

INTERNATIONAL CONFERENCE
ON SORGHUM FOR BIOFUELS

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Sorghum as a feedstock for biofuels has rapidly come to the attention of researchers, producers and industry in the past year. This heightened interest was highlighted by the participation of over 250 participants at the International Conference on Sorghum for Biofuels. Speakers from the public and private sectors addressed the participants on topics associated with sorghum as a crop and as a biofuel feedstock and the implications for its use in the global economy. They emphasized the science associated with these areas and highlighted the scientific opportunities and challenges for sorghum as a major feedstock for renewable energy. This met the intended goal of communicating and sharing data and information on sorghum research in production, utilization, sustainability and economic issues associated with its use as a biofuel feedstock. Perhaps more importantly, this diverse group of people, led by four individuals who are acknowledged leaders in these fields and facilitated by professional facilitators, discussed and identified the critical integrated technologies and approaches needed to enhance the usefulness of sorghum as a bioenergy feedstock. Although these areas were identified in break-out groups, there were several cross-cutting themes that emerged, including:

- The need for inter-disciplinary approaches to identify critical needs/constraints and solutions to help provide perspective and upstream or downstream considerations.
- The importance of understanding sorghum's role as a feedstock in the biofuel value chain from the perspective of how it is used to create value in a biofuel enterprise and by understanding what affects the distribution of economic returns/benefits.
- The identification of key constraints along the critical supply chain and determination of where in the chain each constraint can/must be addressed (on farm, during transportation to the plant, at the ethanol plant, during transportation to the point of use).
- The need to address environmental and economic sustainability throughout the entire on-farm process as well as post harvest.
- The need for scalable technologies for diverse energy needs (e.g., small on-farm systems, community systems, regional systems).

The following four reports were generated from the break out sessions and reflect the compilation of the discussion among the participants using a template as a mechanism. These reports were prepared by the discussion leaders with input and comments by other participants and the conference program and planning committee.

FEEDSTOCK DEVELOPMENT

Dr. Jeff Pederson, USDA-ARS
Dr. Jeff Dahlberg, National Sorghum Producers

Six major knowledge gaps or challenges were identified that are currently limiting progress in developing and utilizing sorghum for biofuels. These are:

1. Establishing the value of feedstocks
2. Making genetic improvement in feedstocks
3. Capitalizing upon the genetic diversity held in the world's sorghum germplasm collections
4. Increasing yield
5. Developing regional approaches to feedstock systems
6. Improving collaboration.

Each will be addressed in more detail in the following paragraphs, including discussion of how solving these challenges would influence productivity, people, and regions or countries, and possible strategies for closing these knowledge gaps and meeting the identified challenges. Comments contained in this report represent the consensus of a break-out group composed primarily of plant breeders and geneticists with representation from biofuel companies.

1. Establishing the value of feedstocks

There is considerable disharmony regarding the value of feedstocks with opinions ranging from some envisioning obtaining feedstocks from agricultural “waste” (very low value), while fully recognizing that other feedstocks such as grass hay commonly command over 100 USD per ton in competing markets. This is understandable in that an actual biofuel market for feedstocks has yet to be developed. Determining actual and market value for various sorghum-based feedstocks including juice from sweet sorghum, cellulosic biomass, and stover following harvest of grain sorghum would provide sound basis for research and development. This was viewed as a world-wide need, and was expected to have positive impact on both people growing and utilizing all types of sorghum, and on the productivity of those groups of individuals and the industries they support. Solution strategies included promotion of multi-disciplinary integrated research programs. A narrowly defined component of this multi-disciplinary approach is the immediate development of a compositional biomass database.

2. Making genetic improvement in feedstocks

Crop developers are confident in their abilities to optimize sorghum for specific industry needs. Compared to other biofuel crops, sorghum is genetically simple (a diploid), an annual permitting multiple breeding generations per year, its genetics are well know following decades of prior investigations on numerous individual genes affecting biofuel traits, and it is amenable to transformation. More importantly, sorghum is the second major cereal crop to be sequenced and the development, testing and deployment of genomic tools that take advantage of the genome will assist breeders in rapidly identifying and moving key bioenergy genes into improved sorghum germplasm for deployment to the field. However, genetic improvement is difficult without clear targets. This group's strongest consensus was

that for rapid genetic improvement, traits important to the biofuel industry need to be defined. Identification of critical traits for biofuel sorghum improvement must be made with consideration of cultures and conditions in individual sorghum growing countries and regions, as well as biofuel industries that might be reasonably anticipated in those countries and regions. Such definition of important traits will strongly impact the genetic improvement of sorghum and overall productivity of biofuel industries. The consensus of the group was that yield (biomass per acre) is the critical component for breeders to concentrate on until other criteria are identified and prioritized. Solution strategies include expeditious completion of a compositional biomass database. In anticipation of the need for inclusion of transgenic approaches to maximize optimization of some biofuel traits, developing strategies for transgene risk assessment, or mitigation of gene flow, was viewed as essential. Lastly, use of sorghum as a model system for developing and evaluating feedstocks with specific traits can simultaneously contribute to the broader biofuels knowledge base while making genetic improvements for biofuel traits in this species.

