Sorghum

2017 Research Accomplishments

USDA

Agricultural Research Service
Plains Area

Sorghum

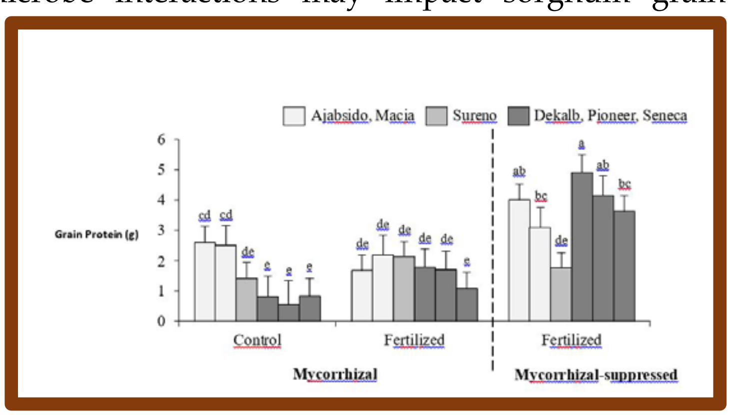
KANSAS

Impact of the Environment on Sorghum Grain Composition and Quality Traits

Grain Quality and Structure Research Unit, Manhattan, KS
Project Number: 3020-43440-001-00-D
Lead Scientist: Scott Bean
Team Members: Thomas Herald, Michael Tilley, Jeff Wilson

Grain quality analysis of samples exposed to different drought stress treatments. Drought stress can have major impact on sorghum grain composition and reduce the quality and value of the crop. To better understand how drought stress impacts sorghum grain quality, ARS researchers in Manhattan, Kansas, analyzed grain composition of sorghum that was subjected to drought stress both pre-flowering and post-flower (samples were grown by ARS scientists in Lubbock, Texas). Stay-green sorghum types were found to have higher levels of total protein and total kafirin content and lower levels of starch across irrigation treatments compared to senescent sorghum types. Increased kafirin levels were linked to increased grain hardness, which increased with increased water deficits. No differences were found between stay-green sorghum and senescent sorghum with respect to protein digestibility and fermentation efficiency. Thus, stay-green sorghum types can be used in drought prone areas without negatively affecting end-use quality of sorghum.

Impact of soil microbes on sorghum grain composition and end-use quality. Soil microbes such as arbuscular mycorrhizal fungi can associate with plant roots, extend the reach of root systems, and increase plant access to growth-limiting resources. To better understand how sorghum-plant microbe interactions may impact sorghum grain composition and end-use quality, ARS researchers in Manhattan, Kansas, analyzed grain composition of sorghum landraces and commercial hybrids grown with little fertilization, but with arbuscular mycorrhizal fungi present in the soil. The sorghum landraces had increased grain production and increased grain



protein content compared to the commercial sorghum hybrids. Soil microbe-sorghum interactions have the potential to reduce fertilization usage and cost while maintaining sorghum end-use quality. This research was conducted in collaboration with scientists at Oklahoma State University.

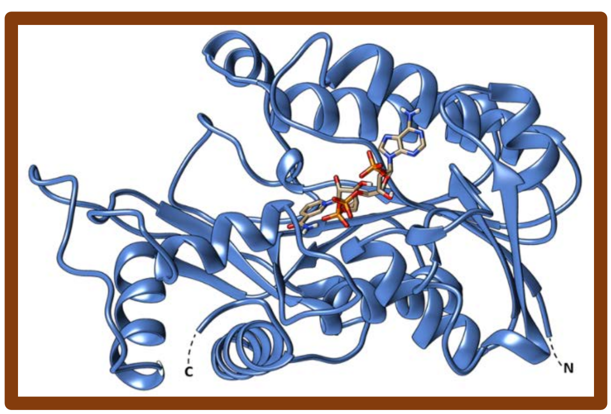
Development of zein-sorghum flour bread. ARS researchers in Manhattan, Kansas, optimized a bread formula containing isolated corn proteins (zein) and sorghum flour. This formula took advantage of the ability of zein to form visco-elastic dough and of sorghum flour's unique health attributes. Breads were successfully made from a dough, based system using white sorghum flour, black sorghum flour, and tannin containing sorghum flour. The optimized formula had substantially improved dough properties and loaf volume compared to initial conditions.

