiente de la Secretaría de Agricultura, encargado de hacer las pruebas y de autorizar aquellas variedades que ofrecen ciertas probabilidades de éxito en una región determinada. Este sistema como ya ha sido indicado ha permitido incrementar la producción de sorgo para grano en diversas áreas de Latino América. Sin embargo, en la mayoría de estas áreas se tienen condiciones ambientales favorables en cuanto a disponibilidad de humedad y temperatura, así como de fertilizantes, siendo todos los híbridos de sorgo disponibles completamente inapropiados para su cultivo bajo condiciones ambientales limitantes. Lo anterior constituye un serio problema, ya que en grandes áreas en

Latinoamérica no se pueden usar estos híbridos.

Por el enfoque de sus programas, se considera que las Compañías de semillas, principalmente norteamericanas que producen variedades de sorgo para ser cultivadas en Latinoamérica, nunca intentarán desarrollar programas de mejoramiento para crear variedades que tengan ciertas posibilidades de éxito en áreas con condiciones ambientales críticas, a través de características tales como resistencia a la sequía, a las bajas temperaturas en la época de la germinación, en estado de plántula y en el estado reproductivo, así como un ciclo apropiado a las condiciones en que se vayan a cultivar, pues esto implicaría el uso de recursos económicos para desarrollar materiales con las características indicadas, así como también sería necesario un cambio en la mentalidad de sus fitomejoradores, que les permitiera captar la problemática de esas áreas y en función de ella implementar los programas de mejoramiento.

En cuanto a variedades, otro aspecto de gran importancia es el de adaptación, ya que la mayoría de las compañías productoras de variedades de sorgo esperan cubrir grandes áreas con características muy variables desde el punto de vista ecológico, con un reducido número de genotipos, lo que realmente resulta muy difícil de lograr y trae como consecuencia problemas de inadaptación de los genotipos usados. Esto se puede observar fácilmente, al considerar que los híbridos usados presentan altos rendimientos (10 a 12 toneladas) en aquellas áreas para las que fueron desarrollados, en tanto que en los países latinoamericanos, los mismos híbridos presentan comparativamente rendimientos muy bajos (2.5 toneladas). Otra evidencia son las fluctuaciones tan grandes en el rendimiento que se tienen en este cultivo a través de varios años en

una misma región. Esto es fundamentalmente porque el tipo de híbridos que se usan son genotipos homogéneos con poca flexibilidad de adaptación y con la necesidad de aplicarles una serie de insumos y de prác culturales que no siempre están al alcance de los agricultores.

Otro de los problemas que necesitan atención, es el tipo de endosperma y de grano de las variedades que se recomienden en algunas áreas de latinoamérica. En la actualidad, las variedades cultivadas son dedicadas a la alimentación de ganado, ya sea en forma directa o en la integración de raciones alimenticias; sin embargo, en grandes áreas de Latinoamérica la agricultura de subsistencia es la que ocupa un gran porcentaje de las tierras cultivadas, o sea que el agricultor siembra lo que realmente se va a comer, y bajo la imposibilidad de poder usar el sorgo que actualmente se cultiva en su alimentación, decide seguir usando los cultivos tradicionales como el maíz con todos los problemas que tiene en estas áreas que generalmente son también de medio ambiente crítico. Por lo anterior, además de las características fisiológicas que deberán tener las variedades de sorgo dedicadas al cultivo en Latinoamérica deberá de considerarse el tipo de grano, y de endospermo que permita al agricultor usar esas variedades para su alimentación, este es un punto de gran importancia.

Prácticas culturales. En este sentido las prácticas culturales tales como distancia de siembra, población por hectárea, prácticas de fertilización, etc. generalmente son extrapolaciones de aquellas que se nacen en las áreas en las que los híbridos fueron desarrollados, esto es, olvidando que un genotipo reacciona diferentemente a diversas condiciones del medio ambiente en cuanto a fotoperíodo, temperatura, etc. y que

al generalizar normalmente se estará perdiendo algún potencial del rendimiento al no tener a las variedades en el medio ambiente en el que puedan expresar al máximo su potencial genético.

Las investigaciones sobre el cultivo del sorgo en México han sido desarrolladas principalmente por el Instituto Nacional de Investigaciones Agrícolas (INIA) y por el Colegio de Postgraduados de Chapingo, México. En el INIA se ha obtenido la información que sirve de base a las recomendaciones sobre prácticas culturales en este cultivo para las diversas áreas sorgueras en el país (2). Así mismo se tiene un programa de mejoramiento genético para la formación de variedades, este programa puso a disposición de los agricultores, las primeras variedades de sorgo mexicanas en el año de 1972 (1) y también desarrolla investigación para la obtención de variedades de sorgo adaptadas a las condiciones de temperaturas bajas de los Valles Altos de México.

En el Colegio de Postgraduados se llevan a cabo investigaciones en sorgo desde 1971, con el propósito fundamental de estudiar los mecanismos desde el punto de vista genético, citológico, citogenético, fisiológico, bioquímico y ecológico, que determina la tolerancia a las bajas temperaturas del sorgo para grano en estado de plántula y reproductivo (6, 7).

Por todo lo expuesto anteriormente; se considera necesario que en los países de Latinoamérica en donde se cultivan grandes áreas con sorgo para grano, se deben tener programas nacionales de investigación en este cultivo basados en la problemática específica que se tenga, para lograr que se desarrollen los genotipos con las características necesarias en cada caso, pues como ya se indicó con el enfoque actual de

usar variedades extranjeras, no será posible el éxito completo de este cultivo en nuestros países. Así mismo estos programas deberán de ser llevados a cabo por técnicos nacionales de cada país que realmente conozcan los problemas y tengan una mentalidad propia de nuestro medio y una actitud de resolver dichos problemas. Lo anterior requiere:

a) Un programa intensivo de formación de investigadores del sorgo con diversas especialidades, (Fisiología, mejoramiento, nutrición, suelos, etc.) para lo cual las instituciones de gran prestigio que participan en los llamados programas internacionales pueden ser de gran valor en este proceso de formación de personal.

b) El acceso irrestricto a los materiales desarrollados en las distintas áreas que trabajan los llamados programas internacionales.

Cuando esto suceda, se considerará que dichos programas serán realmente internacionales y que estarán contribuyendo a la solución de los problemas de los países en vías de desarrollo.

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ESTIMATING THE BIOLOGICAL EFFECTS OF TANNINS IN GRAIN SORGHUM.[1]

D. L. Oswalt[2]

Seed of numerous varieties of Sorghum bicolor (L.) Moench in the world collection contain polyphenols (tannins). They are found associated with a pigmented testa and pericarp (Maxson et al. 1972), and are genetically controlled by the genes B_1, B_2 and S (Quinby and Martin, 1954). Tannins have been associated with an astringent flavor and the pigmented pericarp and testa result in dark-colored flour which is usually undesirable when used in food products. Farmers and breeders continue to use high tannin varieties due to their partial resistance to birds, reduced weathering of mature grain, desirable flavor and storage qualities (Tipton et al. 1970, Doggett, 1970, and Wall and Ross, 1970), and resistance to pre-harvest sprouting in the panicle (Harris and Burns, 1970).

Tannins are generally described as water-soluble, high-molecular-weight polyphenols which precipitate gelatin from solutions and which combine with hide fibers to form leather (Cortner and Cortner, 1953).

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[1]Contribution from the Purdue University Agricultural Experiment Station, West Lafayette, Indiana 47907. Journal Paper No. 5780. Supported by the United States Agency for International Development under contract 1175 entitled "Inheritance and Improvement of Protein Quality and Content in Sorghum bicolor (L.) Moench". Presented at the International Sorghum Workshop, Mayaguez, Puerto Rico, January 7-11, 1975.

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Bates-Smith and Raspar (1969) have isolated luteoforal to which they associated the astringency and tannin-like properties of grain sorghums.

Selected sorghum varieties with similar protein concentrations (N x 6.25) and lysine as a percent of protein for feeding to weanling rats to verify protein quality resulted in a wide scattering of weight gains as percent of check at all protein levels (Figure 1). Weight gains were correlated with protein percent (Figure 2), and low and high tannin r values were similar. The regression of rat weight gain on lysine (g/100 g sample) for high tannin samples was not significantly different from zero, (Oswalt, 1973) while low tannin samples were positively correlated with lysine (Figure 3) as anticipated since it was observed that both high and low tannin samples were deficient in lysine (Figure 4). The modified in vitro dry matter disappearance rate (IVDMD) technique described by Tilley and Terry (1963) gave a significant correlation with rat weight gain (r = .548**) when all genotypes were considered and consistently good correlations at all three group levels of low catechin equivalent (tannins) genotypes (Table 1). It will be noted that rat weight gains for both groups of low catechin equivalent genotypes were similar and higher than the three high catechin equivalent groups of genotypes. These data show that the catechin equivalents were significantly correlated with IVDMD rates (r = -.623**) and; therefore, the vanillin-hydrochloric (VHCl) estimate of tannins described by Burns (1971) is a relatively simple procedure to follow for tannin screening purposes in a breeding program.

Supplementation of low and high tannin varieties with lysine resulted in 14-day rat weight gains of over 20 grams for low tannin

