AFRICAN AGRICULTURAL TECHNOLOGY FOUNDATION
FONDATION AFRICAINE POUR LES TECHNOLOGIES AGRICOLES

P.O. Box 30709–00100 Nairobi, Kenya
Tel: +254.20.422.3700 ● Email: s.oikeh@aatf-africa.org ● www.aatf-africa.org

Combining Breeding and Biotechnology to Develop Water Efficient Maize for Africa (WEMA)

Concept Note

1. Background and Rationale

Sub-Saharan Africa (SSA) is the only region on the globe today where poverty and malnutrition continue to rise both as a percentage of the population and in absolute numbers (Sachs, 2005). Over half of the hungry people are subsistence farmers who can not grow enough food on a consistent basis to feed their families and escape poverty. Maize is the primary grain crop grown for human consumption in SSA, comprising a significant part of the diet (Banziger and Diallo, 2000), yet the average maize yield for a farmer in SSA is approximately 10-fold less than that of farmers in the U.S. and Europe. A Green Revolution for Africa will require a rapid acceleration in maize yields similar to that experienced for wheat and rice production in Asia in the 1960's and 70's. However, the use of improved seed, fertilizer and water control, considered to be fundamental to a Green Revolution in cereal production, has not been implemented in maize production in developing countries as it has in wheat and rice (Heisey and Edmeades, 1999).

The primary reason for this difference is not that the basic technology to increase maize production does not exist. It is that the tools are not consistently used, largely because the farmer is unable to invest in them due to lack of capital, or because she is unwilling to invest what little capital she has for fear of losing her investment to drought. The high sensitivity of maize to drought stress at critical times of the growing season discourages small-scale farmers growing maize under rainfed conditions from risking investment in best management practices (BMPs), including quality hybrid seed and fertilizer. In fact, less than 15% of maize in Malawi is produced using BMPs. Because over 90% of SSA cropland is rainfed and is likely to remain so (CGIAR, 2006), identifying ways to mitigate drought risk, stabilize yields and encourage investment in BMPs is fundamental to enable a Green Revolution and economic development in Africa.

Severe drought accounts for half the world's food emergencies annually (FAO, 2004). In 2003, the World Food Program spent US$565 million in response to drought in SSA (Doering, 2005). According to the Rockefeller Foundation, approximately 20 million metric tons of potential tropical maize production is lost each year due to drought (Doering, 2005). There are also broader, more systemic effects of drought beyond food insecurity such as decreased household income, the loss of assets due to slaughter of livestock, health threats due to the lack of water for hygiene and household uses, environmental degradation, and less sustainable land management.

Emergency food aid is the primary response to the acute effects of drought on food security in Africa. While food aid undoubtedly saves lives, it is an expensive and short-term approach to combat the consequences of drought and should be complemented by projects that effectively address the fundamental problem of agricultural productivity.

Major improvements have been made, and more are anticipated, in maize yields through the combination of traditional breeding, marker-assisted breeding and transgenic agricultural biotechnology. Traditional breeding has provided steady improvements in yield over time. Marker-assisted breeding has the potential to significantly accelerate that rate of improvement. Transgenes have the potential to create major paradigm shifts in a relatively short time frame.

Drought tolerance is a complex phenomenon that will require application of all these technologies in combination. Drought tolerance is not conferred by a single gene but is a complex network of metabolic and physiological pathways that are influenced by the environment and the rest of the genome. The desired “end phenotype” is higher yield under limited water conditions, but this effect can be due to a combination of many factors, such as a more efficient mechanism for water uptake from the soil, a higher rate of photosynthesis per volume of water, a slower transpiration rate, etc. – none of which can easily be selected for under field conditions except as improved yield.

Novel and useful genes in existing germplasm are largely masked by the overall adaptation response of the whole genotype. A breeder with conventional tools cannot identify, let alone evaluate, the one or two useful genes that a line may contain because they are overwhelmed by the environmental response of the other 50,000 genes.

Molecular breeding techniques, including marker assisted breeding (MAB) now make it possible to assess the genotypic value of thousands of genomic regions of maize germplasm under drought conditions in SSA in ways previously not possible. By assessing the breeding value of each individual genomic region, the breeder is able to combine genes from many countries in new and unique ways not possible with traditional testing and breeding methodologies.

