quantitative genetics in order to allow the estimation of genetic parameters (FALCONER, 1981). As was shown by GALLO (1991), this assumption is not realized in studies of enzyme gene loci performed in the same material. The studies also revealed strong deviations from HARDY-WEINBERG proportions as well as gametic phase disequilibria.

These as well as other assumptions, which can rarely be verified in experimental designs, shed doubt on the significance of many of the estimates on additive or non-additive components of variance, genetic correlations, selection gains, etc., communicated in the technical literature. It appears that, in the last analysis, such estimates frequently give the impression of precise quantifiability where, more appropriately, they should be taken as indicators of tendencies. At least in such situations, an ARF as presented in this paper might be preferable.

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Natural Poplar Resources in China and Their Significance for Breeding and Afforestation

By H. WEISGERBER, D. KOWNATZKI and M. MUSSONG[1])

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Summary

China has a distinctly varied flora, especially in the subtropical mountain regions in the South. This is particularly the case with the indigenous poplars, for example in the Southern and Western regions of the Qinghai-Tibet plateau.

The natural forests were however displaced to a very great extent by various anthropogenic influences in earlier times. Lack of forests and shortage of wood have led in many parts of the country to the establishment of monoclonal plantations with fast growing tree species. But these have created unstable forest structures with a high cultivation risk.

The aim of the Chinese-German cooperative project begun in 1984 is both to preserve still existent natural poplar sources and also to use them for breeding and afforestation purposes. Attention is paid to achieving a well balanced relationship of timber yield to yield stability. Great importance is attached to building up multiclonal varieties with high growing potential and good adaptation to the continental, semi-arid climatic conditions in the project region.

In the course of the project up till now numerous fast-growing and healthy sources of 19 indigenous poplar species and 3 natural species hybrids have been recorded in nine provinces and autonomous regions of Central and North China. Preservation measures have been started. In the project centre Jinshatan extensive living collections have been assembled

[1]) Hessian Forest Centre for Management Planning, Research, and Ecology, Hann. Münden, Germany

containing about 650 indigenous and 170 exotic poplar clones. In several hybridization programmes we have produced up till 1995 roughly 400 different intra and interspecific combinations. The trial plots set up so far show considerable differentiation in growth both among the clones and among the hybrid progenies. The resulting consequences and prospects for practical afforestation measures are pointed out.

Key words: Chinese poplar resources, diversity, preservation, hybridization, afforestation project.

FDC: 165.5; 181; 165.71; 176.1 Populus; (510).

Abundance of Chinese Indigenous Flora

Since VAVILOV's research (1928) it has been known that our principal economic plants and their related primitive and wild species occur in some parts of the world in a concentrated diversity of forms. These regions, which VAVILOV referred to as "geographical gene centres", are situated mainly in sub-tropical mountain regions of Central and South America, North and East Africa and in South and Southeast Asia. The geological, climatic and ecological conditions prevailing there are exceptionally diverse and have led over thousands of years to varying evolutionary processes in the respective indigenous flora.

China, particularly with the humid South Chinese Mountains, belongs to the regions with a marked diversity of forms. According to recent data from the Ministry of Forestry in Beijing, roughly 30 000 higher plant species exist; these are ascribed to 3 700 genera and 470 families (Ministry of Forestry 1994). More than half of these species are indigenous in the Southwest Chinese province Yunnan where the climate is predominantly sub-tropical and in some parts tropical (CHEN, 1992).

Among woody plants, too the diversity of forms is exceptionally great. Of the 13 gymnosperm families, with more than 700 registered plant species world-wide, 12 families with more than 300 species occur in China (DAI and SHAO, 1988a). A dominant position in the country's forests is taken up by numerous species of three deciduous tree genera (*Quercus, Betula, Populus*) and of 6 coniferous genera (*Pinus, Larix, Cunninghamia, Picea, Abies, Cupressus*).