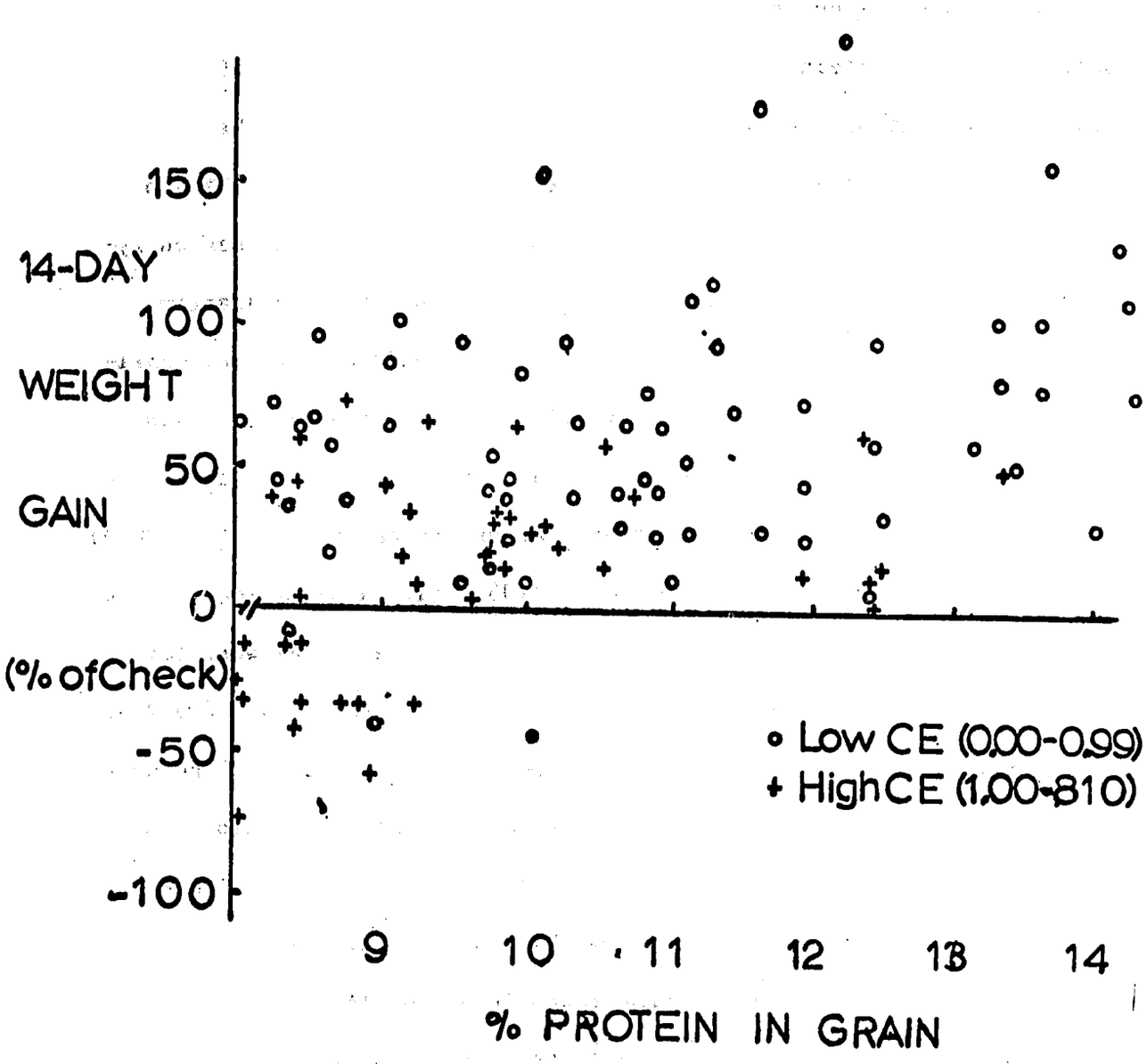

Figure 1. Rat weight gain from 110 grain sorghum genotypes of differing crude protein and catechin equivalent (CE) concentrations (Oswalt, 1973).

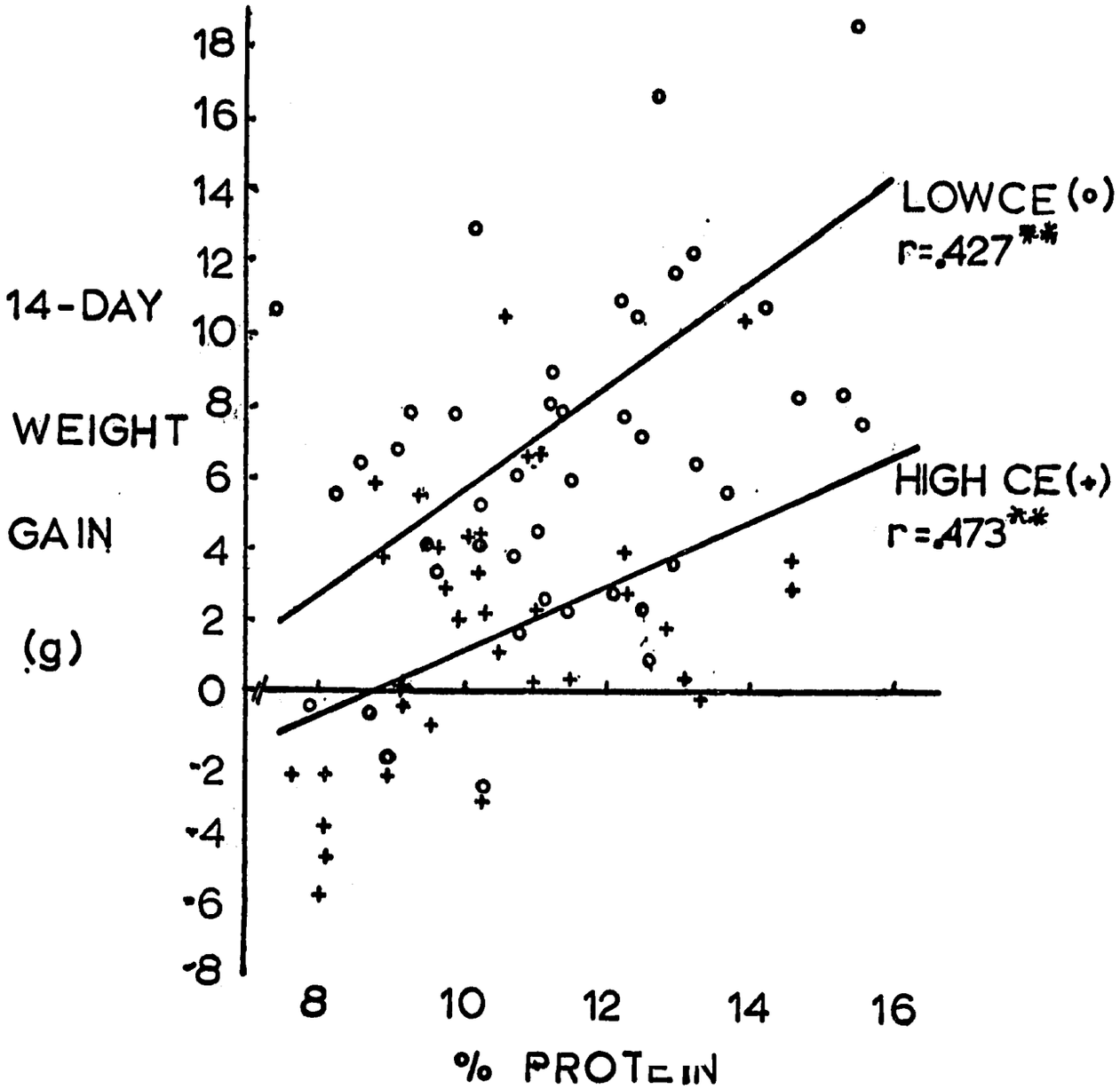

Figure 2. Regression of rat weight gain (g) on percent crude protein in 48 low and 36 high CE concentration grain samples (Oswalt, 1973).

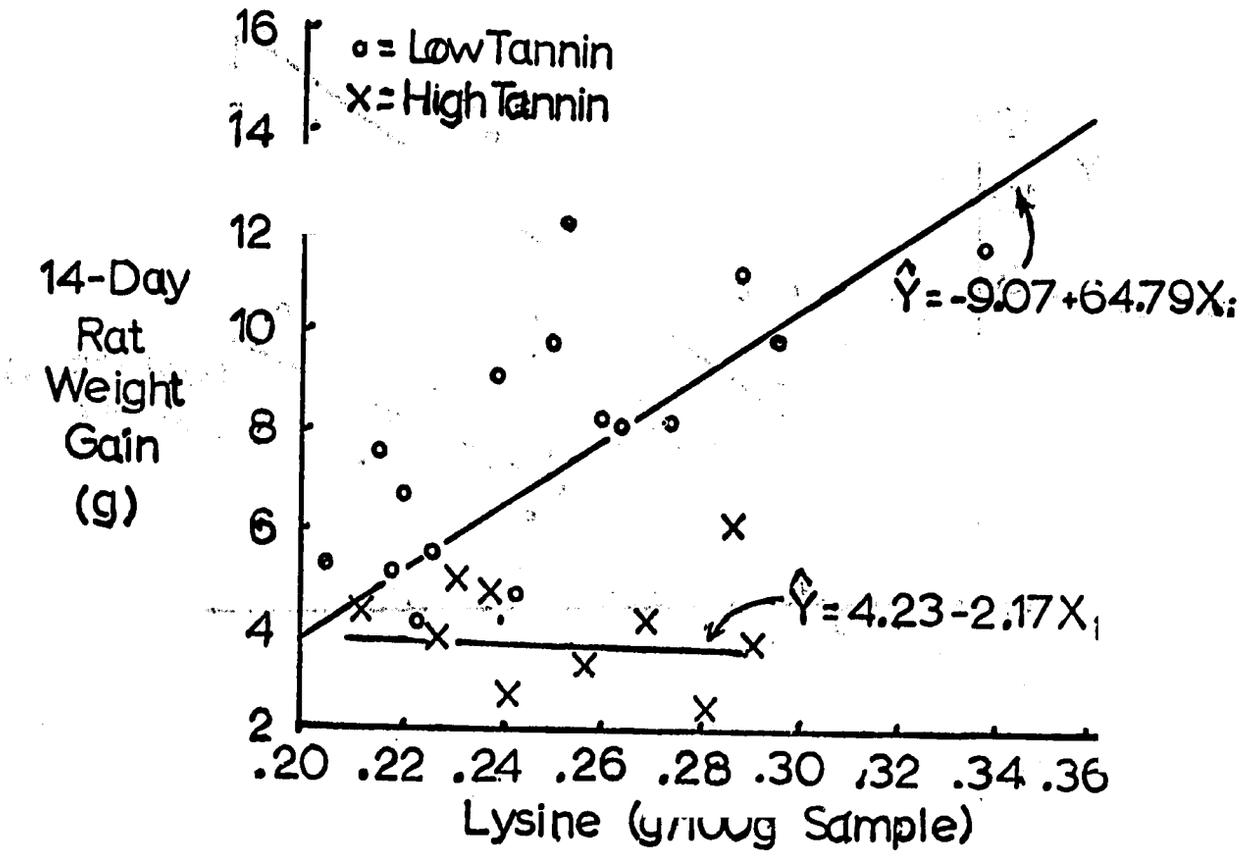

Figure 3. Relationships of rat weight gain with lysine content in high and low tannin sorghum lines (Axtell et al. 1972).