3) Capitalizing upon the genetic diversity held in the world's sorghum germplasm collections: Compared to other biofuel crops, sorghum is unique in that its genetic diversity is extensive, well-collected, and maintained. At the global level, there are approximately 168,500 sorghum accessions held in various repositories with two of the largest being the ICRISAT and USDA collections. This collection has not yet been adequately explored for phenotypic traits of importance to the biofuels industries, nor have they been characterized molecularly. Characterization of the world's sorghum germplasm would be expected to result in rapid progress toward defined goals in that traits of key importance likely exist in this collection. Furthermore, these collections contain accessions of traditional importance to many locales. Solution strategies are straightforward. A merging of the various global sorghum databases needs to be undertaken. This would help to identify duplications amongst world and country collections, harmonize phenotypic information that has already been collected, and identify key areas for further plant exploration if needed. A subset of common genetic resources representing a large portion of the world collection's diversity should be established for unrestricted use world-wide. And finally, more complete phenotypic characterization of the world's collection (especially for traits of importance to biofuels) should be undertaken with emphasis on greater understanding of the basis for phenotypic variation.

4) Increasing yield: Genetic improvement of sorghum for yield has lagged behind crops such as maize since the inception of hybrids, presumably due to a much smaller effort (number of SYs) committed to sorghum improvement. Much potential remains for genetic improvement of sorghum for yield. In this endeavor, a critical question becomes "yield of what?" with answers including juice, sugar, lingo-cellulose, grain, and total biomass. Increasing yield of these components is complicated by the extremely variable locales and conditions in which sorghum is produced. Genetic factor interactions with environmental factors need to be understood for biofuel sorghum, and systems optimized to improve yield of specified traits at specified locales. Proposed solution strategies include both applied and basic approaches. Harmonization of screening technologies, such as development of global NIRS prediction equations for critical components of feedstocks (e.g. sugars) would accelerate breeding for yield of those components. On a more basic level, research with the goal of determining the biology of yield and its components will contribute to sustained yield improvements.

5) Developing regional approaches to feedstock systems: The above leads directly to the challenge of developing regional approaches to feedstock systems. Not only are sorghum production systems divergent, industry's infrastructure and needs vary by regions. Depending upon the region of production, sorghum cultivars and hybrids may require tolerance to biotic and abiotic stresses including drought and extreme heat, frost, acid soils, and numerous region specific insects and diseases. Depending upon infrastructure needs in each region, the type of feedstocks may also vary. For example, it was generally agreed that production of sweet sorghum for juice complimented and would lead to greater productivity in regions with sugarcane processing infrastructure. In other regions with infrastructure being developed for use of biomass from perennial grasses, it was suggested that sorghum would be extremely complementary because it is an annual crop and would provide producers with great flexibility in meeting feedstock needs for biofuel industries. Solution strategies include development of regionally based research and testing programs. Regular world-wide meetings such as this conference are also suggested as an effective mechanism for information sharing, which leads directly to the final challenge.

6) Improving collaboration: Improving collaboration was singled out by this group as a specific challenge, probably because of the requirement that plant breeders work with the very tangible resource of germplasm. Historically, germplasm has been shared quite freely among sorghum researchers. More recently, intellectual property (IP) issues, differing cultures among both corporate and public sector institutions, and a lack of common goals were viewed as reasons that collaborations were at times difficult. Arguments were made highlighting both positive (encourages investment) and negative impacts (discourages germplasm exchange) of use of IP restrictions. However, improving collaboration is not limited to increased germplasm exchange and resolving IP issues. Improved collaboration and/or broadly based research initiatives were offered as strategies for filling knowledge gaps and meeting challenges in all of the above. Furthermore, the potential impact of improving collaboration was identified as strongest in the area of collaboration among regions and countries.

The remainder of this report will therefore be devoted to strategies for improving collaboration, its barriers, and benefits. The first proposed strategy – making contact information for all participants in this conference available to participants – has already been accomplished and is leading to potential collaborations among conference participants. The second proposed strategy is to repeat this conference and expand the venue to include more representation from the biofuels industry, funding organizations, etc. in the near future. Our ability to meet feedstock needs begins with clear definition of producers' and consumers' needs, and inclusion of funding organizations as collaborators will be critical to ensure that those needs are truly heard and addressed. The third and fourth strategy is to develop, as strong collaborative groups, new research proposals and seek new funding opportunities. We envision that development of strong collaborative teams with common goals will break down barriers due to a myriad of barriers (IP, politics, and even regulatory issues). Finally, we envision increased acres of all sorghums due to its increased profitability to producers, and increased rural development and sustainability of agriculture.

