Reintroduction of *Trigonobalanus doichangensis*, a Threatened Plant Species with Extremely Small Populations

Weibang Sun, Fengrong Li, and Yuan Zhou

Abstract Based on the comprehensive studies on the conservation biology of *Trigonobalanus doichangensis*, a globally threatened plant species with extremely small populations (PSESP), some 247 2-year-old saplings propagated from seeds were planted into its originally distributed site (99°44′57.5″E, 22°28′43.0″N and altitude of 1352 m) in south Yunnan province of China in September 2007. In cooperation with the local Forestry Bureau of Lancang County and a local family near the site, the necessary aftercares, monitoring, and data collecting have all been continuously carried out, around 50% of the survived plants bloomed and fruited in 2015. Twelve years after planting in September 2019, a survival rate of 46.56%, an average height increase of 7.89 m, and an average base diameter increase of 5.40 cm of *T. doichangensis* were all recorded and documented. Certainly, this successful reintroduction practice can be a template for accelerating the multiple-scale population restoration of *T. doichangensis* in China.

Keywords *Trigonobalanus doichangensis* · A threatened tree with extremely small populations · Reintroduction · Flowered and fruited · A template for population restoration

1 Introduction

The broadly circumscribed genus *Trigonobalanus* includes three species: *Trigonobalanus verticillata* from Sulawesi, Borneo, and the Malay Peninsula; *T. excelsa* from the tropical forests of Colombia, South America; and *T. doichangensis* distributed in Southern China and northern Thailand (Hsu et al.

W. Sun (✉) · F. Li · Y. Zhou
Yunnan Key Laboratory for Integrative Conservation of Plant Species with Extremely Small Populations, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming, Yunnan, China
e-mail: wbsun@mail.kib.ac.cn

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1981). Alternatively, on the basis of the unique pollen (peroblate shape and presence of endoaperature) of *T. doichangensis*, whorled phyllotaxy with interpetiolar stipules in *T. verticillata*, and lack of bud scales in *T. excelsa*, Nixon and Crepet (1989) proposed dividing the genus into three monotypic genera: *Formanodendron*, *Trigonobalanus*, and *Colombobalanus*, respectively (Sun et al. 2011). *T. doichangensis* was firstly recorded in China in 1981 (Hsu et al. 1981), and it was listed as "a second-class protected key wild Plants of China (First Group)" (Yu 1999), evaluated as a globally endangered species (Sun et al. 2006, 2011), and as one of the 231 targeted species in a China's National Key Program: Survey and Germplasm Conservation of Plant Species with Extremely Small Populations in Southwest China (grant number: 2017FY100100) (Yang and Sun 2017; Sun et al. 2019). *T. doichangensis* is an evergreen tree narrowly distributed in the evergreen broadleaf forests in southern Yunnan and Chiang Rai in northern Thailand at an altitude of 1000–1900 m (Sun et al. 2011). In China, only the populations located in the national natural reserve in Cangyuan county of Yunnan have been well protected, while other populations/individuals have been seriously threatened due to the agricultural land expansion and cuttings for fuelwood and agricultural tools and invaded by the invasive species such as *Chromolaena odorata* and *Tithonia diversifolia* (Fig. 1, Sun et al. 2006, 2011).

2 Description of Reintroduction

2.1 Feasibility

We have studied the seed and seed germination biology (Zhou et al. 2003; Zheng and Sun 2008; Zheng et al. 2009; Chen et al. 2011), population biology, ecology and reproductive biology (Sun et al. 2004, 2006), cytology (Han and Sun 2005; Chen et al. 2007; Chen and Sun 2010), and genetic diversity (Sun et al. 2007) of this endangered species. We have also comprehensively summarized the progress and perspectives of conservation biology on *T. doichangensis* (Sun et al. 2011). Meanwhile, the propagation techniques on seed sowing, cuttings, and tissue culture were obtained, and more than 2000 saplings of *T. doichangensis* from four populations (Menglian, Lancang, Ximeng, and Cangyuan) from south Yunnan and one population from Chiang Rai in northern Thailand have been successfully propagated and ex situ conserved at Kunming Botanical Garden (KBG) under Kunming Institute of Botany, Chinese Academy of Sciences. Some ex situ conserved Plants at KBG have started to bear flowers and fruits since 2010.

2.2 Implementation

In September 2007, in cooperation with Botanic Gardens Conservation International (BGCI) and Forestry Bureau of Lancang County in China's Yunnan province,

Fig. 1 Habitat destruction of *Trigonobalanus doichangensis* caused by agricultural land expansion (**a**), cuttings for fuelwood and agricultural tools (**b**), and invasive species of *Chromolaena odorata* (**c**)

247 2-year-old individuals of *T. doichangensis* from different populations have been planted in the farmland belonging to the Banli village, Donghui town of Lancang County (Fig. 2). We were told that the farmland (reintroduced site) was used to be virgin forest, in which *T. doichangensis* was distributed. The geographical location of the reintroduction site is 99°44′57.5″E, 22°28′43.0″N, and its altitude is 1352 m above sea level.

