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From ornamental to essential: investigating applied drought in *Miscanthus sinensis*, sensitivity, response mechanisms, and subsequent recovery

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Abstract

This study investigates the impact and response mechanisms to drought in several genotypes of the ornamental species *Miscanthus sinensis* during its early developmental stages when it is most susceptible to adverse conditions. The sensitivity and response mechanisms under applied stress conditions and their subsequent recovery were examined. Detailed analyses were conducted to explore the physiological and biochemical responses to water deficit, pinpointing those contributing to tolerance, and charting the underlying carbon economy governing them. The findings demonstrate that *Miscanthus* possesses significant adaptive capabilities, which can be harnessed for agricultural and ecological applications on marginal lands. This research contributes to a broader understanding of plant resilience and supports the development of sustainable strategies for managing water scarcity in various ecosystems.

Keywords: drought, marginal lands, *Miscanthus sinensis*, ornamental plants, post-stress recovery

INTRODUCTION

Conventional oil production (crude oil and natural gas) is nearing its peak (Sorrell et al., 2010), and demand will shortly surpass the supply. The climatic change accelerated by carbon emissions from fossil fuel combustion is equally concerning (Wyman, 2008). The resulting disconcerts among economists and policymakers generate renewed interest in alternative "greener" energy to bridge the forecasted demand gap (Aleklett et al., 2009) and curb global warming. Renewable energy sources like solar, hydroelectric, and wind are being more purposely adopted by developed nations, notably to produce electricity and heat (International Energy Agency (IEA), 2000). This however was not successful in curtailing the growing need for fossil fuels in the transportation sector (Lund, 2007), which overshadows any other domain of energy usage; accounting for approximately 50% of the global oil consumption (ETP, 2008) and responsible for about a third of all greenhouse gas emissions (Wyman, 2008).

Alternatively, liquid biofuels, particularly bioethanol and biodiesel, are excellent candidates to replace fossil fuels as liquid energy carriers and can reduce carbon emissions into the atmosphere (Oumer et al., 2018). However, most produced liquid biofuels are first-generation (1G), derived from food crops (Shell, 2022). This has sparked ongoing debates about their impact on food security and prices, especially in developing countries that rely heavily on food imports. In contrast, second-generation biofuels (2G), produced from non-food feedstocks like dedicated energy crops, such as miscanthus, offer a less controversial alternative (Zhu et al., 2016).

Miscanthus sinensis are ornamental grasses used in gardens and landscaping thanks to their beauty and high adaptability to grow with little maintenance. Native to Asia, these grasses have become very popular, and several cultivars are now available for decorative uses in combination with other ornamental crops. Beyond its use as an ornamental plant,

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Miscanthus has been used as a phytoremediation plant and it has been considered for alternative uses as raw material for the paper industry and for the production of chemicals (Sa et al., 2021). Moreover, *Miscanthus* is considered a promising crop for biomass production (Hanna and Schwartz, 2020).

Miscanthus is highly regarded for its efficient water use and adaptability to diverse environmental conditions, making it ideal for cultivation on marginal soils. Drought is a primary factor contributing to soil marginality and is becoming more frequent and severe due to climate change. Developing drought-tolerant miscanthus genotypes would help maintain economically viable yields on lands susceptible to periodic water shortages.

To better understand the plant's response and tolerance mechanisms, pre-screen for better survivability at plot setup on marginal lands, and identify early stress biomarkers, we explored the genetic diversity in *Miscanthus sinensis* under drought conditions. In this paper, we summarized the results of previously published results (Al Hassan et al., 2022) indicating the resilience of an ornamental grass species to drought and its potential as a sustainable biofuel energy crop.

MATERIALS AND METHODS

The study investigated 24 *M. sinensis* genotypes from Wageningen University and Research, grown from rhizomes in controlled-environment chambers under specific temperature and humidity conditions (long-day photoperiod – 16 h of light – with irradiance kept at a minimum of 200 W m^{-2}, temperature averaging around 20°C, and air humidity set to a minimum of 80%). The experiment had two phases: a 3-week drought period and a 3-week recovery period (a harvest followed each). Plants were grown in a randomized block design with compartments for control and drought/recovery treatments. Soil moisture levels were monitored for uniform stress application. Biochemical and expressional analyses were conducted on collected leaves to study drought response mechanisms, while fresh and dry yields were measured after every harvest. For a detailed description of the biochemical assays, the reader should refer to our previous publication (Al Hassan et al., 2022).

RESULTS AND DISCUSSION

Generally speaking, drought significantly impacted *M. sinensis* growth, reducing fresh yield by 61%, dry yield by 19%, and stem count by 22%. Stem length decreased by 20% on average in stressed plants (Al Hassan et al., 2022). Drought sensitivity varied among the 23 studied genotypes (one genotype was discontinued from analyses and consequently discarded), forming three distinct clusters: mildly, moderately, and severely sensitive/affected. Responses included increased accumulation of osmolytes, such as proline and soluble sugars, likely to adjust osmotic potential. Proline levels rose significantly across the three created sensitivity clusters, with higher increases observed in more sensitive genotypes. Concurrently, chlorophyll degradation, indicative of oxidative stress, was pronounced in high-yielding genotypes, correlating with reduced growth parameters.

Biochemical adjustments involved dynamic starch and soluble sugar turnover, reflecting adaptive strategies. Resources were diverted from cell wall synthesis, reducing cell wall content under stress to support osmolyte synthesis, aiding osmotic balance and drought tolerance. Post-drought recovery showed significant genotypic differences, with more efficient recovery linked to better drought avoidance. Key recovery indicators included restored hydraulic status and reactivation of growth processes. This variability in drought response underscores the importance of genetic diversity in breeding programs for drought-prone areas, highlighting the potential for selecting and developing more resilient *M. sinensis* genotypes.

CONCLUSIONS AND FUTURE PERSPECTIVES

This study highlights the importance of drought avoidance through minimized water loss in *M. sinensis*, despite a significant yield penalty in vigorous genotypes due to the trade-off between growth under favourable conditions and stress performance. Early stress biomarkers, including chlorophyll degradation and proline accumulation, were confirmed, along with changes in carbon allocation, evidenced by increased soluble sugars and amino acids at the expense of cell wall biosynthesis. Post-drought recovery involved rehydration and deactivation of stress responses. Future research should focus on developing drought-tolerant biofuel crop varieties and investigating the legacy effects of drought on yield and feedstock quality.

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