Key Messages:

- There is tremendous need for identification of important feedstock traits
- Industry development in biofuels must be sustainable

- This will require a broad public and private commitment

CONVERSION

Dr. William Orts, USDA-ARS

Multiple knowledge gaps and challenges in the area of “Conversion” were identified that require further development in order to utilize sorghum for biofuels. These gaps and challenges were identified in a break-out group composed of representatives from a diverse range of backgrounds related to agricultural production, processing, engineering, finance, research and commercialization of agricultural commodities. The conversion group first decided that processing and conversion could start at the point of harvest (before the farm gate and well before the factory gate). Multiple critical issues were identified and addressed and will be described in the following paragraphs.

It was noted that sorghum is a flexible crop. It can be grown to target several distinctly different markets, categorized into three general areas (1) grain sorghum, (2) sweet sorghum and (3) forage or high biomass sorghum. The strategies used to grow and process the crop will vary depending on which specific market is being pursued. As such, conversion strategies were addressed, first, by covering over-arching, general issues that affect sorghum conversion, then by highlighting the specific needs of each sorghum target market.

1. Handling & processing, transportation, storage

It was generally agreed that storage and transportation issues were more critical for sorghum than most other biomass feedstocks, especially for sweet sorghum because of its rapid change after harvest. An over-arching concern was a lack of dedicated harvest equipment for sorghum that will optimize bioenergy production. For example, is it feasible to process the entire plant or should extra effort be spent to separate leaves during either harvesting or early in processing? Transportation infrastructure must be established to get this biomass either to the plant quickly, or, if the biomass can be stabilized a system must be established to handle its stabilized form.

- **Grain sorghum:** Equipment has not been optimized for removing the seed grain from the seed head. Most biorefineries have been optimized for corn, so further optimization is required for grain sorghum.
- **Sweet sorghum:** The single most important research issue is to find a way to stabilize the juice. One solution is a locally-operated squeezing process (likely small scale) that creates a stable juice that is ready for transportation. Any technology that extends the life of the juice product would allow easier transportation, and permit production to continue on a more consistent basis rather than on a seasonal basis dependent on harvest time.
- **High biomass sorghum:** Forage sorghum is already harvested commercially. The biggest research issue is to pinpoint to what extent storage conditions and the age of the biomass affects its viability as a feedstock. Breakthroughs in this area will likely be made concomitant with improved utilization of other energy crops for conversion of lignocellulosic feedstocks to bioenergy.

2. Better fermentation agents; microbes & enzymes.

Optimizing enzymes is critical in processing sorghum to bioenergy. The first question is whether fermentation/ distilling can and should be done on farm or done

completely at a large scale biorefinery. Are there specific inhibitors present in sorghum that limit fermentation?

- **Grain sorghum:** To a large extent, grain sorghum can be substituted for corn at a corn-based biorefinery on a nearly equal basis. Improving this process was not considered of highest priority.
- **Sweet sorghum:** What different processes, enzymes, etc are needed for sorghum versus sugar cane? Identifying fermentation inhibitors specific to sorghum is critical. One research decision to make is whether fermentation of sweet sorghum should be pursued in a liquid system, or whether solid-state fermentation can be utilized economically. Improvements in enzymes are still needed.
- **High biomass sorghum:** It is important to develop and optimize enzymes that can convert C5-based sugars derived from hemicellulose into useful products, either bioenergy or bioproducts, including plastics. How will the lignin be utilized? The GMO issue was raised as a potential area of concern. Presumably the industry will embrace biotechnology, whether for GM crops or for improved yeasts, bacteria and enzymes from genetically engineered microbes.

3. Co-products and by-products; in addition to ethanol

Relative to corn, sorghum does not yet present the wide market opportunities for value-added co-products realized by most U.S. biorefineries, especially when considering the value of distillers grains (DDGs).

- **Grain sorghum:** Characterization of the proteins derived from sorghum mills, with a focus on finding target markets (feed usage) is a research area that should be pursued.
- **Sweet sorghum & high biomass sorghum:** What should be done with the biomass remaining after juice is removed? One potential use is thermal conversion to other value-added bioproducts. Biomass from sorghum can be converted to a range of value-added products, depending on which optimized catalysts are utilized. Products include alternative hydrocarbon biofuels (“green” gasoline), alcohols, acids, commodity feedstocks and gases to run turbines for electricity conversion. Research areas include, optimizing the mix of products at the biorefinery, optimizing catalysts (stability, pathways, etc), and determining the best markets for the products. Quality and consistency of the feedstock will ultimately affect quality of these co-products.

4. Small scale vs. large scale; distributed versus centralized: Solid fermentation versus liquid fermentation

Where is the bulk of the processing done? This question is coupled with identifying basic process parameters, such as whether fermentation will be solid or liquid state. Solid-state fermentation is more difficult on a larger scale; thus, opting for solid fermentation implies that processing will take place on a local level.

