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Resources of The White Birch (*Betula platyphylla*) for Sap Production and Its Ecological Characteristics in Northeast China

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Abstract

In northeast China, birch species form dominant tree flora with eleven species of the genus *Betula*, including trees and shrubs have been recorded. Most of the birch species invade after disturbances, such as harvesting of conifers and forest fires, and grow as a pioneer species. Recently, practices of non-destructive forest management have been examined for natural resources preservation. Rich birch forests, especially white birch (*Betula platyphylla*) in northeast China are regarded as an important resource for sap production. Based on phenological observations, the sap of white birch starts to exude from early April in the Zhangguangcai Mountains, northeast China. The optimal period for tapping sap in white birch was from early of April to mid-May. The tree age for producing tree sap in white birch is considered to be from 45 years old and the DBH (diameter of breast height) is above 16 cm. For resource conservation, a method for accelerating the natural regeneration of white birch is discussed in relation to its biological characteristics.

Key words: white birch (*Betula platyphylla*), phenology, sap exudation, ecological characteristics, forest succession

Introduction

In China, production of forest resources, such as timber and charcoal had been mainly provided from the northeastern area (Li 1993). Major forestry species for timber production are pine, spruce and fir in northeast China. However, these forest resources are facing to shortage because of the intensive harvesting and frequent forest disasters, such as landslides or forest fires (Zhou 1991). After harvesting trees or forest fires, birch species usually invade as a pioneer species (Koike 1995, Shi *et al.* 2000b). The eleven birch species are growing in the northeastern part of China.

Recently, non-destructive forest management has been examined for natural resources preservation and conservation (Nie *et al.* 1995, Shi *et al.* 2000a, Taghiltsev and Kolesnikova 2000). Tree sap utilization is one of the candidate methods of non-destructive forest management. As rich in birch forest especially the white birch (*Betula platyphylla*) of northeast China is regarded as a potentially important area for sap production (Shi *et al.* 2000a). Large areas of the northeastern part of China are covered with birch species. However, here is still not enough information available on the regeneration methods for white birch (Koike 1995) and the production structure in a stand (Shibuya *et al.* 2000a, b). Therefore, basic information on the growth characteristics of white birch and the other birch species native to northeast China should be determined to contribute to new ideas for forest management.

For these objectives, we describe the vegetational traits and phenological observations of birch stands in order to determine the suitable period of tree sap production. We discuss the possible method of non-destructive forest management and accelerating the natural regeneration based on the biological characteristics of birch in the northeastern part of China.

Study sites

Birch forests distribute mainly in the Daxingan Mountains, Xiaoxingan Mountains and Changbai Mountains at a latitude of 42°N, under the influence of the cold-temperate (boreal continental) climate (Fig. 1). This area is located far from the sea and has no direct effects of coastal climate. Thus, it shows typical continental characteristics, such as being severely cold during the long winter, and low precipitation with little snow (Chou and Liu 1990). Moreover, this region is characterized by the southern edge of the discontinuous permafrost area (Fukuda 1996, Shi *et al.* 2000b).

Survey site was in the research forests of Northeast Forestry University located in the Zhangguangcai Mountains. The mean annual temperature is about 2.8°C, the annual precipitation is about 724mm and the frost-free period is about 130 days.

