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Growth Performance of Exotic Trees in Korea

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Abstract

There are many countries having a long history of exotic tree introduction from different countries and several countries including New Zealand, Brazil and Hungary have successfully introduced exotic trees. Korea's tree breeding program for introduction of exotic tree was originally started from 1924. Records reveal that hundreds of tree species were introduced from many countries and tested their germination and viability. About 415 introductions were eliminated since they had been introduced and tested. Subsequently, seven exotic trees that proved successful in trials and plantations have planted for afforestation. Simultaneously, several promising exotic trees are still under the test. In this paper, we will succinctly review and evaluate their comparative growth performance of the exotic trees in the plantation programs of the country to coping with climate change.

Key Words: black locust, climate change, exotic tree, white pine, yellow poplar

Introduction

Korea's forests cover 64 percent of its land area and growing stock per ha is 150.2 m^3 in 2016. However, following the Second World War and the Korean War, the average growing stock was less than 5.0 m^3 ha^{-1} in the Korea (Kim and Zsuffa 1994; Lee and Lee 2005). In particular, the devastated forests led to serious social and environmental problems such as severe floods, droughts and lack of firewood (Lee et al. 2015). To figure out these deteriorating conditions, the priority of national forest research projects was given to the genetic improvement of native species as well to the testing and use of exotic trees, and the development of promising interspecific hybrids. Therefore, a systematic tree breeding program was initiated under these circumstances in 1956 to rapidly restore these devastated forests (Shin et al. 2007).

A typical forest tree breeding program is selection of superior phenotypes (plus trees) in a natural or planted forest (White 1987). Another program is the deliberate interbreeding (crossing) of closely or distantly related trees to produce new varieties or lines with desirable properties (Namkoong et al. 2012). The other program is introduction or assist migration of trees from one place to another place (Williams and Dumroese 2014).

There are many countries having a long history of exotic tree introduction from different countries or geographic regions of the world and several countries have successfully introduced exotic trees (Ste-Marie et al. 2011). For instances, radiata pine (*Pinus radiate*) is grown commercially in New Zealand as an exotic species from North America and it is the most significant exotic timber species in New

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Zealand (Wu et al. 2007). Douglas fir (*Pseudotsuga menziesii* Franco) also was the first introduced to Europe from North America more than 150 years ago, then planted on a large scale. It is now the economically most important exotic tree species in European forests (Hermann 1987; Finch and Szumelda 2007). Eucalyptus was introduced from Australia to many parts of the world, notably California, Brazil, Portugal, and Chile. In Portugal and Spain, eucalyptus has been planted in plantations for the production of pulpwood and the plantations have become of significant species (Kellison et al. 2013). Black locust (*Robinia pseudoacacia* L.) was the first forest tree species introduced and acclimated from North America to Europe at the beginning of the 17th century. In Hungary, this species has played a significant role in the forest management, covering approximately 23% of the forested area and providing about 19% of the annual timber output of the country (Rédei et al. 2008; Nicolescu et al. 2018). Eastern white pine (*Pinus strobus*) is a large pine native to eastern North America. The tree was introduced and widely distributed in Europe in the 19th century (Karlman 1981).

According to the literature, tree breeding program for introduction of exotic tree species was originally started from 1924 in Korea. Records reveal that a total of 370 tree species were introduced from 30 countries and tested their germination and viability. However, the information including plantation region, source, year etc. were, unfortunately, lost during the Korean War (1950-1953). After liberation, it was introduced out to test adaptability and reforestion in the situation of extramely devestated forest. Since 1956, new efforts have been made for introduction and testing of exotic trees to find rapid growth trees and soil saving species for erosion control (Kim and Zsuffa 1994). A total of 415 exotic tree species (varieties and clones) was re-introduced from 38 countries and have been established in the plantation program (Table 1). The process steps of introduction were described as the flowchart shown in Fig. 1.

In the first seedling stage of screening tests, most of exotic trees did not show promising growth performances, 318 introductions were eliminated since they were introduced and tested without consideration of their ecological niche. Subsequently, seven exotic trees that proved successful in trials and plantations were planted for afforestation (Table 2) and several promising exotic trees are still under the test. In this paper, we will succinctly review and evaluate their comparative growth performance of the promising species in the plantation programs of the country to coping with climate change.