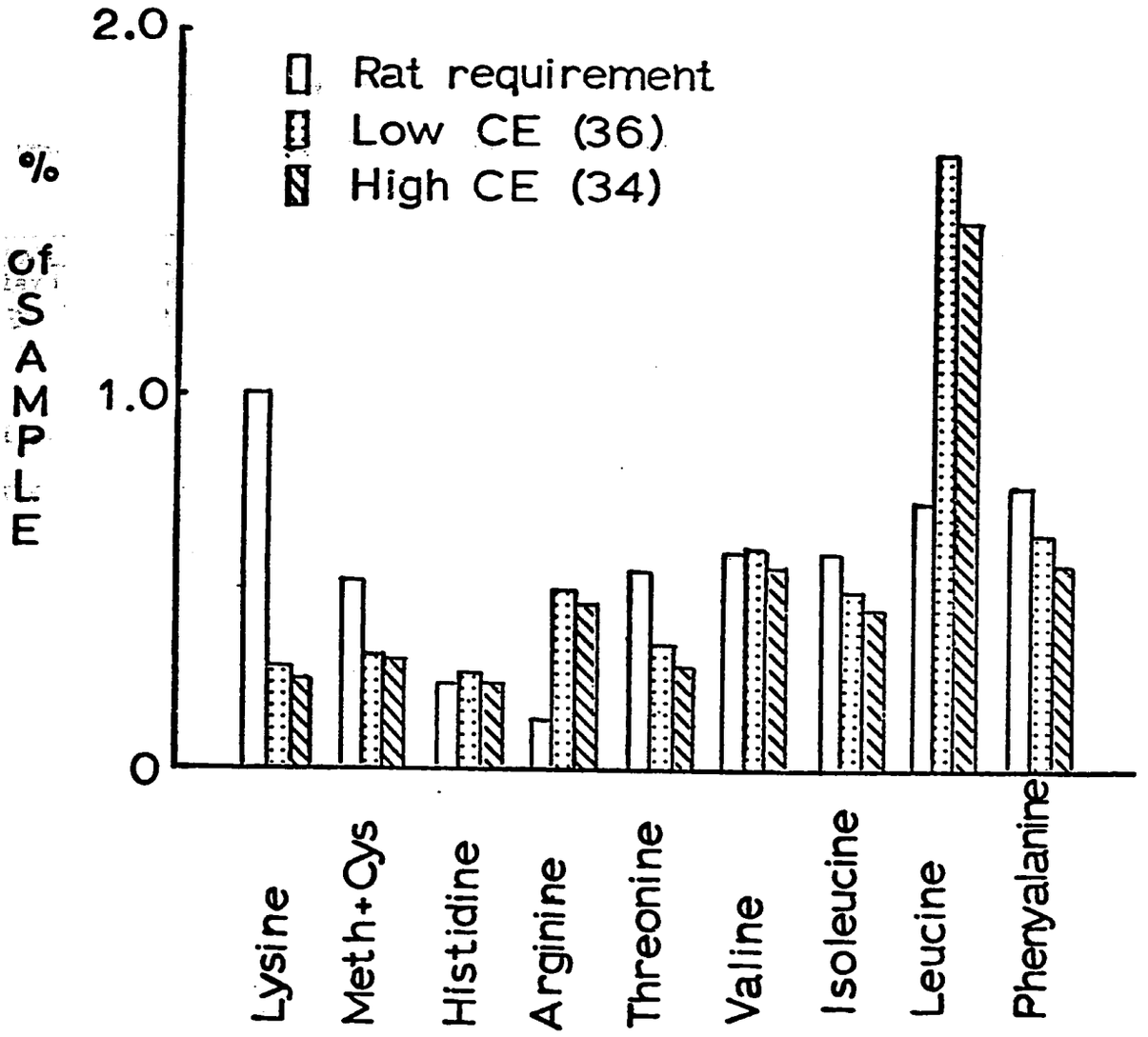

Figure 4. Comparison of essential amino acid requirements of weanling rats with high and low polyphenol (CE) content of grain sorghum. (Oswalt, 1973).

Table 1. Rat weight gain as related to CE,† IVDMD and correlations of rat weight gain as percent of check‡ with protein percent, lysine percent of protein, lysine percent of sample, and IVDMD percent (Oswalt, 1973).§

No. of Samples	C.E. Range	C.E. Mean	Protein Mean %	Weight Gain Mean g	Weight Gain Mean % Check	IVDMD Mean %%	Correlation (r) of % check with: Protein %	Lysine % Protein	Lysine % Sample	IVDMD %
Low CE Group:										
42	.00 - .49	.25	10.60	5.75	63	78	.268	.047	.221	.309*
24	.50 - .99	.61	10.79	5.68	62	74	.306	.218	.537**	.656**
Mean	.00 - .99	.38	10.70	5.72	63	77	.292*	.088	.293*	.459**
High CE Group:										
11	1.00 - 1.49	1.43	10.38	3.37	27	66	.084	.445	.475	.285
12	1.50 - 3.99	3.13	9.09	3.21	28	58	.552	.035	.416	.281
21	4.00 - 8.10	5.96	9.44	.92	4	55	.751**	-.503*	.046	.295
Mean	1.00 - 8.10	4.13	9.69	2.15	17	59	.392**	-.373*	.055	.301*
All Samples:										
Mean	.00 - 8.10	1.90	10.28	4.29	44	69	.400**	-.090	.292**	.548**

* Significant at .05 level. ** Significant at .01 level. † Catechin equivalents estimates of tannins.

‡ IS 2319 was fed with each set of weanling rats as the control sample. § All rat rations were composed of 94% grain sorghum, 2% vitamin,mixture, and 4% mineral mixture (14-day feeding trials)

varieties and less than five grams for high tannin varieties. The supplementation with the four most limiting amino acids resulted in significant increases in weight gains for only the low CE varieties (Figure 5). This would indicate that any toxic effects due to high levels of leucine in relation to isoleucine could be overcome as indicated by the good rat weight gains from low tannin varieties; however, the high tannin variety did not produce as high a 14-day weight gain for weanling rats with or without the added amino acids.

The dehulling of a variety with sodium hydroxide (Blessin, 1971) lowered the CE concentration (Table 2), significantly increased rat weight gain, and when supplemented with lysine-HCl resulted in the anticipated higher rates of weight gain (Figure 6).

Soybean meal supplementation of low and high tannin varieties indicated that the tannins measured as CE were not toxic, but made the protein less available for weanling rat growth (Schaffert et al. 1974). The alteration of the solubility of proteins in high tannin sorghums was demonstrated by changes in the amounts of proteins in various protein solubility fractions (Table 3), lower concentrations of amino acids in blood samples with an increase of nitrogen in the feces of baby chicks (Rostagno, Rogler, and Featherston, 1973), increased protein in the residues of IVDMD tests (Schaffert et al. 1974), reduced chick growth rates (Rostagno, Featherston, and Rogler, 1973), and reduced weanling rat weight gains (Oswalt, 1973). All of these adverse results were attributed to a change of grain protein solubility or availability due to the tannins complexing with the grain proteins after grinding.

Dehulled grain was blended with its high tannin untreated grain of the same variety to provide varying levels of CE in one variety since

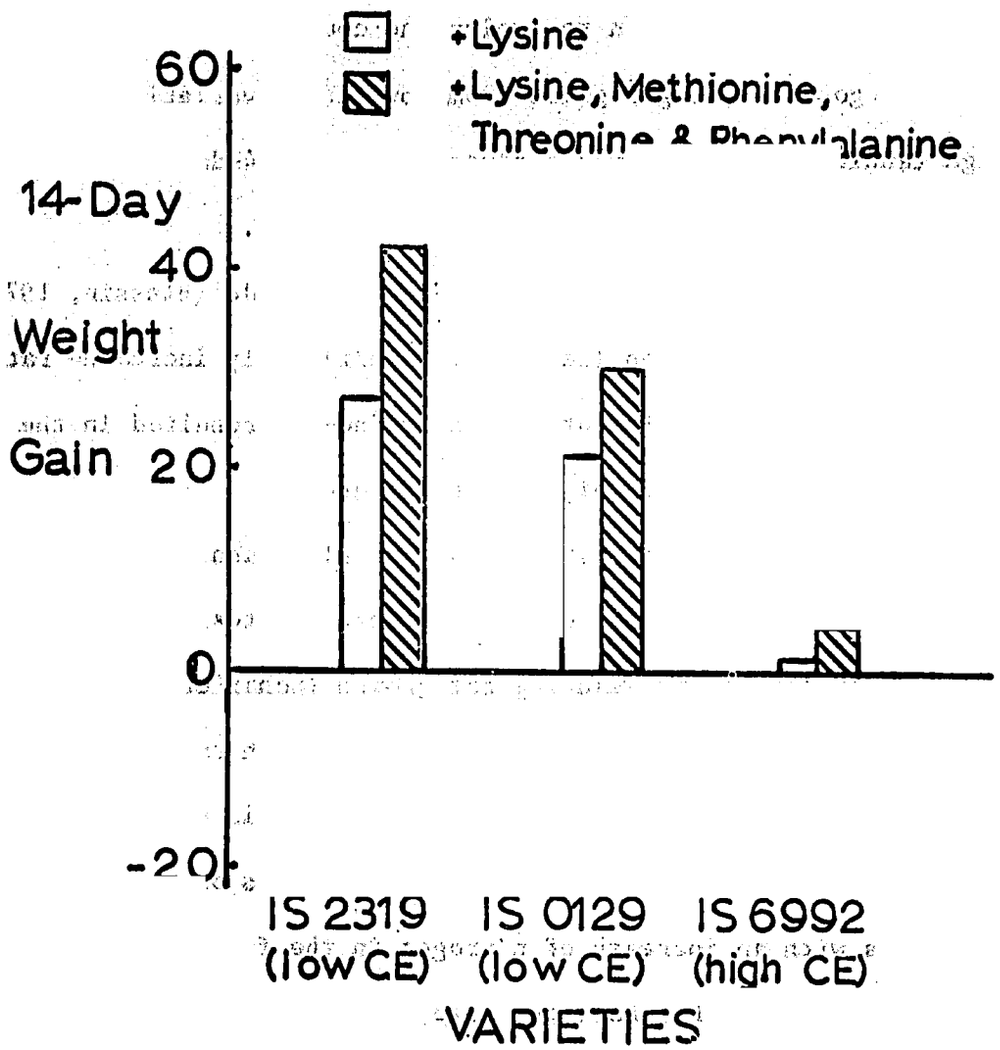

Figure 5. Influence of lysine and lysine, methionine, threonine, and phenylalanine supplemented isonitrogenous low and high CE concentration grain sorghum rations on 14-day weanling rat weight gain (Oswalt, 1973).

Table 2. Influence of alkali dehulling on CE and crude protein percentages of grain (Oswalt, 1973).

