PLANT GERMPLASM REPORT

Collection of Low-Maintenance Turf Germplasm and Seed/Scientific Exchange with China

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Summary: Plant germplasm from China is needed to expand existing germplasm for the improvement of low-maintenance turf grasses for farms, urban areas, roadsides, parks, and golf courses. Currently such germplasm is poorly represented in U.S. and Chinese genebanks. During July and August 2006, Dr. Gu Anlin and cooperating scientists from the Grassland Research Institute (GRI) in Huhhot, Inner Mongolia collected seed of various grasses (*Agropyron, Agrostis, Bromus, Festuca, Leymus,* and *Poa* genera) from central and northern Inner Mongolia. Accompanying passport data were also collected. Expenses for the collection trip were shared equally between the U.S. and China. Johnson and Majerus traveled to China on 19 October 2006 and exchanged 333 accessions of various grasses, legumes, and shrubs (mainly from the National Plant Germplasm System, NPGS) with GRI scientists. Johnson and Majerus also presented a series of lectures concerning germplasm collection, preservation, and utilization in the U.S. They worked with Dr. Gu to process the seed collections and obtain an export permit and Phytosanitary Certificate for the 125 seed collections that were permitted out of China. An additional 40 seed collections of *Zoysia japonica* collected in seven provinces of China were also sent to the U.S. in December. Plans were made for four Chinese scientists to visit the U.S. during June 2007 to observe ongoing plant breeding and improvement programs. Although major challenges exist concerning germplasm exchanges with China, their probability of success can be improved by making collections part of a broader, more comprehensive exchange project.

Johnson and Majerus returned to the U.S. on 5 November 2006, and the Chinese seed collections were delivered to Homeland Security inspectors at the San Francisco International Airport who sent them to the USDA Plant Germplasm Quarantine Center in Beltsville, Maryland. The collections were inspected, released, and forwarded to Logan for final seed cleaning and processing. A portion of the seed will be used at Logan to: 1) develop improved low-maintenance turf for use in the Intermountain Region of the western U.S., 2) conduct physiological and ecological studies to identify accessions with unique adaptations to low-maintenance conditions, and 3) conduct molecular studies to determine the structure of genetic diversity as well as genomic and phylogenetic relationships within the Gramineae. The collections of *Zoysia japonica* were sent directly to the Southern Region Plant Introduction Station in Griffin, GA, where the seed was processed and sent for seed increase to Dr. Milt Engelke at the Texas Agricultural Experiment Station in Dallas, TX. The other 125 seed collections will be sent to the Western Region Plant Introduction Station in Pullman, WA. Both sets of seed accessions will be incorporated into NPGS and be made freely available to users around the world.

Recommendations: Additional seed collections are needed from China and other Central Asian countries for low-maintenance turf germplasm improvement programs. Collaborative collections should be undertaken to ensure that germplasm from this part of the world is preserved and available for future generations.

Acknowledgments: We thank Dr. Gu Anlin from GRI who planned, organized, and facilitated all aspects of our seed exchange project. Dr. Gu's hard work and dedication were instrumental in obtaining the necessary approvals from the Ministry of Agriculture and Chinese Academy of Agricultural Sciences (CAAS) for conducting the seed exchange, and securing Export Permits and a Phytosanitary Certificate for the seed. Appreciation is also extended to Mr. Chen Li Bo, Zhao Lianpeng, Wang Yuqing, and other staff at GRI; Drs. Rong Yuping and Mao Peisheng at China Agricultural University in Beijing; Drs. Han Guodong, Yi Jin, and Yun Jinfeng at Inner Mongolia Agricultural University in Huhhot; and Dr. Gao Hongwen at the Institute of Animal Science in Beijing. Thanks also to Dr. Liu Jianxiu from the Jiangsu Province and Chinese Academy of Sciences Institute of Botany in Nanjing for providing the collections of *Zoysia japonica.*

Germplasm Collection/Exchange Challenges with China: Originally, we proposed to join GRI scientists for seed collection in Inner Mongolia; however, MOA officials did not approve of us joining the collection effort. After considerable negotiation between Dr. Gu and MOA officials, it was agreed that GRI scientists could conduct the collection and we could share in the collections if the U.S. side provided half the collection expenses ($5,000). As part of the exchange, we also facilitated GRI's request for 333 seed collections from NPGS. We also presented a series of lectures on germplasm-related topics at GRI with airfare paid by the U.S. side, and meals and lodging paid by the Chinese side. In June 2007, four GRI scientists will travel to the U.S and participate in a two-week visit to various U.S. germplasm facilities with airfare paid by the Chinese side, and meals and lodging paid by the U.S. side.