Species Diversity of Chinese Poplars

Until now research has dealt mainly with regionally specific aspects of the species diversity of Chinese poplars and their natural variation pattern. Besides a large number of taxonomical studies (in recent years among others SUN, 1986; WANG and DONG, 1988; CHAO and GONG, 1990; CHAO and LIU, 1991, 1994; ZHANG et al., 1991; CHAO, 1993, 1994) literature deals chiefly with species with a large natural range or considerable economic importance. Reports are given, for example, on distribution, provenance research and breeding measures with *Populus davidiana* (LIU and ZHAO, 1991), *P. x hopeiensis* (QIU and MENG, 1991), *P. cathayana* (WANG et al., 1991) and *P. ussuriensis* (ZHANG et al., 1993).

The range of natural poplar resources in the Eastern and Southern regions of the Qinghai-Tibet plateau is particularly impressive. CHAO and GONG (1990) were able to document and assign taxonomically 17 species and 15 varieties of the genus *Populus,* chiefly in the catchment area of the headwaters of the rivers Brahmaputra, Salween, Mekong, Yangtze and Huang. They belong to the sections *Leuce, Leucoides* and *Tacamahaca.* Natural sources of these poplars can be seen approximately in *figure 1.*

Besides the horizontal distribution of the poplars in the Qinghai-Tibet plateau their vertical distribution is also remarkable. Most of the species occur in altitudes between 1500 m and 3500 m. *P. davidiana* and *P. kangdingensis* obviously possess a particularly strong genetic adaptation

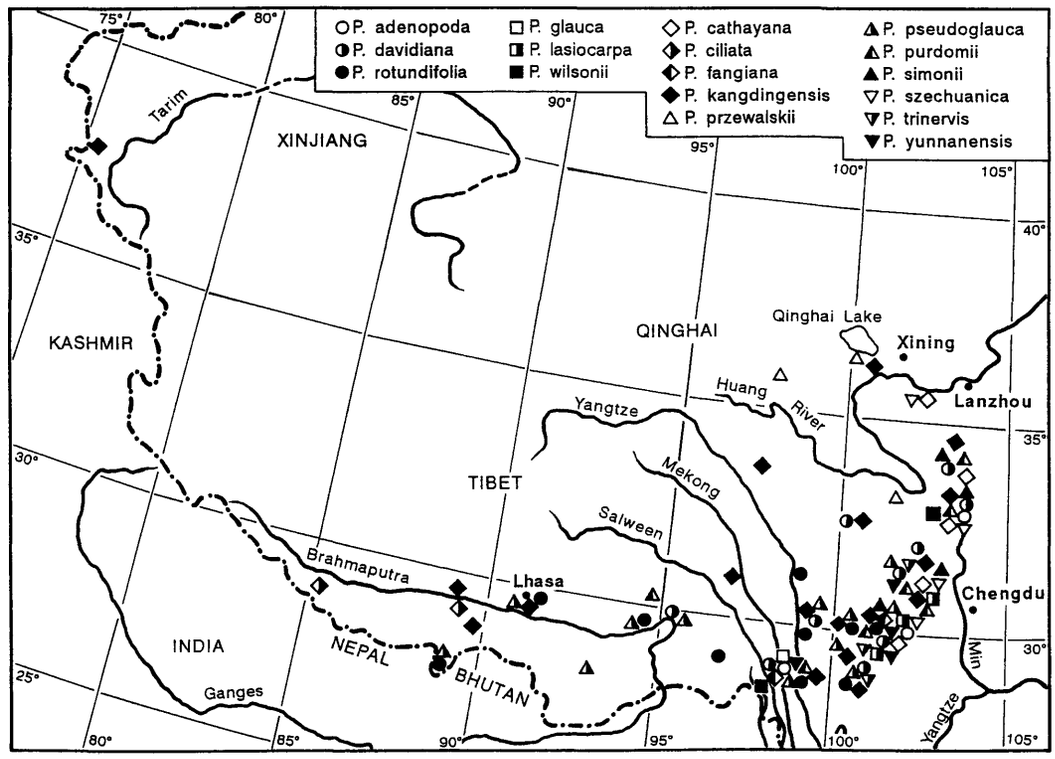


Fig. 1. – Distribution of poplar species in the Qinghai-Tibet Plateau of China (from CHAO and GONG, 1990)

potential and colonize regions with an elevation difference of more than 2000 m. *P. kangdingensis* is still to be found at an altitude of 4300 m above sea level.

