REVIEW ARTICLE

The study of potential vegetation-species and practical cultivation by comparative phy-ecol-geography

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Abstract The research for plant introduction and cultivation is an emphasis on the following principles: (1) an analysis of similarity which is to make sure that there is a similarity in ecological environment between the original region of the species and the introduction region. (2) a principle of analogism which is to discover control species related with the introducing species based upon the plant taxonomy and a good performance of growth. If the above principles can be satisfied, we can infer that the introduced species being a potential species for introducing to the target region. A practical test of cultivation with the inferable species is done in the targeting region to examine domestication, adaptation, and growth of the inferable species. Only if the test is successful, should tested species be used for extensive growing in the target area.

Keywords Analysis of similarity · Principle of analogism · Potential species · Practical cultivation · Domestication-adaptation

In two areas with similar ecological condition for plant, if a plant species is only found in one of region, it could be inferred that such a plant species has the potential to be introduced into the other region with same cultivation techniques as used in original habitat which forms the basis of comparative plant ecological geography research.

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Use similarity analysis method to determine the area with similar ecological environment

To introduce, cultivate and promote the improved varieties from original distribution area to new regions, the first step is to collect the information of ecological and climatic conditions of these two regions, especially precipitation, heat balance and circulation the basis of the global geographical division. For example, the temperature and its association with latitude, is used to zone the earth surface to tropical, temperate, and cold zone from south to north; using the season where precipitation and association with longitude, it is being possible to divide into summer rain and winter rain area; with precipitation and humidity levels, any region can be categorized into one of the humid, semi-humid, semi-arid and drought regions. Therefore, a combined analysis of geographical information and associated water and heat conditions is the basis of this research. In this study, the southeast of China (humid subtropical) and the southeast of United States were used as examples to compare the degree

of similarity and dissimilarity in various aspects. Both areas belong to summer rain zone but southeastern China belongs to the humid subtropical which could be divided into three sub-regions based on the temperature and frost situation. Although the geographical name of the southeastern United States is different from that of southeastern China it is possible to find the corresponding areas with similarity in geographical and climatic conditions in the USA (Box 1986; Box et al. 1988; Huo et al. 1995; Huo 2014).

South subtropical zone in China and USA

The area lies in the north of Tropic of Cancer to south of Nanling mountain, including Guangxi Autonomous Region, Guangdong province, Fujian province and other provinces in China. It is a frost-free area and the minimum temperature is 0 ℃. The similar areas in United States can be identified in south of Florida, south and southeast of Louisiana, the Gulf of Mexico beach that evergreen broad-leaf distribution zone (the areas are defined as subtropical region in the United States).

Mid-subtropical zone in China and USA

The climate zone located on the north of Nanling Moutain and Huangshan Moutain, and reach the south of Ningzhen Moutain. The climate zone includes Hunan, Zhejiang, north of Fujian, south of Jiangsu, Anhui, Hubei province, where a slight frost (–10 ℃) were found. The similar areas in the United States is North Florida, South Georgia and the southeast coastal areas which are defined as a warm temperate zone in the United States.

North subtropical in China and USA

North of the Huangshan and Ningzhen Mountains to the south of Huaihe River, Qinling Mountains (near the 34°-north latitude), it is an area including north of Jiangsu province, Anhui province, Hubei province, south of Shandong province, Henan province, and Shaanxi province. There is frost every year in this area, and sometimes the temperatures are –15~0 ℃ below zero or lower. The similar regions in the United States are Georgia and adjacent areas (North Carolina, Tennessee, Virginia, etc.). This northern boundary of this region was the north-distributing limitation of *Pinus elliottii* and *P. taeda* (They are defined as temperate south in the United States). Globally, China has the biggest subtropical area, with the most abundant evergreen broad-leaved forest resources. China's eastern humid subtropical zone is much larger than America, which was defined as subtropics by American geography. Therefore, to determine the similar ecological environment in the two countries, it is necessary to make further judgments on the distribution and growth of species and vegetation.

