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Shelterbelt Management and Control of
Asian Longhorned Beetle,* Anoplophora glabripennis, *in the Three-North Region of China

Review of Tree Selection and Afforestation for Control of Asian Longhorned Beetle in North China

by

Yin Weilun

Beijing Forestry University

Lu Wen

Bureau of Three-North Shelterbelt Programme, State Forestry Administration

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Background

This paper is one of a series of FAO documents on forest-related health and biosecurity issues. The study was carried out as part of a Technical Cooperation Programme (TCP/CPR/2903), Shelterbelt Management and Control of Asian Longhorned Beetle *Anoplophora glabripennis* in the Three-North Region of China, a technical agreement between FAO and the Goverrnment of the People's Republic of China.

This Working Paper is based on:

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Quantitative information has been compiled according to sources, methodologies and protocols identified and selected by the authors. For standardized forest inventory methodologies and assessments on forest resources, please refer to FAO, 2005. *State of the World's Forests 2005*; and to FAO, 2001. *Global Forest Resources Assessment 2000 (FRA 2000)*. FAO Forestry Paper No 140.

Official information can also be found at the FAO Internet site
http://www.fao.org/forestry/forestry.asp.

Comments and feedback are welcome.

For further information please contact:

Pierre Sigaud, Forestry Officer
(Forest Genetic Resources)
Forest Resources Division
Forestry Department
FAO, Viale delle Terme di Caracalla
00100 Rome, Italy
Fax: + 39 06 570 55 137
Email: pierre.sigaud@fao.org

Gillian Allard, Forestry Officer
(Forest Protection and Health)
Forest Resources Division
Forestry Department
FAO, Viale delle Terme di Caracalla
00100 Rome, Italy
Fax: + 39 06 570 55 137
Email: gillian.allard@fao.org

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I. Introduction

The Three-North Shelterbelt Development Programme under the State Forestry Administration (the Three-North Programme) was launched by the Chinese Government in Northwest, North and Northeast China in 1978. The programme has and continues to have an important role in desertification control, harnessing water and soil erosion, improving living conditions and promoting the local economy. This has been accomplished through the establishment of an extensive network of forest stands, shelterbelts and afforestation.

The Asian Longhorned Beetle (ALB) *Anoplophora glabripennis* Motchulsky (Coleoptera: Cerambycidae) is an endemic tree borer infesting hardwood species in China. The pest has caused significant damage to the Three-North Region. Research has been carried out on the identification, introduction and dissemination of tree species and clones more tolerant to the insect pest; and forestry authorities have developed improved designs and management for plantations and shelterbelts in the Three-North Region.

This document presents a review/synthesis of the experience gained by Chinese scientists and practitioners in ALB management and control, with special emphasis on ALB management, afforestation models, shelterbelt structure and composition, and ranking of tree species according to resistance/susceptibility to ALB. Although this report is mainly focused on the Three-North Region of China, it draws from the extensive experience and references from other parts of the country.

The authors are aware of the limitations of the report, in that methodologies, criteria and protocols for assessing, categorizing, monitoring and reporting differ significantly; ALB is an opportunistic pest which makes it difficult to rank tree species/varieties, especially over wide geographic areas; and there is no globally used nomenclature for Chinese poplar species and varieties.

This document should be read in connection with:
Pan Hong Yang, 2005. Review of the Asian Longhorned Beetle - Research, Biology, Distribution and Management in China. Forest Health & Biosecurity Working Papers, Working Paper FBS/6E, FAO, Rome, Italy.

II. Overview of the Three-North Shelterbelt Programme

II-1. Programme Overview

The Three-North Shelterbelt Programme in China is the largest multi-purpose protection forestry project in the world. Launched in 1978, the Program, from Bingxian County, Heilongjiang Province in the east to Wuzbieri Pass, Xingjiang Autonomous Region in the west, spans 4,480 km from east to west and 560 -1,460 km from north to south. It covers a total area of 4.069 million km^2, accounting for 42.4% of the total land surface of China, including 551 counties (banners, cities, districts) of 13 provinces, autonomous regions and municipalities in the Three-North Region. The overall objective of the Programme is to improve environmental conditions, control dust storms and soil and water erosion and improve local livelihood and economy.

The programme foresees the establishment of 534 million mu[1] (35.6 million ha) of plantations from 1978 to 2050, leading to a predicted increase in forest coverage of the Three-North Region from 5.05% to 14.95%.

The Three-North Shelterbelt Programme has completed its first (1978-1985), second (1986-1995) and third phase (1996-2000) and is currently under its fourth phase (2001-2010). By the end of 2003, an cumulative area of 22 million hectares had been added to the forested land since 1978, leading to an increase in forest cover in the area from 5.05% to 10% as well as significant gains in ecological, economic and social benefits. (1,68)

During the fourth ten-year implementation phase (2001-2010), over 9.5 million hectares of forests will be established, and the risks associated with the Asian Longhorned Beetle will have to been taken into consideration. The Three-North agency is committed to ensuring that proper afforestation practices will be implemented and medium and long term measures for sound forest establishment and pest management set up.

[1] 1 hectare is equal to 15 Chinese mu

II-2. Strategic Shifts in Afforestation and Reforestation Policies

The Three-North Shelterbelt Programme, has since its inception, engaged major policy and implementation shifts, putting afforestation and reforestation in North China in line with overall central government policies.

Forestry based ecological projects are now carried out under general centralized planning and managed by individual households. A shift has been made from focusing exclusively on ecological benefits of protecting farmland to balancing economic and ecological benefits, by integrating agriculture and forestry. Shelterbelt and forest designs have been improved to provide multi-layered systems with appropriate species, provenances and varieties matched to local site conditions.

Forest management pays greater attention to combining silviculture, collection of non-wood products and wood processing. Production of forestry-based commodities is taking shape, fostering local rural industry. In densely-populated areas with irrigated agriculture, shelterbelts and plantations are integrated within agriculture production through windbreak, intercropping and alleycropping systems resulting in increased land use efficiency, maximized protection and increased economic opportunities. Overall, this is a significant departure from the originally protection-oriented tree plantings, which provided limited benefits and lacked biological stability (3).

III. ALB Damage in the Three-North Region

Severe outbreaks of Asian Longhorned Beetle (ALB) were reported from 1980 to 1990(7). Recently, it has been estimated that 587,000 hectares of plantations are annually affected by ALB nationally in China, including 200,000 hectares in Shaanxi, Gansu, Ningxia, Qinghai and Heilongjiang alone (7.8).

III-1. Underlying Causes of ALB Outbreak

1. Originally, the majority of plantations in the Three-North Region consisted of genera susceptible to ALB (i.e. *Populus*, *Salix* and *Ulmus*). Recent estimations show that out of 22 million hectares afforested under the Three-North programme, over 5 million hectares include tree species susceptible to ALB. From 1990 to 2000 the area covered by poplar in the Three-North Region has increased from

4.8 million hectares to 6.0 million hectares. This includes natural poplar forest estimated to be 1.2 million hectares in 1990 (69, 70).