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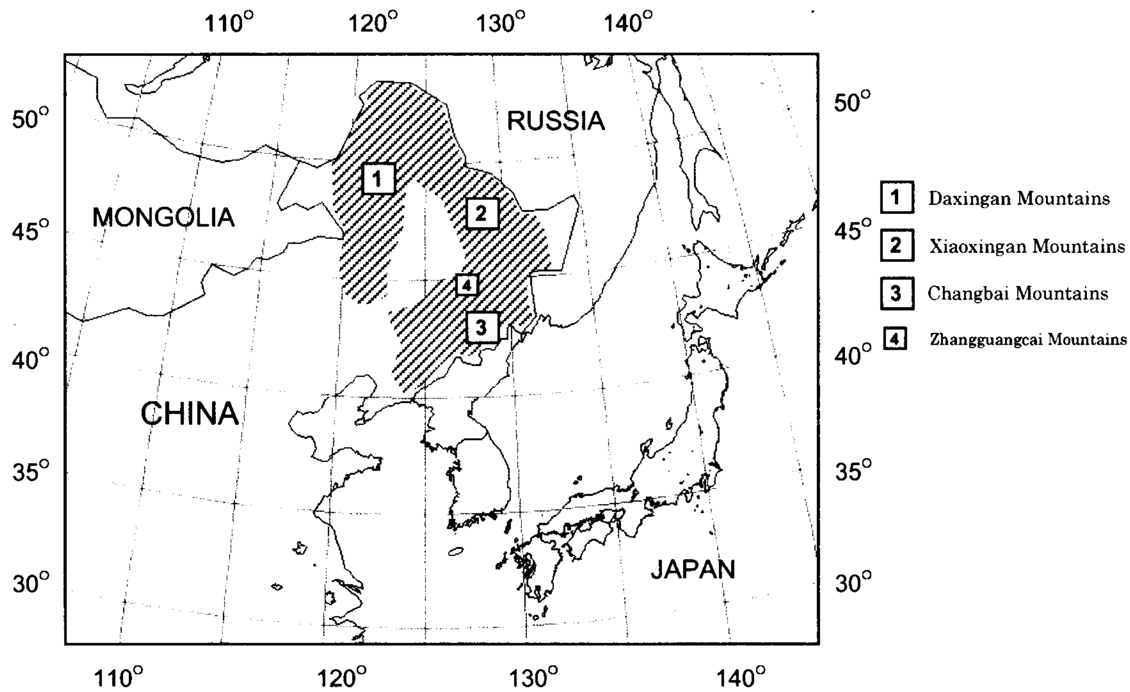

Fig. 1. Study sites and distribution of white birch in northeast China

Methods

Vegetational characteristics of birch forests have been reviewed in several books and research papers (Liu 1959, Li 1993, Zhou 1986, 1991, Zhou and Zu 1993, Nie *et al.* 1995, Shi *et al.* 2000b). Inventory data were modified from Li (1993). Most of the resource data on sap production were cited from Nie *et al.* (1995).

Phenological observations of white birch were carried out in the Zhangguangcai Mountains. Observations were made at two days intervals for ten individual trees. We described the phenological events in different phases of growth through the seasons (phenophase), such as sap exudation, swelling of buds, leaf unfolding, formation of new buds, whole leafing (leaf maturation), turning yellow (autumn coloration), leaf fall for vegetative phenophase, and for reproductive phenophase the beginning of blooming, termination of blooming, fruit bearing, development of fruits, fruit ripening, and whole fruits ripening.

Results

1. Growth characteristics of the genus *Betula*

In northeast China, eleven *Betula* species including trees and shrubs are recorded. Tree species include five species, such as *Betula platyphylla* Suk., *B. costata* Trautv, *B. davurica* Pall., *B. ermanii* Cham. and *B. schmidtii* Regel. Shrub species include six species, e.g. *Betula chinensis* Maxim, *B. liaodungensis* Bar., *B. middendorffii* Trautv., *B. gmelinii* Bunge., *B. ovalifolia* Rupr. and *B. fruticosa* Pall. Among these birch species, the white birch (*Betula platyphylla*) was one of the promising species for sap production because it's broad distribution and large stocked volume. However, the other tree species, such as *B. costata*, *B. ermanii*, *B. schmidtii* and *B. davurica*, were not suitable for sapping because these species have a small mass production and a scattered distribution in the northeastern part of China.

2. Distribution and resources of white birch

The potential distribution area of white birch in northeast China was estimated to be about 1,872,000ha, the largest area of all the above five tree birch species, and covered about 12% of the total forested area of the northeastern forests of China. White birch prefers mesic environments and often forms pure stands after forest fires or slash and burn, as a pioneer species. Although its life-span is relatively short of less than 100 years old, the area of *Betula platyphylla* forests is large and expanding in the Heilongjiang Province as a secondary forest after disturbance on conifers mixed with hardwood forests (Table 1). Average forest density was 200stem·ha^{-1} and the soil was drained off well.

Not all the present birch forests can be used for collecting birch sap. There is a critical size of tree for sap production. Candidate trees for sap production have a size of $D_{1.3}$ (DBH; diameter of breast height) of at least 15cm and are free from disease and insect pests. The area of birch forests that can be used for collecting tree sap is estimated to be about 600,000ha, which is about one third of the total area of the birch forests in the Heilongjiang Province (1,872,000ha). When the stand density would become 200stem·ha^{-1}, 20tons of tree sap could be collected during one month in spring (i.e. sap per stem of 120kg·day^{-1} can be collected). Thus, the whole Province could

Table 1. Area and resources of *Betula platyphylla* forests in each forest region

	Forest bureau of city and county[1)]	General bureau of Forestry industry	Forest region of Daxingan Mts[2)]	Total
Area (10 thousand ha)	66.1	51.0	70.1	187.2
Stock (10 thousand m^3)	2,681.3	3,856.2	4,328.5	10,866.0

Note: [1)]Similar political system to prefecture in Japan., [2)]Belonging to the government of China.