The benefits of breeding can be significantly enhanced through biotechnology, which allows the use of a broader source of genetics than the maize genome alone and provides a greater level of precision to introduce specific genes. Biotechnology has the potential to use a single gene that directly affects these complex pathways resulting in a significant increase in yield under drought conditions. To achieve the same gains through conventional breeding might take multiple breeding cycles over decades, or might not be possible at all for some pathways, due to the lack of native gene variability or because each of the small changes that would need to occur are individually undetectable.

Combining breeding, molecular breeding and biotechnology techniques has the potential to impact multiple water stress pathways and maximize the drought tolerance phenotype through additive or even synergistic improvements. This has led Monsanto to invest in a combination of techniques to develop drought tolerant (DT) maize for commercialization in the US and other temperate areas. Monsanto has completed multiple field trials over the last four years, with a fifth year of expanded field trials underway.

Historically, subsistence farmers in Africa have not had access to new agricultural technologies as quickly as their counterparts in the developed world. Globally, more than a billion cumulative acres of biotech crops have been grown since they were first commercialized over ten years ago. Farmers around the world have benefited significantly, increasing their farm income by more than US$27 billion and decreasing pesticide use by more than 379 million pounds (Brookes and Barfoot, 2005). One of the greatest attributes of biotechnology is its scale-neutral applicability. The power of the technology is delivered through a seed that can be grown by any farmer, regardless of their operations and farm size, without additional equipment or large capital investment. Smallholder farmers around the world make up 90% of the customer base using these products, demonstrating the scale-neutral value of the technology (ISAAA, 2005).

Unfortunately, the vast majority of farmers in SSA have not even had the opportunity to witness field trials of biotechnology products. This "technology gap" is largely due to a lack of science-based regulatory frameworks that would allow testing and evaluation of new agricultural products and reliable delivery systems to reach resource-poor farmers. It means that the most vulnerable African farmers fall further and further behind their counterparts in the developed world. Unless efforts are made now to begin establishing functional regulatory capacity and equipping seed delivery systems, it is unlikely that farmers in SSA will be given the choice to benefit from drought tolerant (DT) technology without an additional decade or more of sequential efforts after its launch elsewhere in the world.

Enabling access to the DT product through an approach that maximizes farmer choice is a major long-term goal of this project. The project is intended to target the vast majority of small-scale, resource poor farmers in the partner countries. Supporting their transition to use BMPs and access to hybrid seed and extension services will be critical to ensure they realize the maximum benefits of the DT trait. Similarly, support to strengthen the local seed industry to produce quality hybrids containing the DT trait in local varieties will be important to ensure farmer choice. Most local seed companies currently lack the expertise and facilities necessary to manufacture seed of the quality and volume anticipated. The seed must be high quality to ensure that the DT trait is expressed effectively and uniformly across a stand of maize, and high volumes are likely to be required as farmers realize the benefits of the trait and come to expect it as a "base" improvement in all germplasm.

2. Mission of AATF

The African Agricultural Technology Foundation (AATF) is an African-led and African-managed not-for-profit organization designed to facilitate and promote access to appropriate proprietary agricultural technologies with potential to increase the productivity of resource-poor smallholder farmers in Sub-Saharan Africa. It achieves its mission through the management of innovative partnerships and development of effective product stewardship activities along the entire agricultural production and food value chain.

Since its inception, AATF identified drought as a major constraint to African agriculture and the search for drought tolerance technology was very high on its priority list. Technologies to introduce drought tolerance in maize through marker-assisted breeding and transgenic approaches have been identified and AATF has entered into legal agreements with owners of such technologies (CIMMYT and Monsanto) to enable their use in Africa and develop products that can be accessed by smallholder farmers without restrictions due to intellectual property rights.

AATF intends to establish a partnership between African institutions, public and/or private, responsible for maize variety development, testing and dissemination in selected countries; CIMMYT Global Maize Program for its excellence in breeding maize adapted to African agro-ecological conditions; and Monsanto, a global leader in developing and marketing traits in crops around the world. Through this partnership, these institutions will work together, under a philanthropic mandate, to develop and deliver drought-tolerant hybrid food maize germplasm improved through molecular breeding and/or biotechnology for use by smallholder farmers in South Africa and by any farmer in the rest of sub-Saharan Africa. The Bill & Melinda Gates Foundation has agreed to fund the activities of this partnership to develop drought tolerant maize varieties with the purpose of making them available to African smallholder subsistence farmers under such philanthropic mandate.