2. A limited number of poplar varieties are used, and have been selected for their fast-growth and adaptability to local conditions, with limited regard to ALB resistance.
3. Most affected areas are not source areas of ALB, thus in these areas ALB has few natural enemies.
4. In many areas poor tree growth due to environmental stresses (i.e. drought and extreme temperatures) has led to reduced pest and disease resistance.
5. Popular shelterbelt and plantation designs have been unable to balance biological risks.
6. Ineffective prevention, quarantine and ALB control measures have been in place.

III-2. Damage Caused by ALB to trees

Rotation length: In the Three-North Region, poplar shelterbelts are designed to be effective for 15 to 20 years depending on site conditions and uses. ALB infestation significantly reduces the life span of poplar shelterbelts to 10 to 12 years.

Tree growth: A study by Luo Youqing(15) showed thst ALB infestation of young (seven-year-old or less) *P. x xiaozhuannica* 'Popularis' decreased DBH 14%, tree height 21%, timber volume 37% and biomass by 37%. Lou reported that these losses increased with forest age and pest density (15). Losses of timber volume and annual increment in poplar Section *Tacamahaca* and Section *Aigeiros* are reported to be up to three times more than those of trees in Section *Leuce* (15).

Timber quality: ALB leaves visible holes on bark and permanent galleries in the wood, significantly impacting wood properties and uses. According to the National Grading Standards, the grade of logs is reduced by one level, and timber value decreased by 25%, once a standing tree is attacked by ALB. Dissection of a 16-year tree of *P. dakuanensis* by Gao Ruitong *et al.* (16) showed that existence of pest galleries in the wood resulted in 89% of timber being classed as 3rd grade with a corresponding 46% loss in value and 11% reduced to 2nd grade with a 25% loss in value.

IV. Progress of Research in Controlling and Preventing ALB

Effective alleviation of ALB damage has been achieved in some areas, however complete control has not been totally accomplished and considerable work and vigilance is still required.

IV-1. Overview of Progress

Research

In 1937, Liu Hechang first reported on the ALB hazard in China [(17)]. In the mid 1950's, Qin Xixiang [(18)] conducted a comprehensive study and published the paper "Study on Biological Features and Its Control Measures of ALB", in 1959. The paper detailed elements of ALB life cycle, biology and control measures.

From 1960 to 1970, five reports were published on ALB occurrence and control. In the 1980s, with expanding poplar plantation and increasing ALB damage, central and local governments initiated systematic studies on ALB. During the past 20 years more than 400 papers related to longhorn beetles have been published, including 200 papers published after 1990.

Management

The ecosystem approach is increasingly used by the Three-North Shelterbelt Programme to develop afforestation designs that include the management of biological risks. The underlying assumption is that resilience to catastrophic pest infestations is related to an ecosystem biodiversity, although this is not a linear relationship. A majority of plantations established under the Three-North Programme areas were not originally (or in historical times) wooded lands, and the ecosystem created after planting is closer to an agro-ecosystem than to a natural forest. In agro-ecosystems it is important to balance relationships between hosts, pathogens and environment within the ecosystem to maintain a dynamic balance, helping to maintain forest pest and disease at acceptable levels. [(29, 30, 31)]

Under the ecosystem approach chosen, afforestation models combine layers of trees, shrubs and grasses. Woody species, varieties and clones are mixed between and within shelterbelts rows [(27, 28)]. A chemical based approach to ALB control on single species/clones stands has given way to more integrated forest management combining planting designs, species/varieties selection, silviculture and chemical, physical and biological control.

IV-2. ALB Control: Silviculture Approaches and Species Resistance

IV-2-1. Poplar Susceptibility and Resistance

Over the past years, several Chinese researchers have studied the resistance of poplar varieties to *Anaplophora*. Through extensive research on poplar and other woody species resistance to *Anaplophora nobilis* in the Northern Yin mountain, Ningxia, Wang *et al.* (32) found that resistance varies according to poplar variety. They found that species of the Section *Leuce* showed resistance, while species within the Section *Tacamahaca* were generally susceptible. Wang *et al.* also found that the genera *Acer*, *Salix* and *Ulmus* were highly susceptible to *Anaplophora nobilis*. They suggested that the high susceptibility of *Acer* makes the genus highly effective as a bait or trap tree attracting *Anaplophora*. Wang *et al.* also found that ALB can be highly selective to tree species and clones, and in the presence of highly susceptible species moderately susceptible species are seldom infested. For example, they cited that poplar species of Section *Leuce* were largely unaffected by ALB whenever the highly susceptible *Populus x beijingensis* hybrid was planted as part of the plantation or shelterbelt. Therefore, Wang *et al.* (32) proposed an afforestation model whereby a certain number of *P. x beijingensis* and *Salix matsudana* were retained and trees with greater *Anaplophora* resistance such as *P. bolleana* and *P. hopeiensis* planted as the main species. Their study showed that when all *P. x beijingensis* and *Salix matsudana* trees were removed and completely replaced with the more resistant *P. bolleana,* this variety was gradually infested with *Anaplophora.*

ALB has been recorded in parts of Gansu Province for over 20 years. Yang (33) studied *Anaplophora* susceptibility in tree species and forest stands in Gansu from 2000 to 2001. Yang's results showed that in a mixed forest with multiple tree species, the susceptibility ranking (from high to low) was *P. dakuanensis*, *P. nigra* 'thevestina', *P. simonii*, *Salix matsudana*, *Ulmus pumila*, *P. bolleana*, *P. tomentosa* and *P. hopeiensis*. Resistant species reported by Yang were *Ailanthus altissima*, *Rhus typhina*, *Robinia pseudoacacia*, *Paulownia tomentosa*, *Sophora japonica*, *Prunus armeniaca*, *Juglans regia*, *Ginkgo biloba*, *Pinus* spp. and cypress.

Studies in Juxian County of Shandong Province, showed that the most *Anaplophora* resistant poplar clones were *P. x beijingensis* # 32, *P. x beijingensis* # 567, P. x e*uramericana* 'Robusta', *P. simonii x P. pyramidalis*, P. x c*anadensis* and *P. x euramericana* 'Sacrau-79' with an average resistance rate of 80.6%(39,46). Observations by Wang *et al.* (34) in Xuzhou, Jiangsu Province identified poplar clones *P. x euramericana* 'I-63', *P. x euramericana* 'I-69' and *P. x euramericana* 'I-72' with higher resistance, whereas, medium resistant clones were *P. x euramericana* 'I-45', *P. x euramericana* 'Sacrau-79' and *P. x euramericana* 'I-214'. Research by Li and Wu (11) in Anhui Province showed that *P. tomentosa* had high resistance to ALB (11). Studies in Gansu province by Zhou (35) indicated that in the Northwest Region, species with resistance to *Anaplophora nobilis* included *P. alba*, *P. hopeiensis*, *P. tomentosa* and *P. bolleana*; whereas susceptible species were *P. dakuanensis*, *P. nigra* 'thevestina', *P. simonii*, *P. cathayana* and *P. x beijingensis*. Yang *et al.* (36) ranked species resistance to ALB in the Northern Yin area of Ningxia (from high to low) to be *Ailanthus altissima*, *Sophora japonica*, *Fraxinus sogdiana*, *Robinia pseudoacacia*, *P. tomentosa*, *P. hopeiensis*, *P. bolleana*, *P. simonii*, *P. pseudo-simonii*, *Salix* spp. and *P. x canadensis*; while the ranking of species resistance (high to low) in southern Yinchuan, Ningxia was *Ailanthus altissima*, *Sophora japonica*, *Robinia pseudoacacia*, *Eleagnus angustifolia*, *P. bolleana*, *P. x xiaozhuannica* 'Opera', *P. pyramidalis* 'thevestina' and *P. simonii*. Research by Zhang and Lu (37) at the Forestry Research Institute of Inner Mongolia, reported that *Tilia* species attracted ALB adults but eggs did not appear to be viable.