- **Grain sorghum:** Biorefineries utilizing grain sorghum will likely follow the same models as corn-to-ethanol plants. The trend in that industry is for large-scale fermentation (>100 million gallons of ethanol per year) in liquid batch processes.
- **Sweet sorghum:** If the juice can not be stabilized for long-term storage or transportation, then processing will be local, smaller in scale, with a decentralized infrastructure. Of course, any breakthrough that stabilizes the feedstock will allow for larger biorefineries, with greater chance to optimize economies-of-scale. Local farm-

scale or township scale biorefineries that do not require sophisticated and expensive equipment were introduced as a viable option for growers if they were shown to be economical. Both small-scale and large scale models had support from this group depending on which technology proves most effective.

- **High biomass sorghum:** Based on the technologies introduced for other biorefineries that utilize lignocellulosic feedstocks. Fermentation would likely be at larger biorefineries in a liquid state. High biomass sorghum utilization will clearly benefit from breakthroughs in energy crop utilization; lessons learned from utilization of straw, switchgrass, miscanthus and algae-derived biomass.

5. Pyrolysis, gasification (thermal processing): Improved catalysts for thermochemical conversion.

Thermochemical processing for sorghum has not been optimized. Competing technologies, such as high vs. low temperature conversion must be investigated. Knowledge of catalysts, their stability, mechanisms of operation and inhibitor behavior must be determined. Markets will need to be created; i.e. if a “green gasoline” or sorghum-derived biodiesel is to be introduced, auto companies and regulating agencies must be ready to utilize these new products.

6. Having economic models for success. When to grow sorghum? What market to target (grain, sweet or forage sorghum)? Addressing regional differences.

Many of the issues addressed in the other break-out groups were also deemed important within this discussion and are briefly included here. How does a grower decide to grow sorghum for bioenergy production and what are the most economical ways to get it off the field and to a biorefinery. These are significant economic decisions for farmers. Research is needed that provides them with models and economic tools for determining whether sorghum is suitable to grow as a bioenergy crop in their region. Who will buy it and why? Process analysis, economic analysis and business plans must be available. Additionally, optimizing the genotypic variation based on processing needs will be critical for selecting the right sorghum cultivar. Finally, picking the process (i.e. microbial conversion vs. thermochemical conversion via inorganic catalysis) will likely vary by region and regional market needs.

Collaboration Required:

Utilization of sorghum for bioenergy is of strategic importance because it will mitigate oil demand by increasing the availability of alternative energy sources in most countries. Sorghum can be produced in many different climates covering a broad part of the world. Thus collaboration is need between industry, government and farmers, public and private institutions, public and private institutions (i.e. industry has access to important enzymes and technologies), financiers and the rural sector, and finally across disciplines with open communication. Utilization of sorghum, along with all potential “energy crops” should be part of our national policy since it is critical for our security and economic development. As such, collaborations between partner countries must be encouraged, especially considering the multinational nature of most large companies (energy and technology companies).

Barriers to Collaboration:

Significant barriers are in place that may slow collaboration and/or development of sorghum as an energy crop. In no particular order, these include

- intellectual property issues,
- the inability to mobilize capital to finance bioenergy technologies,
- the slow speed of government decision-making, regulation and initiation of programs,
- the difficulty in “getting agriculture involved” in technologies, i.e. the gap between technology development and stakeholder involvement,
- inadequate resources for research,
- lack of adequate crop insurance,
- conflicting messages from powerful voices (lobbyists, special interest groups, large industries)
- outside economic influences – tariffs, trade barriers, and competing industries.

Potential Next Steps:

The industry needs to work toward breaking down regional barriers by sharing the economic benefits, via shared risk and, therefore, shared technologies and approaches. Part of this can be achieved by better promotion, better information, better outreach, but that is only useful if new technologies exist that are supported by economic tools that will convince farmers and others in the industry that this will work. Increased funding toward research should be directed so that it rewards science-based collaborations, followed by well-established forums for communication such as meetings, web sites, newsletters and journals. Can the government and industry set up rules on IP up front, perhaps via competitive funding that depends on collaboration? The industry needs to work to establish sensible guidelines for crop insurance that supports this initiative. Finally, the industry needs to work cohesively. Farmers should be involved in research projects early on; developing on-farm trials so that researchers understand their view point and so that the message is clear that sorghum is a viable energy resource.

AGRONOMY AND SUSTAINABILITY

Dr. Mari-Vaughn V. Johnson

Critical challenges/Knowledge gaps

The participants of the Agronomy and Sustainability break out session identified over 30 challenges to achieving sustainable agronomic practices in sorghum biomass production systems. After the initial brainstorming, the group reduced the number to a manageable list, logically combining these challenges to determine the 15 most pressing issues. Voting determined the top 5 critical challenges to be:

1. Biotic and Abiotic Stress Management
2. Nutrients and Water Management
3. Soil Resources Use and Sustainability
4. Cropping and Tillage Systems
5. Climate Change Impacts and Mitigation

Other high-scoring knowledge gaps/challenges included: cultivar development; mechanization; land availability/appropriate land use; and concerns regarding the use of genetically modified organisms.

