Achieving water efficiency with maize

Anne Wangalachi/CIMMYT

Denis T. Kyetere, Sylvester O. Oikeh and Grace Wachoro

Increasing incidences of drought in Africa are affecting maize production, one of the major staple crops for a majority of the population. This has resulted in frequent crop failures leading to hunger and poverty in sub-Saharan Africa. One of the most challenging problems in plant breeding today is that of improving drought tolerance. A public–private partnership known as the Water Efficient Maize for Africa (WEMA) consortium was formed in 2008 and has been working to develop drought-tolerant maize for smallholder farmers in sub-Saharan Africa with promising results that indicate that maize can be made more water efficient by modern methods of plant breeding.

Effects of drought on maize production

Incidences of drought in the world are increasing. This is especially so in Africa, which is now referred to as a drought-prone continent where the vast majority of agriculture is rain-fed. Drought leads to crop failure, hunger and poverty, and

climate change is worsening the problem. Recurring droughts – more than ten drought events between 1970 and 2004 – are a persistent challenge in sub-Saharan Africa, making farming risky for millions of smallholder farmers and their families who rely on annual rainfall to grow their crops. Drought stress is one of the top two factors responsible for limiting maize production[1] and it is estimated that in sub-Saharan Africa it causes yield losses of 10–25 per cent on average.

Maize is the most widely grown staple crop in Africa and it provides food for more than 300 million people. Some countries in Eastern and Southern Africa rely on maize for more than half of their total calorie consumption.[2] However, the average maize yield per hectare for a farmer in sub-Saharan Africa is much less than that of farmers in the USA and Europe. Smallholder farmers in Africa are unable to utilise basic technologies like improved seed and fertiliser due to lack of capital or because they are unwilling to invest the little capital they have for fear of losing their investment during drought.

The Water Efficient Maize for Africa project

Due to both the complexities of drought itself and the plant's response to abiotic stresses such as moisture depletion, a single organisation is unlikely to be in a position to address all the challenges of developing drought-tolerant maize, or that a single technology or methodology will provide a solution. The Water Efficient Maize for Africa (WEMA) partnership is taking multiple approaches and utilising resources across organisations to reach the project's objectives. The focus is threefold: to develop new varieties (germplasm) using conventional breeding techniques, e.g. production of doubled haploid plants or marker-assisted recurrent selection (MARS); to undertake discovery breeding to identify genes that confer drought tolerance in the maize genome; and to test the introduction of drought-tolerance transgenes (GM) into adapted varieties in the partner countries.[3] The aim is to produce WEMA products that will be drought-tolerant (white single-cross and/or three-way cross hybrids), giving at least a 20–35 per cent yield advantage under moderate drought conditions compared to commercial hybrids produced in 2008.

Both conventional and molecular breeding programmes have resulted in positive developments

WEMA is a public–private partnership whose objective is to develop drought-tolerant maize and make it available royalty-free for the benefit of smallholder farmers in sub-Saharan Africa. The project, which is being implemented in five countries of Eastern and Southern Africa, aims to improve food security and rural livelihoods among smallholders by developing hybrid maize varieties that can tolerate conditions of moderate drought.[3] Currently WEMA is field-testing Monsanto's drought-tolerant lead variety (MON87460) which has an introduced transgene (*CspB*) and an inducible cold shock tolerant gene from *Bacillus subtilis* which confers improved adaptation to stress in several plant species. The transgene is expected to provide additional gains in drought tolerance.

The partnership arrangements of the consortium are shown in Box 1 and financial support has come from the Bill & Melinda Gates Foundation and Howard G. Buffett Foundation (2008–2012).

Progress to date

Both conventional and molecular breeding programmes have resulted in positive developments in the last four years. Under conventional breeding, 40 drought-tolerant varieties (not GM) were submitted to the National Performance Trials in Kenya (16 varieties) and Uganda (24 varieties) in 2012. These trials are used to determine the suitability of new varieties to a country's growing conditions. Tanzania and Mozambique are set to do the same soon. Kenya and Uganda are currently carrying out the third round of transgenic (GM) confined field trials while