A comprehensive study by Qin *et al.* (38) quantified ALB resistance of *Populus* clones in Shandong Province, summarized below.

(1) Species/hybrids with high resistance to ALB:

- *P. x euramericana* 'Robusta',
- *P. x euramericana* 'Sacrau-79',
- *P. x xiaozhuannica* 'Opera',
- *P. simonii* x *P. nigra* 'Italica',
- *P. x beijingensis* '243',
- *P. x beijingensis* '32',
- *P. x beijingensis* '567',
- *P. x xiaozhuannica* 'Opera # 8294',
- *P. deltoides* 'Lux 69/55',
- *P. deltoides* '2KENS',
- *P. deltoides* '55/65',

- *P. deltoides* ’2821’.

(2) Species/hybrids with medium resistance:

- *P. x euramericana* ‘G-158’,
- *(P. simonii x P. nigra* ‘pyramidalis’) # 4,
- *(P. simonii x P. nigra* ‘pyramidalis’) # 2,
- *P. x canadensis,*
- *P. dakuanensis* ‘Daguan’,
- *P. balsamifera,*
- *P. x euramericana* ‘Vegeherata 272’,
- *(P. simonii* x *P. nigra* ‘pyramidalis’*)* ‘Baichenisis’,
- *P. x euramericana* ‘Veruirubens’,
- *(P. simonii* x *P. nigra* ‘pyramidalis’*)* ‘Taiqing’,
- *P. x euramericana* ‘I-214’,
- *P. simonii x P. nigra*;
- *P. x euramericana* ’Triplo’
- *P. x euramericana* ‘Gattoni’,
- *P. x euramericana* ’Cima，
- *P. x euramericana* ’1070’
- *P. x euramericana* ’Costanzo’
- *P. x euramericana* ’Carpaccio’
- *P. x euramericana* ’Tiepolo’
- *P. x euramericana* ’Cappa bigliona’
- *P. x euramericana* ’1476’

(3) Susceptible species/hybrids (with poor resistance):

- *P. nigra* ‘pyramidalis’,
- *P. generosa*,
- *P. nigra* ‘thevestina’ x *P. nigra*
- *P. deltoides* ‘Brangarsi’
- *P. x euramericana* ‘Luisa Avanzo’
- *P. x euramericana* ’Bellini’
- *P. x euramericana* ’Guardi’.

Through field observation and laboratory experiments in Ningxia, Cao *et al.* (39) have studied ALB resistance of selected poplar species and hybrids. Their results are shown in Table 1.

Table 1. Results of Laboratory Experiment with ALB Adults (from Cao *et al.* [39])

Species/Hybrid	DBH (cm)	Eggs (no.)	Larvae (no.)	Density of oviposition sites	Rate of affected trees (%)	Hatching Rate (%)
P. deltoides 'Zhonglin 46'	4.90	25.66	38	12.66	100	49.35
(P. deltoides x *P. simonii*) NL—105	4.50	22.3	25	8.33	100	37.31
(P. deltoides x *P. simonii*) NL—108	4.23	8.66	22	7.33	100	84.6
(P. tomentosa x *P. bolleana)* x *P. tomentosa* 66	5.06	1.66	0	0	66.67	0
(P. tomentosa x *P. bolleana)* x *P. tomentosa* 67	3.63	0.33	1	0.33	33.3	100
(P. tomentosa x *P. bolleana)* x *P. tomentosa* 73	4.63	0	0	0	0	0
P. (tomentosa x *P. bolleana)* x *P. tomentosa* 75	4.60	5.66	7	2.33	100	41.17
(P. tomentosa x *P. bolleana)* x *P. tomentosa* 80	4.26	3.33	2	0.66	33.3	20
(P. tomentosa x *P. bolleana)* x *P. tomentosa* 92	4.67	0.66	1	0.33	33.33	50
(P. tomentosa x *P. bolleana)* x *P. tomentosa* 96	4.97	4.33	4	1.33	66.67	30.76
triploid *P. tomentosa* 80	4.43	1.33	4	1.33	66.67	100
P. pyramidalis x *P. tomentosa*	4.50	0	0	0	0	0
(P. alba x P. glandulosa) x *P. tomentosa* 5L-25	5.03	22.33	25	8.33	100	37.31
P. bolleana (CK)	4.00	3.66	5	1.66	100	45.5
(P. alba x P. hopeiensis) x *P. hopeiensis* 605	3.56	0	0	0	0	0
(P. alba x P. hopeiensis) x *P. tremula* 698	3.36	0 .033	1	0.33	33.3	100
(P. alba x *P. bolleana)* x (*P. alba* x *P. bolleana*)104	3.63	0	0	0	0	0

In laboratory tests, Cao *et al.* [39] showed that Section *Leuce* hybrids have relatively high resistance to ALB, though resistance varied among species and hybrids. The most highly resistant hybrids were *P. pyramidalis* x *P. tomentosa*, (*P. tomentosa* x *P. bolleana)* x *P. tomentosa* #73, (*P. tomentosa* x *P. bolleana)* x *P. tomentosa* #66, (*P. alba* x *P. hopeiensis)* x *P. hopeiensis* # 605 and (*P. alba* x *P. bolleana)* x (*P. alba* x *P. bolleana)* #104. Cao *et al.* [39] noted that these hybrids require further field testing before large scale planting. They noted that Section *Aigeiros* hybrids were generally susceptible to ALB.

Wang *et al.* [32] ranked susceptibility of poplar species in Ningxia (Table 2).