In the overlapping areas between populations of different poplar species naturally developed hybrids were found, for example between *P. adenopoda* and *P. rotundifolia, P. kangdingensis* and *P. purdomii, P. purdomii* and *P. yunnanensis or P. kangdingensis* and *P. szechuanica.* 10 different hybrid swarms have been registered so far. However, it is evident that introgressive hybridization takes place only between species which belong to the same section.

Despite the – in some cases – extremely high altitude and the short vegetation period the poplar sources of the Qinghai-Tibet plateau are generally vigorous and fast-growing. They usually regenerate both generatively and vegetatively without problems. They prefer to colonize sites near groundwater, in the form of riparian forests alongside streams and rivers.

Displacement of Natural Forests and Afforestation Risks

According to the results of the forest resources inventory made from 1989 to 1993 China has at present an area of 134 mill. ha covered with forests (LIN et al., 1994). This is 13.9% of the total area of the country.

The ecological and economic disadvantages of this relatively small amount of forest are increased still further by its uneven distribution. Large unbroken forests exist primarily in the Northeast and South of the country.

The densely populated Eastern and Central Chinese provinces have lost their originally rich forests to a large extent as a result of manifold anthropogenic influences in the preceding centuries. Those remains of natural forests still in existence are greatly endangered by further exploitation, uncontrolled removal of fuelwood and litter and intensive forest pasturing.

The displacement of the natural forests as a result of extreme demands for use of the land for agriculture and forestry means a drastic restriction of the genetic variation of all tree species concerned (WEISGERBER, 1995). Poplars are particularly affected because

- their sources are easily accessible as they often follow the course of rivers;
- their fast growth provokes premature felling;
- their entire biomass can be used in many different ways, especially in a farming enterprise.

Poplars with relatively small distribution areas, such as the *Tacamahaca*-species *P. pamirica, P. pseudoglauca* or *P. trinervis* are in danger of extinction as genetic erosion increases.

The Chinese government has been trying for a long time to counteract the lack of forests and shortage of wood by directed afforestation measures. Above all the realization of 6 major national programmes for the reafforestation of the country is intended to bring lasting improvement to the basic living conditions of the population in an area of 5.8 mill. km^2 (roughly 60% of the total area of the country) (Ministry of Forestry, 1992). Particular importance must be attributed to the Sanbei-project "Green Great Wall" begun already in 1978, which has been frequently reported on (i.a. LI, 1989).

Preferably fast-growing tree species are being planted in order to achieve as quickly as possible effective protection of settlement areas and those used for agricultural production from sandstorms and soil degradation. In the moderate climatic regions of North China there were already 6.7 mill. ha of poplar plantations in 1988 (QIU, 1990).

However, as a rule only a few clones were available for these poplar afforestation projects. In most cases they originated back in the sixties as a result of selections from the progenies of controlled pollination. For example, the clones or clone groups 'Opera' and 'Popularis' which are widely distributed today in China can be traced back to crossings between *P. simonii* and *P. nigra* var. *pyramidalis* which were instigated by HSU Weiying. Some European cultivars such as 'Robusta', 'I 214', 'Lux' or 'San Marino' were also planted.

As the start of afforestation measures there was no or very little cultivation experience with most of these clones – that little being accidental and localized. Systematic comparative tests on different sites to examine adaptation, growing and resistance behaviour hardly existed.