Impact of addressing challenges on productivity, people, and regions/countries

The group considered biotic and abiotic stress management, soil resource use and sustainability, and climate change impacts and mitigation to be the critical issues with the most potential overall impact. Mechanization, land use/availability and genetically modified organisms concerns also ranked high among key issues to be addressed in terms of overall impact of the development of sorghum systems.

The group agreed that sorghum productivity would be greatly impacted by focusing efforts on biotic and abiotic stress management, nutrient and water management, soil resource use and sustainability, and cropping and tillage systems. Addressing climate change issues was not considered a key factor in improving productivity. In addition to the five primary challenges, this break out session group felt productivity could be improved using cultivar development, mechanization, and co-product development.

Of the 15 critical areas initially identified, solutions to the five critical challenges listed above were deemed to have the highest potential impact on people, both in terms of geography and population numbers. Additionally, land use/availability, cultivar development, and seed availability were considered important challenges in regards to affecting the largest regions and most people on the globe.

Difficulties associated with addressing challenges & timelines for tangible results

The group agreed that all 15 issues could have at least some tangible results within five years of the initiation of a well considered, well funded project. A primary reason for this optimistic outlook is the existence of ongoing research in most of these areas, off of which future research will be able to springboard. Another important point regarding achievement of progress in these areas is that even though our group agreed that tangible goods could be produced in all five areas within five years, it was also adamantly noted that research in all five areas would not be able to solve the larger issues within that timeframe. All five areas

need long-term funding to determine the best long-term solutions. Of the five areas, those considered the most difficult to address were biotic and abiotic stress management, soil resource use and sustainability, and climate change impacts and mitigation. Group members also perceived substantial difficulty would be involved in addressing issues related to mechanization, land use/availability, water quality management, and genetically modified organisms concerns.

The role of cooperative/collaborative research

Climate change impacts and mitigation require a collaborative global effort. The group felt the reasons for the need to work together on this issue are self evident. To address these long-term, complex issues well funded, multi-disciplinary, international teams must be built. To maintain these important collaborations, international support will be essential.

The group recognized the utility in cooperative endeavors in addressing biotic and abiotic stress management, which includes addressing weeds, insects, pathogens, and soil salinization, among other issues. These issues present a multi-dimensional challenge because they involve species and systems interactions. Further, many pests (bacteria, fungi, viruses, and weeds) are capable of fast-paced evolutionary adaptations. As such, they are moving targets, requiring continued attention to control. These issues are also trans-national and will require cooperation by neighboring nations/states for effective management.

Cultivar development requires cooperation as well, due to regional adaptation. Participants felt that there are a number of barriers related to the exchange of genetic material that are slowing potential progress in cultivar development appreciably. If germplasm were more available, we felt cultivar improvement and regional diversification could proceed at a more effective pace. This work also requires multi-disciplinary involvement. Mechanization issues were seen in a similar light, being greatly impacted by geographic location and appropriate cultivar choices for a given location.

We also agreed on the value of cooperation in addressing soil resource use and sustainability. Because the timeframe to address this issue is long, the group felt this was a particularly challenging knowledge gap that would, like all key challenges we identified, have regional variation. Thus, cooperation that will allow monitoring and long term experiments on soil resources, including carbon storage, tillage, etc., will require a trans-national effort. Cooperation would be beneficial to nutrient and water management in sorghum production systems for the same reasons.

A closer examination of the 5 most critical challenges/knowledge gaps

The group identified a number of approaches that must be applied to all of the key challenges facing the development of a sustainable, high yielding sorghum production system. First, sorghum production must be considered on a regional basis; soils, precipitation regimes, day lengths, local cultural practices, local economies, etc. will all affect the sustainability and impact of the system. Second, all scientists and stakeholders maintained that an integrated approach to developing solutions will be necessary. This means that for a long-term solution, knowledge gaps and associated problems will have to be solved in conjunction with one another, by multi-disciplinary teams uninhibited by national boundaries. Further, in all instances, our group felt that an “economic break even point” must be determined.