Table 2. Severity of ALB by various species and hybrids (Wang *et al.* [32])

Species/Hybrid	Susceptibility Ranking
P. hopeiensis	1
P. alba x *P. hopeiensis* '2'	2
P. tomentosa	3
P. davidiana	4
P. bolleana	5
P. deltoides 'Nankang'	6
P. deltoides 'Zhonglin 46'	7
P. x *xiaozhuannica* 'Opera'	8
P. pyramidalis 'thevestina'	9
Acer negundo	10

According to Wang *et al.* [32], *P. hopeiensis* and *P. tomentosa* have high ALB resistance. Their research showed that in the mountainous areas of southern Ningxia the percentage of trees affected by *Anaplophora nobilis* reached 8.5% in *P. hopeiensis* forest, compared to over 43.4% in *P. x beijingensis* and other poplar plantings. In Shandong Province, Qin[38] reported that the percentage of ALB affected *P. x euramericana* 'I-69' trees was less than 1%. In Hebei Province studies on ALB resistance and growth performance of six poplar species/hybrids showed that *P. x canadensis* was susceptible to ALB; *P. x euramericana* 'I-214' and *P. deltoides* 'Shenanigan' had medium resistance with fast growth and *P. tomentosa*, *P. hopeishaanxi* # 1 and *P. hopeishaanxi* # 2 had the highest degree of resistance [40].

IV-2-2. Progress in Design, Management and Species Selection

Considerable research has been directed to silvicultural design, forest management and appropriate selection of species and varieties for ALB control. Zhou *et al.* [41] emphasized that afforestation and pruning efforts are effective for ALB prevention and control. Zhou reported that in Juxian County, Shandong Province, the ALB infection of *P. x euramericana* 'Robusta' stands was 30% lower when intensive practices such as irrigation and fertilizer management were practiced. These practices enhanced growth and tree health and reduced susceptibility to pests and diseases. The study also showed that the pest-resistance rate of *P. x euramericana* 'I-72' with fertilizer application was 13.3% higher than when non-fertilized. Zhou reasoned that intensive management contributed to rapid and healthy tree growth, thus enhancing resistance ALB attack.

Wang *et al.* (34) and Gao *et al.* (42) reported that pruning lateral branches, which are favorable entry sites for ALB, effectively reduced the number of eggs laid on branches thereby reducing ALB severity. In addition, Wang *et al.* (34) and Gao *et al.* (42) reported that taking advantage of ALB's selective feeding habit depending on tree species can effectively control its spread. Gao *et al.* (43) and Gao (44) showed that resistance of tree species and varieties to ALB is relative, with species arrangement, climatic conditions and silvicultural management having a significant impact on ALB infestation. An important principle in ALB management is matching species to site conditions and using appropriate proportions of susceptible and resistant species, which contributes to the overall stability of the shelterbelt system (Xia *et al.* (43), Gao (44)).

Using diverse tree species and varieties in shelterbelts is intended to minimize risks from pest and disease outbreaks and potential catastrophic decline of the entire system. Shelterbelts with multiple species, particularly mixed conifers and broadleaves, provide a three-dimensional structure. This diversity is expected to build the foundation for shelterbelt stability and health. Research by Luo (45) showed that there are inter-relationships between species arrangement, proportions, diversity of insect groups and severity of ALB attack in a stand. Luo's study showed that the more diversified the tree species and varieties within a shelterbelt, the greater stand's ability to withstand pest infestation.

Forest stand structure and tree age are factors affecting the severity of ALB infestation. For example a poplar species that shows resistance in a mixed stand may well be affected by ALB in monocultures. The most susceptible age for most tree species is 5 to 10 years. According to Shao *et al.* (60) a complex stand structure with a carefully planned species arrangement is less likely to have ALB infestation.

IV-2-3.Introducing and Breeding Poplar for Resistance to ALB

In recent years introduction of new poplar species and breeding for resistance to drought, cold, salinity, pests, and diseases has been intensified. Research efforts have focused on the following aspects:

(i) Breeding programs

Cao *et al.* [39] reported that more than 20 hybrids of the Section *Leuce,* with reported resistance to ALB, have been developed. For example, in Ningxia hybrids *P. hopeiensis*, *P. alba* x *P. hopeiensis* # 2, (*P. alba* x *P. bolleana)* x (*P. alba* x *P. bolleana)* and *P. pyramidalis* x *P. tomentosa* have demonstrated fast growth, adaptability to unfavorable growing conditions and resistance to ALB. Studies with *P. tomentosa* triploids have indicated that they demonstrated fast growth but their resistance to ALB was inferior to that of pure *P. tomentosa*.

(ii) Genetic modification

Lu *et al.* [6] and Hu *et al.* [46] reported on afforestation experiments in the Three-North Region with genetically improved poplar clones such as *P. deltoides* 'Beikang' and *P. deltoides* 'Nankang' selected by crossing trees with higher tolerance to ALB damage. In addition, insect tolerant poplar varieties developed by genetically modification using insect toxin gene from *Bacillus thuringiensis* (Bt.) (Hu *et al.* [46]) have been obtained and installed in field tests. Commercial transgenic *P. nigra* and hybrid poplar '741' were used successfully in the control of defoliating insects. However, they have not proven effective in controlling ALB larvae, which feed on wood. Recent work (Chen *et al.*, 2005)[73] has shown that a toxin encoded by gene *Bt886cry3Aa* from Bt is effective in killing ALB. The bioassay using larvae of long horned beetles fed with poplar plants transformed with this gene has shown high mortality of beetles, although field test will be needed to confirm the effectiveness of the gene construct.

IV-2-4. Studies on Selection of ALB Resistant Species.

Studies have shown that ALB resistance is related to tree specie's chemical composition and/or bark and xylem structure. Some studies have focused on analysis of the relationship between a tree species internal chemical composition and resistance to ALB. These studies have highlighted the potential of selection of tree species and varieties with unique chemical substances for ALB control. [32,50,51]

Several researchers [32,50,51] have suggested that selection of tree species with specific chemical characteristics may be effective in ALB control. Studies by Wang and Zhou [49] and Wang *et al.* [50] noted that chemical composition differences between species made certain species more attractive to ALB adults, which facilitated targeted control opportunities. Other studies have suggested that volatile chemicals such as terpenoids, phenolic acids, alkaloid and flavonoid compounds have an important role in ALB resistance [51,52]. Species with reported resistance to ALB, such as *P. hopeiensis,* contain more phenolic substances than species demonstrated to be susceptible to ALB [33,53,54]. Li *et al.* [55] reported that volatile esters and terpenoids which attract ALB account for more than 70% of all the volatiles found in ALB susceptible species such as *Salix matsudana* and *P. x xiaozhuannica* 'Opera'. In artificial stand-simulation tests it was found that *Ailanthus altissima* has several organism activated volatile substances, which reportedly repel ALB adults. Chao *et al.* [56] reported that among eight substances tested, pinene and syringene were among the most effective in repelling ALB.

There are limited studies on the relationship between bark and xylem structure and ALB resistance. Yang *et al.* [57] reported that severity of ALB attack was linked to the density and hardness of the xylem. They noted that several tree species and varieties with hard xylem appeared to inhibit adult ALB egg-laying reducing the severity of ALB attack. However, this does not explain the susceptibility to ALB of species like *Eleagnus angustifolia* and *Ulmus* spp. which have a hard xylem structure. Years of studies and investigations show that ALB resistance is most likely jointly determined by internal chemical composition and bark and xylem structure.