In the meantime the unstable genetic structures of the monoclonal plantations which originated in this way have led to diseases and insect damage and thus to considerable production losses in many parts of the country. According to DAI and SHAO (1988b) 40% of the poplars cultivated in China were already damaged or destroyed by *Anoplophora, Leucoma* and *Plaeacrita* species or other insects in the eighties.

The damage created by the mass propagation of the longhorn beetles *Anoplophora glabripennis* and *A. chinensis* in nearly all of the North Chinese provinces participating in the Sanbei project is particularly serious. According to information from the forest administration responsible 60 million poplars have died within a few years in the autonomous region of Ningxia. This is more than 50% of all the protective forests in that area. Besides poplars and willows both insects increasingly attack other tree and shrub species such as *Robinia pseudoacacia, Ulmus pumila, Elaeagnus angustifolia, Tamarix spec.,* and in the orchards apple, pear and plum trees.

The negative consequences of this calamity are clearly noticeable in large regions. The destruction of extensive windbreakers has resulted not only in a loss of timber but also in a renewed increase in the number of violent sandstorms. In many places desertification and erosion have led to sizeable production losses in agriculture.

Preservation of Still Existent Poplar Resources and Their Appropriate Utilization for Breeding and Afforestation Purposes

Aims and significance of a Chinese-German cooperative project

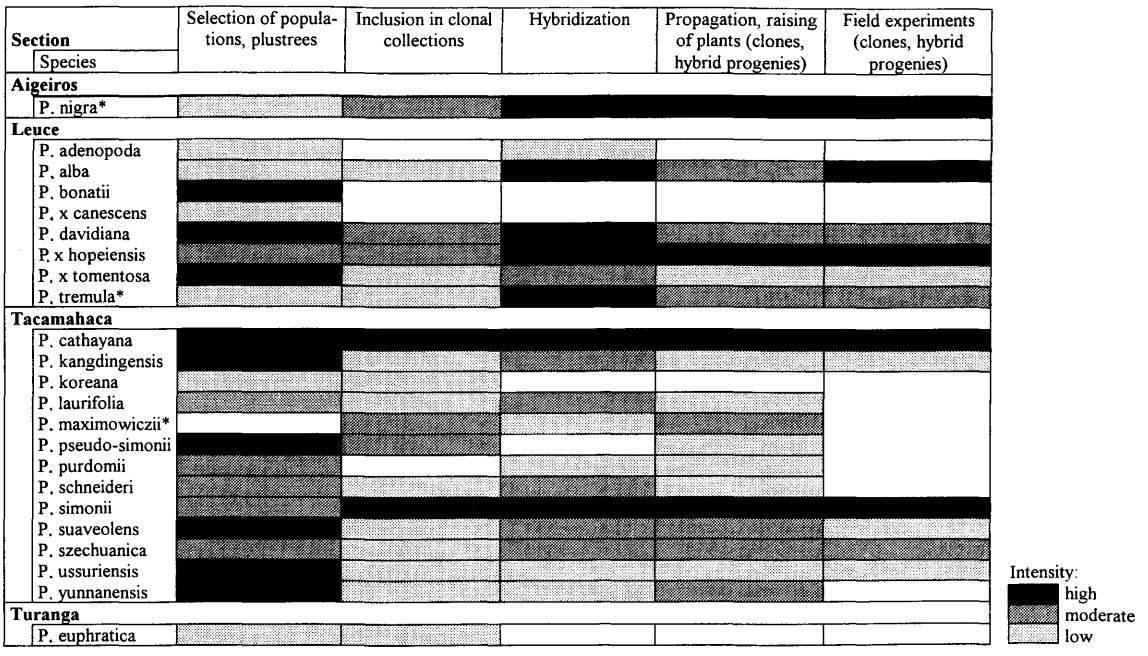
Two urgent consequences must be drawn from the situation just described:

– The still existent natural poplar resources are particularly worthy of protection and require special conservation measures.

