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論文名	「Studies on Diversity and Conservation of the Genus <i>Begonia</i> L. (Begoniaceae) in China（中国におけるベゴニア属（シュウカイドウ科）の多様性と保全に関する研究）」
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論文要旨

The understanding of the diversity and ecological nature of a plant group is fundamental necessity for conservation and sustainable use of plant and genetic resources. The genus *Begonia* L. is among the ten most species-rich angiosperm genera and has approximately 1,500 species comprising nearly all the species of the family Begoniaceae. It is considered as one of the most diversified genera in morphological characters and habitats among the plant kingdom. The genus is mainly distributed in tropical and subtropical regions in Central and South America, Africa and Asia. Begonias are the famous ornamental plants.

China is one of the richest regions of *Begonia* species in the world. Studies on Chinese begonias have been continuously carried out since 1940s. A detailed review of these studies revealed discrepancies and uncertainties in sectional and specific assignment. There were 255 *Begonia* species (legitimate taxa by 2006) described in China. However, there is no clear systematic classification of them. It is, therefore, scientific and pragmatic merit to clearly delimit the species and systematic revision of the Chinese *Begonia*.

Since previous researches on Chinese *Begonia* merely focused on systematical taxonomy, a comprehensive study on its biodiversity would be of great significance

to the effective conservation and sustainable utilization as genetic resources. The present study aims to revise the known species, acquiring more basic scientific data of specific, genetic and ecological diversities as well as the threatened status of *Begonia* in China and accumulation of basic knowledge of horticulture.

Based on the published papers, herbarium specimens and field investigations as well as observation on the live plants cultivated in the begonia house of Kunming Botanical Garden, 210 taxa (including species, subspecies and varieties) were recognized as real representatives of *Begonia* in China. The majority of Chinese *Begonia* species are distributed in the provinces and regions south of the Changjiang River, especially in southwest China. The natural distribution of *Begonia* in China ranges from 90 m to 3,400 m above sea level. Over 190 *Begonia* species grow in the areas of 700-2,000 m in altitude. It was confirmed that the majority Chinese *Begonia* species are typical subtropical plants.

The Chinese *Begonia* has high morphological diversity in its growth habit, leaf, inflorescence, flower, fruits and seed. The leaf anatomy was studied on thirty species in China. The leaf constitution characters were highly variable among inter-section, unable to use for discrimination of sections. However, similarity of leaf constitution was recognized between the species within the horticultural classification groups. The micro-morphological study on seeds of 68 species indicated high interspecific diversity but unable to use at sectional level.

The chromosome numbers of 14 species were newly described. Cytological review showed high diversity of Chinese *Begonia* in chromosome numbers. The diverse chromosome numbers suggested that aneuploidy and polyploidization may have played an important role on the speciation of *Begonia*.

The threatened status of Chinese *Begonia* was determined on the basis of IUCN Red List Categories and Criteria (Version 3.1). Among 210 Chinese *Begonia* taxa, 126 are critically endangered (CR), 45 endangered (EN), 28 vulnerable (VU), 4 near threatened (NT), 4 least concern (LC), 1 extinct (EX), and 2 data deficient (DD). The results suggested that both external and internal factors cause to the threat of endangered *Begonia* species in China. The main external cause is owing to the decrease of natural forests and human activities. The internal cause is the

extremely local distribution of *Begonia*. Around 60% of the Chinese *Begonia* species are known only from single localities, and some of their populations are very small.

In an endangered species, *B. parvula*, pollination and reproductive nature were monitored. *B. parvula* is insect pollinating and its four most frequent flower visitors were *Halictus* sp., *Luciola sericata*, *Amellia* sp. and *Nomia* sp. The efficient visitors discriminated female flowers. *B. parvula* could reproduce by particular bulbils, which were produced from the vein of back surface of leaves. This phenomenon is unique to this species. That the flower visitors discriminated female flowers explained the fact of not many fertile seeds and seedlings of this species in the wild. The fertilization of female flowers of *B. parvula* is highly dependent on pollinator visits suggesting variation of pollination impacts on the reproduction.

The survival status of 277 introductions, including 146 species and/or taxa of Chinese *Begonia*, under cultivation was examined. Eighty-nine introduced species could healthily or normally grow in Kunming, which occupied 61% of the total introduced species. Fifty-five introduced species (ca. 38%) could survive in the begonia houses, slightly damaged either by frost or heat, and the majority of them grew again next year.

The Chinese *Begonia* species were classified into three horticultural groups on the basis of their morphological characteristics and growing habits. Among 210 taxa of *Begonia* in China, 131 species belong to rhizomatous type, 44 erect-stemmed type, and 35 tuberous begonias. Some Chinese *Begonia* species were suggested to have a high ornamental merit. And some are precious genetic resources for breeding purpose. The species like *B. asperifolia* and other species growing in high altitude will be valuable genetic resource for development of cold resistant cultivars. The species like *B. silletensis* will be used for breeding of scented begonia cultivars.

The majority Chinese *Begonia* can be propagated by sexual or vegetative propagation. However, some species were difficult to propagate. Tissue culture of ten species with high ornamental value or difficult naturally to propagate was unsuccessful. Most begonias could grow well in humus or compost soil with pH 6.0-6.8. Suitable temperature is around 20°C for growing most begonias. Some Chinese *Begonia* species were damaged by a temperature below zero, despite a high

temperature (above 34°C) didn't cause serious damage. The hybridization experiments showed high interspecific cross-compatibility. Twenty new begonia cultivars were bred and registered through hybridization or selection of spontaneous mutants including one scented cultivar.