Infer the potential species for plant introduction planning with principle of analogy

P. elliottii and *P. taeda* are important native tree species in America. They are widely distributed and applied as afforestation in the United States because they are important raw materials for paper and rosin. In China, these pine seeds were brought into China from the United States in the early 20th century or earlier and planted in Taishan city, Guangdong province. After the War Against Japan, these trees species were promoted for plantation in some areas (e.g., Jiangsu and Anhui province) in China by the United Nations Relief and Rehabilitation Administration. After 1949, the growing area of the species had been further expaned to the south of Qinglin and Huaihe (34° north latitude the north border of China's northern subtropical area). These trees are even suitable in some areas such as south of Shandong and Henan provinces. These two-pine species grow even better than *P. massoniana*, the Chinese native species. By comparing the adapted region of the two species in China and original habitats in the United States, it could be concluded that there is a great similarity between the area in the United States and the newly adapted northern subtropical area in China.

P. massoniana a subtropical native species in China which is selected as a control species in this study. The better growth of *P. elliottii* and *P. taeda* than that of *P. massoniana* indicates that *P. elliottii* and *P. taeda* were successfully adapted to the Chinese subtropical area. China's subtropical area is about 2.2 million km^2,

accounting for about 1/4 of the land area. While the subtropical area of the United States is roughly defined based on the distribution of existing evergreen broad-leaved forests and subtropical crops (*Citrus reticulata*, *Saccharum officinarum*, etc.), accounting for about 1/20 of land area (9.3 million km^2). In China, the *P. elliottii* and *p. taeda* are introduced over the entire subtropical region. However, the distribution area of the two species in the United States accounts for only 1/10 of the land area. Using similar analytical laws and analogy reasoning it is inferred that the tree species has great potential for expansion in the United States.

Evergreen broad-leaved forest is a representative of the subtropical vegetation. It is also known as the "top community". China is rich in vegetation types and species. For example, the subtropical evergreen broad-leaved forest is a typical evergreen broad-leaved forest, and the northern subtropical is occupied by evergreen and deciduous mixed broad-leaved forest. In contrast, the evergreen broad-leaved forest in the United States is small in distribution area with few species, possible due to the flat alpine terrain of the United States, which cannot stop the cold from the North Pole and Canada. At the same time, North America (especially the United States) has the most abundant tree species. Gymnosperms species ranks first in the world, deciduous broad-leaved species is also very rich. Many widely planted species in China are from the United States. This is the foundation of the cooperation, mutual benefit and win-win basis between China and the United States (Huo et al. 1995; Wang et al. 1990; Wang and Jiang 1995).

Selection of introduction and reference species

Because both the eastern China and eastern parts of the United States belong to the "summer rain" climate zone, the potential to introduce plant species from one to another between the two climate zones. For a successful introduction of certain plant species, it is necessary to analyze the similarity of the ecosystem in the origin habitat and the place targeted for an introduction. Plants with close genetic relationship and similar ecological habits could be selected as a control species to assess the success of a plant introduction. Only when a selected species is determined as a potential species at a targeted site, could it be introduced into this site (Huo et al. 1995; Wang and Jiang 1995; Cloud et al. 1990; Liao and Zhang 1994; Zeng et al. 2013; Chen et al. 2014).

Gymnosperms tree species

The North America is abundant in gymnosperms tree species, especially in the United States. About 183 gymnosperms tree species were reported in the USA, ranking first in the world (Wang et al. 1990; Wang and Jiang 1995). *Robina virginiana* is a widely distributed native tree species in North America. The species covers southwest Canada and 7 states of the United States, including California, Arizona, New Mexico, Texas, North Carolina, Georgia, and Florida. The specie showed a great ecological adaptability and high resistance to cold, drought and salt, covering both winter rain zone and summer rain zone. *R. virginiana* is a fast-growing tree species which has good performance in the soil with salt concentration of 0.3% and pH value of about 9. It is also a fine landscaping tree species and provides precious timber. This tree species was gradually introduced into China since the early 20th century, and mature individuals could be found in several places such as Tai'an city in Shandong province and Nanjing city in Jiangsu province. The planting area ranged from Inner Mongolia Autonomous Region in Northern China to Jiangxi province in south China (Wang et al. 1990; Cloud et al. 1990). *R. virginiana* is a tree species with great potential for introduction to China, while it can also be used as an auxiliary control species to promote the tree introduction.