– Low-risk clonal forestry with poplars is only possible when the cultivation suitability of the plant material to be used has been proved by previous tests. Furthermore a sufficiently large number of clones must be available, preferably in the form of multiclonal varieties.

A Chinese-German cooperative project begun in 1984 has taken up these demands. It plans to establish an efficient centre for forest tree breeding in the province Shanxi. The project partners are the Chinese Ministry of Forestry and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. The specialist work is being carried out on the German side by employees of the Hessian Forest Administration.

The aim is to produce high quality reproductive material for reafforestation in the North of the country. Particular importance is attached to the employment of as broad a genetic basis as possible and to a specific adaptation to the semi-arid conditions prevailing in that region. Those involved in the project



*) Exotic clones included in hybridization programmes.

Fig. 2. – Chinese-German cooperative project Jinshatan. Selection and breeding activities with Chinese poplar resources 1984 to 1995.

are also greatly interested in the preservation of still existent indigenous forest sources.

Priority is given to the treatment of poplars. Other tree species are included step-by-step according to priorities with the aim of building up mixed stands at a later stage.

The project work is part of the Sanbei afforestation programme. If it is successful we expect to achieve supraregionally

– effective protection for agriculture against erosion and desertification;
– improvement in ecological conditions;
– a short-term production of wood for fuel, industry and building;
– utilization of low-yield areas and wasteland in a way which is appropriate to the national economy.

Recording and preservation of poplar resources

The existing diversity of forms among the natural poplar sources in China presents in principle good preconditions for achieving the project aims. Working together the two project partners have so far succeeded in recording and documenting vigorous and healthy sources of 19 indigenous poplar species and 3 natural species hybrids in nine provinces and autonomous regions of Central and North China. They have also initiated measures to ensure their preservation (*Fig. 2*).

Protection of the selected and marked basic material which is often situated in most inaccessible country is generally undertaken by arrangements with the respective responsible forest administration. In this way illegal tree cutting and intentional damage should be prevented.

There are as yet no national initiatives for the systematic preservation of natural forest sources. Besides the already existent official regulations for the prevention of further exploitation it seems necessary above all to map, catalogue and describe the forest areas under consideration and to mark them where they stand as protected. Directed silvicultural treatment (appropriate tending and thinning operations, natural regeneration) can also have a share in safeguarding the stands in the long term.

Generative and vegetative propagation material was obtained from the selected populations and single trees. The plants were raised for both gene conservation and advanced breeding purposes in a special nursery in the project operation centre Jinshatan. Extensive clonal collections are now present there with roughly 650 indigenous and 170 exotic poplar clones. In addition, a gene bank with a tissue culture laboratory has been equipped.

We have given several reports on the method of procedure when recording poplar resources and on the details of preservation measures (KARNER and WEISGERBER, 1988; HAN et al., 1991; WEISGERBER, 1991, GROSSCURTH, 1994; WEISGERBER and HAN, 1994).

Breeding work

The poplar resources which have been recorded in situ and ex situ are of considerable importance – apart from preservation purposes – for advanced breeding work. The diversity of the basic material presents good possibilities for effectively enlarging the supply of poplars worth using for afforestation by means of selection and hybridization breeding.

It is in the common interest of both project partners here to refrain from developing only a few high-yield cultivars which are supposedly suited for all uses. Instead we stress the importance of the following procedure for improving yield stability:

– On experimental plots with varied site conditions the cultivation suitability of as large a number of clones as possible from different populations is tested, in particular for site adaptation, vitality and fast growth.

– Depending on the composition of the material being tested about a fifth to a third of the clones involved can be considered for practical cultivation at the end of the tests. They are assembled into groups with a similar growing rhythm and

should be used only in this form as multiclonal varieties (FRÖHLICH and WEISGERBER, 1987; comp. also ZSUFFA et al., 1993).

Figure 2 gives information on the extent and intensity of some principal research work. To supplement the Chinese poplar sources mentioned, numerous clones from different poplar species of the sections *Aigeiros, Leuce* and *Tacamahaca* from our Forest Research Centre in Hann. Münden were also included in the breeding programme.