NEBRASKA

Genetic Improvement of Sorghum for Non-Grain Energy Use

Wheat, Sorghum, and Forage Research Unit, Lincoln, NE
Project Number: 3042-21220-032-00-D
Lead Scientist: Scott E. Sattler
Team Members: Deanna Funnell-Harris

Characterization of the sorghum Cinnamoyl-CoA reductase (CCR), a key enzyme in lignin synthesis. Sorghum biomass (stalks and leaves) serves as an important forage crop for livestock. In addition, sorghum is being developed as a bioenergy crop for advanced or second-generation biofuels production. Advanced biofuels are derived from the breakdown of the cellulose and hemicellulose components of biomass into sugars, and their subsequent conversion into biofuel molecules. A third biomass component, lignin, impedes breakdown of biomass in either livestock digestive systems or bioenergy conversion processes. Cinnamoyl-CoA reductase (CCR) gene encodes an enzyme involved in the



synthesis of lignin. ARS researchers in Lincoln, Nebraska, together with scientists from Washington State University, examined how this enzyme makes precursors to lignin. In sorghum, two classes of CCR enzymes were discovered, which have different roles in lignin synthesis. The second class of CCR enzymes is involved in making a specific type of lignin associated with plant defenses against pathogens. Collectively, this research gives a new perspective on the dual functions of this enzyme in lignin synthesis, and may lead to ways to protect plants from pathogens or insects while altering biomass composition of sorghum and other grasses to improve bioenergy conversion.

Identification of bmr lines with resistance to stalk diseases. Reducing lignin increases conversion efficiency of biomass into sugars, but lignin is important for plant defenses against pathogens. ARS researchers in Lincoln, Nebraska, investigated how fungi that cause the stalk diseases Fusarium stalk rot and charcoal rot, affected sorghum plants with two different mutations, bmr6 and bmr12, that impair lignin synthesis in cell walls. Plants with either bmr mutation or both mutations had similar responses to the pathogens as normal plants. Some of the bmr plants were more resistant than the normal plants to the stalk rot pathogen Fusarium proliferatum, and to the charcoal rot pathogen Macrophomina phaseolina. To determine whether soluble compounds produced within bmr6 stalks are able to inhibit the stalk rot pathogen Fusarium, the pathogen was grown on artificial media containing these soluble extracts. Surprisingly, Fusarium grew faster on media with the bmr6 soluble extracts than on the one with normal stalk extracts, which indicated that other factors contribute to increased resistance in bmr6 plants.

Several fungi can cause sorghum grain mold, which reduces grain quality in the field and during storage. Fusarium fungi were isolated from air and from brown midrib (bmr; plants with reduced lignin) and normal sorghum from two fields in Nebraska, one under irrigation and the other rainfed. ARS researchers in Lincoln, Nebraska, analyzed DNA sequences of these fungi and identified a common sorghum pathogen on the plants, but this fungus was only found at low levels in air. In contrast, numerous Fusarium pathogens of wheat and corn were identified from air samples, but only a few of these fungi were found at low levels on sorghum plants. Analysis of air samples during the growing season showed that Fusarium populations early in the growing season were different from the populations present at grain development and harvest.

Fusarium populations found in grain from normal and bmr plants at the irrigated field were different. However, Fusarium populations found in bmr and normal grain grown at the rainfed field were very similar. These results showed that bmr affected Fusarium populations in plants, but the environment also strongly influenced Fusarium populations.