Identification	C.E.	Protein %
RS 610 (low tannin)	0.48	9.90
RS 610 (dehulled)	0.10	9.95
BR 64 (high tannin)	8.10	9.30
BR 64 (dehulled)	0.35	9.38

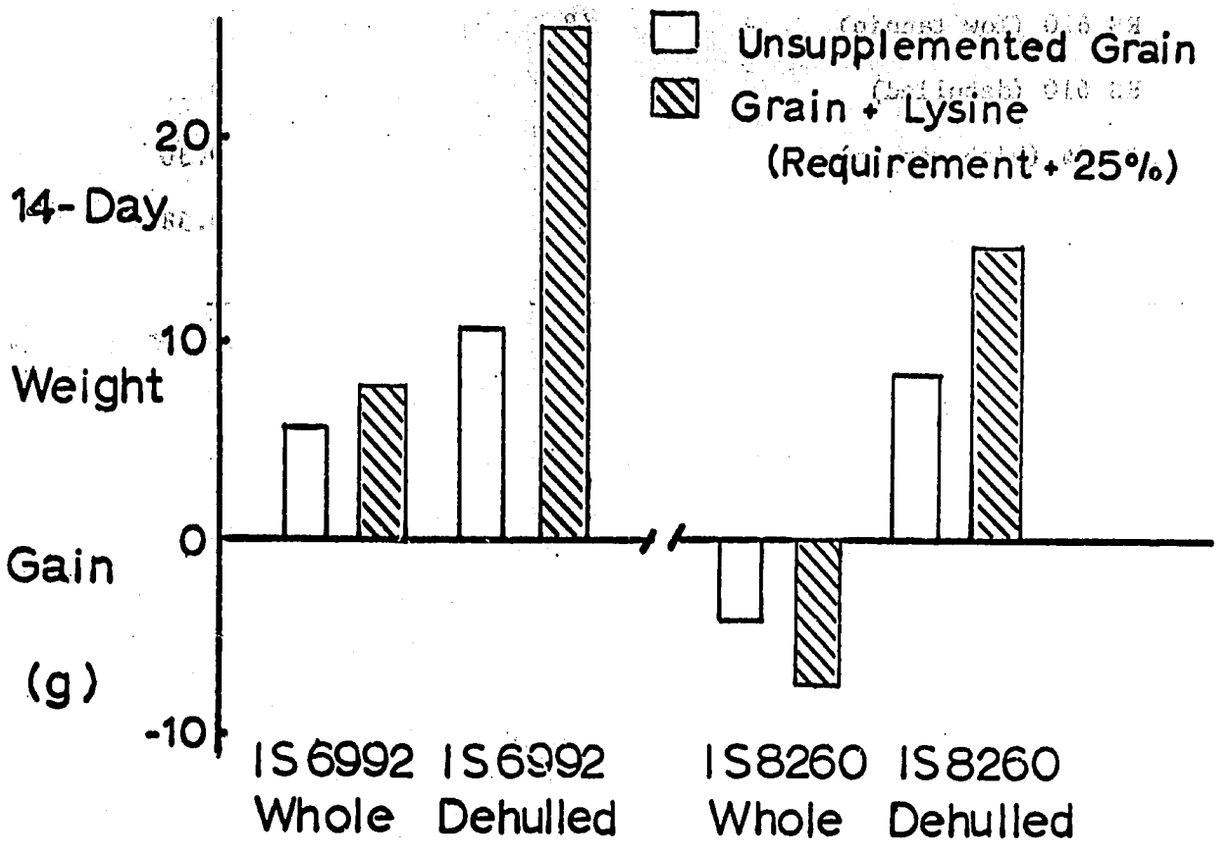

Figure 6, Rat weight gain on rations with and without lysine supplemented whole and dehulled high CE concentration grain sorghum genotypes (Oswalt, 1973).

Table 3. Nitrogen distribution in sorghum endosperm* (lysine as percent of protein in parenthesis) (Axtell et al.. 1972)

Fraction	Low Tannin	High Tannin
I (Saline)	7.3 (5.1)	2.9 (3.0)
II (Isopropanol)	16.8 (0.3)	11.3 (0.3)
III (Isopropanol + 2-Mercaptoethanol)	32.4 (0.2)	27.6 (0.3)
IV (Borate Buffer + 2-Mercaptoethanol)	7.8 (1.2)	10.9 (2.4)
V (Borate Buffer + 2-Mercaptoethanol + Sodium Dodecyl Sulfate	25.3 (3.6)	40.4 (3.0)
Total Nitrogen Extracted	89.5	92.9

* Percent of soluble nitrogen.

isogenic sorghums with varying CE levels were not available. It was found that low levels of CE in a ration showed a non-linear reduction in rat growth and the greatest reductions occurred at the lower CE levels (Figure 7).

It had been generally assumed that the presence of a pigmented testa indicated the presence of tannins. However, Cummings (1973) separated by use of both the vanillin-HCl (VHCl) procedure (Burns, 1973), and the modified vanillin-HCl (MVHCl) procedure (Maxson and Rooney, 1971) F_2 segregates from a low x high tannin cross into three groups. Group I with no testa had low CE values (below 1.0) with both the VHCl and MVHCl procedures, group II had a testa (verified with microscopic examination), tested low (below 1.0) with the VHCl and high (above 2.0) with the MVHCl procedure, and group III had a testa and tested high (above 2.0) with both the VHCl and MVHCl procedures. It was significant that his group II gave rat weight gains and feed efficiency ratios comparable to group I samples (Figure 8).

Oswalt (1974) verified the use of the VHCl and MVHCl tests, as described by Cummings (1973), to classify varieties from the world collection into the three (I, II and III) groups (Table 4). Microscopic examination showed that only groups II and III possessed a testa. Most of these pigmented testa selections in group II varieties possessed a white chalky pericarp (Oswalt, 1974), but it was not possible to accurately separate varieties visually into the three groups. Sample no. 10, in group III, had initially the lowest CE values from both tests and at the completion of the feeding trial had CE values of less than 1.00 from both tests, indicating that factors measured as tannins,

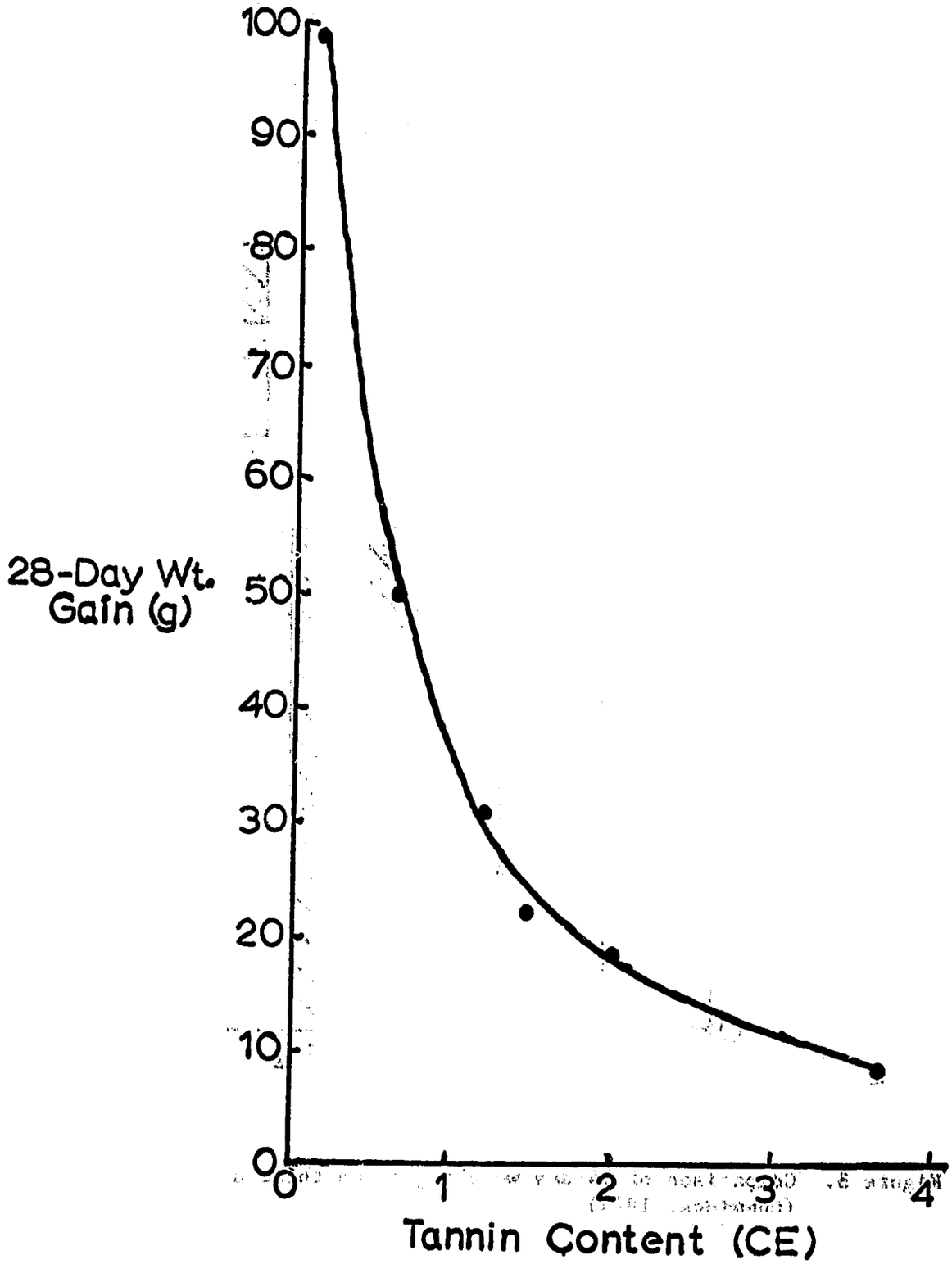

Figure 7. The effect of CE level on 28-day weanling rat weight gain. (Rations made of a high tannin sorghum diluted with its dehulled counterpart to obtain desired tannin content, Cummings, 1973).