Twenty-six Chinese *Begonia* species were used traditionally as medicine, food, beverage and pig feed. The antimicrobial activity of volatile emissions was recognized in 16 Chinese *Begonia* species to *Staphylococcus epidermidis*, *Escherichia coli* and *Candida albicans*, respectively. Begonias may be used for medicinal and ecological phytodesign.

Two hundred and ten taxa of *Begonia* were recognized as real representatives in China. The Chinese *Begonia* has high specific, genetic and ecological diversities. Around 81% of the species are endangered. Both external and internal factors cause to the threat of endangered *Begonia* species in China. The majority species can be protected by *ex situ* conservation. Many species have ornamental merit or are important genetic resources. The results in this study are considered to be much useful for sustainable use of genetic resources and for effective conservation of endangered species in the genus *Begonia*.

審査結果の要旨

ベゴニア属植物は 1500 種を含む世界の 10 大属のひとつで、形態および生態ともに多様性高く、観賞用をはじめとして有用かつ自然資源として重要な群である。中国はその多様性中心のひとつで、約 255 種が亜熱帯を中心に記録されている。このような植物の有効利用や遺伝資源の活用には、その多様性と生態を十分に把握する必要がある。本研究では、中国の自生ベゴニアについて分類学的整理、形態的多様性および細胞遺伝学的特性の評価、稀少種としての現状把握、導入評価手法や保全手法にわたって網羅的に研究を行い、資源植物の多様性の保全と活用について考察している。

まず、ベゴニア属植物について資源植物学上のこれまでの情報と分類学的研究を整理した後、中国に実存する種を 210 種（分類群）と査定し、それらの大多数が長江以南に分布し、標高 90m から 3400m におよぶベゴニア属の垂直分布のうち 190 種が標高 700m から 2000m の亜熱帯気候帯に生育分布することを指摘した。次に、形態的生態的多様性について考証し、生活型、葉形、花序、花器、果実、種子について外部形態、組織、表面構造がベゴニア属においては極めて多様で、種としてのまとまりはみられるものの従来の属内分類として提唱されていた節とは対応しないことを明らかにした。細

胞学的研究では 14 種の染色体数をあらたに明示するとともに、従来から調査していた中国産ベゴニア属植物の染色体変異と全世界の種の染色体数の変異パターンを分析し、大陸間で基本染色体数を異にする基本 2 倍体種から倍数化と異数性をともなった種分化によってベゴニア属の多様化がすすんだと考察している。

また、フィールド研究に基づいて中国に自生するベゴニアについて種ごとに稀少化・絶滅の程度を国際自然保護連合の国際基準に従って分析し、210 種のうち、126 種はレッドリストカテゴリーの絶滅危惧 I A 類 (CR) に、45 種は絶滅危惧 I B 類 (EN) に、28 種は絶滅危惧 II 類 (V N) に、4 種は準絶滅危惧 (NT) に、さらに 4 種は LC にあたり、1 種は絶滅 (EX) し、2 種は情報不足 (DD) にあたるとし、ベゴニア属植物の稀少化や絶滅の原因には人間活動による影響の大きいことを指摘している。希少種のうち、*B. parvula* においては種生物学的解析を行い、送粉者の行動実態、花の性分化の生態学的意義、送粉者欠乏にともなう有性繁殖からの逃避など、希少種にみられる特性の進化を考証した。

さらに、中国産ベゴニアの 146 種について 277 回の昆明植物園への導入試験を行い、61% にあたる 89 種は導入可能で、55 種 (38%) は通常の条件で維持できることを明らかにした。生育形については 130 種が園芸品種分類系における根茎型、44 種が直立茎型、35 種が球根型にあたりと査定し、その特性は良くまとまった傾向を示し、この分類系による評価がベゴニアの園芸的利用のうえでは極めて有効であるとしている。中国産ベゴニアの栽培方法についても分析し、育成に適切な土壌条件や温度条件を明らかにし、繁殖方法も分析している。また、いくつかの種については交雑実験を行い、種間交雑親和性の程度を明らかにするとともに、交雑による具体的な育種を試み、多数の新品種を育成し、ベゴニアにおける実際育種の基盤を構築した。

中国産ベゴニアは、観賞用として使われるだけでなく、多面的な有用性をもつことを、フィールド研究と耐菌性試験によって明らかにし、伝統的には様々な種が食用、薬用、醸造、飼料用に使われることと、その耐菌性の高い種においては室内デザイン植物としての意義を指摘した。

以上のように本論文は、これまで不明瞭であった中国のベゴニア属植物の分類、形態、生態、遺伝的特性、資源価値に関する実態を包括的に明らかにするとともに、多様性の保全と遺伝資源としての意義を考究している。本論文のモノグラフ的成果は、遺伝資源の保全と活用を含む資源植物多様性学および生態保全学における学術基盤を構築するだけでなく、育種学、植物分類学、景観植物学など、植物バイオサイエンスとその関連領域へ大きく貢献すると考えられる。したがって、学力確認試験の結果と併せて、申請者に博士 (応用生命科学) の学位を授与することを適当と認める。