1. Biotic and Abiotic Stress Management

- Integrated stress management is needed
- We must determine how individual and multiple stresses impact a crop to prioritize future research; this includes development of a systems perspective
- Construction of “stress matrices” will allow us to discern the differential impacts of particular stresses on plant products, including sugar, biomass, cellulose, etc.
- Stress tolerance/avoidance of different species and cultivars needs to be explored
- Alternative biotic stress controls need to be explored, including chemical, genetic, biological, mechanical, and cultural options and synergies
- This is a moving target that will require ongoing research

2. Nutrients and Water Management

- On-site management for productivity
- We need to develop timing and rate guidelines for macro- and micro- nutrient management, to maximize yields and minimize deleterious off-site impact
- Identify nutrient and water requirements for sorghum cultivars as they relate to optimal tissue composition and product yield
- We need to better understand water use efficiency and nutrient use efficiency of sorghum compared to other crops so appropriate cultivars may be selected for given regions
- We need to assess interactions of water and nutrient management with tillage systems and cropping systems
- We need to mitigate, prevent, and minimize off-site impacts
- Nutrient, pesticide, and sediment losses (runoff, percolation, lateral flow) need to be measured and managed

3. Soil resource use and sustainability (several items under, carbon, nutrients)

- We need to determine sustainable nutrient removal rates
- We need to identify the components that maintain / build soil organic matter
- Baseline, threshold carbon values need to be defined on a regional basis
- Carbon pool sizes and fluxes under different managements and systems need to be determined and monitored in long-term studies
- Changes in physical, biological, and chemical soil properties (including compaction, structure, aggregation, acidification, etc.) need to be quantified, managed, and monitored for optimal production and minimal deleterious ecological impact
- Microbial interactions need to be identified. Beneficial microbial communities need to be managed to improve yield and provide biotic stress management.
- Impact of various cropping systems on soil erosion must be determined and managed

4. Cropping / tillage systems

- Cover crops should be explored as a supplement to inorganic nitrogen fertilizer; nitrogen and soil organic matter should both be explored.
- Tillage system comparisons must be conducted.
- We need to identify a regions-specific menus of crops that maximize economic value; this may include rotational and/or inter-cropping systems development
- We need to determine the agronomic practices that maximize sorghum productivity (e.g. impact of ratoon cropping)
- We need to consider the integration of sorghum with grazing systems

- The potential for enhancement of wildlife benefits by sorghum systems should be explored both in terms of conservation and economic gains
- Management systems that maintaining ground cover while allowing the extraction of a large fraction of residues should be explored
- The inclusion of “break crops” in rotations to mitigate pest and disease cycles should be explored on a regional basis.
- Perhaps most importantly, future sorghum cropping systems must effectively balance resiliency, flexibility and profitability

5. Climate Change Impacts and Mitigation

- Life Cycle Analyses of optimized cropping systems must be conducted (supports inclusion in the renewable energy mix, assessing potential for carbon trading)
- We must determine the impact of atmospheric CO₂ and temperature changes elevation on crop/cultivars growth, phenology, water use, and nutrient demand; assess interaction with other factors
- Model / measure the impact of sorghum production systems on greenhouse gas emission and the environment
- Model / measure the impact of climate change on sorghum production systems
- Identify early indicator species for climate change (insects, weeds, diseases) that can interact strongly with sorghum systems

Barriers to Progress

- There is currently limited reward for integrative approach to research. This problem is evident both in the dearth of appropriate funding levels and in the emphasis on singular/lead authorship rather than many-authored manuscripts.
- There is limited expertise to assess issues like life cycle analyses and complex policy analysis. We need to train people in multiple-disciplines and reward people for developing diversified skills rather than rewarding/valuing only specialization.
- There is a slow response time of research (and policy) system to current demands.
- Scientists need to work on articulating complex issues in common vernacular so that they may better reach the general public. Public outreach needs to be encouraged and improved so that the public may gain a better understanding of sorghum cropping impacts and benefits.
- Funding amounts and duration to conduct integrated research need to increase significantly for such teams to deliver products and develop long-term, meaningful experiments.
- Expectations for deliverables on a quick turnaround must be moderated as developing teams will requires a longer time frame.

Potential Next Steps

- Motivational resources need to be increased, both in terms of support for training and experiments.
- Additional forums to identify targets and establish teams to address this issues are necessary
- Perhaps a “training grant” could be established to prepare the next generation of integrative researchers and systems scientists

- International consortiums to facilitate and finance the development of international teams (including private global companies) need to be developed. This allows interested stakeholders to assist in the development of their goods.
- Closer linkages across disciplines and among government agencies, academic institutions and private companies from the US and abroad (shared positions/sabbaticals) need to be encouraged.

What are the key messages needed to be conveyed from this workshop?

1. Members of our global community must be committed to similar future workshops and associated activities in order to ensure the continuation of technology transfer within the community. The community may need to be enlarged to encompass persons working on the development of other biofuel crops, as biofuel cropping systems will need to be diversified.
2. “Agronomy” and “sustainability” are integrated issues and cannot be addressed separately.
3. All five of the top issues (and many of the secondary issues discussed as sidebars) involve an integrative approach across disciplines and across the five issues themselves.
4. In order to achieve the necessary level of cooperation to address these issues, long-term, multi-disciplinary research must be funded and experiments must be established in a variety of regions to develop working solutions for particular ecologies, economies, and cultures.
5. Development of best management practices and decision aids for each component of each critical issue are necessary. Dissemination of best management practices must be concurrent with ongoing research to provide for future refinement and continued gains. We felt that the development of modeling tools to assist with each of the critical challenges is essential to developing working solutions.