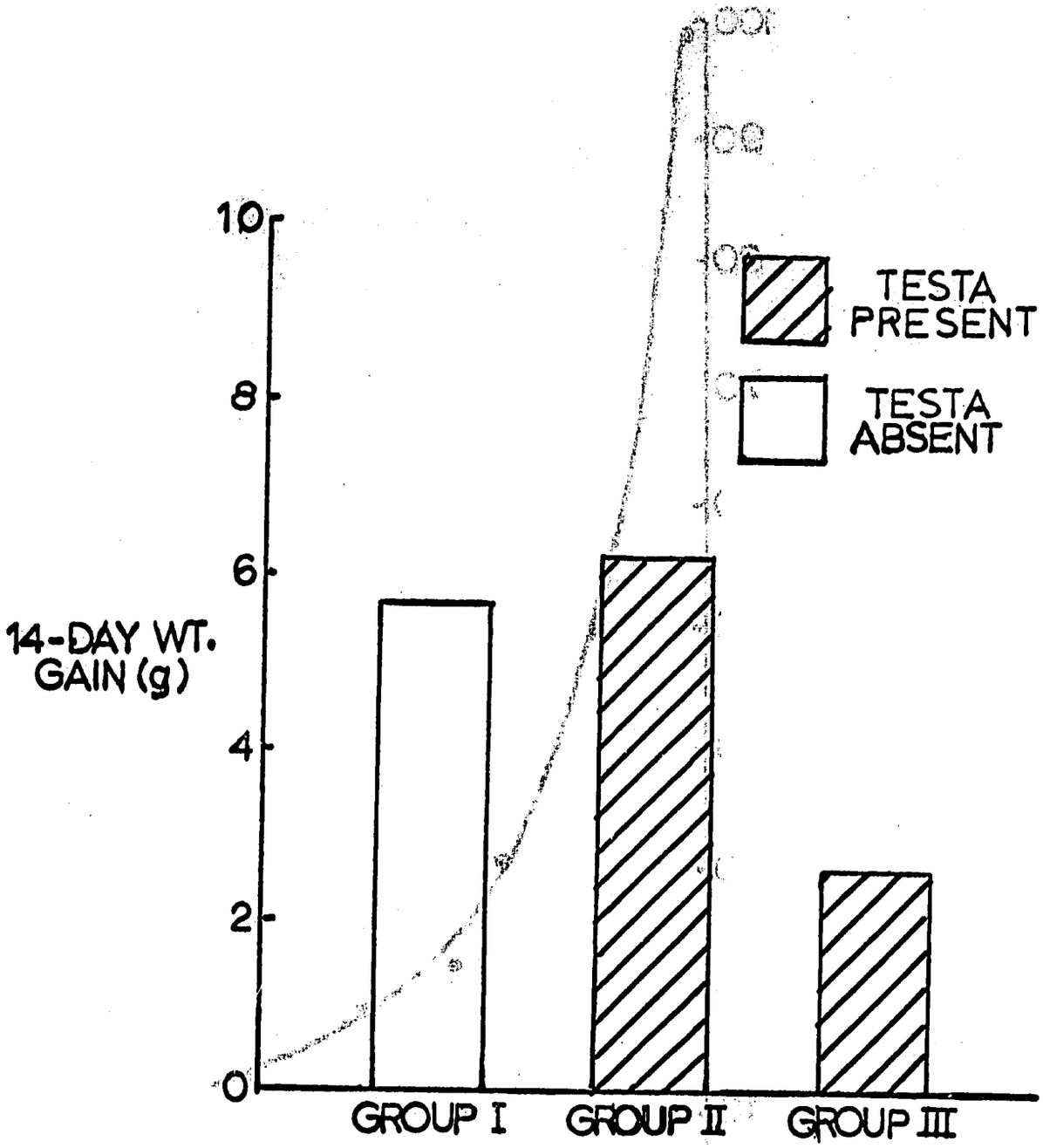

Figure 8. Comparison of 14-day weight gain on three diets in Experiment I. (Cummings, 1973).

changed during the duration of the feeding trial. Additional observations at Purdue University showed other varieties which change with time, especially after being ground. Weight gains and feed efficiency ratios from varieties classified in Groups I and II were not significantly different from each other (Table 5), but both were different from group III, except entry no. 10 which started at a lower CE value and lost the measurable influences expressed as CE before the completion of the 28-day feeding trial.

Unpublished data (Oswalt, Purdue University, 1974), showed that the estimated CE contents of a sorghum sample can be influenced by grinding, variations in temperature and length of storage (Figure 9). The higher the temperature and the longer the time in storage, the lower the CE values become for most varieties. However, variations among varietal responses to temperature and time have been noted.

The failure of varieties containing high levels of tannins to respond to lysine content or supplementation makes it mandatory that any studies comparing different sorghum varieties for their biological values of proteins, amino acids, or other grain quality factors, have the tannin level of each variety identified and taken into consideration. Any initial or ending variation of tannins in samples would influence greatly the biological estimates of the grain quality (Oswalt, 1973).

SUMMARY

The CE estimates of tannins by the VHCl procedure and the MVHCl procedure can be used to predict the influence of tannins on rat weight gains. These two tests can be used to divide sorghum varieties into low tannin groups with and without a testa and a high tannin group for

Table 5. Twenty-eight-day weanling rat weight gains, feed consumed, feed efficiency ratios and protein efficiency ratios (Oswalt, 1975).*

Sample No.	Group	Weight Gain (g)	Feed Consumed (g)	Feed Efficiency Ratio
1	I	88 b	328 ab	3.7 a
2	I	82 b	340 ab	4.2 ab
3	I	65 c	306 b	4.7 b
4†	II	106 a	368 a	3.5 a
5	II	85 b	348 ab	4.1 ab
6	II	84 b	351 ab	4.2 ab
7	II	84 b	343 ab	4.1 ab
8	III	24 d	212 d	8.7 d
9	III	37 d	222 d	6.1 c
10	III	60 c	264 c	4.4 ab
Mean		71	308	4.8
C.V. (%)		8.6	6.0	7.7

* Values followed by the same letter are not significantly different at the .05 probability level.

† Check.

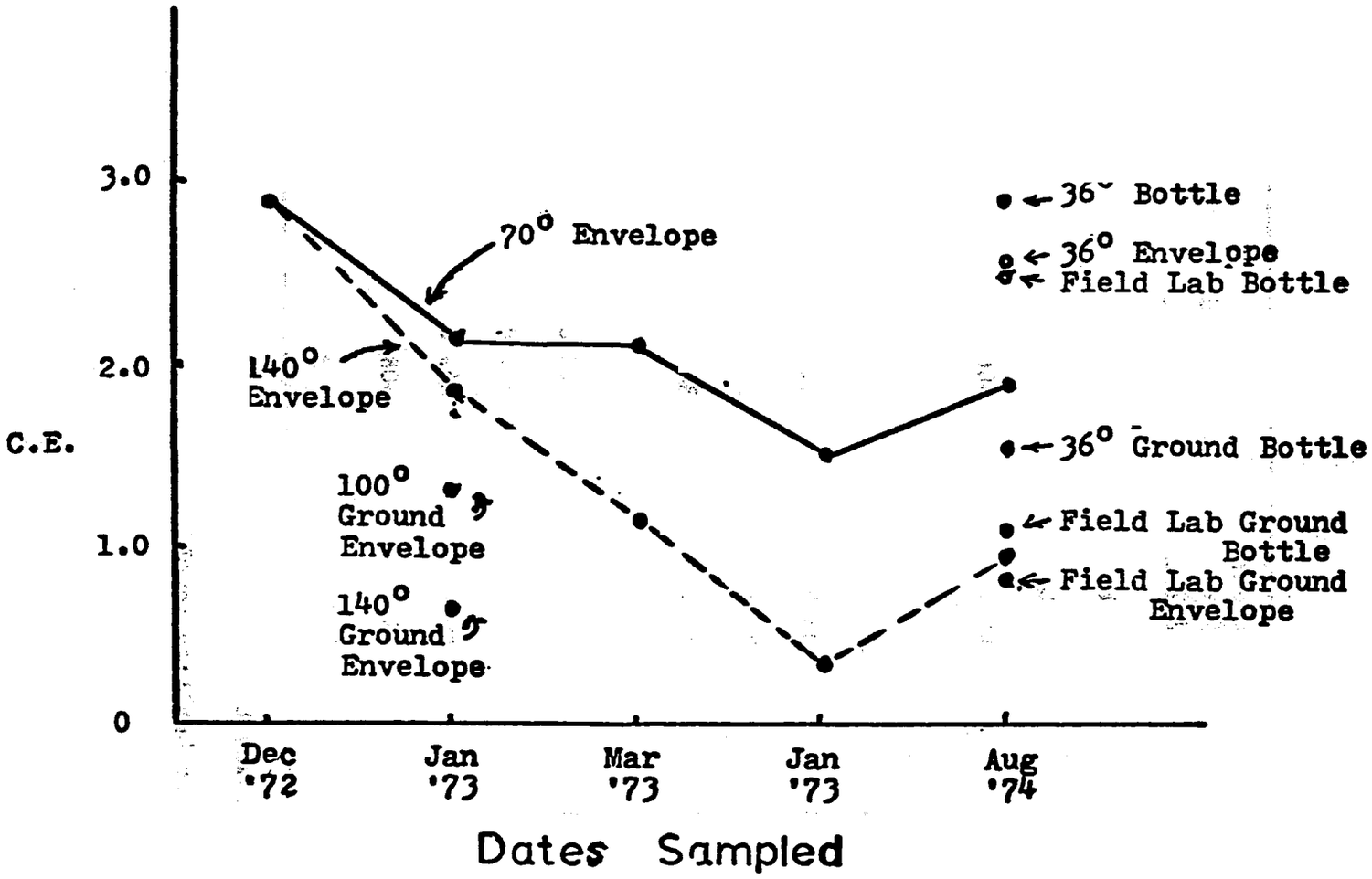

Figure 9. Relationship of CE content of whole seed and ground samples of grain sorghum (IS 6992) in closed bottles or envelopes to temperature (F) and length of storage (Unpublished data, Oswalt, Purdue University, 1975).

breeding program selections and selections for comparisons of nutritional qualities of sorghum varieties. The VHCl tests appeared to be the best single test for predicting biological values other than the IVDMD procedure. The identification of varieties (Group II types) which have a testa and low levels of tannins when mature, or which have tannin levels which are reduced in early storage, may provide varieties which have partial bird and weathering resistance and not reduce protein availability, but even low levels of tannin in grain samples will reduce the potential availability of proteins for animal growth. It is important that breeding and production programs recognize the presence or absence of tannins in selections being made or produced for utilization as feeds or foods.

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PROTEIN QUALITY IMPROVEMENT IN GRAIN SORGHUM[1]

D. P. Mohan and J. D. Axtell[2]

Grain sorghum is an important human food in many parts of the world, especially in Africa and Asia. Unfortunately, the nutritional quality of most of the grain sorghum varieties being used today is poor relative to that of other major cereals. The purpose of this report is to summarize our research on some of the problems associated with the poor nutritional quality of sorghum, and to review some of our recent research in this area. This report is not intended to provide experimental details which are available by reference from technical publications.