Box 1. Contribution of partners to the WEMA project

Organisation	Expertise	Contribution
African Agricultural Technology Foundation (AATF)	• Public–private partnership management • Legal affairs and intellectual property management • Seed system operations • Stewardship of conventional products in smallholder settings • Communications • Regulatory affairs • Project leadership	• Partnership management • Licensing, intellectual property and legal affairs management, including facilitating negotiations of all agreements • Product deployment and stewardship strategy • Project communications, outreach and awareness • Regulatory approvals and compliance • Project monitoring and evaluation
International Maize and Wheat Improvement Center (CIMMYT)	• Conventional, abiotic and biotic stress breeding • Conventional, molecular and doubled haploid breeding	• Sub-Saharan Africa adapted drought-tolerant germplasm • DNA marker information
Monsanto	• Conventional, molecular and doubled haploid breeding • Biotechnology testing and stewardship • Seed production, deployment and licensing	• Global germplasm • DNA marker information • Transgenic traits for drought tolerance (with BASF) and insect-pest protection • Seed deployment strategy
National Agricultural Research Systems (Kenya, Uganda, Tanzania, South Africa and Mozambique)	• Conventional breeding • Field-testing and regional trials • Knowledge of farmers' product needs	• Locally adapted germplasm

South Africa is in the fourth trial. Mozambique and Tanzania continue to work towards securing regulatory approvals to conduct transgenic trials.

During the first four years of research, insect infestation, especially maize stem borers, was identified as a major potential threat to the anticipated benefits of drought-tolerant maize varieties. To overcome this challenge, the project is adding insect-pest protection with the introduction of genes (*Bt*, *Cry1Ab*) to WEMA-developed varieties to enable farmers to secure an insect-pest-resistant maize crop through healthier plants that are able to use the water and nutrients more efficiently during drought stress.

The first WEMA varieties developed through conventional breeding could be available by 2014. Varieties developed using transgenic approaches will be available to farmers depending on research results and regulatory approvals in each of the WEMA countries. Farmers could have access to these drought-tolerant and insect-pest-protected maize varieties within six to seven years.

Regulatory compliance

In order to conduct confined field trials and eventually commercialise the maize varieties, there must be enabling biosafety laws in place. Only two project countries – Kenya and South Africa – have functional biosafety laws that allow for testing and commercialisation of biotech crops. The project depends on policy-makers in the various countries to put in place the necessary regulatory frameworks so that the farmers of those countries do not miss out on the benefits that biotechnology can bring to enhancing agricultural productivity.

Creation of awareness

Meeting the technical milestones of the WEMA project also requires buy-in, ownership and support of key stakeholders. However, the introduction of bio-

technology crops into Africa is controversial, compounded by social, ethical and political considerations. The WEMA communication and outreach strategy has sought to ensure a good understanding and appreciation of the project, its partners and the technology that will support the safe transfer, adaptation and delivery of the maize varieties. The project supports the creation of awareness on biotechnology among all stakeholders for informed decision-making.

Lessons learned

In the course of the four years that the project has been in operation, some lessons learned have informed implementation of activities and will be valuable as the project progresses into the next phase. The involvement of the National Agricultural Research Systems (NARS) in breeding promotes opportunities and builds a foundation in crop improvement in the partner countries. The approval of applications to conduct confined field trials in some of the countries has enabled the project to make progress towards delivering the much-needed drought-tolerant maize varieties to smallholder farmers. This can be attributed to the capacity-building support that the project has given regulators in risk assessment and decision-making.

Way forward: deployment of the maize varieties

To ensure that the drought-tolerant and insect-pest-protected maize varieties from the WEMA project are available to smallholder farmers in sub-Saharan Africa, strategies are already being put in place for the deployment phase. This phase requires financial support from funding agencies so as to strengthen the local seed industry to produce quality drought-tolerant varieties and promote the delivery of the products to smallholder farmers. Most local seed companies currently lack the expertise and facilities necessary to produce certified seed of the quality and volume anticipated for farmers to realise the benefits of the drought-tolerant and insect-pest-protection traits. A further problem is that hybrid maize seed cannot

be saved from one year to the next and will have to be purchased by or donated to farmers every year.

Conclusion

The project has made good progress since its launch and is on course to deliver drought-tolerant and insect-pest-protected locally adapted maize varieties to smallholder farmers in sub-Saharan Africa. This has been largely possible because of the excellent collaboration among all the partners. The regulatory environment in South Africa, Kenya and Uganda has enabled confined field trials to be conducted in these countries and the results from the trials are promising. The project is looking forward to moving on to the next deployment phase that will see the varieties delivered to smallholder farmers.

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Dr Denis Kyetere *is the Executive Director of the African Agricultural Technology Foundation (AATF);* ***Dr Sylvester O. Oikeh*** *is the Project Manager of the Water Efficient Maize for Africa (WEMA) project;* ***Grace Wachoro*** *is the Corporate Communications Officer (AATF).*
African Agricultural Technology Foundation (AATF), PO Box 30709, 00100 Nairobi, Kenya.
D.Kyetere@aatf-africa.org; S.Oikeh@aatf-africa.org; G.Wachoro@aatf-africa.org