The main emphasis of the investigations lies at present with the species *P. davidiana, P. x hopeiensis, P. cathayana* and *P. simonii* which are indigenous in the North of the province Shanxi, and with the species *P. nigra* and *P. alba* which have proved suitable for hybridization purposes. These species would seem most likely to be able to adapt to the semi-arid site conditions on the loess plateau in the middle reaches of the Yellow River.

In order to understand *figure 2* better, it should be noted that progress differs in the measures listed: We already have comprehensive findings regarding selection work and the compilation of clonal collections as also in the technique of controlled pollination. On the other hand the propagation and raising of plants and especially the establishment and supervision of field experiments could not yet be pushed forward with the desired and necessary intensity.

This is due both to the relatively large amount of time required for the treatment of breeding questions and to reasons relating specifically to the project: among other things the equipment necessary for propagation (greenhouses, tissue culture laboratory) has only recently become available; difficult climatic and soil conditions and damage by grazing animals delay field tests of clones and hybrid progenies; special fields of work connected with propagation and trial management require thorough advanced training and advice to the Chinese counterparts.

Since 1987 intra and interspecific hybridization has been carried out on a large scale. 400 different combinations have been realized up to 1995.

After initial technical difficulties a special greenhouse with pollen-proof crossing chambers is now available. Up to 30 000 plants can be produced annually from the seed created there.

Propagation takes place partly generatively (especially with hybrid progenies), and partly vegetatively following the methods proven with poplars. In the tissue culture laboratory erected in 1993 clones are propagated for which the conventional techniques of rooting of cuttings cannot be used or only with difficulty. This is true particularly for *Leuce* poplars belonging to the subsection *Trepidae* which are of considerable importance for afforestation purposes in mountainous regions.

On the experimental plots already set up, most of which are still at a very early stage, a strong differentiation can be seen between the treatments. Some black, white and balsam poplar clones already distinguish themselves by convincing growing performance and shape characteristics. In addition, we consider the progenies from the following crossings to be promising:

P. simonii x P. nigra

P. simonii x P. kangdingensis

P. cathayana x P. nigra

P. szechuanica x P. cathayana

P. deltoides x P. cathayana

P. davidiana x P. alba 'bolleana'

P. davidiana x P. x tomentosa

Prospects for afforestation

The development so far and first findings from the project in Jinshatan encourage us to an optimistic assessment of future measures for the establishment of stable protective forests with fast growing tree species. We are confident that already in the coming years forestry practice will have tested reproductive material of poplars in the form of multiclonal varieties at its disposal for the first time. This reproductive material is intended to replace, or at least supplement, to an increasing extent the few poplar clones at present still being used extensively for afforestation which are endangered by calamaties. This would represent an effective contribution to an ecologically and economically sensible utilization of the soil in wide areas which have up till now been neglected as regards both agriculture and forestry.

The possibility of technical and financial cooperation means that the project site Jinshatan also offers good preconditions for the direct utilization in afforestation of the findings obtained so far in many years' field trials. A new financial cooperation project to begin in 1996, sponsored by the Kreditanstalt für Wiederaufbau, Frankfurt/M. in the region around Jinshatan would provide the chance to introduce into practical forestry for the first time reproductive material which has proved itself in tests.

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Growth Performance and Reaction to Biotic and Abiotic Factors of Douglas Fir Progenies (*Pseudotsuga menziesii* [MIRB.] FRANCO)[1][2]

By M. LIESEBACH and B. R. STEPHAN[3])

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Summary

Seed of 24 progenies of Douglas fir (*Pseudotsuga menziesii* [MIRB.] FRANCO) from 7 states of the USA and of 1 progeny from Mexico collected within the natural range of the species was sown in 1963. In spring 1966 a field trial was established in the forest district of Nordhorn, northwestern Germany, as part of the Emsland afforestation program to test the suitability of Douglas fir progenies on former agricultural land. In the field trial several traits were measured or assessed regarding growth performance, susceptibility to biotic and abiotic agents, and volume production after 32 years of growth. Regarding these characters the provenances show a great variation and can be divided into at least 6 main groups (clusters). At the age of 32 the progenies from coastal Oregon would have produced in a pure stand 220 m³/ha. The performance of the Douglas fir progenies was compared also with tree species regenerated naturally in the field trial.