We have been studying two major components of nutritional quality in grain sorghum (Axtell et al. 1972). First, protein availability is apparently limited in some sorghum genotypes by the presence of unidentified polyphenolic compounds located primarily in the testa layer of the grain. These pigmented compounds have not been well characterized chemically and are referred to generically as "tannins". Second, the protein quality of sorghum is limited by the low lysine content of the

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grain which reflects the high prolamine content of the endosperm. If one looks at the essential amino acid composition of sorghum grain, in comparison with monogastric nutritional requirements, it is obvious that lysine is deficient and also that there is great excess of leucine. The methionine content of sorghum is low, but considering the cystine content of 1.5%, the overall sulfur amino acid content approaches that of the weanling rat requirement. The tryptophan content of sorghum seems to be adequate in contrast to the low tryptophan content in normal maize. Since the tannin problem has been discussed elsewhere in this symposium we will concentrate on the improvement of protein quality in sorghum.

HIGH LYSINE SORGHUM FROM ETHIOPIA

In 1972 we initiated two approaches which we hoped would lead to the identification of sorghum lines with increased lysine content. The first of these approaches involved cross-sectioning of approximately 9,000 lines of sorghum from the world collection, and screening these sectioned kernels for floury endosperm lines (Singh and Axtell, 1973). Using this procedure we identified 62 floury endosperm lines and evaluated each for lysine and protein content. Most of these floury endosperm lines were normal for lysine content in relation to their protein content. There were two floury endosperm lines, however, which had a high lysine content at relatively high levels of protein. IS 11167 and IS 11758 were both collected from Wollo Province in Ethiopia during the 1960's. The protein and lysine content of these two lines was subsequently verified in Puerto Rico, and the average of these determinations is shown in Table 1 in comparison with the average for several hundred normal sorghum lines from the world collection. The significant point

is that lysine content when expressed as percent of sample is approximately double that of normal sorghum.

The reason for this increase in lysine can be understood by looking at the distribution of endosperm proteins by solubility fractionation using the Landry-Moureaux procedure (1970). The distribution of protein in the five solubility fractions for normal sorghum is shown in Table 2, along with the lysine content of each of the five fractions (Jambunathan and Mertz, 1973). Over 50% of the endosperm protein in sorghum is present in fractions II and III, which are both lysine-poor fractions. Fractions II and III are generally referred to as the prolamine fractions. Note that fractions I and V are relatively high in lysine.. The nitrogen distribution in normal and high lysine sorghum endosperm tissue using the same procedure has been obtained by Jambunathan (unpublished data). The high lysine seed used in this determination is an average of five high lysine lines collected from farmers fields in Ethiopia, whereas the normal control was from a normal variety grown in the same environment. There is a substantial reduction in the amount of protein in fractions II and III among the high lysine lines, accompanied by an increase in the proportion of protein in the lysine-rich fractions I and V. The reduction in prolamine from approximately 55% to 39% largely accounts for the increased lysine content of the high lysine Ethiopian lines. The high lysine content of these Ethiopian lines is controlled by a single gene which has been designated hl. The biological value of the Ethiopian high lysine sorghum grain in comparison with normal has been reported (Singh and Axtell, 1973). Data obtained by feeding high lysine and normal samples at isonitrogenous levels (10% protein) to weanling rats in a 28-day trial demonstrated that rats fed the high lysine ration

increased in weight approximately two to three times more than rats fed the normal control ration.

The kernel phenotype of the Ethiopian high lysine varieties is partially dented. This suggested the possibility that there may be a block in the biosynthesis of starch from water soluble polysaccharides similar to that found in shrunken, sugary, or brittle endosperm mutants in maize. The data in Table 4 shows the carbohydrate composition of both high lysine lines and a normal control. There is no change in the quantity of reducing sugars and only a slight increase in the amount of sucrose in the high lysine lines. Water soluble polysaccharides content is similar to that of normal, and there is only a two to three percent reduction in starch which can be accounted for by the slight elevation in the levels of sucrose. We concluded; therefore, that there is no disruption in starch synthesis from water soluble polysaccharides in hl genotypes and that it may be possible to identify plump seeded high lysine kernels in an appropriate genetic background.

We travelled to Wollo Province, Ethiopia, in November of 1973 to see if we could find these same high lysine varieties under cultivation, and if possible to find out how the people were using them. We first found them growing within one or two kilometers of the site where they were originally collected, thanks to some excellent records and notes from Dr. Jack Harlan. Seeds of the high lysine varieties were collected in cooperation with Dr. Brhane Gebrekidan, who is in charge of the sorghum breeding program at Alemaya, and Mr. Gebisa Ejeta, a graduate assistant from Alemaya, who is now studying at Purdue. The high lysine types were always found growing in mixtures with normal sorghum varieties--a standard practice for most of the sorghum cultivated in Ethiopia. The

local farmers could recognize and identify the high lysine varieties and reported to us that it was used primarily for roasting in the late dough stage. They also recognized that the yield of this variety was lower than that of their normal sorghum varieties, but they included it in the mixture because they liked the taste of the roasted grain.

CHEMICALLY INDUCED HIGH LYSINE SORGHUM MUTANT

The second approach initiated in 1972 was the use of chemical mutagen treatments, specifically diethyl sulfate, to try to induce a mutant which would increase the lysine content of the sorghum grain. D. P. Mohan screened 23,000 M_2 heads (bearing M_3 seeds) during his Ph.D thesis research at Purdue for the occurrence of opaque kernel mutants. All heads from treated seeds were bagged each generation to prevent outcrossing. Seeds from each M_2 head were placed over a light box and examined for segregating opaque kernels. Mohan identified approximately 475 heads segregating for opaque kernels, and both classes of seed from each segregating head were analyzed for protein and lysine content. The percent increase in lysine of these 475 putative opaque mutants is shown in Table 5. Most of the opaque mutants were normal in lysine content, but there were 33 with at least a 50% increase in lysine. The mutant from this group that appears to have the most promise at this time is P-721. The average protein and lysine content of P-721 opaque seed and normal sib seed is shown in Table 6. There is an approximately 60% increase in lysine in the P-721 mutant grain.

The inheritance of this opaque mutant is not yet clearly understood, but it appears to be controlled by a single gene which expresi partial dominance in the triploid sorghum endosperm. In some cases,

F_2 segregation ratios fit a 1:1 ratio, but in others there is a deviation in favor of more opaque and fewer vitreous kernels (Table 7). This ratio would be expected if two or three doses of the opaque gene produced opaque kernel phenotypes, whereas one dose of the opaque gene in the triploid endosperm is recessive to normal vitreous expression. We expect that this ratio will vary with genetic background.

A comparison of the biological value of the Ethiopian high lysine sorghum with the newly recovered mutant P-721 is presented in Table 8. This data was obtained from two different feeding trials using a standard ANRC casein diet as a check which allows comparison between trials. RS 610 was used as a normal sorghum control in the IS 11758 trial, whereas normal sib seed of mutant P-721 was used as a normal control in the P-721 evaluation. All rations were isonitrogenous (10% protein) and were fed to weanling rats for 28 days. Feed efficiency ratios and protein efficiency ratios of both high lysine mutants appear to be similar, and we conclude from this preliminary experiment that the protein quality of both sources of high lysine sorghum germplasm is essentially the same. This is, both sources of high lysine germplasm give an approximately two-fold increase in protein quality in comparison with the casein control. (This is a tentative conclusion. A recent chick trial showed that the Ethiopian high lysine sorghum has slightly better biological value than P-721 sorghum. Both; however. were twice as good as normal controls.)

Since mutant P-721 was recovered in a photoperiod insensitive, three-dwarf line with relatively broad agronomic adaptability, this mutant may be most useful in temperate sorghum growing regions of the world. The increased protein content of the Ethiopian high lysine

varieties, on the other hand, may provide useful sorghum germplasm for use as a protein supplement or weanling food for young children, which is needed in many parts of Africa and Asia.

FUTURE RESEARCH

If we look at the prolamine content of the major cereals we can see that they fall into three rather distinct groups, as shown in Figure 1. Since the protein quality of cereals is inversely related to their prolamine content, these groups increase in protein quality as they decrease in prolamine content. This figure also shows the changes in prolamine content associated with high lysine mutants in three of these cereals. These changes appear to occur in two steps from higher to lower prolamine content. Dr. Oliver Nelson (1974) has suggested that this may be coincidence <u>or</u> it may mean that the regulation of prolamine synthesis is controlled by two major genes in these cereals. If the latter interpretation proves to be correct, it should be possible to find a "second-step" mutation in sorghum (or corn) which will reduce the prolamine content to approximately 10%, with further concomitant increases in protein quality. This would provide us with a cereal grain which combines the photosynthetic efficiency and stress tolerance of sorghum with the protein and nutritional quality of oats or rice.

We can speculate still further into the future in our search for a more "perfect" cereal and ask the following question. Will it be easier to breed for increased photosynthetic efficiency in rice or oats, or to take the alternative approach and breed for increased nutritional quality in sorghum and corn which already have the genetic machinery for a more efficient photosynthetic pathway? The answer will depend

on which biochemical process is easiest to manipulate genetically, which in turn can only be decided when we understand the genetic control of these important biochemical pathways in cereal grains.

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7. Classification of kernels from three self-pollinated panicles of heads heterozygous for opaque mutant P-721.

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Table 1. Protein and lysine concentration of whole grain samples of high lysine and normal sorghum lines.

Protein	High Lysine Lines		
Composition	IS 11167	IS 11758	Normal
Protein (%)	15.70	17.20	12.70
Lysine (% of Protein)	3.33	3.13	2.05
Lysine (% of Sample)	0.52	0.54	0.26

Table 2. Protein and lysine distribution in normal sorghum endospe

Solubility Fraction*	Protein (%)	Lysine (% of Protein)
I	7.3	5.1
II	16.8	0.3
III	32.4	0.3
IV	7.8	1.2
V	25.3	3.6

* Landry-Moureaux proceuure.

Table 3. Protein distribution in normal and Ethiopian high lysine sorghum endosperm.

Solubility Fraction*	Protein (%)	
	Normal	High Lysine (hl)
I	6.33	13.58
II	19.16	16.54
III	36.26	23.02
IV	6.65	4.00
V	25.60	33.86

* Landry-Moureaux procedure.

Table 4. Carbohydrate composition of whole kernel samples of Ethiopian high lysine and normal sorghum lines.

Carbohydrate Composition	High Lysine Lines		Normal
	IS 1116	IS 11758	
Reducing Sugars	0.38	0.32	0.34
Sucrose	3.08	2.61	1.03
Total sugars	3.46	2.93	1.34
Water soluble polysaccharides	0.91	1.01	1.11
Starch (% of Sample)	58.90	57.80	60.80
Total carbohydrates	63.27	61.74	63.25

Table 5. Distribution of lysine increases (% of sample) of 475 putative opaque endosperm sorghum mutants derived from diethyl sulfate treatments.

Percent increase in lysine	Number of putative opaque mutants
0 - 9	135
10 - 19	114
20 - 29	85
30 - 39	53
40 - 49	25
> 50	33

Table 6. Protein and lysine composition of high lysine opaque mutant P-721 and normal sib grain.