IV-3. Selection of Species for Use as ALB Bait Trees

The use of bait trees is one of the most effective measures used for ALB control in China. A 2002 study showed that *Acer* species planted along roadsides in Heilongjiang Province were totally affected by ALB and had to be removed, while the nearby *P. nigra* 'pyramidalis' were unaffected by ALB. In Hebei Province, roadside *Salix* species were heavily infested, with over 100 ALB larvae recorded per tree and 20% of the affected trees dead, while only 8% of the nearby *P. langfangnesis* were infested and displayed only 1 to 2 larvae found per tree. Gao *et al.* [58] reported that ALB adults favor *Acer* species for food and *P. x euramericana* 'Luisa Avanzo' for adult egg laying. This finding suggested the use of *P. x euramericana* 'Luisa Avanzo' as bait trees in North China as an alternative to *Acer*. However, experiments are needed in Northwest China to determine adaptability of this clone to the region. Finding a replacement to *Acer* in the northwestern region would alleviate difficulties and costs associated with the production of *Acer* seedlings.

Host preference of ALB adults is related to various factors including the structure of tree bark and xylem, temperature and environment. In an experiment with six tree species and cultivars (*Acer* spp., *Betula* spp., *P. x beijingensis*, *P. tomentosa*, *P. x euramericana* and *Ailanthus altissima*), *Acer* had the highest attraction to ALB, with an average of 31.8 out of 100 ALB adults captured inhabiting it with an average daily feeding area of 57.6 cm^2. In comparison *Ailanthus altissima* was the least preferred species with an average of 2.6 out 100 found with an average feeding area of 0.5 cm^2. The study showed that *P. x euramericana* was the preferred variety for egg laying by ALB adults

Study by Gao Ruitong *et al.* (42) shows that lifespan and reproduction ability of ALB adults vary with the tree species that they feed on. Lifespan of female adults is 4 times longer and quantity of eggs laid increased by average of 7.5 eggs when ALB feed on *Acer negundo* (or *A. saccharum*) compared to poplars in Section *Tacamahaca*. The study shows that *A. negundo* is not only an ALB bait species but also a host species promoting ALB propagation. Therefore, when using maples as bait, monitoring should be reinforced and the beetles should be treated to avoid that bait trees might otherwise become ALB propagation bases.

In 1998, Shao *et al.* (61) reviewed resistance to ALB and the economic benefit of seven afforestation models in Ningxia Plain. The study included a comprehensive assessment of shelterbelt resistance to ALB as wel as economic, ecological and social benefits. The study results showed that a mixed shelterbelt of two rows *P. bolleana* and two rows of the ALB susceptible clone *P. x xiaozhuannica* 'Opera' had better overall value than monoculture poplar shelterbelts of *P. x xiaozhuannica* 'Opera'. The study also showed that pure stands of *Ailanthus altissima* were a good model for ALB control, however, due to characteristic large tree crowns and competitive root systems, use of *Ailanthus altissima* is limited in farmland shelterbelts.

Taking into consideration host tree resistance and pest adaptability, as well as relative susceptibility rankings, tree species, varieties and clones used for plantations and shelterbelts need to be constantly renewed. In this regard, Shanxi Province developed the following guidelines for ALB control:

(i) Severity Ranking System: ALB free regions are marked as protected areas and regions with ALB occurrence as affected areas. Affected areas are classified as lightly, medium and heavily infestation based on ALB density. The control strategy is to afforest a 500 m wide separation belt with ALB immune tree species along the boundaries of the protected areas. In the case of light, medium and heavily infested areas, removal of affected trees and reforestation with a mixture of ALB immune species plus poplar species resistant to ALB have been adopted.

(ii) Integrated Control System: Specific measures include treating felled trees by destroying ALB eggs, killing larvae with pesticides, protecting and utilizing natural enemies of ALB; promoting planting of non-host species, such as *Ailanthus altissima* and *Paulownia tomentosa;* and restricting the planting of susceptible species as main target trees (i.e. *Acer, Ulmus* and *P. x euramericana*).

(iii) Regeneration by stump grafting: Bud grafting of resistant species on stumps of ALB affected trees improves their resistance. Experiments showed good results when *Populus* Section *Leuce* species were grafted on stumps of species in Section *Aigeiros*.

Pan and Wu (62) reported that ALB should not be segregated as a single target pest to be controlled, but regarded as a component of the whole shelterbelt ecosystem. In other words, a shift from “focused regulation of ALB” to “integrated regulation of ALB”, where the inter-relationship between host species, ALB, beneficial organisms and the living environment are considered (62). This approach mimics the unique structure as well as the spatial and temporal stability of a forest ecosystem, which is characterized by a strong ability for self-adjustment to biological risks.

IV-4. ALB Ecological Control Model

The ecological control model for ALB as reported by Yan and Yan (30) has received considerable attention. The core of this theory lies in pest and disease control through the study of pest ecology in forests and adjustment of inter-relationships among host trees, pest organisms and the environment. By studying pest ecology, including spatial distribution, quantity change, inter-species relationships and capacity of insect populations; a greater understanding of co-existence, interdependence and conflicting relationship among environment, host plants and organisms can be obtained. This will help in optimizing arrangement and co-ordination of the man-made ecosystems. Meanwhile, basic parameters of pest populations, such as hatching and mortality rates, pest movements, should be studied since they are subject to climate, natural enemies. In addition human activities that have a direct impact on the ecological control capability need to be considered. Guided by population, community and ecosystem ecology, Yan and Yan (30) reported that ecological control of forest pests and diseases aims at reaching a dynamic balance among population, community and ecology structure and functions (particularly in food chains and networks). This involves co-ordinating inter-relationships between organisms and environment as well as among the organism populations, meeting the goal of effectively controlling forest pests and diseases.

An ecological control system includes the utilization of scientific monitoring and forecasting mechanisms, implementation of regulatory quarantine systems, establishment of stable artificial ecosystems, promotion of biodiversity, initiation of multi-species synergetic prevention systems, development of tree species with immunity or high resistance to pests, adoption of measures for establishing healthy shelterbelts and application of integrated control measures with a focus on bio-control. To minimize pest disasters, the most basic strategy is to enrich the diversity of a forest stand, which in turn enhances the diversity of the insect community. This strategy ultimately results in comprehensive control of pests and diseases by self-adjustment of species in a stand (bio-control) and enhancement of tree self-resistance capacity.

Basic issues for forest pest control are: to determine pest resistance within a mixed forest, set up indicators for evaluation of a stand's resistance to pests and design pest resistant plantations. However, the difficulty in introducing methodology for insect pest control studies is a lack of in-depth studies on the relationships between tree species diversity in forest stands and severity of pest attack. This leads to difficulties in evaluating the pest-resisting ability of a forest stand using stand diversity indicators.

V. Results of ALB Control in the Three-North Region

V-1. ALB Resistance of Major Tree Species and Clones

Field experience has shown that ALB resistance of different tree species and poplar clones varies significantly. Within the Three-North Region, even the same species or clones show differences in ALB resistance depending on site conditions, growing environments and severity of ALB infestation. Therefore, it is difficult to rank the ALB susceptibility of the main tree species and clones used for afforestation in North China.