Table 1. List of countries and number of introduced tree species

Continent	No. of country (No. of species)	Country
Asia	12 (35)	China, Hongkong, India, Indonesia, Iran, Japan, Nepal, Pakistan, Pillipine, Thailand, Turkey, Taiwan
Europe	20 (141)	Austria, Belgium, Bulgaria, Denmark, Czech Rep., Nederland, Finland, Yugoslavia, France, Germany, Hungary, England, Italy, Norway, Poland, Spain, Sweden, Rumania, Switzeland, Russia
North America	4 (171)	USA, Brasil, Canada, Chile
Oceania	2 (68)	Australia, Newzeland

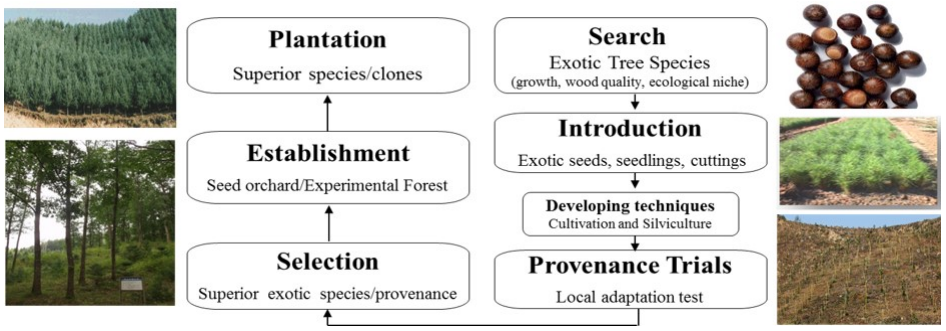

Fig. 1. Flowchart of the introduction process of exotic tree species.

Table 2. List of recommended exotic tree species and plantation area for afforestation

Species	Year	Superior provenance	Plantation area (ha)	Purpose
Populus euramericana I-214, I-476 (Hybrid)	1961	Italy	739,599	Afforestation, Fast-growing tree plantation
Pinus taeda	1971	U.S.A.	11,257	Economic forest plantation, Timber production
Alnus inokumai	1971	Japan	11,839	Afforestation, Wood fuel production
Populus euramericana Eco28, Lux	1973	Italy	20,800	Afforestation, Fast-growing tree plantation
Pinus strobus	1985	U.S.A.	951	Timber production
Pinus virginiana	1985	U.S.A.	574	Timber production
Liriodendron tulipifera	2004	U.S.A.	25,654	Bioenergy and timber production

Provenance Test of Exotic Trees

Eastern white pine (Pinus strobus L.)

Eastern white pine (*Pinus strobus* L.) is one of the most important softwood timber species in eastern Canada and the Northeastern United States (Rajora et al. 2000). In natural distribution region, the average precipitation was ranged of 500 mm in northern part of Minnesota and over 2,000 mm in southern part of Georgia. Climate conditions in Korea is similar to the natural provenance in US as to the 13.1 degree of average annual temperature and 1,100-1,700 mm of annual precipitation. In general, *P. strobus* grows well in cool and moist conditions. It was recorded that the pine was the first introduced to Korea in 1924 to test adaptability in the country according to local plantation record. To select superior provenances of exotic species, six provenances of eastern white pine, two from USA, one from New Zealand and three from Italy, were re-introduced and planted to Korea in 1968. Simultaneously, Korean pine (*Pinus koraiensis* S.et Z.) was planted with as a control. Three provenances from USA were additionally introduced and tested in 1986. The growth volume per hectare of the best provenance, North Carolina, USA, showed 31 percent more than average of six other provenances and 196 percent more than that of native Korean pine (Choi et al. 2008; Choi et al. 2009; Choi et al. 2011). The white pine had been planted 745 ha until early 2000, but it was not planted much for planting in mountain area since the blister was first developed in 1936, and after 1970-1980. The disease caused severe damage to the pine forest plantation in South Korea and after that most white pines have been planted for street trees and landscape trees. Since it is strong against various pollutions and growing speed is comparatively fast for a conifer.

Northern red oak (Quercus rubra L.)