Table 2. The growth of height, DBH and stocked volume of mean tree of white birch stands

Growth indices	Age (years)					
	10	20	30	40	50	60
Total height increment (m)	4.12	9.65	14.3	15.63	16.30	16.40
Current annual height increment (m)	0.40	0.53	0.51	0.37	0.25	0.27
Mean height increment (m)	0.40	0.47	0.47	0.41	0.33	0.27
Total increment of DBH (cm)	3.17	8.66	12.77	14.00	16.60	17.30
Current annual increment of DBH (cm)	0.30	0.53	0.43	0.34	0.37	0.22
Mean increment of DBH (cm)	0.31	0.44	0.45	0.34	0.33	0.28
Stocked volume increment (m^3)	0.0040	0.0366	0.1069	0.1245	0.1543	0.2032

produce birch sap of 12,000,000tons per annual growth period (=600,000ha x 20ton). Namely, there is a large potential amount of sap produced in natural birch forests to be exploited and used in the northern part of China.

The growing processes of white birch stands are shown in Table 2. The seedlings of white birch grow slowly during the initial stage, however, after they reached to be 3-5 years old, the seedlings began to grow fast, and the annual growth was estimated to be up to 70cm. The mean height of white birch stands was about 12.6m for a 22 years old stand, the DBH about 10.5cm and the stocked volume about $125m^3 \cdot ha^{-1}$ in the Zhangguangcai Mountains. At the mature stage, the mean height of 72 years old white birch stands reached 23m, mean DBH 38cm and mean stocked volume $508m^3 \cdot ha^{-1}$ in the Daxinggan Mountains. We could conclude that the optimal age of white birch for sapping (DBH>16cm) was after 45 years old.

3. Phenophase of white birch stands

Phenophase of the white birch stands varied in different areas. The phenophase of white birch stands at the Zhangguangcai Mountains is shown in Table 3. According to Table 3, the optimum sapping of white birch in the Zhangguangcai Mountains was from the first ten days of April to that of May 15. The sap exudation of white birch stands in the Xiaoxingan Mountains was estimated to be about 5-7 days later, and that of the Daxingan Mountains was simulated to be about 10-14 days later than that of the Zhangguangcai Mountains.

Discussion

Recently, with the establishment of idea of the

Table 3. Mean phenophase of vegetative and reproductive organs of white birch in the Zhangguancai Mountains

Phenophase of vegetative organs	Date	Phenophase of reproductive organs	Date
Sap flux	Apr. 1	Blooming begins	May 16
Bud inflation	Apr. 25	Bloom falls	May 21
Buds unfold	May 6	Fruit bearing begin	May 24
New buds formed	Jul. 1	Fruit development	May 27
Leafing begins	May 12	Fruits ripen	Jun. 12
Whole leafing	May 26	Whole fruits ripen	Aug. 11
Turning yellow	Sep. 4		
Leaf fall begins	Sep. 13		
Whole leaf fall	Oct. 6		

Natural Forest Protection Engineering through the whole of China, the focus of forestry had been changed from timber production to forest comprehensive management, namely sustainable development including the forests conservation of natural resources (Li 1998). Therefore, tree sap utilization is expected to become a non-destructive use of forest resources (Nie *et al.* 1995). The amount of sap production by individual trees varies significantly (Nie *et al.* 1995, Shibuya *et al.* 2000b). To optimize the production of sap, we should know the mechanism of tree sap formation, especially the relation of plant biomass production.

Recently, Shibuya *et al.* (2000b) suggested that white birch with large crowns could produce larger amount of sap. If we would produce a large amount of sap, we could increase the space for growth of individual white birch. Sap is produced mainly from the part of sapwood (Kozlowski *et al.* 1991). Thus, we can predict the production from a tree of possessing high capacity of sap production by measuring the crown size. Based on the Pipe Model Theory (Shinozaki *et al.* 1964a, b), we can estimate the amount of leaves of a crown correlated well with the diameter at the position of lowest large branches (D_B). Therefore, firstly, we should find the relationship between DBH and the D_B or DBH and the area of sapwood. Secondly, the relationship between DBH and the amount of leaves should be determined. Then, we will be able to estimate the amount of sap by measuring the DBH.