Deciduous broad-leaved forest tree species in North American

In North America, especially in the United States, deciduous broad-leaved species are very abundant. Some deciduous broad-leaved species cultivated in China, such as *Robinia pseudoacacia*, *Platanus occidentalis*, *Liriodendron tulipifera*, are introduced from the United States (Wang et al. 1990; Chen et al. 2007a; Zhang 2004). *Robinia pseudoacacia* is a native fast-growing

tree species in the United States, and it has been widely introduced and cultivated in Europe and Asia. The introduction of *Robinia pseudoacacia* in China began at the beginning of the 20th century. The main planting area is in the north of the Yangtze River, including the Loess Plateau, the middle and lower reaches of the Yellow River, the south part of Northeast China, the coast of the Yellow Sea and the Bohai Sea. *Robinia pseudoacacia* is a strong light demanding tree species with wide ecological adaptability and high resistance to chill and barren. It could even survive in the acidic soil, calcareous soil, and saline soil with salt content of 3%. As *Robinia pseudoacacia* is the actual natural tree species and the actual artificial tree species (already planted species) in its country of origin. Moreover, it has become a tree species widely grown in the introduction area. Therefore, it can be set as auxiliary control tree species for further judgeing the success of the introduction of the new tree species in another place.

Chinese evergreen broad-leaved forest species

Cinnamomum camphora is a native evergreen broad-leaved tree in China. It has a variety of uses. For example, it could be used to beautify the garden and regional environment; the wood has aroma to avoid pests and could be used to make wardrobe, wooden boxes, and specimen cabinets. The wood texture of camphor is elegant, so it is often used for statues and art craft. In industry, camphor is the main material for camphor tablet and camphor oil, which were widely used in medicine and chemical (Chen 1953). This tree species is widely distributed in 3 sub-regions (south, middle and north in subtropical region) in southeastern and south-central China. Therefore, it can be used as a reference tree in the tree introduction and cultivation using the law of Analogy inference (Huo 2014; Huo et al. 1995). *Loropetalum chinense* var. *rebrum* is a representative of the subtropical evergreen broad-leaved tree native to China. The flower and leaves of the tree presents red and it is high in ornamental value. However, the characteristics of its original species (*L.* chinense) is white flower and green leaves. *Loropetalum chinense* var. *rebrum* was collected by Peizhong Ye in the Yuelu Mountain. In 1929, when Peizhong Ye studied in the Royal Botanical Garden in Britain, he published the scientific name and description of *L. chinense* var. *rebrum*. For a long period, this tree species was mainly promoted in Hunan and its neighbor provinces. It has not been popularized until the beginning of this century and gradually extended to the whole subtropical region of southern, central, and northern China and many places abroad. During this period, Michae Dirr, professor of the University of Georgia, and the author vigorously promoted *L. chinense* var. *rebrum* in the United States (Huo 2014; Huo et al. 1995). Native American evergreen broad-leaved species are widely distributed in Virginia (*Quercus virginana*) (Cloud et al. 1990), and most of these species have small, thick leaves and are resistant to drought and cold. The author suggested the United States to introduce similar evergreen broad-leaved species from the northern subtropical of China, such as *Castanopsis eyrei* and *Cyclobalanopsis glauca*. In addition, we can gradually test the introduction of Lauraceae, Camellia, Myrica and *Rhododendron,* as well as other suitable evergreen broad-leaved species (Wang et al. 1990; Wang and Jiang 1995; Chen et al. 2007a; Zhang 2004; Chen et al. 2007b).

