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EDITORIAL

Perennial biomass crops for a resource-constrained world

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In this special issue, we publish a total of 20 papers arising from a conference held at the University of Hohenheim in September 2015, which brought together five European Framework Programme 7 research consortia to report the results of their work over the previous five years. The research programme was initiated in recognition of Europe's need for sustainably produced biomass to support European strategic objectives for the bioeconomy.

The conference title was 'Perennial Biomass Crops for a Resource-Constrained World', and we have retained this for the title of the special issue. The focus of the papers is on the growth and utilization of second-generation, nonfood bioenergy crops, such as perennial rhizomatous grasses (PRGs), for example *Miscanthus* and *Arundo donax*, and short rotation coppice (SRC) species, like poplar and willow. Both of these types of perennial biomass crops (PBCs) are established only once in a plantation's lifetime and can then be harvested regularly over a lifespan of at least 20–30 years. The overarching questions are related to the suitability of perennial crops for feedstocks for a European bioeconomy and in particular the need to exploit environments for biomass crops which do not compete with food crops. We focus on two major issues relating to the future use of biomass energy: the identification of the most suitable second-generation biomass crops, and the need to utilize land not used for intensive agricultural production (broadly referred to as 'marginal' land) so that we avoid the potential conflict between food and fuel production.

The papers have been grouped into three broad categories. In the first category, the papers review the potential of bioenergy resources from perennial crops grown in largely 'marginal areas' across Europe. *Miscanthus* is probably the most widely planted PRG in Europe, but establishment costs are currently high because the crop is established from pieces of rhizome. In their paper, Clifton-Brown *et al.* (2017) review progress in upscaling *Miscanthus* production with seed-based hybrids. One of the advantageous features of *Miscanthus* is that it possesses the potentially more productive form of photosynthesis (C_4 as opposed to the more common C_3 photosynthesis) which appears to be unusually well adapted to cool temperate climates. However, Jiao *et al.* (2017) ask the question 'Can *Miscanthus* C_4 photosynthesis compete with the temperate grass hybrid festulolium C_3 photosynthesis in a temperate climate?' A crucial enzyme involved in C_4 photosynthesis is PPDK, and Peltek *et al.* (2017) in their paper report on a new quantitative method for the rapid determination of this enzyme in *Miscanthus* leaves. A wealth of information on the cultivation of PBCs has been collected, but few side by side comparisons have been made between herbaceous and woody crops. In Amaducci *et al.* (2017), they compare the biomass production and energy balance of PRGs and woody crops on marginal land in one location in Europe, the Po valley. On a larger spatial scale, Perdreau *et al.* (2017) illustrate the extensive population genetic variation in wild populations of the PRG *Phalaris arundinacea* in north-western Europe. There is increasing interest in the potentially beneficial effects of the presence of soil bacterial endophytes, and in their paper, Cope-Selby *et al.* (2017) report on the role of endophytic bacteria in *Miscanthus* seed germination and a potential role in plant breeding. Marginal areas that are not used for crops are frequently subjected to stressful conditions for plant growth, such as high salt content or shortage of water. In this special issue, there are six papers that report on the effects of abiotic stress on *Miscanthus*. Malinowska *et al.* (2017) investigate the response to drought in plants collected from different geographical locations, and Stavridou *et al.* (2017) report on the impact of soil salinity on *Miscanthus* growth while Sánchez *et al.* (2017) describe their approach to cultivating the PRG *Arundo donax* on surplus saline lands of Spain. Two other papers report investigations into the drought responses in *A. donax*. Haworth *et al.* (2017a) report on the physiological responses of *A. donax* ecotypes to drought, and Haworth *et al.* (2017b) show how xylem morphology influences drought responses in ecotypes of *A. donax* from contrasting habitats. Finally, the paper by Cordero & Osborne (2017) cautions plant breeders screening for low temperature tolerance that variation in leaf-level photosynthesis among switchgrass genotypes exposed to low temperatures does not scale with the final biomass yield.

In the second category, there are six papers that focus on examples of end-uses of perennial biomass crops. The papers illustrate how end-uses of biomass can be novel and lead to new applications and products like using specific plant fragments for biorefining. Three of the papers consider uses for *Miscanthus* feedstock.

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Kiesel & Lewandowski (2017) report on the potential of *Miscanthus* for anaerobic digestion and biogas production while Frydendal-Nielsen *et al.* (2017) compare methods for measuring the digestibility of *Miscanthus* in bioethanol or biogas processing and Weijde *et al.* (2017) evaluate *Miscanthus* biomass quality as a feedstock for conversion into different bioenergy products. The remaining three papers in this section consider, the use of perennial species mixtures for multifunctional production of biomass on marginal land (Carlsson *et al.*, 2017), the use of sida (*Sida hermaphrodita*) biomass for multiple energy purposes (Jablonowski *et al.*, 2017) and the relevance of environmental impact categories for perennial biomass production (Wagner & Lewandowski, 2017).

The two final papers in the special issue consider some of the environmental impacts of growing energy crops. McCalmont *et al.* (2017) have measured the carbon budget of a newly established *Miscanthus* crop grown on land formally used for semi-improved grassland production, to show how long it takes to recoup the carbon losses during the establishment of the crops, and Ferrarini *et al.* (2017) have investigated the impacts of willow and *Miscanthus* bioenergy grown as marginal buffers on the nitrogen budget and show that this form of management mitigates the disservices of agricultural activities such as groundwater nitrogen pollution.

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