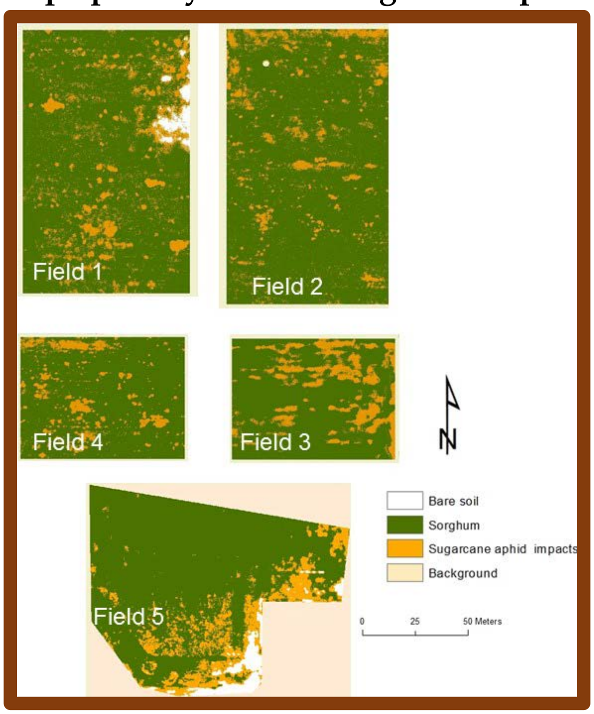
OKLAHOMA

Management of Aphids Attacking Cereals

Wheat, Peanut, and Other Field Crops Research Unit, Stillwater, OK
Project Number: 3072-22000-016-00-D
Lead Scientist: Gary Puterka
Team Members: J. Scott Armstrong, Norman Elliott, Xiangyang Xu

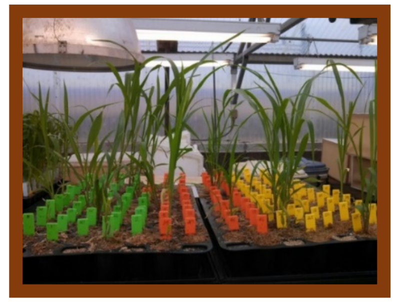
Genetic discoveries of the sugarcane aphid. Five different USDA-ARS laboratories (Stillwater, OK; Manhattan, KS; Lincoln, NE; Hilo, HI; and Beltsville, MD) teamed up to sequence the entire genome of the sugarcane aphid. The genome can be observed through accessing the National Center for Biotechnology Information (NCBI), which should help the correct identification of the aphid in the future. A new "sugarcane" genotype of the sugarcane aphid has just recently been identified. This "ecotype" or "biotype" was discovered through studying its biology on a set of host differentials, and by genotyping.

Multispectral and hyperspectral imagery to map spatially variable sugarcane aphid infestations and yield in sorghum. ARS researchers in Stillwater, Oklahoma, investigated the utility of multispectral imagery to delineate spatially variable infestations of sugarcane aphid in commercial grain sorghum fields. Multispectral images were acquired from fields by using a Duncan Tech MS3100-CIR, a 3-band (NIR, R, G) digital camera, and a mounted nadir in an aircraft fuselage. ERDAS Image was used for unsupervised classification of multispectral images of five fields. The study indicated that it is feasible to use multispectral imagery to detect and spatially delineate patches of plants infested by sugarcane aphids in sorghum fields. The overall classification accuracy ranged from 89% to 96% for differentiating areas damaged by sugarcane aphid, from areas where plants were not damaged. Results indicated good

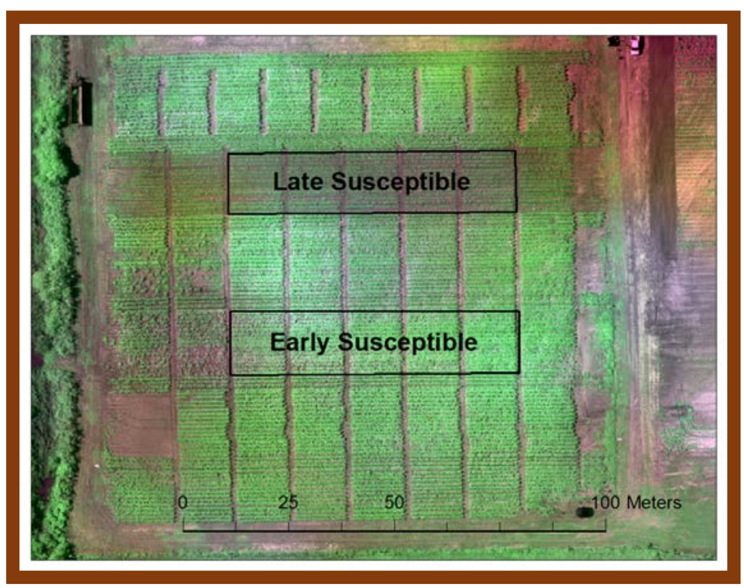


potential for mapping spatially variable sugarcane aphid infestations in grain sorghum fields.

Further developments in the search for sugarcane aphid resistant germplasm. Through team research involving ARS researchers in Stillwater, Oklahoma, and plant breeders and geneticists from Texas A&M, several additional sources of sugarcane aphid resistant germplasm have been discovered. Many of the sources of resistance come from what is known as the Sorghum Conversion Program, and from the plant introductions (P.I.'s) in the Germplasm Resources Information Network (GRIN). Public release of these resistant sorghum germplasm is ongoing through the Journal of Plant registrations where > 40 sources are released to the public and to industry breeding programs.



