Research Application Summary

Development of plant nutrient efficient use sorghum varieties to support livelihood strategies of East African farmers

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Abstract

Seventy five percent of the over 100 million people in Eastern and Central Africa region live in marginal areas and are dependent on agriculture. Agricultural productivity in those areas is mainly low resource based and suffer especially from limited access by plants to the macronutrients Phosphorus and Nitrogen. For marginal areas sorghum has been prioritized as essential to stimulate the needed 6% Comprehensive African Agricultural Development Programme (CAADP) GDP growth target. Accordingly, this project focuses on the development of methodologies and technologies to improve breeding of resilient sorghum varieties for farming communities who live in marginal and drought prone areas of Kenya and Uganda. Work elsewhere and recent advances in science show the existence of novel genotypes of sorghum with either phosphorus or nitrogen use efficiency. The focus of this research is on improved nitrogen, phosphorus use and uptake as well as tolerance to aluminium toxicity. The project will employ a research and training approach that uses genomics, quantitative genetics and plant physiology to develop breeding systems for sorghum improvement as well as resilient sorghums. This project builds on going efforts both at Makerere and Moi Universities. It will involve other partners who are part of ongoing efforts as well as attract new ones as necessary.

Key words: Aluminum toxicity, Kenya, nitrogen use efficiency, p hosphorus use efficiency, Sorghum, Uganda

Résumé

Soixante-quinze pour cent des plus de 100 millions de personnes dans la région de l'Afrique centrale et orientale vivent dans les zones marginales et dépendent de l'agriculture. La productivité agricole dans ces zones est principalement de faible ressource, surtout basée sur un accès limité aux macro-nutriments de phosphore et d'azote par les plantes. Pour les zones marginales, le sorgho a été une priorité aussi essentielle pour stimuler le besoin global de 6% des objectifs de croissance du PIB au

Programme Compréhensif de Développement de l'Agriculture Africaine (CAADP). En conséquence, ce projet met l'accent sur le développement de méthodologies et technologies pour l'amélioration génétique des variétés de sorgho résistant pour les collectivités agricoles marginales qui vivent dans les zones sujettes à la sécheresse du Kenya et de l'Ouganda. Le travail ailleurs et les progrès récents de la science font apparaître l'existence de nouveaux génotypes de sorgho, soit avec du phosphore ou de l'azote utilisés efficacement. L'objectif de cette recherche est l'amélioration de l'azote, l'utilisation du phosphore, l'adoption ainsi que la tolérance à la toxicité de l'aluminium. Le projet fera appel à une démarche de recherche et de formation qui utilise la génomique, la génétique quantitative et la physiologie des plantes pour développer les systèmes de reproduction pour l'amélioration du sorgho, ainsi que le sorgho résistant. Ce projet s'appuie sur les efforts personnels en cours des universités Makerere et Moi. Il impliquera d'autres partenaires qui font partie des efforts en cours ainsi qu'attirer de nouveaux si nécessaire.

Mots clés: Toxicité de l'aluminium, le Kenya, Utilisation efficace de l'azote, Utilisation efficace du phosphore, le sorgho, l'Ouganda

Background

Investing in staples for dry lands. Nearly 60% of agricultural land in the East and Central Africa is found in semi-arid areas. These areas are also characterised by poor soil fertility and aluminium toxicity induced acidity and have over 100 million people living there. The areas in question include vast areas of north-eastern Uganda, western and northern Kenya, the Sudan, Ethiopia, Eritrea, and Tanzania. For these regions, sorghum (*Sorghum bicolor* Moench) has been identified as one of the staple crops where investment in research for development (R4D) can increase economic growth and generate mutual benefits across the region as part of agriculture-led growth (Omamo *et al*., 2006; ASARECA, 2008).

Justification for investing in sorghum R4D. Agricultural sector of Eastern and Central Africa has experienced decline in labour productivity, being less in 2000 than it was four decades ago (Omamo *et al*., 2006). Currently, the agricultural sector which is growing at about 2% per annum, compared to population growth rates of over 3% per annum, will be out striped by population growth. This population threat is intensified by the endemic production constraints (biotic and abiotic, as well as

climate change and its effects of drought, increased pests and diseases). Yet increasing agricultural productivity, especially by doubling cereal production is needed to meet the current and future food demands (Pingali and Pandey, 2001). In this regard, sorghum in particular has been prioritized as a critical crop for Eastern and Central Africa food and nutrition security (Tatwangire, 2006; ASARECA, 2008).Doubling of agricultural food production worldwide over the past four decades has been associated with a 7-fold increase in nitrogen fertiliser use and other macro-nutrients (phosphorus and potassium) (Hirel *et al*., 2007). Intensification of inorganic fertiliser application has potential negative environmental consequences and is not affordable for Uganda's and Kenya's resource constrained farmers. Therefore, the challenge is to accommodate the needs of the expanding population by developing highly productive agricultural systems, while at the same time preserving the quality of the environment. This requires developing crop plants that are resilient to biotic and abiotic constraints and with efficient nutrient uptake and management systems. The focus of this project is to enhance sorghum production especially among resource constrained farmers, by generating and promoting the use of varieties that have enhanced nutrient uptake (Nitrogen and Phosphorus) and are well adapted to farming environments.