	Protein (%)	Lysine (% of Protein)	Lysine (% of Sample)
P-721 opaque	13.9	3.09	0.432
Normal sib	12.9	2.09	0.270

Table 7. Classification of kernels from three self-pollinated panicles of heads heterozygous for opaque mutant P-721.

	No. of kernels				
Pedigree	Vitreous	Opaque	Total	X^2*	Prob.
443 176-1	144	158	302	0.648	.25 - .50
443 176-2	114	116	230	0.016	.90 - .75
443 119-1	137	157	294	1.360	.25 - .10

* Based on 1:1 expected ratio.

Table 8. Biological value of isonitrogenous (10% protein) diets of Ethiopian (IS 11758) and P-721 high lysine sorghums and their respective normal checks, RS 610 and normal sib grain in a 28-day weanling rat feeding experiment.

	Weight Gain (g) (28 days)	FER	PER	% of Casein
IS 11758	40	5.8	1.7	58
RS 610	16	10.5	0.9	32
P-721	33	5.7	1.8	64
Normal sib	11	10.6	0.9	32

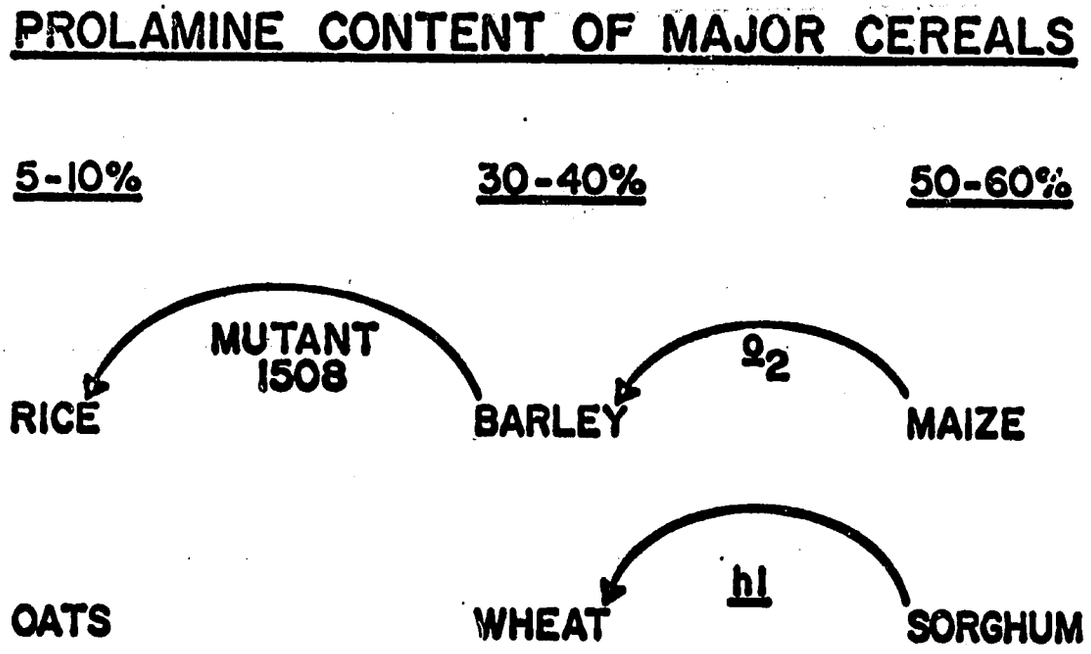

Figure 1. Effect of high lysine gene mutations in maize (o_2), sorghum (hl), and barley (1508) on prolamine content.

Studies on the Nutritional Quality of Sorghum Grain[1]

W. R. Featherston[2] and J. C. Rogler[2]

INTRODUCTION

Sorghum grain offers an excellent potential for cereal grain production in many areas of the world where for one reason or another other cereal grains are not well-suited. Two major factors which may limit utilization of sorghum grain by monogastric animals are the concentration of the amino acid lysine in the grain and the interference of tannins found in some varieties of sorghum grain. This report is concerned primarily with studies conducted in the authors' laboratory on these two problem areas. The majority of the report is devoted to studies on the interference of tannins on utilization of sorghum grain by the chick and rat. Sufficient high lysine sorghum became available in mid-1974 to permit evaluation of this grain in chick diets. The latter part of the report summarizes the findings of these studies.

EFFECTS OF DIETARY TANNINS

Growth and feed efficiency effects in chicks and rats

Poorer chick growth and feed efficiency have been consistently noted when bird resistant sorghum grains have been compared with non-resistant grain (1,2,4,5). The bird resistant sorghum grains used

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in these studies were BR64 and IS8260, while the non-resistant varieties were RS610 and RS671. These grains have been compared on both an isonitrogenous and an equal weight basis. Studies to be reported later will show that there is good evidence that the biological value of the protein per se from the bird resistant grain is of comparable quality to that of the non-resistant grain and that the poor performance of chicks fed the bird resistant grain is due to the grain tannins.

A dietary protein level of approximately 15-16% has been used in most of these studies with the day-old chick in an effort to develop a sensitive assay which would permit good chick growth but which is free of excess dietary protein. A dietary protein level of 20% was fed in one study (4), however, with decreased weight gain and feed efficiency noted as compared with chicks fed the non-resistant grain; these results agree with those observed at 15% dietary protein.

Only limited growth studies have been conducted with rats in our laboratory (5). The results agree with those of Jambunathan and Mertz (6) which indicates that sorghum grain tannins result in decreased weight gain and feed utilization.

Extraction of tannins from sorghum grain

In order to determine whether the poorer performance of chicks fed bird resistant sorghum grain could be overcome by extraction of the tannins, bird resistant and non-resistant grains were subjected to an alkaline-hot water treatment similar to that described by Blessin et al. (7). This extraction process had little influence on the protein content of the grain as measured by the Kjeldahl procedure

but did result in removal of the tannins to approximately the same level found in non-resistant sorghum grain.

Subjecting a non-resistant grain to the extraction process had little influence on chick weight gain but did result in better feed efficiency in some cases, probably due to the decreased fiber content of the diet resulting from the removal of a portion of the grain pericarp during extraction (3). Extraction of the tannins from bird resistant grain resulted in marked improvements in weight gain and feed efficiency as compared with chicks fed the intact bird resistant grain. The performance of chicks fed the extracted bird resistant grain was similar to that of chicks fed a low-tannin grain.

Similar to the results observed with chicks, extraction of the tannins from bird resistant sorghum grain resulted in rat growth which was 1.8 times that of rats fed the intact grain (5). Feed efficiency was also markedly improved.

These results suggest that once the detrimental influence of the tannins has been removed, the bird resistant sorghum grains are of comparable biological value as low-tannin non-resistant grain.

Digestibility studies with rats

The digestibility of the protein and utilization of calories in intact high-tannin sorghum BR64, extracted sorghum BR64 and low-tannin sorghum RS671 were determined with 220-g rats (5). The caloric utilization was determined by measuring the caloric content of the feed and feces in a bomb calorimeter. Similar amounts of feed were consumed by rats fed the three diets. Rats fed the intact sorghum BR64 showed nitrogen absorption values which were approximately 30% lower than values noted for the extracted sorghum BR64 or sorghum RS671,

The total caloric utilization of the intact sorghum BR64 was approximately 10% lower than that noted for the other two diets.

These results suggest that the dietary tannins have a detrimental effect not only on protein digestion but of the other components of the grain as well. Calculations of the calories lost as a result of the decreased protein digestion indicate that this loss accounts for only about one-third of the total decrease in calorie utilization noted with rats fed the intact sorghum BR64.

Use of dietary supplements to alleviate tannin effect

The supplementation of a chick diet containing a bird resistant sorghum grain with 0.15% DL-methionine has been shown to result in significant and consistent improvements in growth rate and feed efficiency (2,4,5). These improvements were of a greater magnitude than those noted when a low-tannin sorghum grain diet is supplemented with a similar amount of methionine. The growth of chicks fed the methionine-supplemented bird resistant grain diets was similar to that noted with chicks fed methionine-supplemented low-tannin grain diets. However, feed efficiency was usually poorer with methionine-supplemented high-tannin grain diets than with methionine-supplemented low-tannin diets. Increasing the amount of DL-methionine added to the diets to 0.30% did not result in any further response than that noted with 0.15% (5). The response to DL-methionine was observed with chicks fed a 20% protein diet as well as with 15-16% protein diets.

Recent studies have shown that the hydroxy analogue of methionine was also effective in alleviating the detrimental effects of the high-tannin diets (5). In contrast to the results noted with the chick, supplementation of rat diets containing the high-tannin

sorghum BR64 grain with either methionine or the hydroxy analogue of methionine was totally ineffective.

The addition of 1.0% polyvinylpyrrolidone (PVP) to a sorghum BR64 diet was equally as effective as methionine in alleviating the tannin effects (2). These results agree with a previous report by Rayudu et al. (8) that PVP would reduce the growth depressing effect of tannic acid. Since PVP is not metabolized or absorbed, its action must be mediated in the intestinal tract, presumably by binding tannins in vivo as it is known to do in vitro (8).

The reason for the observed species differences in response to methionine as well as the mechanism by which methionine exerts its effect remains obscure. If methionine is acting as a methyl group donor in a detoxification reaction, choline should also exert a beneficial response and a response to methionine should be noted in the rat as well as the chick. Such has not been the case (2,5). It was thought that free methionine might be acting like PVP and binding tannin in the digestive tract. However, one would expect the binding to occur in the rat as well as the chick. Since a sorghum-soybean meal diet should be first limiting in methionine for the chick, it might be reasoned that the methionine deficiency is aggravated by a reduced protein digestibility or amino acid availability produced by the tannins. The response observed by methionine supplementation of low-tannin sorghum indicates that methionine is first limiting. In preliminary studies, methionine supplementation of a sorghum-safflower diet (first limiting in lysine) failed to elicit a response, lending credence to this theory. However, the sorghum-soybean diets (15% protein) used were deficient in other amino acids (lysine, threonine

and arginine); and although methionine availability would have the greatest effect, availability of other limiting amino acids should also be affected. Therefore, methionine supplementation should not completely overcome the detrimental influence of tannins. The observations that it does render this explanation also open to question. This does not deter from the fact that supplementation of sorghum-soybean meal chick diets with methionine or its hydroxy analogue would appear to be a practical solution to tannin interference in those situations where it is imperative that bird resistant sorghum grains be grown.