UAS-derived crop height and normalized differenced vegetation index (NDVI) metrics for sorghum yield and aphid stress assessment. A small, fixed-wing unmanned aerial system (UAS) was used by ARS researchers in Stillwater, Oklahoma, to survey a replicated small plot field experiment designed to estimate sorghum damage caused by an invasive aphid. The raw imagery was processed to generate NDVI maps of the fields and 3D point clouds. NDVI and plant height metrics were averaged on a per plot basis and evaluated for their ability to identify aphid induced plant stress. Experimental ground filtering was performed on both metrics and a method filtering low near infrared (NIR) values before NDVI calculation was found to be the most effective. Plot averages of NDVI and canopy height values were compared to per-plot yield at 14% moisture and aphid density. The remotely sensed measures of plant height and NDVI were correlated to plot averages of plant height, yield, and insect density. Negative correlations between aphid density and NDVI were seen near the end of the season in the most damaged crops. Negative correlations indicate that injury to plants caused by sugarcane aphid is distinguishable in multispectral imagery acquired from a miniaturized multispectral imaging system installed on a

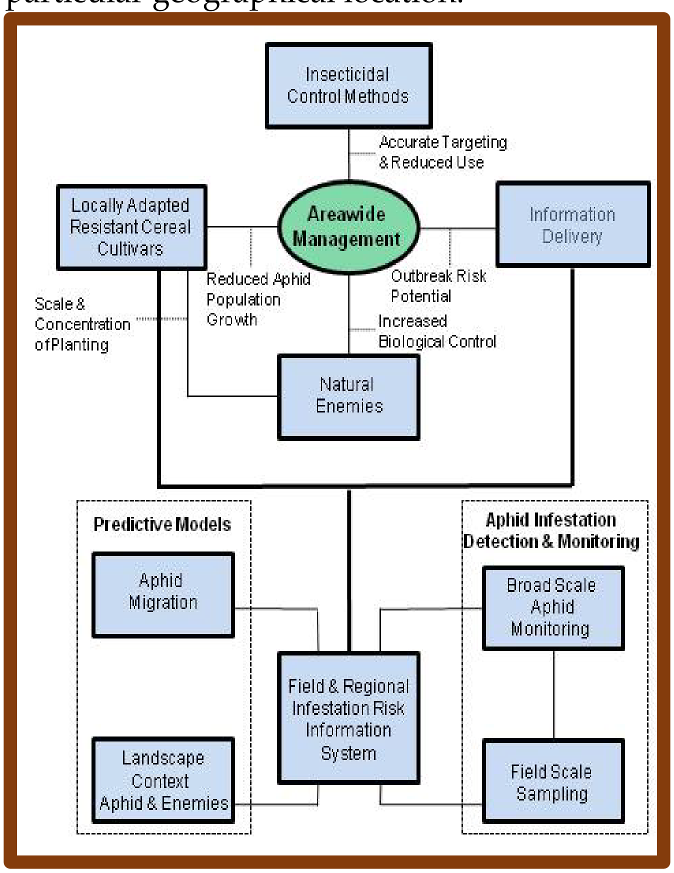


UAS. The results progress toward the goal of monitoring insect pests and injury on a spatially explicit, sub-field scale using UAS based systems, which can lead to cost effective methods for site-specific pest management.

Areawide Pest Management of the Invasive Sugarcane Aphid in Grain Sorghum

Wheat, Peanut, and Other Field Crops Research Unit, Stillwater, OK
Project Number: 3072-22000-016-00-D
Lead Scientist: Norman Elliott
Team Members: Scott Armstrong, Yinghua Huang

Progress on areawide pest management of the invasive sugarcane aphid in grain sorghum. Areawide planting of sugarcane aphid (SCA) resistant sorghum hybrids will reduce SCA infestations. In 2017, ARS researchers in Stillwater, Oklahoma, initiated mass screening of sorghum germplasm collections for SCA resistance and identified and characterized new resistance genes in grain sorghum. Field trials of resistant and susceptible sorghum varieties and germplasm lines were made at several geographic locations in Texas (3 trials), Oklahoma (5 trials), and Kansas (1 trial). Each trial included 12 varieties/germplasm entries, which were considered useful for growing in that particular geographical location.