Key words: Douglas fir, single tree progenies, variation, growth characters, *Rhabdocline,* needle cast, winter frost, late frost, volume production.

FDC: 232.11; 232.12; 165.5; 174.7 *Pseudotsuga menziesii;* (430).

Zusammenfassung

Im natürlichen Verbreitungsgebiet der Douglasie wurde von 24 Einzelbäumen in 7 Bundesstaaten der USA und von einer Population in Mexiko Saatgut eingesammelt und 1963 in Großhansdorf ausgesät. Im Frühjahr 1966 wurde im Landwirtschaftskammer-Forstamt Nordhorn im Rahmen des Emslandprogramms ein Feldversuch angelegt, um die Eignung verschiedener Douglasienabsaaten bei der Erstaufforstung auf ehemals landwirtschaftlichen Flächen zu prüfen. Im Feldversuch wurden mehrere Merkmale, u.a. Wachstumsmerkmale, Anfälligkeit gegenüber biotischen und abiotischen Schadfaktoren, erhoben und die Derbholzmenge nach 32 Jahren berechnet. Die erhobenen Merkmale variieren zwischen den Douglasienabsaaten stark und erlauben eine Unterteilung der Absaaten in sechs Gruppen (Cluster). Im Alter von 32 Jahren hatten die Absaaten aus dem küstennahen Oregon rund 220 Fm/ha Derbholz produziert. Verglichen wurde auch die Derbholzmenge mit auf der Versuchsfläche natürlich verjüngten Baumarten.

Introduction

Douglas fir (*Pseudotsuga menziesii* [MIRB.] FRANCO) is the most important exotic forest tree species in German forestry and covers 1.3% of the forest area in Germany (BML, 1990, 1994). In appropriate stands Douglas fir produces far more timber than comparable native forest tree species as for example Norway spruce (*Picea abies* [L.] KARST.) (SCHOBER, 1963) or Scots pine (*Pinus sylvestris* L.) (KLEINSCHMIT, 1978). In Northwest Germany the area with Douglas fir will be increased mostly at the expense of Scots pine.

In the following paper an evaluation of a progeny test is given, which had been initiated in 1963 by KLAUS STERN during his time at the Institute for Forest Genetics at Großhansdorf. The field trial was established as part of the afforestation program in the Emsland (Northwest Germany) in spring 1966. Aim of the progeny experiment was to prove the early performance of provenances on a poor site and to compare seed lots from the northern and southern interior of the natural distribution area in the United States and Mexico. Populations of some of these regions were rarely represented in one of the numerous previous studies in central Europe. First results of this progeny test were published by HERRMANN (1973), STEPHAN (1973a and b), STERN et al. (1974) and HATTEMER and KÖNIG (1975). The present paper is based on recently collected data and on additional statistical analyses of previous data.

Materials and Methods

The 25 Douglas fir seed lots were collected in the natural distribution area of 7 states of the USA (24) and of a Mexican province (1), mainly from open-pollinated single trees. The origin of the progenies and their geographical data are given in

[1]) Dedicated to Dr. G. H. MELCHIOR on his 70th birthday

[2]) A modified version of a paper presented on the IUFRO meeting on "Evolution of breeding strategies for conifers from the Pacific Northwest" at Limoges, France, August 1 to 4, 1995.

[3]) Bundesforschungsanstalt für Forst- und Holzwirtschaft, Institut für Forstgenetik, Sieker Landstraße 2, D-22927 Großhansdorf, Germany