Dr. Gu had to overcome numerous hurdles to obtain approvals from the Ministry of Agriculture

(MOA) for the seed exchange. Dr. Gu tried to get approvals for the various grass species prior to her two collection trips in July and August; however, MOA officials would not provide prior approval. Although the endemic species list is available on the web, this list does not include all the species that are restricted for exchange. MOA's comprehensive, restricted species list is confidential, and even Chinese scientists do not have access to this list. We did not receive final MOA approval for the allowable seed collections until two days after we arrived in Huhhot. Some of the restricted genera (including *Festuca, Puccinellia,* and *Melica*) are widespread in Central Asia. Although some MOA officials agree that the current restricted species list is too restrictive, they indicated that the list probably will not be revised for several years. Chinese scientists must follow MOA regulations to avoid harsh penalties (fines, job loss, or even prison). Many Chinese scientists do not want to get involved in germplasm exchange projects because of the time and effort involved in obtaining the required approvals. Before obtaining final approval for the Phytosanitary Certificate in Huhhot, Ministry of Forestry officials had to certify that the 125 seed accessions were not sensitive forest species.

Technical Report

Introduction

China's biodiversity: China has unique biodiversity, which has been summarized according to the following key points (State Environmental Protection Administration of China, 2006):

1) Species richness- China possesses more than 30,000 species of higher plants and has 2,200 species of bryophytes (9 % of the world's total). China has 52 families of ferns with 2,200 to 2,600 species, which comprises 22 % of the world's total. The world's gymnosperms comprise 15 families, 79 genera, and about 850 species, and China alone has 10 families, 34 genera, and about 250 species of gymnosperms. China is the most species-rich country in the world for gymnosperms.

2) Endemic genera and species- Large numbers of ancient and relic species (paleoendemic genera and species) and also newly produced species (neoendemic species) exist within China. For example, species known as "living fossils" include: *Ailuropoda melanoleuca, Lipotes vexillifer, Metasequoia glyptostroboides, Ginkgo biloba, Cathaya argyrophylla, Cycas panzhihuaensis,* and others. There are 17,300 endemic species of higher plants in China, which constitute more than 57 % of China's total number of higher plants.

3) Ancient origin of China's flora- Because most parts of China rose above sea level after the end of the Mesozoic era and during the Quarternary Period, China's land was not subjected to continental ice sheets. As a result, ancient and relic elements of the Cretaceous and Tertiary Periods are preserved in various areas of China. For example, pines and firs appeared in the late Palaeozoic, thrived in the Mesozoic, and began to decline in the Tertiary Period. However, their distributional ranges were reduced greatly during Quaternary glaciation. Consequently, six out of the total of seven of these families in the world are found in China.

4) Rich germplasm resources of cultivated plants- The history of agriculture in China goes back more than 7,000 years. Since early times, Chinese have engaged in utilizing, cultivating, and breeding the rich and varied genetic resources contained in the diverse natural environments of China's vast territory. The richness of China's cultivated plants are unequaled in the world. Not only did many plants on which human survival depends originate in China, but China also still contains large numbers of their wild relatives. For example, China is one of the origins of rice (*Oryza sativa*) with about 50,000 local varieties, and soybean (*Glycine max*) with about 20,000 local varieties. More than 11,000 species of medicinal plants have been discovered in China, and about 4,215 species of forage plants have been recorded. In addition, China is the origin of 30 genera and 2,238 species of ornamental plant species.