A spatially explicit simulation model of SCA population dynamics was developed and interfaced with the Hysplit model. The model simulates SCA population dynamics and migration over the sorghum-growing season. Currently, a geographically explicit database is being developed of the distribution of sorghum throughout the region of interest. Detailed population monitoring data from geographically separated commercial sorghum fields was collected in south Texas, north Texas, west Texas, Oklahoma, and Kansas. For example, in Oklahoma and south central Kansas, 45 sorghum fields were sampled approximately weekly between May 31st and October 16th. SCA monitoring data from the above-mentioned locations are currently being checked for accuracy and format and combined into a single data set for use in parameterizing the SCA population dynamics model.

Myfields.info was revised to facilitate real-time, geographically explicit mapping of seasonal distribution of SCA in the U.S. and was used for that purpose during this last field season.

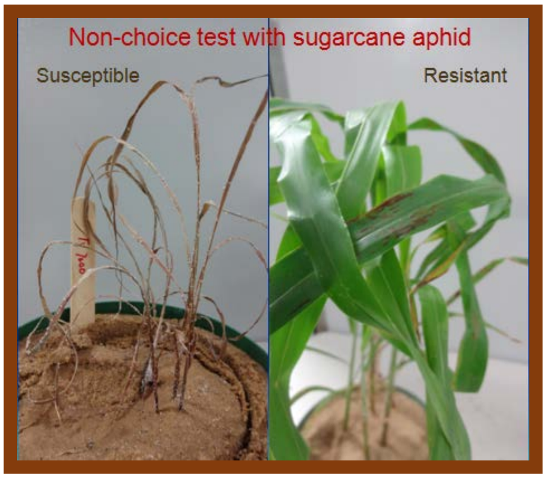
Managing a pest on an area-wide basis has been shown to be more effective and economical for some insect pests than managing the pest on an individual field basis; this is often the case for insects like SCA that are capable of long distance dispersal. In order to document whether an area-wide pest management approach based on broad scale deployment of SCA resistant sorghum varieties is more effective than individual field based management, we established a broad scale SCA AWPM demonstration project in the coastal bend area of South Texas. South Texas area-wide pest management demonstration activities were initiated by establishing collaboration agreements with farmers and training the scouting team to identify SCAs and natural enemies. Two zones of approximately 15,000 acres each were identified to represent sorghum-producing areas predominantly cultivating hybrids that are considered either resistant or susceptible to SCA. The SCA-susceptible zone consisted of mid-size to large sorghum fields (300-1,000 acres) cultivating the varieties DKS 5367, P83P73, P83P99, or P84G62. Sorghum represented a half of the total acreage (≈7,500 acres), and cotton represented the complementing half of the SCA-susceptible zone. The SCA-resistant zone was situated approximately 30 miles from the other zone, and field sizes were similar to the SCA-susceptible zone. The resistant sorghum variety DKS37-07 was cultivated on at least 90% of the SCA-resistant zone. The level of genetic tolerance of the remaining 10% of the sorghum acreage was unknown because farmers were not participating in our crop survey.

Identification, Characterization, and Development of Insect-Resistant Wheat, Barley, and Sorghum Germplasm

Wheat, Peanut, and Other Field Crops Research Unit, Stillwater, OK
Project Number: 3072-21000-008-00-D
Lead Scientist: Yinghua Huang
Team Members: Xiangyang Xu, Dolores Mornhinweg

Identification of the regulatory mechanism of the brown midrib (*bmr*) trait in sorghum. Plant biomass (i.e. lignocellulosic materials) has great potential for use as a feedstock for bioethanol production. However, challenges with respect to processing steps in converting biomass to liquid transportation fuel like pretreatment, hydrolysis, microbial fermentation, and separation still exist. Lignin is a major component of plant biomass and negatively affects the saccharification and bioethanol production. This study focused on characterization of the gene that encodes a key enzyme for lignin biosynthesis in plants. As a result, ARS researchers in Stillwater, Oklahoma, discovered an 8-basepair DNA deletion in its 5'-untranslated region of the gene (SbCAD2), which confers the spontaneous brown midrib (bmr) trait and lignin deficiency in sorghum germplasm line PI595743. In summary, the findings from this study will be beneficial to design preferred lignocellulosic feedstocks for bio-ethanol processing to meet the industry's need for cost-effective biofuel production.

