Developing miscanthus value chains for marginal site conditions in OPTIMISC project

O. Kalinina[1], J. Clifton-Brown[2], I. Donnison[2], K. Farrar[2], L.M. Trindade[3], O. Dolstra[3], G. van der Linden[4], I. Roldan-Ruiz[5], G. Harding[6], M. Mos[6], C. Nunn[2], L. Huxley[2], A. Kiesel[1], Y. Iqbal[1], T. van der Weijde[3], P. Lootens[5], H. Muylle[5], S. Fonteyne[5], H. Meyer[7], K. Schwarz[7], K. Müller-Sämann[8], Q. Xi[9], M. Ozgüven[10], H. Schüle[11], C. Chen[4], I. Tarakanov[12], N. Khokhlov[12], A. Anisimov[12], and I. Lewandowski[1]

Introduction

Miscanthus inhabits a wide range of environments in nature. However, despite large genetic variability of miscanthus in these habitats, the production of miscanthus in Europe is currently dominated by a single clone, *M.* × *giganteus*. Cultivation of *M.* × *giganteus* is limited by low winter temperatures in the North and East Europe and by drought in the southern regions [1]. Expanding the gene pool beyond *M.* × *giganteus* and using genotypes better adapted to particular environmental conditions could extend the climatic and edaphic ranges in which this crop can be grown.

Salinization and sodification are among the major degradation processes endangering the agricultural use of European soils. There are estimated 20.7 million ha of sodic and saline soils in the EU, Ukraine and Russia [2]. Genetic variability of miscanthus in nature and its high resource-use efficiency provide opportunities for developing miscanthus genotypes suitable for cultivation on marginal land chracterized by drought or salinization [3]. However, for miscanthus production under such conditions safe and low cost establishment and harvesting technologies are needed.

At present the main application of miscanthus biomass in Europe is combustion. Due to high variability in quality parameters of the biomass of different miscanthus genotypes, it has a good potential for higher-value uses such as building materials, bioplastics, animal husbandry and chemical applications [4].

In the project OPTIMISC, the options for miscanthus production on marginal land are investigated and optimized production systems for miscanthus for different applications will be recommeded based on the costs and ecological performance.

Project OPTIMISC: objectives and approach

The main objective of OPTIMISC (“Optimizing Miscanthus Biomass Production” project founded by the European Union's Seventh Framework Programme) is to optimize miscanthus bioenergy and bioproduct chains by trialling elite germplasm types over a range of sites across Europe, Russia and China, analysing the key traits that currently limit the potential of miscanthus, identifying high-value bioproducts and modelling the combined results to provide recommendations to policy makers, growers and industry. Broadening the genetic variability of miscanthus crop should allow miscanthus cultivation under adverse environmental conditions on marginal land and optimize its use for different industrial applications.

In 2011-2012, over 100 miscanthus genotypes were selected from the material made available by miscanthus breeding programs at Aberystwyth University in the UK (IBERS) and Wageningen University in the Netherlands and *in-vitro* or seed-propagated. Since 2012, 15 of these genotypes were assessed at agricultural plot scale at six field trial locations in Germany, the Netherlands, the UK, Turkey, Russia and Ukraine.

In 2012, a large-scale field trial has been established at Blankney Farms (the UK), where miscanthus is produced at commercial scale implementing the whole pelleting chain. In 2013, two large-scale plantations were established on the farms at the German Agrarian Centre (DAZ) in Ukraine and the University of Hohenheim in Germany. Different planting techniques, planting and harvesting machinery, herbicides and herbicide mixture applications are tested in these trials.

A broad spectrum of miscanthus genotypes (ca. 100) is screened for the tolerance to the adverse environmental conditions (drought, cold, frost, salinity) at Plant Research International (DLO) in the Netherlands, at Aberystwyth University in the UK (IBERS), at the Institute for Agricultural and Fisheries Research (ILVO) in Belgium and at Dongying Agricultural Institute in China.

The composition of the biomass and its suitability to provide feedstock for energetic use and higher quality products is being investigated at the Universities of Wageningen and Hohenheim, the Institute for Agricultural and Fisheries Research and at Blankney. This includes the biochemical characterization of the lignocellulosic and juice fractions, the characterization of non-cell wall carbohydrates and the evaluation of the performance of the most promising genotypes in different processes of various bioenergy and biorefinery chains.

Miscanthus value chains will be assessed using the input from OPTIMISC experiments. Cost assessments are performed by the Agency for Sustainable Management of Agricultural Landscape (ANNA) and Life Cycle Analysis (LCA) by the University of Hohenheim.

Overwiev of the progress

The results of multilocation field trials showed high variability in growth, ripening time and biomass yield among the 15 miscanthus genotypes. The best performing high yielding genotypes at each location and the genotypes performing well at all locations were identified. The data collected will be used for modeling miscanthus yields and predicting the areas where novel germplasm can be grown.

The protocols for the efficient screening of a high number of miscanthus genotypes for their tolerance to abiotic stresses were developed and implemented. In total, about 100 miscanthus genotypes were evaluated for their tolerance to the four key abiotic stresses (drought, cold, frost, salinity) under controlled conditions. Large genetic variability in stress tolerance and different mechanisms of stress tolerance in miscanthus were found. This will allow the development of stress tolerant miscanthus varieties for marginal lands. For this purpose, the most tolerant and the best yielding genotypes for each of the abiotic stresses (Fig. 1) will be recommended for use in breeding programmes.