China's rangeland ecosystems: Of China's total land area of 960 million hectares, 400 million hectares (about 42 % of the country) are classified as rangelands. Geographically, 42 % of China's rangelands are located in the Tibetan Plateau Region; 37 % are found in the temperate steppe of northern China (Inner Mongolia and Xinjiang); and 21 % are found in southern and eastern China. The arid rangelands of China, which includes the grazing lands across northern China and the Qinghai-Tibetan Plateau, encompasses about 311 million hectares (3.1 million km^2) or 32 % of China's total land area (Table 1). This enormous land area (equivalent to 4.5 times the area of Texas) has a wide variety of climatic and topographic features that have led to considerable diversity in species that have potential for low-maintenance turf applications.

Table 1. Rangeland areas in northern and western China by province.

Province/Region	Area (million ha)	Total rangeland (million ha)	% of province in rangeland	Useable (million ha)	%
Inner Mongolia	118.3	86.7	73.3	68.0	78.4
Tibet	120.0	84.0	70.0	67.2	80.0
Xinjiang	160.0	57.3	35.8	48.0	83.7
Qinghai	72.1	38.6	53.5	33.5	86.8
Gansu	45.0	16.1	35.8	9.7	60.2
Sichuan	23.6	13.9	58.8	--	--
Heilongjiang	45.4	7.5	16.5	4.8	64.0
Ningxia	5.2	3.0	57.7	2.6	86.6
Liaoning	14.6	2.0	13.7	--	--
Jilin	18.7	1.9	10.2	1.3	68.4
Total	622.9	311.0	49.9		
China (total)	960.0	400.0	41.7		

Adapted from National Research Council, 1992.

The rangelands of China display highly distinctive species and ecological processes, and a number of China's rangeland areas are included in the World Wildlife Fund's Global 2000 Ecoregion Priority List. These ecoregions include the Daurian Steppe in northeastern Inner Mongolia, the Tibetan Plateau Steppe, and the Middle Asian Mountain Temperate Forest and Steppe in Xinjiang. In addition, the Sichuan-Yunnan Temperate Forests Ecoregion on the southeastern edge of the Himalayan Foothill Region, contains extensive rangelands and forested grazing lands. The Tibetan Plateau alone has 85 % of its area lying above 3,000 m and is the highest and most imposing plateau on earth. Some 2.5 million km^2 in size, the Tibetan Plateau is about one-third of the continental U.S. In post-glacial times, during the Holocene, there have been three wet periods and four dry periods in the past 10,000 years on the Tibetan Plateau. The past 3,000 years have become both drier and colder, and plants growing there have had to adapt to these adverse growing conditions. Adaptations for growth under dry, cold, and low-fertility conditions are of particular interest for low-maintenance turf applications.

Northern China is a climatic and topographic analog of the Intermountain Region of the western U.S. This region of China has vast arid rangelands, deserts, high mountains, saline soils and lakes, and fertile valleys very similar to those of the western U.S. Past disregard for the carrying capacity of rangeland resources in Inner Mongolia and other parts of northern China led to severe overgrazing and subsequent removal of critical plant cover from vast areas. This led to soil erosion and progressively more serious dust storms in the 1990s. In 2000, the dust storms became so severe and extensive that they darkened the skies above Beijing for several weeks, similar to the Dust Bowl era in the U.S. These dust clouds reached North America and had global consequences. This situation received the attention of political leaders in the Central Chinese Government who undertook unprecedented measures to restore plant cover and reduce erosion on the rangelands of northern China. The Chinese Government imposed grazing restrictions in the eroded areas of Inner Mongolia and northern China after 2000. They are also providing economic incentives including new houses and animal facilities to move herders and farmers out of severely degraded areas. These policies are beginning to stabilize the overgrazed, eroded areas responsible for the dust storms.

Germplasm available in NPGS prior to the collection/exchange trip: Prior to our collection/exchange trip, only 103 collections of targeted genera (*Agrostis, Festuca, Koeleria*, *Poa,* and *Puccinellia*) from China were available in NPGS. Of these, 62 accessions were from Xinjiang Province, 30 accessions were from Sichuan Province, and 11 accessions were from Gansu Province. No collections were available from Inner Mongolia. With China also having relatively few accessions of turf species in their genebanks, collected low-maintenance grass germplasm from Inner Mongolia will more adequately represent the genetic diversity of turf species from northern China in both U.S. and Chinese genebanks.