New sources resistant to sugarcane aphids in sorghum. Sugarcane aphid (SCA) has become a severe pest of U.S. sorghum crop over the last few years and has caused significant loss of the crop production. In order to prevent the damage by the sugarcane aphids, resistant hybrids and cultivars must be developed for sorghum growers. An ARS sorghum geneticist from Stillwater, Oklahoma, worked with his collaborators to evaluate a diverse collection of sorghum germplasm for resistance to this devastating pest. After several years of evaluation in greenhouse and in the field, forty-two sources of SCA resistant lines have been identified. These newly-identified resistant sources hold great value for utilization in sorghum breeding programs worldwide.



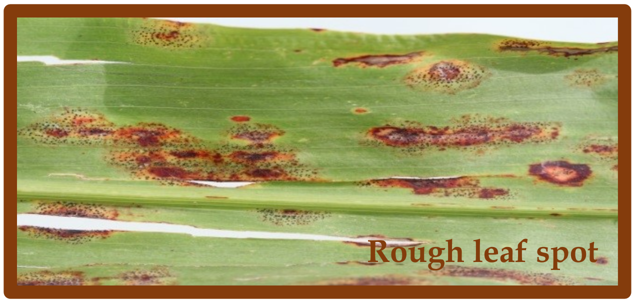
TEXAS

Identification of Resistance in Sorghum to Fungal Pathogens and Characterization of Pathogen Population Structure

Crop Germplasm Research Unit, College Station, TX
Project Number: 3091-22000-034-00-D
Lead Scientist: Louis Prom

New sources of anthracnose, downy mildew, and grain mold resistance in sorghum. Annually, these three diseases cause economic losses in sorghum yield and seed quality amounting to hundreds of millions of dollars globally. The most appropriate strategy in controlling these fungal diseases would be development of new disease-resistant sorghum varieties. ARS researchers in College Station, Texas, and Mayaguez, Puerto Rico, working with collaborators from Texas A&M University and Kansas State University, evaluated a number of sorghum lines drawn from various sources, with focus on identifying resistance to anthracnose, downy mildew, and grain mold. The work established that a number of these lines are highly resistant to one or more of the diseases. This work is a significant advancement in sorghum disease research in that it provides to sorghum breeders and other researchers critical new germplasm that will be foundational in developing new, disease-resistant sorghum varieties for productive use in world agriculture.

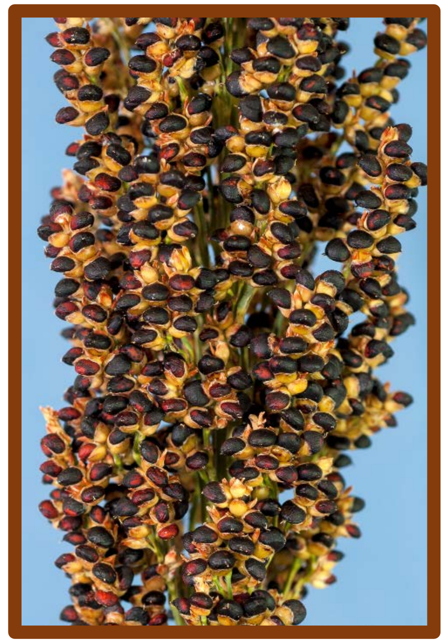
New sources of zonate leaf spot and rough leaf spot in sorghum. Changing weather pattern is likely to alter the frequency or severity of fungal diseases such as zonate leaf spot and rough leaf spot, which under humid weather condition can cause significant losses in sorghum. Identification of resistant sources to major sorghum diseases is the most effective management strategy. ARS researchers in College Station, Texas, and Mayaguez, Puerto Rico, working with collaborators from Texas A&M University and Kansas State University, evaluated numerous sorghum lines drawn from a number of sources for resistance to zonate leaf spot and rough leaf spot. Several lines were found to be highly resistant to both diseases. This work provides sorghum breeders and other researcher's critical new germplasm that will be foundational in developing new, disease-resistant sorghum varieties for productive use in world agriculture.



