Taxonomic evaluation of *Miscanthus nudipes* (Poaceae) based on morphological and molecular evidence

HONG-ZHENG MA¹,², ZHE CAI¹, FU-MIN ZHANG³, HUI ZHANG³, SONG GE³, SI-LAN DAI*¹ & WEN-LI CHEN*²

¹College of Landscape Architecture, Beijing Forestry University, Beijing 100083, P. R. China
²State Key Laboratory of Systematic and Evolutionary Botany, Institute of Botany, Chinese Academy of Sciences, Beijing 100093, P. R. China
*Authors for correspondence: WEN-LI CHEN, chenwl@ibcas.ac.cn; SI-LAN DAI, silandai@sina.com

Abstract

*Miscanthus* species including the famous energy plant *M. × giganteus* are considered to be second-generation energy crops. *Miscanthus nudipes* is an endemic species from Himalaya-Hengduan Mountains and provides important germplasm for *Miscanthus* breeding given its high tolerance to frost and drought. However, the taxonomy of this species remains controversial in terms of intraspecific classification, with one to nine subspecies or species recognized previously. The variation patterns of the morphological characters are not understood clearly as there have been no intensive analyses of the morphological variation across individuals and populations. Here, by sampling 15 natural populations from the entire distribution area of *M. nudipes*, we investigate patterns of population variation based on 39 quantitative and nine qualitative morphological characters and 14 microsatellite loci, with the aim to provide a reliable taxonomic treatment of this important species. Morphological analyses from ANOVA, UPGMA and PCA indicate that *M. nudipes* populations show significant differences between the Himalayas and Hengduan Mountains. A neighbor-joining tree and principle coordinates analysis of the microsatellite data support the results of the morphological analyses. Based on our results, we recognize two subspecies under *Miscanthus nudipes* (*M. nudipes* subsp. *nudipes* and *M. nudipes* subsp. *yunnanensis*) and provide a taxonomic treatment for the species. We propose three diagnostic characters for the subspecies identification, i.e., the ratio of callus hair length to spikelet length, the hairiness of the panicle axis and the hairiness of the peduncle.

Keywords: classification, Hengduan Mountains, Himalayas, morphology, microsatellite markers

Introduction

Lignocellulosic-based ethanol is referred to as second-generation biofuel. It is a better choice than starch and sugar-based ethanol in temperate regions, and may play an essential role in reaching the target to replace petroleum-based fuels in the future (Yuan *et al.* 2008). The genus *Miscanthus* Andersson (1855: 165) is known for having potential in developing second-generation energy crops in marginal and degraded land (Beale & Long 1995, Clifton-Brown *et al.* 2008, Yan *et al.* 2012). Some *Miscanthus* species have been cultivated and show excellent potential to offset gasoline and CO₂ emissions from petroleum (Heaton *et al.* 2008). However, their low frost and drought tolerances results in low survival rate in degraded land (Jørgensen & Schwarz 2000, Yan *et al.* 2012), which substantially restrict the cultivated area of this crop and reduces its biomass productivity (Yan *et al.* 2012).

*Miscanthus* consists of more than 10 species distributed across the Old World continents and harbors a high level of genetic variation (Clifton-Brown *et al.* 2008, Yan *et al.* 2012, Yook *et al.* 2014). The morphologically similar species *M. nudipes* (Grisebach 1868: 92) Hackel (1889: 109) and *M. nepalensis* (Trinius 1833: 333) Hackel (1889: 104) are distinguished from other *Miscanthus* taxa by stamen number (two vs. three; Chen & Renvoize 2006, Sun *et al.* 2010) and chromosome number (n=20 vs. 2n=38; Mehra & Sharma 1975), and are treated as *Miscanthus* sect. *Diandranthus* Keng (1959: 748) or *Miscanthus* subgen. *Diandranthus* (Liou 1987: 308) Sun & Lin (2010: 206). Liu (1997) argued that stamen number is a very important character and separated these two–anther species from *Miscanthus* as a new genus, *Diandranthus* Liou (1987: 308). *Miscanthus nudipes* and *M. nepalensis* are the only *Miscanthus* members endemic to the Himalaya-Hengduan Mountains and provide important germplasm for *Miscanthus* breeding given its high tolerance to frost and drought.
Amended morphological description:—Peduncle and panicle axis glabrous. Panicle 6.9–20.4 cm long, 1.0–15.1 cm wide; axis 1.7–17.1 cm long. Spikelets 3–6.9 mm long, 0.4–1 mm wide, awned; callus hairs 0.8–5 mm long, white. The ratio of callus hair length to spikelet length less than 0.65.

**Distribution:**—Guizhou (1000–1500m), Sichuan (1400–3400m) and Yunnan (1750–3300m) in China.

**Acknowledgements**

We thank Si-si Huang and Xiao-xia Gao from College of Landscape Architecture in Beijing Forestry University for their contribution in morphological characters measurement. Special thanks are due to Prof. Xiang-yun Zhu for helpful discussion. This study was supported by the Chinese Academy of Sciences (KZCX2-YW-034) and the National Natural Science Foundation of China (31470300, 91131902, 31070168).

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