Based on the current ALB infestation in shelterbelts and observation of tree response to ALB, species have been classified by the authors according to five grades (Annex I). A tentative ranked list of species/variety susceptibity or resistance to ALB is provided in Annex II. This list is based on a review of Chinese literature reporting ALB damage on selected species/varieties and requires verification through local testing.

V-1-1. Pilot Shelterbelts in Yinchuan Plain, Ningxia Hui

Based on ALB resistance ranking, recommended designs for the ALB resistant pilot plantations in Ningxia and Inner Mongolia have been designed as follows.

V-1-1-1. Forest blocks or scattered plantations around farmhouses:
Recommended main species are immune or non-host species or species with high resistance to ALB, such as *Ailanthus altissima*, *Sophora japonica*, *Fraxinus sogdiana*, *P. hopeiensis* and *P. tomentosa* supplemented with a limited number of bait trees *P. pyramidalis*, *Acer negundo*, *Salix* or *Ulmus*. The recommended proportion of bait species for forest blocks is 5% and 10-15% for scattered plantations around houses.

V-1-1-2. Shelterbelts for farmland:
Recommended main species are immune or non-host species or species with high resistance to ALB, such as *Ailanthus altissima* , *Fraxinus sogdiana* and *P. hopeiensis*, as well as limited numbers of trees with moderate resistance such as *P. bolleana* and *P. deltoides* 'Zhonglin-46'. The recommended bait species are *P. pyramidalis*, *P. x xiaozhuannica* 'Opera' and *Salix* spp. with a proportion of 10-20%. For single-row shelterbelts, bait species can be mixed equally with the main tree species within the row, while for multi-row shelterbelts, bait species can be mixed in belt with the main species.

V-1-2. Plantations and Shelterbelts in the Southern Yinchuan Mountains

V-1-2-1. Forest blocks or scattered plantations around farmhouses:
Recommended main species are ALB immune species such as *Ailanthus altissima*, *Sophora japonica, Fraxinus sogdiana, Fraxinus mandshurica, Juglans regia, Pyrus betulaefolia* and *Euonymus alatus*, as well as species with high ALB resistance including *P. hopeiensis, P. tomentosa* and *P. alba*. A limited number of species with moderate ALB resistance, such as *P. bolleana* and *P. deltoides* 'Zhonglin-46', should be added. The recommended bait trees include *Acer* spp., *Ulmus* spp., *P. pyramidalis* and *Salix matsudana*, with proportions of 10% for forest blocks and 10-20% for scattered plantations around houses.

V-1-2-2. Shelterbelts for farmland:

Recommended main species are immune or non-hosting species or species with high resistance to ALB, such as *Fraxinus sogdiana*, *Fraxinus mandshurica*, *P. hopeiensis* and *P. bolleana*, as well as species with moderate resistance to ALB or can be eaten by ALB, including *P. deltoides* 'Zhonglin-46'. The recommended bait species are *P. pyramidalis*, *P. x xiaozhuannica* 'popularis' and *P. pseudo-simonii* with a proportion of 10-20% for a single-row shelterbelts, bait species are mixed within the main woody species within the row; while for multi-row shelterbelts, bait trees can be mixed in rows with main species to form bait belts.

V-1-3. Shelterbelts in Hetao Plain, Inner Mongolia

V-1-3-1. Forest blocks or scattered plantations around farmhouses (with low incidence of ALB or not yet affected areas):

Recommended main species have high resistance to ALB or not affected by ALBs, such as conifers, Chinese date trees, *Fraxinus sogdiana*, *P. hopeiensis*, *P. tomentosa*, *P. bolleana* and *P. deltoides* 'Zhonglin-46', with a small number of bait species such as *Acer negundo* and *Ulmus* spp. The proportion of bait species for forest blocks shall be 5% and 10 -15% for scattered plantations around farmhouses.

V-1-3-2. Forest blocks or scattered plantations around farmhouses in severely affected areas:

Recommended main species include ALB immune or non-hosting species, species with high resistance to ALB, such as *Sophora japonica*, *Robinia pseudoacacia*, *Fraxinus sogdiana*, *P. hopeiensis* and *P. tomentosa*, as well as species with moderate resistance such as *P. bolleana*, *P. deltoides* 'Zhonglin-46' and *P. x euramericana* 'Neva-107'. Bait species include *P. x xiaozhuannica* 'popularis' and *Salix* spp., with a proportion of 10% for forest blocks and 10-20% for scattered plantations around houses.

V-1-3-3. Shelterbelts for farmland (with low incidence of ALB or not yet affected areas):

Recommended main species are trees with high resistance to ALB such as *Fraxinus sogdiana*, *Sophora japonica*, *P. hopeiensis*, *P. tomentosa* and *P. euphratica*, as well as species with moderate resistance including *P. bolleana*, *P. x euramericana* ' Neva-107' and *P. deltoides* 'Zhonglin-46'. Bait species can be *Ulmus* spp. and *P. pyramidalis*, with a proportion of 10-15%. For a single-row shelterbelt, bait species are mixed within the main woody species within the row; while for multi-row shelterbelts, rows of bait trees can be mixed with the main species to form bait belts.

V-1-3-4. Shelterbelts for farmland in severely affected areas:
Main species are ALB immune or non-hosting species, species with high resistance to ALB or disliked by ALB, such as *Fraxinus sogdiana, P. hopeiensis* and *P. tomentosa*, as well as species with moderate resistance to ALB or which can be eaten by ALB, including *P. bolleana* and *P. deltoides* 'Zhonglin-46'. Bait species can be *P. x xiaozhuannica* 'popularis' and *Salix matsudana* with a proportion of 10-15%. For a single-row shelterbelt, bait species are mixed within the main woody species within the row; while for multi-row shelterbelts, rows of bait trees can be mixed with the main species to form bait belts.

V-2. Silvicultural Approaches for ALB Control in the Three-North Region

Ten silvicultural models recommended for ALB control in the Three-North region have been developed. The main prescriptions for each are summarized as follows.[36, 41, 60, 61, 64, 65, 66]

V-2-1. **Mixing species** – In this model multi-species mixed forests unfavorable to ALB existence so as to reduce the risk of serious damage caused by ALB and other pests are established. The core of this model is to allow the co-existence of various tree species and varieties, including immune, highly resistant, resistant, susceptible and bait trees, each with a different proportion in an area, for a joint defense against ALB infestation.

V-2-2. **Use of fast growing species** – This model recommends the use of fast-growing tree species and varieties for healthy and fast-growing shelterbelts by ensuring optimal water and fertilizer supply as well as other intensive management measures, in an effort to enhance trees' pest-resisting capacities and anti-ALB capabilities. For example, it is suggested that ALB eggs beneath the bark of a tree with an annual diameter growth increment (DBH) over 3 cm and newly incubated larvae may be destroyed due to the trees' fast growth and the rapid increment of its healing compounds at the wounds of the bark.