Innovative Genetic Approaches to Sorghum Germplasm Improvement and Analysis of Traits Critical to Hybrid Development

Crop Germplasm Research Unit, College Station, TX
Project Number: 3091-21000-034-00-D
Lead Scientist: Robert Klein

Elite material from converted tropical sorghum accessions. Sorghum is an important grain crop in many areas of the U.S. and other temperate regions worldwide. However, much of the potentially valuable sorghum germplasm is tropical in origin and does not successfully flower and produce seed in temperate environments, making these sources of genetic variability unavailable to many of the world's sorghum producing areas. ARS researchers in College Station, Texas, working with a retired private seed company scientist, used molecular tools in conjunction with classical plant breeding techniques to convert ARS tropical sorghums to short stature, early flowering versions with the objective of making new elite inbreds available to the sorghum industry. From a large panel of converted germplasm, individual converted plants with superior breeding value were selected and are being evaluated for the development of higher-producing sorghum hybrids for farmers in the U.S. and worldwide.



Restoration systems critical to production of hybrid sorghum. In sorghum, the combination of moderately complex genetic control and environmental variation in cytoplasmic male (pollen) sterility and pollen fertility restoration makes the development of new male and female lines both laborious and costly. ARS researchers in College Station, Texas, detailed the cellular expression within mitochondria of candidate genes that likely control cytoplasmic-male sterility. Detailed knowledge of cytoplasmic male-sterility/nuclear fertility restoration systems in sorghum provides insight into a process critical to hybrid seed production and will facilitate the development of molecular diagnostic tools to rapidly assess breeding material for use in hybrid breeding programs.

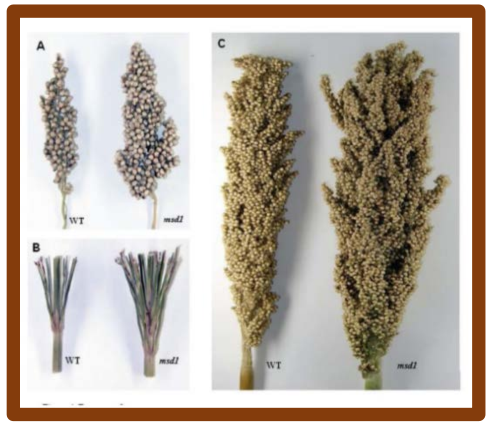
Genetic Enhancement of Sorghum as a Versatile Crop

Plant Stress and Germplasm Development Research Unit, Lubbock, TX
Project Number: 3096-21000-020-00-D
Lead Scientist: Zhanguo Xin
Team Members: Gloria Burow, John Burke, Yves Emendack, Chad Hayes,

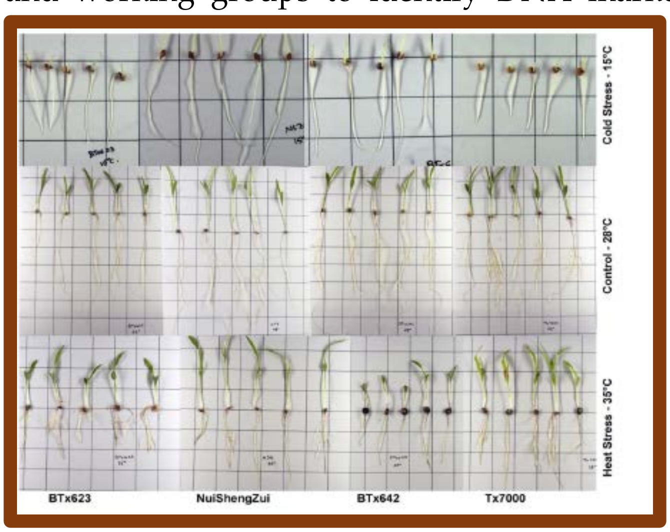
Developed two sugarcane aphid resistant sorghum pollinator lines. The recent emergence of the sugarcane aphid as a perennial pest of grain and forage sorghums in the United States has resulted in significant yield losses in susceptible hybrids, increased costs of chemical control, and a significant reduction in the market price of the crop. ARS researchers in Lubbock, Texas, developed two new pollinator (restorer or R) lines designated R.LBK1 and R.LBK2 (tested as R.11259 and R.11143) that have shown significant resistance to sugarcane aphid. These pollinator lines can produce grain sorghum hybrids resistant to sugarcane aphid. Both R.LBK1 and R.LBK2 have been transferred to four seed companies via Material Transfer Agreements. Hybrids using R.LBK1 and R.LBK2 have been high yielding and have performed very well throughout Texas, Oklahoma, and Kansas.