Trip Details

Objectives: The main objective of the trip was to collect seed of *Poa, Agrostis, Festuca, Koeleria,* and *Puccinellia.* These species have been exposed to heavy grazing for thousands of years in Inner Mongolia and, therefore, likely have developed tolerance to defoliation. Other important characteristics include seedling establishment, production, and persistence of high quality turf under low precipitation, minimal fertility, salinity, and cold temperatures.

Collection Route (Figure 1)

8-21 July 2006 (blue line): The route for the July collection went through the following counties: Wuchuan, Siziwang, Suniteyou, Xilinhot, Baiyinxile (Xilinguole), Keshiketeng, Kezuozhong, Changling (Jilin Province), Aohan, Hongshan, Songshan, Wengniute, Keshiketeng, Xincheng District (Huhhhot), and Wulateqian.

18-31 August 2006 (red line): The route for the August collection went through the following counties: Huhhot, Abaga, Xilinhot, Dongwu, Xing'an Meng, Xinba'erhu Zuo, Ewenk, Chenba'erhu, Erguna, Hulunbeier Meng, Zhalantun, Arong, Alukerqin, Balinyou, Linxi, Keshiketeng, Zhenglan, and Taibusi.

Collections made in Inner Mongolia: Seed was collected across a broad diversity of plant communities in central and northern Inner Mongolia. A total of 187 collections were made during the two collection trips. We were allowed to take 123 of those collections, plus two other accessions from the GRI Genebank (for a total of 125 accessions, Table 2) back to the U.S. Dr. Gu also supplied hard copies and electronic files of the passport data for each of the allowable collections. The U.S. portion of the collected seed will be sent to the Western Regional Plant Introduction Station at Pullman, WA for incorporation into NPGS. Collected accessions from Inner Mongolia will be grown in field plots at Logan, UT and used to: 1) develop improved low-maintenance turf for use in the Intermountain Region of the western U.S., 2) conduct physiological and ecological studies to identify accessions with unique adaptations to low-maintenance conditions, and 3) conduct molecular studies to determine the structure of genetic diversity, and genomic and phylogenetic relationships within Gramineae.

Collections of *Zoysia japonica*: Dr. Liu Jianxiu from the Jiangsu Province and Chinese Academy of Sciences Institute of Botany in Nanjing provided collections of *Zoysia japonica* that he had collected in 2005. These were collected in seven provinces including: Anhui, Henan, Jiangsu, Jiangxi, Liaoning, Shandong, and Zhejiang.

Collections exchanged from U.S.: We exchanged a total of 333 accessions with GRI scientists for testing and evaluation. These included the following genera: *Agropyron* (3), *Elytrigia* (90), *Krascheninnikovia (3), Leymus* (33), and *Medicago* (204).

Itinerary of germplasm exchange visit

Oct. 19-23: Left Logan Oct. 19, and arrived in Beijing Oct. 20. We were met at Beijing International Airport by Dr. Rong Yuping from the Grassland Science Department at China Agricultural University (CAU) who spent six months with Dr. Richard Johnson at Pullman, WA. We were taken to a guesthouse at CAU. On Oct. 21, Johnson presented two lectures at the Institute of Animal Science. After the lectures, Johnson and Majerus met with Dr. Gao Hongwen from the Institute, Dr. Rong Yuping (CAU), Dr. Lu Xinshi (Beijing Forestry University), and Drs. Vladimir Chapurin, Nickolai Dzubyenko and his wife Elena for discussions and lunch. Dr. Dzubyenko is the new Director of the N.I. Vavilov Institute of Plant Industry (VIR) in St. Petersburg, Russia. Drs. Chapurin and Gao are cooperating on a multi-year project to increase seed of VIR collections. Johnson and Majerus flew to Huhhot on Oct. 23 where they were met by Dr. Gu Anlin.

Oct. 24-25: Traveled on a portion of the northern collection route to Xilinhot in central Inner Mongolia and returned to Huhhot the next day by a southern route. We stopped periodically to examine collection sites and associated vegetation types.