Introduction of potential species and cultivation of potential vegetation in the domestication - adaptation process

After determining a species has the potential to be introduced to another similar climatic region of another region through the analysis, comparison and extrapolation, it is possible to scientifically start the introduction and cultivation work, and the species will gradually adapt the environment and form artificial vegetation in the introducted area. This is a species adaptation process to the area with similar ecological conditions. The process comprised physiological mechanism of domestication and trait variation (Klaus and Lawrence 1989). Detail information can be summarized as below.

This domestication-adaptation process is a very complex process involving multidisciplinary processes. Physiological mechanisms of plant growth and development

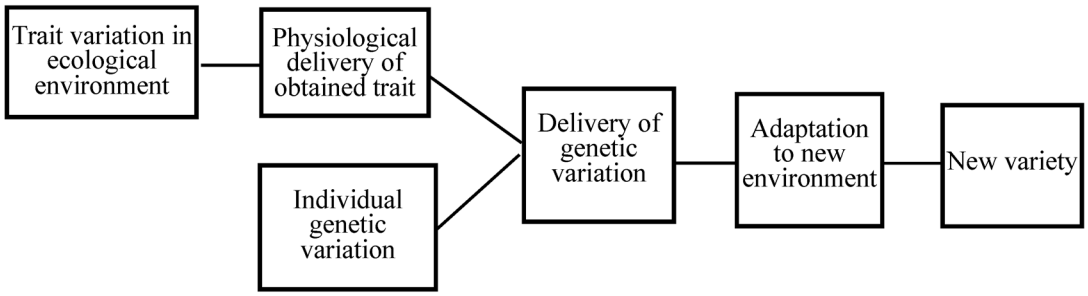

Fig.1 The domestication - adaptation process of plant during introduction

include photosynthesis, respiration, vegetative propagation, material metabolism and similarity of enzyme activities and metabolic physiological activities, especially the activity carried out by the assimilation to absorb the external substances from the ecological environment. These physiological mechanisms directly affect the formation of various resistance abilities of introduced species to cold, drought, water, salt and so on. If necessary, plant hormones are used to regulate the growth rhythm and stress resistance of introductions (Zhang 2004; Klaus and Lawrence 1989; Shao et al. 2013; Chen et al. 2012). The growth status of the introduced plants can be the overall indexes for the evaluation of whether a species is adapted to the introduced environment through domestication. The growth of trunk can be observed (life span, tree height, DBH or ground diameter, etc.), and plant growth performance (the color of flowers, leaves, and branches, flowering pattern, the length and heading date of branches, and growth-stopping season, etc.) can be evaluated for the introduction (Huo 1985; Zhang 2013; Wang 2014).

Conclusion and prospect

Introduction of tree species needs a domesticated adaptation process to obtain the ecological physiological ability to new areas, because the ecological conditions in the targeted area cannot be the same with the origin area of a species. A successful introduction can be expected when the growth and growth conditions are similar between the origin and introduced areas. The successfully introduced species can be used in breeding program, which can be combined with genetic breeding disciplines. If the introduced tree species cannot survive, or have poor growth in the new area and the introduction was a failure.

The eastern part of China and the eastern part of the United States belong to the summer rain zone, and the climate and ecological conditions are basically similar, with similar precipitation season and similar temperature pattern. Therefore, they could become the plant resources for introduction to each other. There are some differences in the composition of the tree species. However, it should be noted China's evergreen broad-leaved species are more abundant than the United States, while the gymnosperms and deciduous broad-leaved species in the United States of are more abundant in China, indicating that both countries are complementary to each other.

The restoration and renewal of degraded ecosystems in China is a major issue, in particular, the destruction of terrestrial ecosystems. Forests are the mainstay of terrestrial ecosystems and the restoration of damaged forests has a highest priority. Restoration of ecosystems can follow the laws of vegetation succession, identify vegetation species (potential vegetation species) that are benign and not yet developed, and then introduce and cultivate such plants to support the restoration of damaged ecosystems.

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