Genetic Adaptation of Sorghum: Genomics-based breeding of a sustainable, next-generation bioenergy crop for Europe

Acronym: ERANET-GAS

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Introduction

Biogas production from maize is one of the best-established bioenergy production systems in Europe. However, maize varieties grown for bioenergy have a high water usage and relatively poor nutrient use efficiency. Sorghum, the world's fifth most important cereal crop, can grow well in arid and nutrient-poor environments where other crops suffer strong yield reductions; on the other hand it also tolerates temporary waterlogging considerably better than maize, ensuring a good yield stability even in extreme or strongly fluctuating environments. Sorghum is also regarded as completely resistant against Diabrotica, a major pathogen of maize, hence it can potentially be used as a resistant break crop to secure farmers' return of investment in biogas production facilities that currently rely solely on maize as a feedstock.

Results

Detailed analyses of resource use efficiency and environmental performance of biofuel cropping systems have shown that sorghum can achieve exceptional energy return and sustainability indices, including high net energy yield, high net energy production per land area, low greenhouse gas emissions and high water use and nitrogen use efficiency. In comparison to maize, presently the most important bioenergy crop in temperate Europe, sweet sorghum cropping for biofuel production was found to have around 12 times superior nitrogen use efficiency, 5 times the net energy yield and 8 times the net energy production, despite savings of around 60% on nitrogen input, over 70% on water use efficiency and over 60% on potential greenhouse gas emissions (De Vries 2010, Biomass and Bioenergy 34: 588-601). In comparison with alternative bioenergy crops for temperate climates, sorghum is one of the most sustainable currently available alternative for bioethanol and biogas production, with the additional advantage that it can potentially directly substitute maize in existing production systems. Another major advantage of sorghum is its suitability for energy production on marginal land not used for food cropping. These arguments demonstrate the potential value of sorghum as an environmentally sustainable, economical and energetically superior alternative to maize for both methane and bioethanol production in Europe. However, present sorghum cultivars suffer from poor emergence and dry matter yields due to cool springtime temperatures which prevent early sowing in northern latitudes and consequently reduce the time-frame for biomass accumulation. Due to the very young history of sorghum breeding for energy use in Europe, however, modern breeding techniques based on genomics technologies are expected to result in considerable further improvements in biomass yields, energy gains and environmental sustainability.

The ERANET-GAS project developed novel plant populations and genomics tools for genomics-assisted breeding of sorghum forms suitable for high-yielding bioenergy production in Northern European production environments. The project united public and private sector plant breeders, geneticists, crop physiologists, agronomists and phytopathologists in Germany, Poland and Sweden in a multidisciplinary consortium. A particular focus was placed on adaptation of sorghum for cooler climates and abiotic stress constraints, along with resistance to major fungal diseases. Large, highly novel breeding populations were generated from crosses between four genetically and phenotypically diverse breeding lines contributing interesting diversity for abiotic and biotic stress resistance, along with relevant bioenergy traits associated with high methane yield. Whole-genome sequences of the parental lines were used to develop a new high-density genome-wide genotyping array which was used to genetically characterize more than 1600 breeding lines over the course of the project. Comprehensive phenotypic evaluations of the multi-parent mapping population in multi-location field trials and in controlled-environment experiments enabled genetic dissection of early-stage cold tolerance, important fungal diseases, root traits associated with water-use efficiency and phosphorous uptake, and bioenergy traits, respectively. Based on these datasets, the ERANET-GAS partners developed statistical models to predict performance of non-phenotyped individuals based on "genomic breeding values" (GBVs) calculated from the genome-wide sequence variants. The screening tools, plant resources and project results flowed directly into a commercial breeding program aiming towards release of sustainable, high-yielding bioenergy sorghum cultivars to the Northern European market. the time-frame for biomass accumulation. Due to the very young history of sorghum breeding for energy use in Europe, however, modern breeding techniques based on genomics technologies are expected to result in considerable further improvements in biomass yields, energy gains and environmental sustainability.

Acknowledgment

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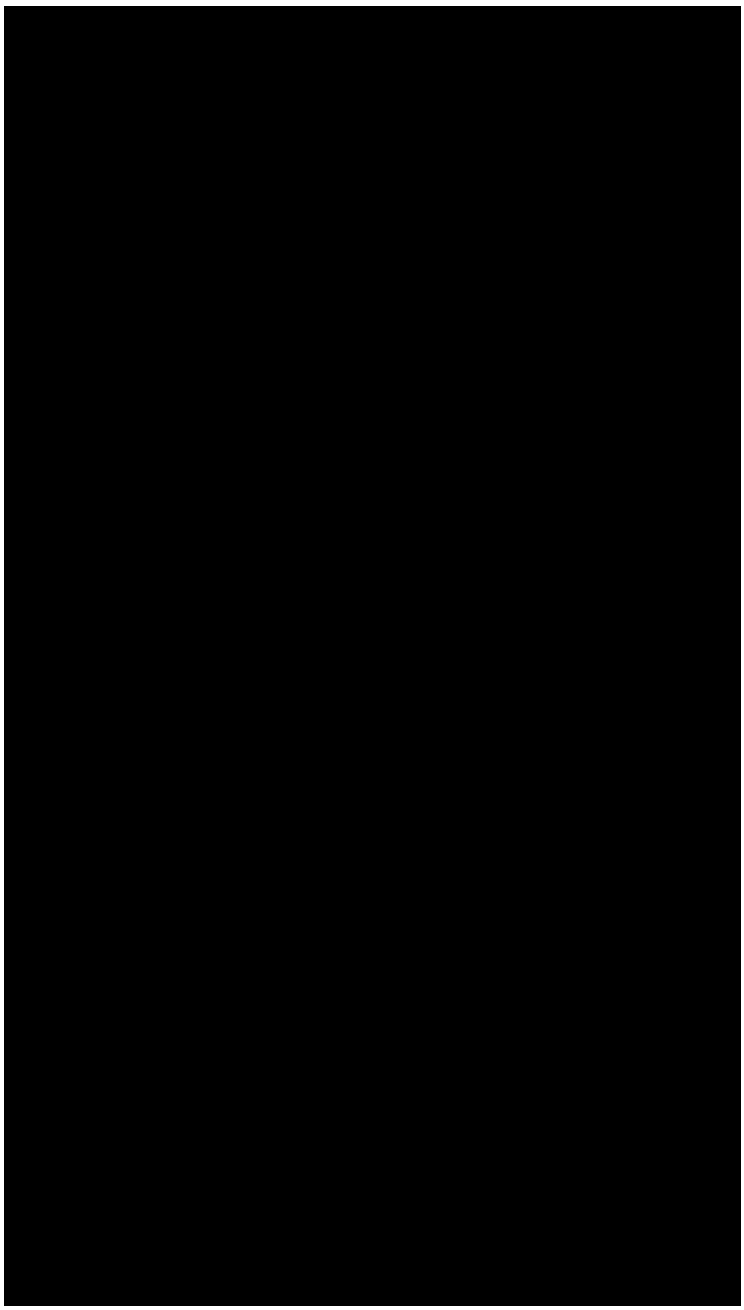

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