Fig. 2 The reintroduced 2-year saplings of *Trigonobalanus doichangensis* (**a**), planting (**b**), and group photo (**c**)

Fig. 2 (continued)

2.3 Post-planting Monitoring

Under the supervision of Forestry Bureau of Lancang County, one family in Banli village was responsible to maintain the reintroduced plants without damage from people and animals and necessary watering and weeding. We have comprehensively monitored the survival, height, diameters of stem base, and the trunk 1.3 m above the ground (if the plants are big enough) every year from 2007 to 2011 (Fig. 3) and every 2 years from 2011 to 2019. The reintroduced plants were growing well, with about 50% of the surviving individuals having bloomed and fruited in 2015 (Fig. 4). By September 2019, the survival rate was 46.56%, the average plant height was 8.84 m (an average height increase of 7.89 m), and the average base diameter was 6.07 cm (the average increase of 5.40 cm). In summary, this reintroduction project provides a template for the multiple-scale population restoration practices for *T. doichangensis* and even other threatened woody plants in China.

3 Problems and Recommendations

- To make this reintroduction truly successful, the long-term maintenance, monitoring, and data documentation and analysis on blooming/fruiting and population regeneration and expansion of *T. doichangensis* are essential.

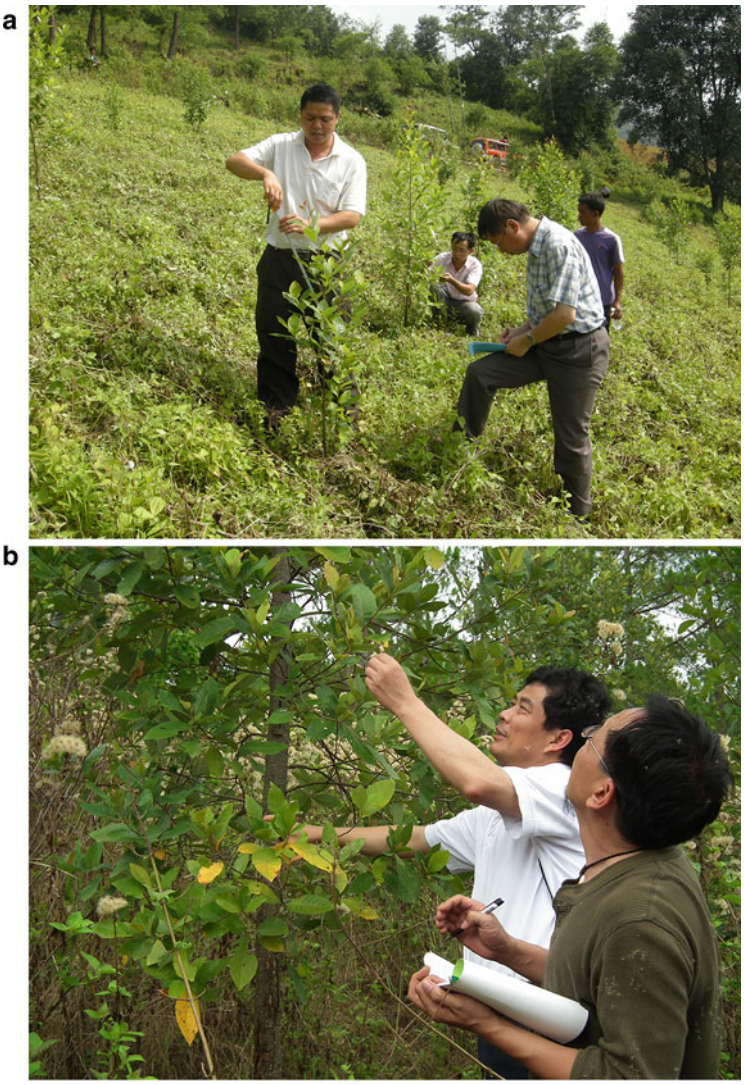

Fig. 3 Monitoring and data collecting of *Trigonobalanus doichangensis* in 2009 (**a**) and 2011 (**b**)

- It is also very important to get funding or project supports to continue the cooperation with local forestry departments and communities. This might be another challenge.
- More reintroductions or reinforcements for *T. doichangensis* based on the practice of this demonstration project might be urgently needed for effective conservation of the species and its populations.

Fig. 4 The flowered and fruited plant (**a**), inflorescence (**b**), and infructescence (**c**) of *Trigonobalanus doichangensis*

- To alternatively protect *T. doichangensis* (even the reintroduced plants), it might be also necessary to create the artificial plantings to meet local residents' needs for fuelwood and agricultural tools.

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