The worst management of forests after harvesting is to leave the harvested area in a naked state or discard of tending forests. Openlands are usually suffered from landslides or erosion after heavy rain. Therefore, it is an urgent subject to stabilize and rehabilitate forests after harvesting or forest fires. Fortunately, white birch have a broad capacity to grow under various conditions (Sato et al. 1986, Shi *et al.* 2000b). Moreover, white birch is a cold-tolerant tree species and can even survive under conditions as low as –53°C during winter (Zhou 1986). During spring, white birch can avoid low temperature stress by developing two types of leaves, namely early leaves and late leaves. Producing late leaves is observed after the early leaves are completely expanded (Koike 1995). By contrast, mountain birch continuously develops all their leaves and is sometimes suffered from the low temperature of late frost.

Not only morphological traits, but also, based on vegetational observation, white birch has high tolerant capacity of the frost and sun-burn. However, white birch cannot survive under extremely severe drought, therefore, there is barely distribution where the precipitation was less than 400mm (Shi *et al.* 2000b).

The characteristics of the root system of white birch are well developed fibrous roots and undeveloped tap ones, so it is a pioneer tree species even at the drought slope facing south and rigid soils (Zhou 1991). This unique characteristic is also found in Japanese white birch as number and size of perforation plate of vessels (Tabata 1966). The litterfall of white birch stand can be easily decomposed and formed the high-quality humus, furthermore improving the fertility of the soil (Shi *et al.* 2000a). Wind-blow and wind-breakage occur commonly in natural birch forests because it's stands are thinned well in the high density stands, but in low density stands at the gentle slope established on infertile condition, the growth and thinning were not so well known (Li 1993).

How can we accelerate the regeneration of white birch after several types of disturbance? For this, we should know not only the biological characteristics of white birch, but also the interspecific competition with other light demanding species. White birch grows commonly with the poplar (*Populus davidiana* Dode), however, white birch grows more slowly than

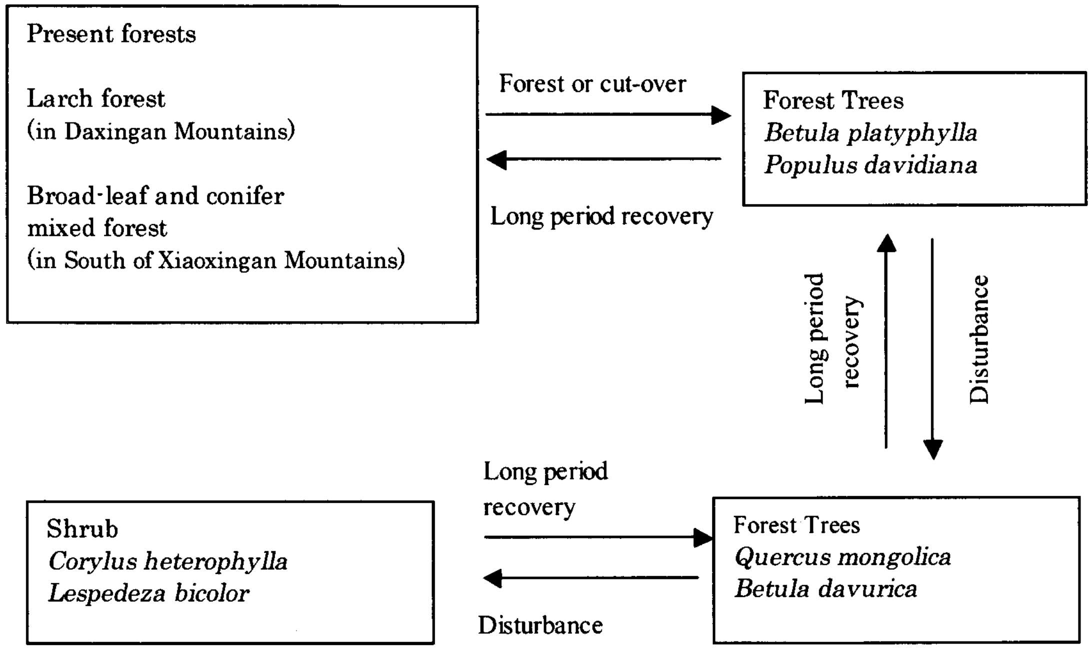

Fig. 2. Schematic representation of the successional processes in a white birch stand in northeast China

the poplar. Its fast growth period is about 5-10 years later than that of the poplar. White birch is a typically intolerant species (Tabata, 1966, 2000, Koike and Sakagami 1985, Koike 1995, Shi *et al.* 2000b). The growth of seedlings require intensive light and this growth characteristics is similar to *Larix gmelinii* Rupr., therefore the height increment of the two species could be improved in mixed larch and birch forests. But, in larch forests, due to the lack of light, white birch doesn't grow well. Therefore, white birch is a typical pioneer species and can form pure stands in the clear cutting and burned area.