AATF is responsible for the administration, governance and evaluation of this project. Its initial role will be to sensitize African policymakers and stakeholders to the importance of biotechnological improvements in maize and to improve regulatory policy. In later stages of the project, AATF will assist in the identification of and licensing of drought tolerant maize to commercial and parastatal seed producers. Together with its partners, AATF will design a system to ensure quality assurance and responsible stewardship of drought tolerant maize, and develop a strategy for its rapid deployment to smallholder farmers in drought-prone areas.

3. Vision of Success, Project Objectives and Necessary Steps Forward

3.1 Vision of Success**:** The project intends to apply state-of-the-art breeding and biotechnology techniques to accelerate the development of drought tolerant hybrid maize seed that provides the yield stability and performance necessary to drive a more rapid rate of adoption of best agricultural management practices. Our vision is to provide drought tolerant hybrid maize seed to farmers in Sub-Saharan Africa, royalty-free for the drought tolerant trait, as soon as technically possible.

3.2 Project Components and Objectives: There are four main components of the planned project, each with specific objectives:

1. **Technical Component:** To improve drought tolerance of African maize by combining the benefits of Monsanto’s molecular, genomics and biotechnology platforms, CIMMYT’s breeding program and adapted maize varieties, AATF’s expertise in product stewardship, regulatory affairs management and technology delivery, and national institutions’ capacity for testing multiplying and distributing new maize varieties.
2. **Regulatory Component:** To develop capacity within national and international product development teams to conduct risk assessment and prepare safety data dossiers for submission to regulatory authorities to authorize confined field testing of the drought tolerance trait.
3. **Communication Component:** To ensure public awareness and consumer acceptance of maize lines resulting from the project, to test this maize in five Sub-Saharan African countries and to develop incentives for its rapid deployment to needy smallholder farmers.

4. **Governance Component:** To conduct and manage support of the research, product development and innovations funded by the grant in a manner that brings drought tolerant maize within reach of African smallholder farmers and build capacity within partner countries to carry out similar activities in the future.

Specifically, the project intends to accomplish the following:

a. Establish capacity in selected African countries to enable technical work, including materials, people and plans for analysis, backcrossing, mapping, breeding and field testing.
b. Conduct molecular analysis of existing CIMMYT maize lines entering the breeding program in sub-Saharan Africa to enable objectives c and d.
c. Improve CIMMYT lines by incorporating relevant QTLs using state-of-the-art marker assisted breeding system.
d. Conduct marker-assisted breeding using Monsanto's proprietary marker and bioinformatics systems to improve CIMMYT drought tolerant germplasm and identify Quantitative Trait Loci (QTLs) in CIMMYT drought tolerant germplasm.
e. Develop tropical hybrids containing drought tolerance genes for testing in selected African countries.
f. Develop Standard Operating Procedures (SOPs) and conduct rigorous field tests in compliance with all regulations in the selected countries.
g. Develop and implement strategies to secure regulatory approval for safe confined field trials on the basis of professional applications in the selected countries.
h. Establish a Communication Strategy and Plan to cover all phases of the project in the selected countries.
i. Improve understanding and develop positive working relations with national governments, partners and other stakeholders in the selected countries.
j. Ensure that the developed drought tolerant maize products will be accessible to smallholder African farmers.
k. Ensure effective management of the project.

***3.c Necessary Steps Forward*:** The project will work with international, regional and local institutions to develop drought tolerant maize products suitable for African conditions, building capacity to manage transgenic traits as part of the process, and will work with local governments and organizations to provide the necessary regulatory and policy environment to enable field testing, development and deployment of drought tolerant maize in selected African countries. Capacity building will be a significant outcome of this project as various African institutions will be engaged in efforts to develop, deliver and deploy drought tolerant maize.

Meeting the diverse objectives of the project will require the partnership of multiple stakeholders conducting a wide range of activities that are all critical to success. We propose the establishment of an initiative to be known as the "**Water Efficient Maize for Africa**" (WEMA) project; this will build on the Drought Tolerant Maize for Africa (DTMA) project currently led by CIMMYT and funded by the Bill and Melinda Gates Foundation, and complement it with the speed and power of marker-assisted breeding (MAB) and genetic engineering. WEMA will be funded through and managed by AATF. The work plan and governance structure of the project will be discussed and finalized in a planning meeting with the participation of all project partners.