Miscanthus: Beyond its Use as an Energy Crop

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Miscanthus is a tall perennial rhizomatous grass with C_4 photosynthesis. Because of its high biomass yield, high carbohydrate and low ash content, high calorific value, remarkable environmental adaptability, high water and land use efficiency, and low fertilizer and pesticide requirements, it has become one of the most promising energy crops. Apart from energy uses, it can also be used as raw material for paper-making and for production of a variety of chemicals. Moreover, *Miscanthus* can also play an important role in environmental remediation and ecological improvement. It has been used to remedy polluted soil, improve the soil quality, and increase the biodiversity by providing habitat for animals and insects. However, its commercialization is still facing great challenge. More study is needed to further decrease its cultivation, harvesting, and processing costs. This editorial discusses opportunities and challenges of *Miscanthus* as an energy crop and in other applications.

Keywords: Miscanthus; Bio-fuels; Chemicals; Paper-making; Ecological remediation

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Miscanthus: One of the Most Promising Energy Corps

Energy consumption is closely related people's lives and social development. The energy demands have been growing steadily in recent years. At present, the conventional fossil fuels are still the main source to meet the ever-increasing energy demands. The growing consumption of these fossil fuels has put heavy pressures on their steady supply and our environment and ecology. Therefore, searching for their alternatives is highly essential to improve our environment (Zhu *et al.* 2015a,b, 2017). An effective way to achieve this is to replace these fossil fuels with renewable bio-energy fuel sources (Chen *et al.* 2014; Cao *et al.* 2019). Energy crops are well known as indispensable components of the renewable bio-energy fuel sources; they not only reduce greenhouse gas emissions but also have the potential for carbon sequestration (Jones *et al.* 2019). Hence, searching for suitable energy crops to meet the ever-increasing energy demand is very important for sustainable development for society.

Miscanthus is a perennial rhizomatous grass with the C_4 photosynthetic pathway, which is originated in East Asia. It is a genus comprising 14 to 20 species and can grow under a wide range of climatic conditions (Jones *et al.* 2019). It is traditionally used as an ornamental grass, and it is currently identified as one of the most promising energy crops (Jones *et al.* 2019; Rivas *et al.* 2019). It has several key advantages:

1) High biomass yield and land use efficiency. It is reported that its average annual biomass yield can reach 30 t ha^{-1} (dry matter) with minimal agricultural inputs. This is much higher than other energy crops, such as switchgrass and reeds. This means that

planting *Miscanthus* has higher land use efficiency by using less land to meet more energy demand;

2) Remarkable environmental adaptability and strong stress-tolerance ability. *Miscanthus* can grow under a wide range of climatic conditions and has strong stress-tolerance ability. This assures that it can be planted at large scale and that it can maintain a steady supply for energy use. Moreover, it can be planted in such marginal lands as saline alkali land, wasteland, hillside land, and desertified land. This allows the more arable land to be used for food production;

3) Low fertilizer and pesticide inputs and high water use efficiency. Compared with other energy crops, *Miscanthus* needs low fertilizer and pesticide inputs and has high water use efficiency, which lowers the maintenance cost;

4) Low labor and management costs. *Miscanthus*, as a perennial rhizomatous grass that can be harvested for 15 to 20 years after its establishment. Compared with annual crops, it has much lower labor and management costs;

5) Low ash content and high calorific value. In contrast with agricultural wastes and other herbaceous energy crops, *Miscanthus* has low ash content and high calorific value, making it an ideal bio-fuel for heat and electricity;

6) High carbohydrate and low lignin content. Compared with commonly used types of lignocellulosic biomass, such as agricultural and forest wastes, *Miscanthus* has high carbohydrate and low lignin content. It is an ideal feed-stock used for transport fuel production. It can be efficiently converted into such transportation fuels as bio-ethanol, hydrogen, bio-oil, and bio-hydrocarbons via biochemical or thermo-chemical methods.

The energy uses of *Miscanthus* include two aspects. One is direct combustion for heat and electricity, and another is to convert it into transport fuels through biochemical or thermo-chemical approaches. Apart from energy uses, it can also be used as raw material for paper-making, building materials, packaging material, and for production of a variety of chemicals (Zhu *et al.* 2016, 2018; Rivas *et al.* 2019).

Combination of *Miscanthus* Planting and Ecological Remediation Together

Miscanthus is not only able to replace the fossil fuels as a renewable and clean energy source but also it can play an important role in environmental remediation and ecological improvement (Zhang *et al.* 2020; Wagner *et al.* 2019). Firstly, *Miscanthus* has the ability to accumulate heavy metals and degrade organic pollutants in the polluted soil. Planting it in the polluted land, the pollutants in this polluted soil can be effectively removed. For example, *Miscanthus* planting is often used for the mine restoration and its ecological remediation. Secondly, *Miscanthus* can be planted in such marginal lands as saline alkali land, wasteland, hillside land, and desertified land. It can not only protect the soil from wind and water erosion but also increase the organic and mineral nutrients available in its rhizosphere through the complex relationship establishment with the microbial community. Hence, the soil quality in these marginal lands has been comprehensively upgraded. Moreover, *Miscanthus* planting can increase the biodiversity. This is because the tall stands of M*iscanthus* can serve as cover and habitat for animals and insects, especially for birds and mammals. Anyway, the combination of *Miscanthus* planting and its environmental remediation and ecological improvement together makes it outstanding as an energy crop that stands out from other energy crops.

Although there are so many advantages, the commercially planting of *Miscanthus* is still facing great challenges. More efforts should be made to decrease its cultivation, harvesting, and processing costs. For its cultivation, novel agronomic methods as well as genetic improvements need to be adopted to reduce its establishment and management costs. Specific machinery items are needed to improve its harvesting and transportation efficiency. A bio-refinery process needs to be established for comprehensive utilization of its components and improvement its process economy. After the joint efforts of researchers, it is reasonable to expect that *Miscanthus* will become an important energy crop to meet the ever-increasing energy demand.

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