ECONOMICS SESSION

Dr. Gregory Pompelli, USDA-ERS

Overview

An overarching theme of the discussions in the International Sorghum for Biofuels Conference Economics Session was the importance of understanding sorghum's role as a feedstock in the biofuel value chain. Economic success in a sorghum feedstock venture anywhere in the world hinges on how well producers' understand the entire ethanol value chain and how it is affected by market forces, policies, risk and uncertainty, events in energy markets, and access to investment capital. Sorghum's importance as a feedstock is best understood from the perspective of how it is used to create value in a biofuel enterprise and by understanding what affects the distribution of economic returns/benefits. Sorghum's potential as a renewable energy feedstock is noteworthy, but challenges and knowledge gaps to date have limited the use of sorghum as a primary contributor to meeting growing energy demands.

Though about eighty percent of the world's area devoted to sorghum production is located in Africa and Asia and these growers face different constraints, many of the same concepts apply for assessing the feasibility of growing sorghum and deciding how well sweet, grain, forage, or energy sorghum varieties compete against alternative uses for the land. The ability of farmers to generate profits, control input costs, benefit from genetics/breeding programs, or even take advantage of full or partial on-farm distillation are all important considerations. A complete analysis also needs consider the effects of key constraints such as the availability of harvesters, ethanol processors, transportation, feedstock uniformity requirements, storage and how those constraints affect the attractiveness of sorghum in a given area.

Challenge Number One: Understanding the Sorghum Value Chain

Understanding the factors that affect the market for sorghum as a feedstock and recognizing the market forces that affect uncertainty and variability in commodity and ethanol markets around the world are perhaps the greatest challenges facing sorghum producers. As with any crop, profitability is a critical measure of business success, and the comparison of relative returns to alternative crops is a fundamental part of sound farm management. Producers and processors need to recognize and understand these factors to make informed investments in their operations.

While sorghum as an input is unique, ethanol made from it is not. Sorghum growers must weigh forgone income opportunities for all crops they could potentially produce while understanding the factors that affect the market for ethanol. As growers make planting decisions and related investment decisions, they need information about the likely returns to planting sorghum as well as other viable crop options. They also need to reflect on their potential marketing alternatives for sorghum products, which might include use as a feed, fuel stock, food, or for sale in international markets. Assessing the consequences of each alternative use is important, as decisions based on the intended use are critical and may limit revenue opportunities especially if the primary market is unable or unwilling to purchase a

grower's output as planned.

A better understanding of temporal and spatial considerations is also needed as storage and transportation services are expensive and may require additional investments to meet the needs of producers and processors. Investments may also need to ensure the consistency of the feedstock and the availability of economically viable supplies over extended periods.

Challenge Number Two: Assessing Market Effects of Policy Interventions

Policy interventions have a direct and significant impact on all aspects of the biofuel industry. Changes in policies represent an important set of risks to the industry as those policies affect the financial attractiveness of sorghum, or any other potential biofuel feedstock crop. Within each country the regional nature of sorghum production means that the outcome from some ethanol-promoting policies may not be equally distributed across the industry. This highlights the need to conduct both regional cost of production studies as well as regional assessments of policy options. For example, a trade policy change may more heavily affect producers whose markets are more integrated with international markets than those whose markets are buffered by greater transportation costs or other regional factors.

Challenge Three: Learning More about Industry Risks and Uncertainty

More needs to be learned about the business risks facing the industry and how those risks can be effectively mitigated or managed. In some cases these risks are inherent to all crops, such as weather, and pest pressures, but also the effects of events and developments in general economic, regulatory, trade, and energy markets. The risks include concerns about excess capacity in mandate-driven markets, as well as the potential development of new technologies for making ethanol or other transportable fuels. Even if these new technologies apply to sorghum operations, they may require substantial new investments. Advances in the use of other feedstocks serve as a potential risk that could adversely affect market opportunities for sorghum.

To the extent macroeconomic factors contribute to uncertainty in biofuel markets sorghum producers will also face those uncertainties and risks. As with all industries, the macroeconomic environment plays a critical role in both forecasts for and the realization of the growth in biofuel and energy markets that guides investment decisions and affects investors' returns over time. These macroeconomic factors include overall growth in the economy, unemployment, interest rates, and variations in exchange rates.