Oct. 26-28: Weighed and split the collected seed, prepared seed lists, and obtained an Export Permit and Phytosanitary Certificate. Obtaining the Phytosanitary Certificate required considerable effort and multiple trips to the Quarantine Office in Huhhot. Dr. Gu had to hire a freight expediter to electronically submit the required forms to the Quarantine Office.

Oct. 29: Hosted by Drs. Han Guodong and Yi Jin at Inner Mongolia Agricultural University (IMAU) in Huhhot where we presented a series of lectures to staff and students.

Oct. 30-Nov. 4: Visited GRI facilities**,** held discussions with GRI staff and students, presented a series of lectures at GRI, and took two days of annual leave in Xian. We returned to Beijing where we were hosted by Drs. Rong Yuping and Mao Peisheng (who had spent six months at Bridger, MT in 2005). Held discussions with Dr. Zhang Xueyong from CAAS Institute of Crop Germplasm Resources in Beijing.

Nov. 5: Met with Dr. Han Jianguo at CAU concerning the joint International Rangeland and Grassland Congress that will be held in Huhot during June 29-July 5, 2008. Departed Beijing and delivered the U.S. portion of the seed collections to Homeland Security inspectors at the San Francisco International Airport. Prior to our trip to China, Maryann Loftus made arrangements for the necessary permits and alerted Homeland Security officials concerning importation of our seed collections into the U.S. Inspectors forwarded our seed collections to the USDA Plant Germplasm Quarantine Center in Beltsville, MD for inspection.

Benefits to U.S.

With the expanding human population in the U.S., demand for water is increasing for human consumption, recreational uses, landscaping, and industrial purposes. This is especially true in the arid and semiarid western U.S. where water resources are limited due to low precipitation and high evaporative rates. Typical high-input turf species for lawns, parks, and golf courses are becoming increasingly scrutinized for their high water consumption. Costs for water usage have increased dramatically the last few years and will likely increase in the future. In addition, water restrictions are being imposed during the hot, dry summer months in many metropolitan areas of the western U.S. As a result, homeowners, golf course managers, and park superintendents are actively looking for ways to reduce water consumption. Xeriscaping is becoming more and more popular and homeowners, park managers, and golf course superintendents are replacing high-input turf grasses with low-maintenance grasses.

Collected seeds will expand existing low-maintenance turf germplasm for tolerance to low temperatures, soil salinity, drought, and other adverse growing conditions. Ecotypic diversity for response to defoliation is potentially extensive because plants from Inner Mongolia have been exposed to intensive grazing by wild and domesticated herbivores for thousands of years and likely have been genetically modified through natural selection. As a result, collections are likely tolerant to defoliation and beneficial for turf improvement. Incorporation of the collected germplasm into NPGS will allow the preservation and conservation of this unique germplasm.

Benefits to China

The exchanged seed from the U.S. will add important germplasm to the Chinese Genebank for breeding and genetics studies. In addition, the seed collections of low-maintenance turf species made in Inner Mongolia will expand limited collections currently in the Chinese Genebank. Also, immediate conservation of low-maintenance turf germplasm from Inner Mongolia is important because possible changes in grazing restrictions in northern China threaten to limit future seed availability of these unique germplasm pools. These collections will be evaluated by Chinese turf scientists in their breeding and improvement programs, and eventually will lead to improved cultivars for low-maintenance turf in China. With China's 1.3 billion human population and need for conservation of limited water resources, China's demand for low-maintenance turf cultivars is potentially large. Scientific interactions between U.S. and Chinese scientists during and after our lectures and during the Chinese visit to the U.S. in June 2007 will provide opportunities for strengthened professional ties related to plant breeding, low-maintenance turf, and rangeland improvement.

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Table 2. Species and numbers of collections exchanged with China (2006).

Accessions Collected in China

Species	**Number**
Agropyron cristatum	14
Agropyron michnoi	14
Agrostis gigantea	15
Bromis inermis	9
Leymus chinensis	27
Leymus secalinus	6
Festuca rubra	4
Poa pratensis	13
Poa sphondylodes	23
Zoysia japonica	40
Grand Total	**165**

Accessions Sent from U.S.