By selecting fast-growing species and maximizing soil, fertilizer and water management, increases in DBH can be realized. By observing and statistically analyzing ALB attack to these trees and comparing them to trees with no supplemental fertilizer and water, quantitative experimental results can be obtained that describe the relationships between severity of ALB attack and a trees' growth rate.

V-2-3 **Short Rotation Plantations** – Poplar trees are grown under a short rotation scenario where newly established shelterbelts and timber forests are harvested at a DBH of 6-8 cm. After harvest, the trees are regenerated from stumps. This silvicultural approach to lower ALB hazard is based on harvesting trees at a size prior to their becoming susceptible to ALB. Trees that are already affected by ALB are harvested and regenerated from stumps, which clears out infested trees and renews forest stands.

V-2-4. **Use of Bait Trees** – When 5-10% of trees in a shelterbelt consist of bait species, these trees attract ALB allowing focused control efforts. Although a small number of trees are sacrificed, the primary shelterbelt species and the whole stand are protected from ALB hazard. For example, in farmland shelterbelts in the Ningxia irrigation area, *P. x xiaozhuannica* 'Opera' is planted as bait species along with *P. bolleana* which is the primary shelterbelt species, With this system, ALB attack of *P. bolleana* is reduced from 60-70% to less than 15%; and from 30-40% to less than 1.6% for shelterbelts with *P. hopeiensis* as the primary shelterbelt species. In Bayanaor League of Inner Mongolia, bait species of *Acer* and *Ulmus* can effectively protect *P. x xiaozhuannica* 'popularis' and *P. bolleana* from ALB attack or reduce its damage. In heavily damaged ALB areas, target species *P. bolleana* and *P. euphratica* can be protected from ALB attack with *P. x xiaozhuannica* 'popularis' as bait species.

V-2-5. **Pruning Lateral Branches** – In ALB affected areas, intensive pruning that continuously removes lateral branches infested with ALB is effective means of controlling ALB. This practice removes preferred oviposition sites for ALB thus reducing ALB damage.

V-2-6. **Use of ALB-resistant Species** – This is silvicultural model adjusts species structure, increasing the proportion and quantity of ALB resistant species in a region therby reducing a stand's susceptibility to ALB hazard. By actively introducing ALB immune or highly resistant species or clones, the stand or shelterbelt can be quickly restructured with an increased proportion of ALB resistant species. For example, in heavily ALB affected areas, the proportion of affected trees will be greatly reduced and ALB damage alleviated by vigorously planting resistant species such as *P. hopeiensis*, *P. alba* and *P. davidiana*, together with *Sophora japonica*，*Robinia pseudoacacia, Ailanthus altissima, Fraxinus sogdiana*，*Paulownia tomentosa, Euonymus alatus, Catalpa bungei* and conifer species. In ALB free or slightly affected areas, species like *P. x euramericana* 'I-214', *P. x euramericana* 'Robusta', *P. bolleana*, *P. tomentosa* and *P. hopeiensis* can be planted.

V-2-7. **Use of Genetically Modified Trees** - Genetically improved poplars such as *P. deltoides* 'Nankang' and *P. deltoides* 'Beikang' have the potential to limit the spread of ALB in North China, provided the adaptation of these new clones to the environmental conditions of the Three-North Region has been fully investigated. In addition, the development of new poplar varieties using genetic engineering is being actively carried out in China, although their deployment is subject to a number of technical and regulatory processes including extensive testing in laboratory and field trials and the completion of relevant administrative endorsement from regulatory authorities. Post release monitoring will also be valuable, especially in view of assessing risks related to changes in the predator habits, and possible break down of the newly conferred resistance.

V-2-8. **Pollarding** – In ALB affected areas, pollarding affected poplar and willow trees at a height of 1.5m to 1.8m reduces ALB damage and creates habitat unsuitable to ALB, thus reducing attack intensity.

V-2-9 **Stump Grafting** – Grafting rapidly renews tree species and varieties and increases the number of resistant poplar species. This model has been in practice for over 10 years in the Three-North Region and positive results have been obtained. In ALB prone areas, badly affected trees are removed and 3 or 4 twigs of highly resistant poplar species grafted on the remaining stumps. In this way, a new shelterbelt with resistance to ALB can be quickly developed.

V-2-10. **Protection Rows** – This model involves planting a percentage of protection rows with ALB-resistant or ALB repelling tree species and varieties in strategic locations. Recommended species with ALB immunity include *Sophora japonica*, *Robinia pseudoacacia, Fraxinus sogdiana* and *Paulownia tomentosa* while ALB repelling species include shrubs such as *Ailanthus altissima, Syringa fruticosa* and *Amorpha fruticosa.* The application of this model for establishing farmland shelterbelts is to plant ALB immune or repelling species along each side of main roads or main canals.

V-3. ALB Control Projects in the Three-North Region

A number of projects have been carried out to tackle ALB infestations in Northern China. These projects have highlighted that it is crucial to establish healthy shelterbelts with adapted and diversified species. This includes mixtures of appropriate trees, shrubs, grasses, conifers and broadleaved trees arranged in appropriate designs, integration of silvicultural activities and forest management with ALB control as well as the systematic control of various pests and diseases.

To develop ALB control measures, which currently have achieved preliminary results, into normative guidelines, the Three-North Bureau needs to continue research on bio-control applications, including the use of parasitoid *Dastarcus helophorides* and woodpeckers, bait tree arrangement and treatment technology, application of synthetic pheromones, development of genetically modified poplars with resistance to pests and establishment of eco-control system.

VI. Conclusion

ALB management is a complex phytosanitary issue, over a large geographic scale, that requires holistic approaches. Given the current state of knowledge, no single control measure has proven effective in the eradication ALB. Only interlinked mitigation strategies, based on sound forest management, can be recommended to lower the impact of the pest in existing stands, and reduce risks associated with the establishment of new plantations, in particular poplar plantations.

Experience has shown the importance of building mixed shelterbelts with an array of tree/shrub species and clones selected on the basis of their adaptation to local conditions. A number of site-specific silvicultural models have been developed where species with different levels of susceptibility to ALB are combined.

There are about a hundred poplar species in the world, and China is located in the center of poplar diversity with 74 native species[2]. The genetic resources of many indigenous species have not been systematically explored, tested and used in North China. Natural populations of native poplars may in particular exhibit varying degrees of resistance to ALB. Provenances of native species need to be evaluated for their adaptability, including resistance to ALB. In species selection and tree breeding programmes, traditionally narrowly focused on growth and vigor, it is important to integrate selection for pest and disease resistance. This will require a long-term breeding programme customized to the needs of North China.

Genetic modification may be used to complement, but not replace, conventional breeding and selection programmes. Several issues will have to be investigated before large-scale deployment of genetically modified trees in North China takes place. The assessment of environmental impact of GM trees as well as an efficient monitoring system should be in place once they are released.

Improving monitoring and forecasting capacities at national and provincial stations will enhance the scientific basis for targeted action. As in any long-term management strategy, a key element will be to promote awareness, technical training and extension at all levels, including farmers and rural communities.

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Annex I. Classification of ALB Resistance [71]

The authors have proposed the following classification for ranking species and clones susceptibility to the Asian Longhorned Beetle. The classification is used in Annex II.