Challenge Four: Working and Competing in Energy Markets

Participants in the Economics Session noted that sound working relationships between sorghum producers and firms in energy markets are important and a challenge. This challenge recognizes the reliance of the ethanol industry's access to consumers through the very large and established gasoline firms and interests. Small dispersed sorghum producers and ethanol processors attempting to sell ethanol as a fuel additive to reduce emissions, an octane enhancer, or as a partial gasoline substitute face challenges supplying large firms who are concerned with their profit margins and the effects of mandates that require the use of ethanol in gasoline. These challenges include regional and seasonal risks associated with the production, and air quality requirements, as well as developments in oil and gasoline markets that could lead consumers to drive less or purchase vehicles that deliver better mileage. For ethanol producers, potential marketing areas may be relatively small due to logistical

constraints, yet producers may face competition from other local and regional ethanol producers using similar or different feedstocks. In these cases transportation and distribution factors may play a greater role in determining the success of sorghum-based ethanol ventures.

Challenge Five: Improving Access to Capital Markets

The need for better access to capital markets and the sense that the investors and bankers have a difficult time understanding sorghum's potential as a biofuel feedstock were common themes in the Economics Session discussions. Problems concerning access to investment capital were largely considered the outcome of knowledge gaps about the risks and uncertainties facing sorghum-based biofuel ventures. These gaps were viewed as a serious challenge to investors, even when the same risks affected production for other agricultural crops. As a result, participants felt risk-averse lenders and investors were apprehensive about supporting enterprises that had limited commercial experience converting feedstocks into fuel.

Strategies for Filling-in the Gaps and Overcoming the Challenges

Participants in the Economics Session generally agreed that research, outreach within the agricultural and energy sectors, education, and communication were common ingredients for overcoming the challenges and filling in the knowledge gaps. While each previously noted knowledge gap or challenge presents unique features that may affect the application of the general strategy, participants felt confident collaboration offered the greatest potential for success.

One of the first steps toward meeting the challenge of understanding sorghum's place in the biofuel value chain is to learn more about the cost of production for sorghum compared to other crops that could be grown in the similar locations. These studies could be conducted by individual farmers or associations. However, greater investment in public extension and research efforts was considered a more efficient means for gaining greater insights. A starting point for these efforts would be support for cost of production studies within and across regions, and countries. These same research teams would be well suited to expand their comparative studies to examine the markets for co-products that may result when sorghum is processed in biofuel applications. Session participants also thought it would be beneficial to support the analysis of how changes in oil prices, livestock markets, or trade opportunities affect the derived demand for sorghum as a feedstock. In short, producers could better evaluate their crop options and position themselves to take advantage of biofuel market opportunities and policies, if they knew more about the factors driving the markets for competing crops and feedstocks, and knew more about the factors driving biofuel markets.

A second and perhaps contemporaneous step would be to study the factors that affect the availability and provision of infrastructural and logistical services. These factors have a great influence on the competitiveness of sorghum as a feedstock and affect the extent to which changes in market opportunities or pressures are magnified in local or regional markets. Given that the availability and cost of transportation services significantly influences grower harvest, storage, and output conditioning decisions, additional logistical studies may be needed.

The communication and dissemination of results from these studies would support farmers' efforts to make informed production decisions and evaluate alternatives. A related line of discussion within the session highlighted the value of assembling and providing

sorghum research results, information, and expertise through one or more recognized sorghum information sharing centers or organizations. A consensus did not develop around a set of best practices, but the discussion did recognize the need for good and consistent communication and the potential value in developing formal and informal associations for assembling and sharing information with energy partners, investors and policymakers.

One strategy suggested for addressing concerns about the influence of policies on sorghum's potential as a biofuel feedstock is to stress the importance of developing robust relationships with key stakeholders in the agricultural, biofuel, and energy sectors. These interactions may take many forms, including advisory groups, but should always strive to help others understand the advantages of sorghum. This could be part of a larger effort to promote the interests of sorghum producers with those energy sector stakeholders, federal and state policymakers, and possibly international partners and associations whose interests dovetail with sorghum industry concerns and objectives. Efforts arising from this strategy include information sharing and planning efforts that address important economic, policy, legal and environmental issues in the context of stakeholder interests. These efforts could be advanced by communication of realistic shared visions based on research and technological advances to policymakers, stakeholders in the energy sector, and investors.

Some participants in the Economics Session discussed the need to enable all sorghum growers the option to buy crop insurance which could offset the negative effects of crop hazards. The addition of this option would also aid growers' efforts to improve their access to loans and other funds needed to support sorghum production, as lenders consider crop insurance an important tool for offsetting their lending risks.

To the extent value chain research, outreach and education efforts are successful, many of the fundamental risks and uncertainty surrounding sorghum's use as a biofuel feedstock will be better understood. As a result, any strategy aimed at reducing the risk and uncertainty faced by sorghum growers needs to be based on the knowledge gained about the factors driving the markets for competing crops and feedstocks as well as knowledge more about the factors influencing driving biofuel. As more is learned about the economic and technological risks facing sorghum growers, better options for mitigating those risks will become available. The same will be true for efforts assessing the impact of changing policies on sorghum growers' options. In many cases the research and outreach efforts strategies needed to fill one set of knowledge gaps may lead to significant gains in meeting other challenges faced by the sorghum industry.