Effects of adding commercial tannins to normal sorghum

The addition of 0.84-1.00% commercial tannic acid to a normal sorghum (RS610) diet has been shown to depress weight gain and feed conversion of chicks similar to that observed when bird resistant sorghum grain was fed (2). In contrast to the results noted with bird resistant grain, methionine supplementation did not alleviate the effects of the commercial tannic acid (2,4); PVP, on the other hand, appeared to be effective with both sources of tannins. The molecular weights of the tannic acids did not seem to be a factor as compounds with molecular weights varying from 950 to 1701 appeared to be equally detrimental (4).

NUTRITIVE VALUE OF HIGH LYSINE SORGHUM FOR CHICKS

Amino acid composition

High lysine sorghum (IS11758) from two separate plantings grown in Puerto Rico during the first half of 1974 was evaluated in three experiments with day-old chicks (9). The first planting of grain used in the first experiment was found to contain 13.62% protein and

0.48% lysine (3.52 g/100 g protein). It was compared in a chick trial to a commercial low-tannin sorghum RS671 which contained 11.54% protein and 0.25% lysine (2.15 g/100 g protein). The second planting of high lysine sorghum used in the second and third experiments contained 12.19% protein and 0.45% lysine (3.67 g/100 g protein). It was compared with another commercial low-tannin sorghum (RS610) which contained 11.93% protein and 0.24% lysine (2.06 g/100 g protein).

Chick growth studies

When the sorghum grains were compared on either an equal weight or equal protein basis in diets in which all the protein was supplied by the sorghum grains, the high lysine sorghum produced chick weight gains of approximately three times those noted with the normal sorghum and with approximately 50% less feed required per unit gain (9). Supplementation of the normal sorghum diet with lysine to equal the level supplied by the high lysine sorghum at an equal protein level resulted in a similar chick growth and feed efficiency. These results indicate that the improved performance of chicks fed high lysine sorghum as compared with normal sorghum was due solely to its higher lysine content.

The sorghum grains were also evaluated in chick diets at higher protein levels. High lysine sorghum was compared on an isonitrogenous basis with normal sorghum in 15% protein diets with the non-sorghum protein provided by either safflower meal or soybean meal. Chicks fed the high lysine sorghum diets supplemented with safflower meal or soybean meal grew 2.5 and 1.9 times faster, respectively, and were significantly more efficient in feed utilization than chicks fed corresponding diets containing normal sorghum. When the high lysine

and normal sorghum grains were compared on an equal weight basis in diets supplemented with 21.2% soybean meal and 0.2% DL-methionine (20.0 and 18.6% protein, respectively), high lysine sorghum produced significantly greater chick growth and slightly improved feed efficiency.

These results indicate that the nutritional quality of high lysine sorghum grain is markedly superior to that of two commercial sorghum grains.

SUMMARY

High-tannin bird resistant sorghum grains have been shown to produce poorer growth and feed efficiency of chicks and rats as compared with the performance noted with low-tannin non-resistant grains. Extraction of the tannins from bird resistant sorghum resulted in chick performance equal to that noted with chicks fed low-tannin sorghum grain. Thus, the biological value of the various grains appears to be approximately equal once the detrimental effects of the tannins have been removed.

Digestibility studies with rats demonstrated significantly lower protein and caloric digestibility by rats fed a bird resistant grain as compared with rats fed the same grain with the tannins removed or a non-resistant sorghum grain.

The detrimental effects of the tannins in sorghum grain, but not commercial tannic acid, can be overcome by the supplementation of chick diets with methionine. The manner in which methionine exerts its effect remains obscure. The addition of 1.0% polyvinylpyrrolidone to the diet has been shown to overcome the effects of both sorghum grain tannins and commercial tannic acid.

High lysine sorghum IS11758 was shown to have superior nutritional quality as compared with two low-tannin commercial sorghum grains. Approximately three-fold more rapid growth was noted with chicks fed the high lysine sorghum than was noted with normal sorghum when all the protein in the diet was provided by the grain. The improved nutritional quality of the grain appears to be due to its higher lysine content.

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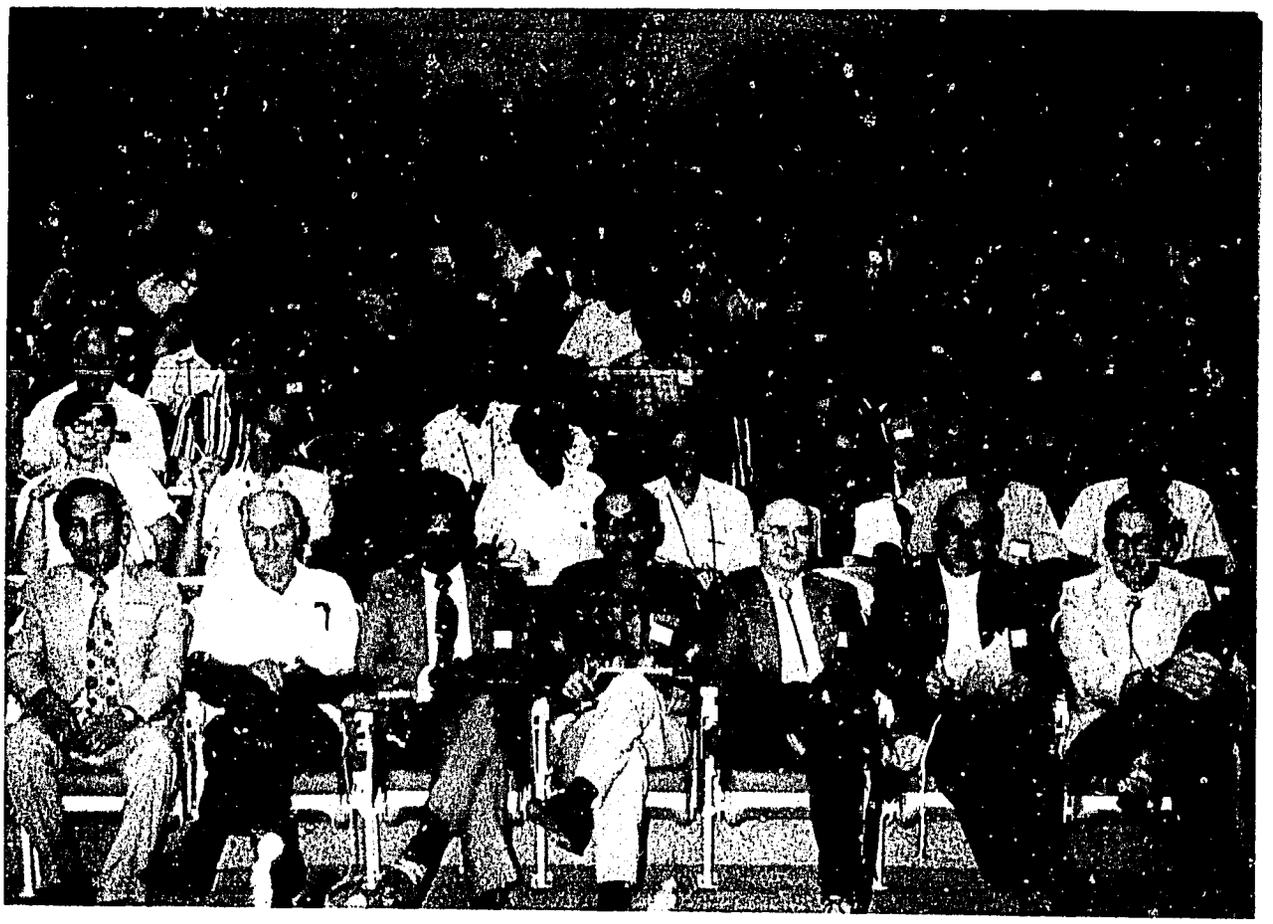

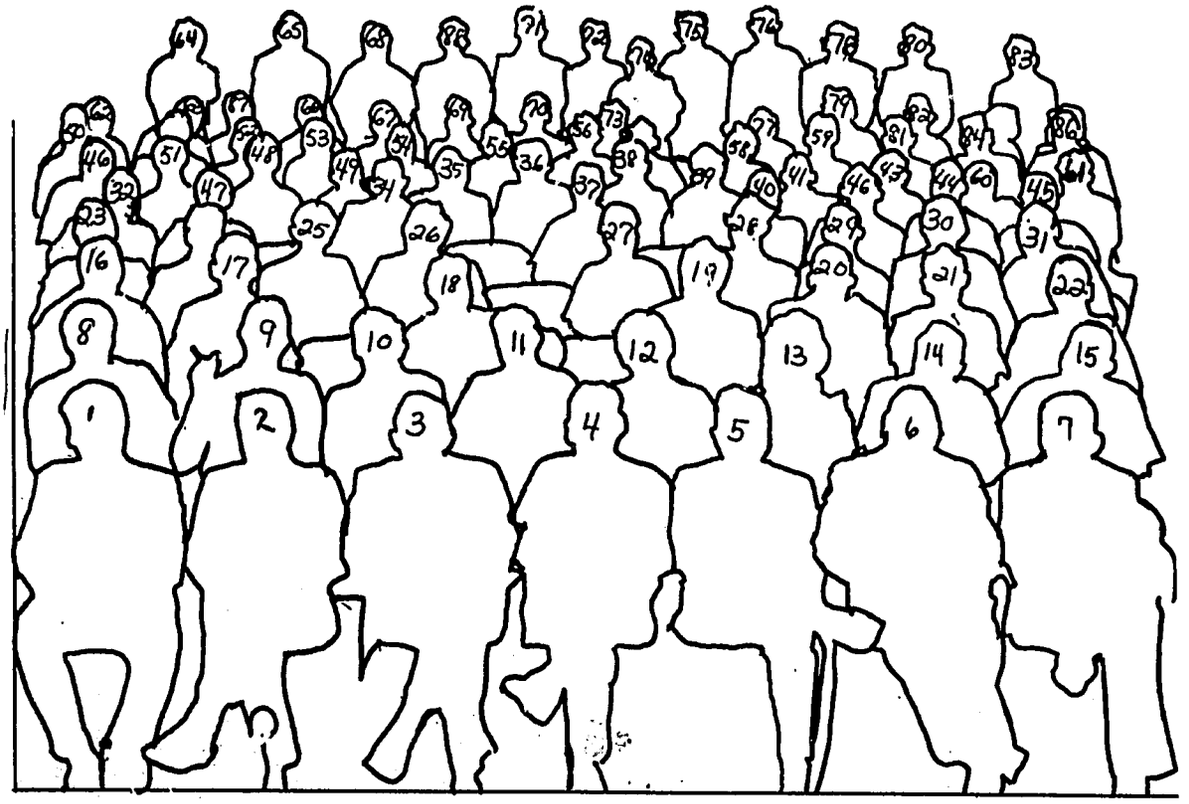
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