Grade	ALB feeding and life cycle features	Impact on Tree Growth
Grade 1 Non-host/immune species.	No feeding activity; No eggs laid.	Normal growth.
Grade 2 Highly resistant species	Entry sites can be found; Limited feeding; Small number of eggs laid; Can escape ALB attack if nearby trees are more susceptible to ALB.	Normal Growth; Slight damage with recoverable wounds.
Grade 3 Moderately resistant species, which can be attacked by ALB	Moderate feeding; ALB can complete life cycle.	Dieback on some branches; Dieback of the whole tree crown or the entire tree if stressed.
Grade 4 Susceptible species preferred by ALB	Extensive ALB feeding on the tree; ALB routinely completes life cycle.	Severe damage; Dieback on the tree crown or the entire tree.
Grade 5 Highly susceptible /bait tree species that attract ALB	Species attracts ALB; Feeding in large quantity; ALB completes life cycle on tree with population increases.	Entire tree dies quickly.

Annex II - Ranking of Main Tree Species and Clones According to ALB Resistance [71]

The classification system outlined in Annex I is used in the present Annex to harmonize different ranking systems used in the literature and provide a tentative list of species and clones according to their susceptibility to ALB in the Three-North Region of China. It should be noted that ALB susceptibility is relative and its intensity on target species/clones depends, among other factors, on the presence of species and clones with different degrees of resistance in the vicinity. The list should therefore be seen as indicative.

First Grade: Non-host/Immune Species	
Poplar Species and Clones	**Other Species**
None	*Ailanthus altissima* *Albizzia julihrissin* *Broussonetia papyrifera* *Catalpa bungei* *Cercis chinesis* *Chinnonanthus praecox* *Coriaria nepalensis* *Crataegus pinnuttifida* *Diospyros kaki* *Eucommia ulmoides* *Euonymus alatus* *Fraxinus americana* *Fraxinus mandshurica* *Fraxinus sogdiana* *Ginkgo biloba* *Juglans regia* *Liriodendron chinensis* *Magnolia denudata* *Malus pumila* *Melia azedarach* *Morus alba* *Paulownia tomentosa* *Platanus orientalis* *Prunus armeniaca* *Prunus cerasifera* *Prunus salicina* *Punica granatum* *Pyrus betulaefolia* *Quercus liaotungensis* *Rhus typhina* *Robinia pseudoacacia* *Sambucus williamsii* *Sophora japonica* *Tilia paucicostata* *Toona sinensis* *Toxicodendron verniciflnum* *Zunteocylum bungeanum*

Annex II - Ranking of Main Tree Species and Clones According to ALB Resistance (contd.)

Second Grade: Highly Resistant Species				
Poplar Species and Clones				Other Species
Section *Leuce*	**Section *Turanga***	**Section *Tacamahaca***	**Hybrids**	*Koelreuteria paniculata*
P. alba	*P. euphratica*			*Prunus persica*
P. davidiana	*P. euphratica* 'pyramidalis'			
P. hopeiensis	*P. euphratica* 'PE-214'			
P. tomentosa	*P. pruinosa*			
P. tomentosa 'honanica'	*P. ertyschensis*			
P. tomentosa 'hopeinica'				
P. tremula				
P. tremuloides				

Annex II - Ranking of Main Tree Species and Clones According to ALB Resistance (contd.)

Third Grade: Moderately Resistant Species				
Poplar Species and Clones				**Other Species**
Section Leuce	***Section Aigeiros***	***Section Tacamahaca***	***Hybrids***	
P. alba ‘pyramidalis’ *(syn. P. bolleana)*	*P. deltoides ’Nankang’* *P. deltoides ‘Qingji # 1,2’* *P. deltoides ‘Shanhaiguan’* *P. nigra ‘pyramidalis’*	*P. balsamifera*	*P. alba x P. bolleana* *P. alba x P. tomentosa* *P. x canadensis* *P. deltoides x P. simonii* *(P. deltoides x P. simonii)* ’NL-105’ *(P. deltoides x P. simonii)* ’NL-108’ *(P. simonii x P. nigra* ‘pyramidalis’) # 2 *P. x euramericana* ‘ND-182’ *P. x euramericana* ‘’158” *P. x euramericana* ‘Neva-107,108’ *P. x euramericana* ‘Luisa-Avanzo’ *P. x canadensis* ‘Vernirubens’ *P. x euramericana* ‘Shanlin-1’ *P. x euramericana* ‘Vegeherata 272’ *P. x euramericana* ‘Polska-15” *P. x euramericana* ‘Polska 15’ *P. x euramericana* ‘I-214’ *P. x euramericana* ‘I-69’ *P. x euramericana* ‘Robusta’ *P. x euramericana* ‘Sacrau-79’ *(P. pyramidalis x P. simonii*) # 4	*Vitis vinifera* *Elaeagnus angustifolia*

Annex II - Ranking of Main Tree Species and Clones According to ALB Resistance (contd.)

Fourth Grade: Susceptible Species				
Poplar Species and Clones				**Other Species**
Section Leucoides	***Section Aigeiros***	***Section Tacamahaca***	***Hybrids***	
P. lasiocarpa	*P. deltoides*	*P. cathayana*	*(P. simonii x P. pyramidalis)* ‘Baichensis’	*Salix*
P. pseudoglauca	*P. nigra*	*P. dakuanensis*	*(P. simonii x P. pyramidalis)* ‘Taiqing’	*matsudana*
	P. thevestina x P. nigra	*P. gansuensis*	*P.deltoides* ‘Zhonglin-46’	*Salix*
		P. pseudosimonii	*P. deltoides* ‘Zhonglin-56’	*babylonica*
		P. simonii	*P. nigra x P. simonii*	*Ulmus pumila*
		P. ussuriensis	*P. simonii x P. nigra* ‘pyramidalis’	
			P. simonii x P. nigra ‘italica’	
			P. x beijingensis	
			P. x berolinensis	
			P. x russkii	
			P. x stalinetz	
			P. x xiaohei	
			P. x xiaohei ‘Heilin-1’	
			P. x xiaozhuannica	
			P. x xiaozhuannica ’Opera’	
			P. x xiaozhuannica ‘Popularis’	
			P .’Lux’ *(I-69/55)*	

Annex II - Ranking of Main Tree Species and Clones According to ALB Resistance (contd.)

Fifth Grade: Highly Susceptible/Bait Tree Species	
Poplar Species and Clones	**Other Species**
P. nigra ‘italica’	*Acer buergerianum*
P. nigra ’thevestina’	*Acer mono*
P. x euramericana ‘Luisa-Avanzo’	*Acer negundo*
P. x xiaozhuannica	*Acer truncatum*
P. x xiaozhuannica ‘Opera’	*Elaeagnus angustifolia*
P. x xiaozhuannica ‘Popularis’	*Salix babylonica*
	Salix matsudana
	Ulmus pumila

Resistance of a tree to ALB is relative. The present ranking list is for reference only.