Species	**Number**
Agropyron	3
Elytrigia	90
Leymus	33
Medicago	204
Krascheninnikovia	3
Total	**333**

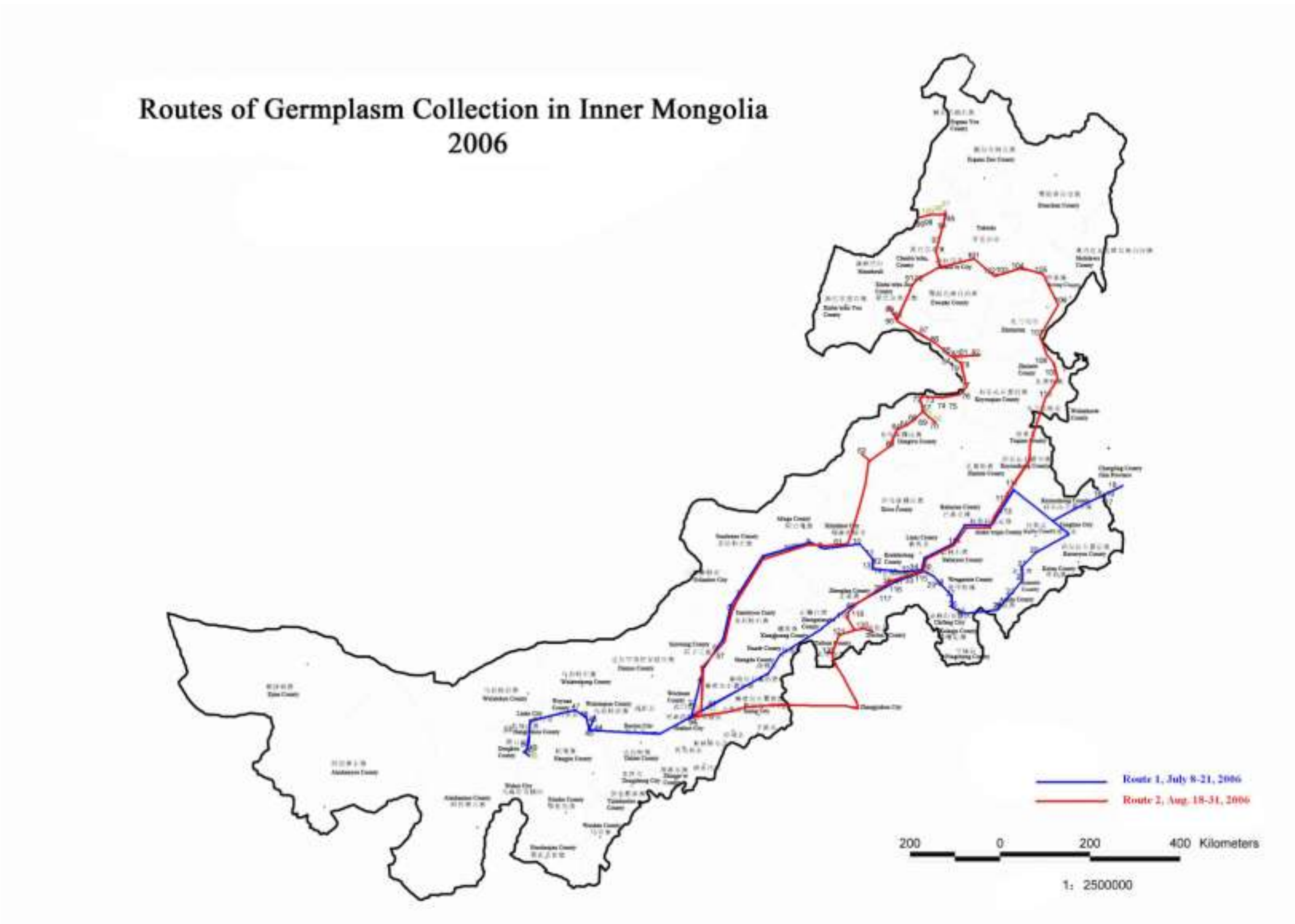
Routes of Germplasm Collection in Inner Mongolia
2006
Route 1, July 8-21, 2006
Route 2, Aug. 18-31, 2006
200
0
200
400 Kilometers
1: 2500000

Figure 1