The formation of white birch stands establishes through the destruction and disturbance of larch forests, even-aged conifer forests, and mixed deciduous hardwoods with Korean pine forests by the extrinsic factors in northeast China. Forest fires and the large area of clear cutting are the direct reasons for the formation of the stands. Based on the above mentioned features, we propose a schema for the regeneration of white birch in northeast China (Fig. 2).

White birch of around 15-20 years old can produce plenty of seeds in almost all years. The small seeds with wings can spread over a long distance by wind (Tabata 1966), regenerating secondary forests easily in cut-over and burned areas, but the natural longevity of white birch stands is only about 70-80 years, and then trees would be dead due to the degenerate growing and infection of disease and insects. Afterwards, it is easily replaced by *Larix gmelinii*, *Pinus koraiensis*, *Picea koraiensis* and *Abies nephrolepis* in the process of succession. Thus, white birch stands can be regarded as a kind of transient forest phase (Zhou 1991, 1986).

Conclusions

The forest area in northeast China is the major forest area. The stocked volume of forests is equivalent to one third of the total forest area in China. However, the forest had been destroyed seriously because of overemphasizing timber production in last decade. Especially the dominant tree species of primary forests such as larch (*Larix gmelinii*), Korean pine *(Pinus koraiensis)* and so on have almost been destroyed completely. Then, white birch and poplar replaced the dominant species of the primary forest and have formed secondary forests, and white birch stands cover the majority of the secondary forest. These birch stands supplied plenty of resources for sap production of white birch stands. Up to date, for the implementation of the Natural Forest Protection Engineering in the whole country, the emphasis of forestry has changed from timber production to forest comprehensive management. This has given the sap production of white birch stands an opportunity to develop, so there must be an extensive market perspective if the sap production was markedly developed in northeast China.

There are a few places where people have tried sap production from white birch in northeast China, but many problems such as the small scale, poor technology and maintenance of products, need to be solved. Therefore, cooperation with researchers and traders of overseas developing new methods of sap production of white birch has become necessary to further develop with this resource.

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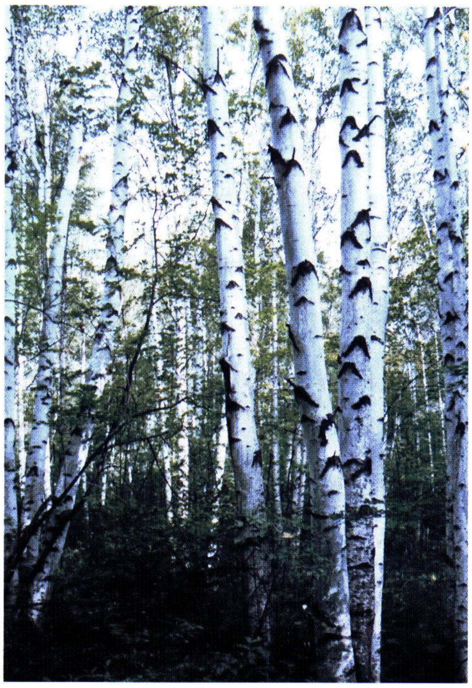

Photo.1. A *Betula platyphylla* forest in the Xiaoxingan Mountains

The shrub species are mainly composed of *Lonicera chrysantha* and *Corylus mandshurica*

Photo.2. Leaves and fruits of *Betula platyphylla*

Photo.3. The bark of *Betula platyphylla*

White powders are observed on the bark surface, which may act as defense chemicals against voles and hares

Photo.4. A *Betula platyphylla* forest in the Xiaoxingan Mountains in autumn

Deciduous broad-leaved trees, such as *Acer mono* and *Populus davidiana* are mixed in the forest

Photo.5. The successive regeneration of a *Betula platyphylla* forest in the Xiaoxingan Mountains

Picea koraiensis seedlings begin to invade into the birch stnads

Photo.6. A *Betula plyatyphylla* forest in the Daxingan Mountains

Mosses are dominant in the forest floor

Photo.7. A *Betula davurica* forest in the Zhangguangcai Mountains

The shrub species are mainly composed of *Lespedeza bicolor* and *Corylus heterophylla*

Photo.8. A *Betula ermanii* forest in the Changbai Mountains

Stems of *B. ermanii* show creeping in shape for the adaptation to the strong wind environments