Literature Summary

The development objective of this project is to "***harness genetic potential of sorghum to improve the productivity and adaptability of sorghum based farming systems for production in marginal areas.***" The focus on sorghum is under pinned by the fact that it plays central roles in the livelihood strategies of farming communities in semi-arid and drought prone areas of Uganda and Kenya. It is the crops of choice in over 60% of Eastern and Central Africa's semi-arid areas. This project focuses on two critical macronutrients, phosphorus (P) and nitrogen (N) whose efficient use by sorghum plants can be genetically enhanced and bred for (Furlani *et al*., 1984; Gardner *et al*., 1994; Maranville and Madhavan, 2002). The project builds on work initiated elsewhere, with a main focus of identifying locally adapted genotypes with similar properties, as well as the introgression of these novel traits into locally adapted genotypes from introductions. A brief description of targeted areas of research is presented in the next paragraphs.

Phosphorus. Most of the work on sorghum varieties with improved phosphorus use efficiency has been done at EMBRAPA- Brazil and Cornell University-USA. Through these

efforts lines with improved P uptake and Al toxicity tolerance have been developed (Anonymous, 2005). Within the Eastern and Central Africa region some work has been initiated in Kenya on improved P-uptake under Bio-EARN programme under the leadership of Moi University. Phosphorus limitation is challenging in Uganda and there is need to undertake extensive studies to improve phosphorus use efficiency. This research will build on the work initiated on sorghum at Moi University to undertake related studies in Uganda.

***Nitrogen*.** Nitrogen use efficiency (**NUE**) has been reported in rice, maize and wheat (Gallais and Hirel, 2004; Duan *et al.*, 2007; Hirel *et al*., 2007). It is proposed to study this trait in sorghum whose genome is now sequenced. Comparative studies will be used to investigate two major attributes of NUE i.e. uptake efficiency- the ability of the plant to remove N from the soil as nitrate and ammonium ions) and the utilisation efficiency (the ability to use N to produce grain yield) (Hirel *et al*., 2007).

Study Description

Project design. This project will use a research and training model to generate the outputs. In each country, studies will involve one MSc student who will be guided in the study and research by two advisors, one of whom shall be the collaborator. Each student will have access to a soil scientist or plant physiologist supervisor. The project is divided into two major components each implemented by one MSc student as described below.

Study 1. Development of sorghum varieties with improved nitrogen and/or phosphorus use efficiency. The research hypothesis for this part of the work is that "Sorghum varieties posses a heritable variation in phosphorus use efficiency as an adaptation to high P fixation common in African soils. This genetic variability can be used to improve low P-use varieties." The research will include studies on Phosphorus Use Efficiency (PUE) as well as Nitrogen Use Efficiency (NUE). NUE studies will focus on uptake efficiency (NupE**)** and the utilisation efficiency (NutE**)**. This challenge is particularly relevant to cereals for which large amounts of N fertilizers are required to attain maximum yield and for which NUE is estimated to be far less than 50% (Wu *et al*., 2000). Mapping populations will also be developed for QTL analysis and molecular marker development. In the case of PUE the study will exploit the fact that plants have evolved two broad strategies for P acquisition, i.e., conservation of use and enhanced acquisition or uptake

(Vance *et al*., 2003). In this study, we will focus on mechanisms that enhance acquisition or uptake of phosphorus being the most reliable and amenable to breeding (Lynch and Ho, 2005). These studies will be conducted over a 2-year period involving field, greenhouse and laboratory work. So far the materials for the studies have been assembled and preliminary screening work is ongoing.

Study 2. Development of sorghum varieties with improved phosphorus use efficiency for acidic soils of Kenya. The research hypothesis for this part of the work is that "Sorghum varieties posses a heritable variation in resistance to aluminium toxicity and phosphorus use efficiency as an adaptation to high P fixation and aluminium toxicity common in African soils. This genetic variability can be used to develop resilient sorghum varieties." Two populations developed by Moi University for PUE and aluminium toxicity tolerance and S*triga* tolerance will be used. The populations include F2:F3 and BC2 populations respectively. Putative molecular markers have been developed for Aluminium toxicity but none for phosphorus. The major work will involve advancing the populations and subsequently screening them for early variety development; identification of additional elite phenotypes; and development of putative molecular markers for mapping target loci. The outputs of this project will include:

a) Improved sorghum lines for phosphorus use efficiency acquired and used to develop locally adapted/ farmer preferred sorghum varieties
b) Improved sorghum lines for nitrogen use efficiency acquired and used to develop locally adapted/ farmer preferred sorghum varieties
c) Processes for breeding for both improved phosphorus and nitrogen use efficiency as well as Aluminum toxicity developed and tested
d) Two MSc level graduates trained in plant breeding and seed systems
e) RUFORUM member university research scientists mobilized and engaged with other actors in addressing development challenges
f) Capacity of Makerere University and Moi University to use research and training to generate relevant outputs (human resources and technologies) for the region's development enhanced.

Research Application

This work is a response to one of RUFORUM thematic areas of "***increasing productivity and enhancing sustainable natural resource use and management.***" Specifically, we aim at enhancing productivity of sorghum, a crop that holds a central position in the livelihood strategies of communities in over 40% of Kenyan and Ugandan farm lands (Conway, 2007). These farmers cannot largely afford inorganic fertilizers yet the soils are degraded and infertile. Moreover there is increasing threat to farm productivity due to climatic change. In effect therefore, there is need to address in part, the issue of climatic change adaptability via crop production. Sorghum being the resilient crop that it is, provides opportunity that can be enhanced by improved nutrient use. Overall, this proposal offers scope and scale for RUFORUM to fulfil part of its mission of mobilising universities of the region to proactively engage in development processes and practice through graduate training and research for development activities.

Recommendation

Given that this study is still in its formative stage no major recommendations can be made. Once completed however, the project will for the first time in Uganda generate sorghum varieties well adapted to low resource agriculture. It will also develop systems for breeding for genotypes well adapted to low nitrogen and phosphorus soils, attributes that are common with resource constrained agriculture.

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