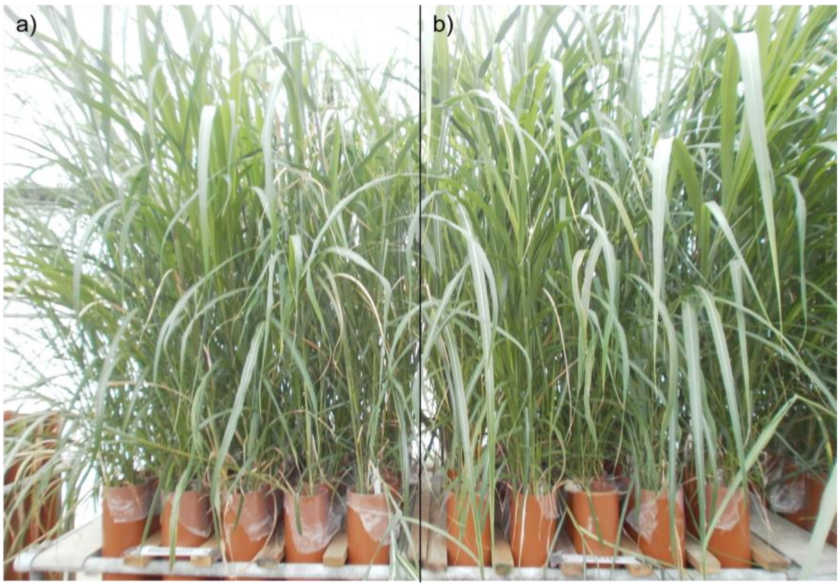

Fig. 1. One of the miscanthus genotypes showing good recovery after drought stress: a) drought-treated plants, b) control plants (Photo provided by L. Huxley).

Twenty five miscanthus genotypes, including five genotypes from European breeding programs and 20 wild miscanthus accessions collected in China, were additionally screened for salinity tolerance in a halophyte garden in the field in Dongying. The best-performing five genotypes on normal soils and the best five on saline soils were identified. One Chinese miscanthus accession showed good performance both on normal and saline soils, indicating high salinity tolerance. The genotypes showing good biomass yield on saline sites or high salinity tolerance can be used as genetic material for breeding purposes to develop miscanthus varieties for marginal land with high soil salinity.

The experience with the large-scale trials in OPTIMISC allowed issuing recommendations on the establishment and maintenance of the large-scale miscanthus plantations, in particular on the establishment of plantations from pre-grown plantlets (plugs), herbicide application and fully mechanized planting of miscanthus plantlets at a large scale.

Biochemical analysis of the lignocellulosic fraction of a large part of OPTIMISC germplasm, including the 15 miscanthus genotypes from the six agro-plot field trials, has been completed, and genotypes with highly contrasting cell wall profiles were identified. The findings will support recommendations for the choice of genotypes suited for ethanol and biochemical production. Also, miscanthus genotypes optimized for other applications, such as biogas production, are selected. To identify the best value chains and "genotype x biomass application x location" combinations, the following miscanthus value chains are assessed in OPTIMISC:

1. Combustion (CHP) – pelleting chain
2. Combustion (CHP) – chopping chain
3. Ethanol
4. Biogas (methane)
5. Particle boards
6. Chlorophyll production

Life Cycle Assessment (LCA) and cost assessment will be performed for optimised miscanthus biomass production, processing and use chains. As an important outcome of the project, a decision support tool will be provided with regard to cost reduction and environmental performance of specific value chains and for the selection and cultivation of miscanthus genotypes for different industrial uses.

The project results will be used to provide recommendations for breeders, growers, users and manufacturers of miscanthus, which will be published on OPTIMISC public platform platform.optimisc-project.eu.

References

[1] Clifton-Brown JC, Breuer J, Jones MB (2007): Carbon mitigation by the energy crop, Miscanthus. Global Change Biology 13, 2296–2307.

[2] Brouwer F, Baldock D, Godeschalk F, Beaufoy G (1997): Marginalisation of agricultural land in Europe. “Livestock systems in European rural development” – international conference in Nafplio, Greece, LSIRD Napoli Conference Papers.

[3] Hansen EM, Christensen BT, Jensen LS, Kristensen K (2004): Carbon sequestration in soil beneath long-term Miscanthus plantations as determined by ^{13}C abundance. Biomass and Bioenergy 26, 97–105.

[4] Auderset U, Freudiger U (2010): Miscanthus-Entwicklungen in der Schweiz. In: Pude, R. (Ed.), Miscanthus - Netzwerke und Visionen. Proceedings of the 6th International Miscanthus Conference from 24–26 Nov. 2010, Austria, 87–92.

1) Department of Biobased Products and Energy Crops, Institute of Crop Science, University of Hohenheim, Stuttgart, Germany

2) Aberystwyth University, United Kingdom

3) Wageningen University, the Netherlands

4) Plant Research International (DLO), the Netherlands

5) Institute for Agricultural and Fisheries Research (ILVO), Belgium

6) Blankney Estates, United Kingdom

7) Schwarz, Braunschweig, Germany

8) ANNA, The Agency for Sustainable Management of Agricultural Landscape, Germany

9) Dongying Agricultural Institute, China

10) Çukurova University, Turkey

11) German Agrarian Center in Ukraine, Ukraine

12) Russian State Agrarian University, Russia