Northern red oak (*Quercus rubra* L.) is a major-dominant hardwood species in the North America (Magni et al. 2005). It is known as the most important species in wood production since the tree is produced in lumber and plywood. Moreover, it is one of the trees loved by the beauty of the leaves that turn red in autumn. Northern red oak was first introduced in Korea to test and produce high value-quality oak in the country. It was recorded that Northern red oak was first introduced to Korea in 1935 according to local record. Northern red oak is distributed around Appalachian Mountains as to the northeastern region of the USA and southeastern region of Canada. This species is highly ability to adapt, grows in a variety soil and climate conditions. To produce high quality seed sources for Korean environment, the eight provenances of northern red oak were introduced from Canada and USA in 1988 (Ryu et al. 2004b) and twenty-three provenances of northern red oak was planted in 1993 (Cho et al. 2013). Additionally, growth of the oak was superior 18.9% in height, 7.2% in DBH, and 45.3% in volume to that of Korean indigenous oak *Quercus acutissima* (Ryu et al. 2004a). The distribution area of Korean wild oak trees is 28% of the total forest area of 1.7 million ha. However, the wood quality and stem straightness of Korean native oak are not better than the red oak. Northern red oak is well adapted to Korean climate and shows 200% better growth than the comparative

species of native oaks. We have established several experimental forests for selecting superior provenance and clone in nationwide since 1985. In addition, the experimental forests of the trees have been expanded by the National Institute of Forest Science (NIFoS) which is the governmental research institute in forest sector in Korea to monitor their adaption and develop high quality seed and wood.

Yellow poplar (Liriodendron tulipifera L.)

Yellow poplar (*Liriodendron tulipifera*) is native to eastern North America. It is fast growing and resistant to pests and diseases. The poplar also called tulip-tree, tulip-poplar, and white-poplar, and it is one of the most attractive and tallest of eastern hardwoods (Beck 1990). Original provenance is located in Appalachian Mountains and is widely distributed from Florida to Maine in USA. This species has excellent adaptability to environment and grows in a variety of climate and soil conditions. The tree was first introduced from the United States in the 1960's and it has been comparatively well adapted to the Korean climate environment. As a result, the ministry of forestry recommended plantation of the yellow tree as a major species for production of woody bioenergy and timber. Twenty thousand hectares of yellow poplar trees have been planted with six experimental forests (Ryu and Kim 2003). Although the differences of growth performance existed based upon geographical location, the average volume growth per ha of all six plantations was 321m^3 and the volume growth was similar to that of original habitat in the USA. The growth of yellow poplar was 90% superior to that of *Larix kaemperi* and *Pinus strobus* at Chuncheon and Wanju, which were located even at 350-400 m above the sea level with steep slope and high ridge (Ryu et al. 2003). In addition, the NIFoS produced 368,000 copies of excellent clone seedlings of the trees with somatic embryo reproduction technology (Lee et al. 2003).

Black locust (Robinia pseudoacacia L.)

Black locust (*Robinia pseudoacacia* L.) is a native to southeastern North America and now naturalized extensively in the temperate regions of North America, Europe, and Asia (Barrett et al. 1990; DeGomez and Wagner 2001). The tree was first introduced in Korea to plant street tree at the beginning of the 19th century. The Korean government particularly in the 1960's launched large-scale tree planting campaigns to reforest denuded mountains after deforestation during the Japanese occupation period (1910-1945) and the Korean War (Huntley 1990; Lee et al. 2004). Black locust was considered a promising tree for reforestation due to its fast growth and ability to fix atmospheric nitrogen (Vítková et al. 2015). Black locust is one of the most extensively established exotic trees in Korea (Boring and Swank 1984; Noh et al. 2010). Recently, several varieties and provenances from Hungary were introduced to Korea to improve wood quality since Hungary developed several cultivars for forestry and beekeeping (Keresztesi 1983; Rédei 2002; Rédei et al. 2008). The NIFoS has established 12 ha of experimental forests for selecting superior provenance and clone in over 10 places nationwide since 2012. Recently, the tree becomes more interesting for producing honey, wood and bioenergy.

Conclusion

Introduction of exotic tree is challenging long-term endeavors that require thoughtful planning, implementation and monitoring. Many other countries have a long history of plant introduction from different countries or geographic areas of the world and some countries successfully have utilized the introductions for the economically significant resources. Migration or introduction of trees from one place to another may be natural. A government-led reforestation program in Korea has succeeded in producing a substantial increase in forest cover over the past 50 years. In addition, introduction of some rapid growing trees and soil saving trees for erosion control was notably contributed to achieve forest restoration and rehabilitation. Extensive studies should also be carried out by scientist and foresters on further effect of these species in the ecosystem.

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