New early-season cold tolerant lines with late-season drought tolerance released. Cold tolerance is an important trait for sorghum improvement for early planting to take advantage of early season moisture. ARS researchers in Lubbock, Texas, have developed four-grain sorghum germplasm lines, PSLS-SGCTB01, PSLS-SGCTR02, PSLS-SGCTB03, and PSLS-SGCTB04, that possess excellent post-flowering drought tolerance based upon the stay-green trait and excellent early-season cold tolerance. These lines have large potential in developing sorghum hybrids that are drought tolerant and can be planted early under cold temperatures.

Development of new sorghum lines with enhanced grain number. Grain number per panicle is a major determinant of grain yield. ARS researchers in Lubbock, Texas, have developed new sorghum lines with increased seed number through marker-assisted breeding. To date, accelerated development of BC_4 introgression lines of the multi-seeded trait was accomplished in BTx399 and RTx430 by marker-assisted rapid trait introgression. These new lines are now being evaluated for development of hybrid combinations aimed to increase grain yield of sorghum.



Molecular markers for thermal stress identified through translational genomics. Temperature stress, both high and low, is a major yield-limiting stress in most crops grown on the U.S. Great Plains. For sorghum, specifically, the range of production areas and planting dates exposes the plant to a wide-range of temperatures at all growth stages. ARS researchers from Lubbock, Texas, analyzed the genetic variation associated with responses to thermal stresses in a sorghum association panel representing major races and working groups to identify DNA markers as single nucleotide polymorphisms (SNPs) that are associated with resilience to temperature stress. Genome-wide studies identified significant SNPs that were strongly associated with traits measured at seedling stage under cold and heat stresses. The tagged genes are related to the regulators of anthocyanin expression and soluble carbohydrate metabolism. These findings provide foundation for use of DNA for development of temperature resilient sorghum cultivars and further



characterization of genes and their networks responsible for adaptation to thermal stresses.

Early screening method for the stay-green trait developed. Stay-green is an important post flowering drought tolerance trait in sorghum. Germplasm with excellent stay-green maintains green leaves longer during post flowering moisture stress and drought conditions. The screening for the stay-green trait in sorghum has been expensive, time consuming, laborious, and often unpredictable. The identification of a stay-green line requires growing crop in field and visually rating leaf plant death ratio following postanthesis drought stress. Climatic unpredictability makes this approach unreliable. Furthermore, leaf dhurrin content in leaves of mature plant can differentiate stay-green from senescent lines, but this requires enormous resources in growing out plants to mature stage and the expensive determination of leaf dhurrin content on HPLC. ARS researchers in Lubbock, Texas, have developed a screening method, which allows seedlings of stay-green lines develop significantly fresher biomass than senescent lines, after growing for 14 days in play sand in the absence of inorganic nutrients. This approach is cheap, easily applicable, efficient, and more reliable in selecting for post-flowering drought tolerance in sorghum germplasms.

Identified a new easily recognizable sorghum nuclear male sterile mutant. Nuclear male sterile lines are important tools for population improvement and evaluation of potential of breeding lines. ARS researchers in Lubbock, Texas, have identified a new nuclear male sterile mutant (ms8) that can be easily recognized at early stage of anthesis. The male sterile phenotype is stable under multiple environments. The ms8 mutant can be used as an important tool to backcross sorghum mutants and as a parent for population improvement through random mating. The mutant has been transferred to several ARS scientists and academic scientists through MTA.

Sorghum lines with non-detectable leaf cyanide potential identified. Dhurrin is a metabolite produced in sorghum, and many other plant species, as a protective mechanism against herbivores. The metabolism of dhurrin in leaves and stems results in the production of hydrogen cyanide, which is not only toxic to insects, but also many other animals, including humans. Dhurrin content varies with environmental factors, management, crop developmental stage and variety used. To date, no acyanogenic variety has been identified in natural collections. ARS researchers in Lubbock, Texas, conducted a multi-year study where 40 diverse sorghum lines were evaluated for their cyanide potential throughout plant development and under water deficit stress. Researchers were able to identify five sorghum lines (SC1506, SC847, SC191, SC270, and SC774) with very low to non-detectable dhurrin content in the leaves, even under water stress and at all stages of crop development. If the traits of low cyanide potential from these lines are successfully introduced into elite lines in the feed and food industries, it will add enormous agronomic value to sorghum farmers and producers, raising the agronomic value of the crop.