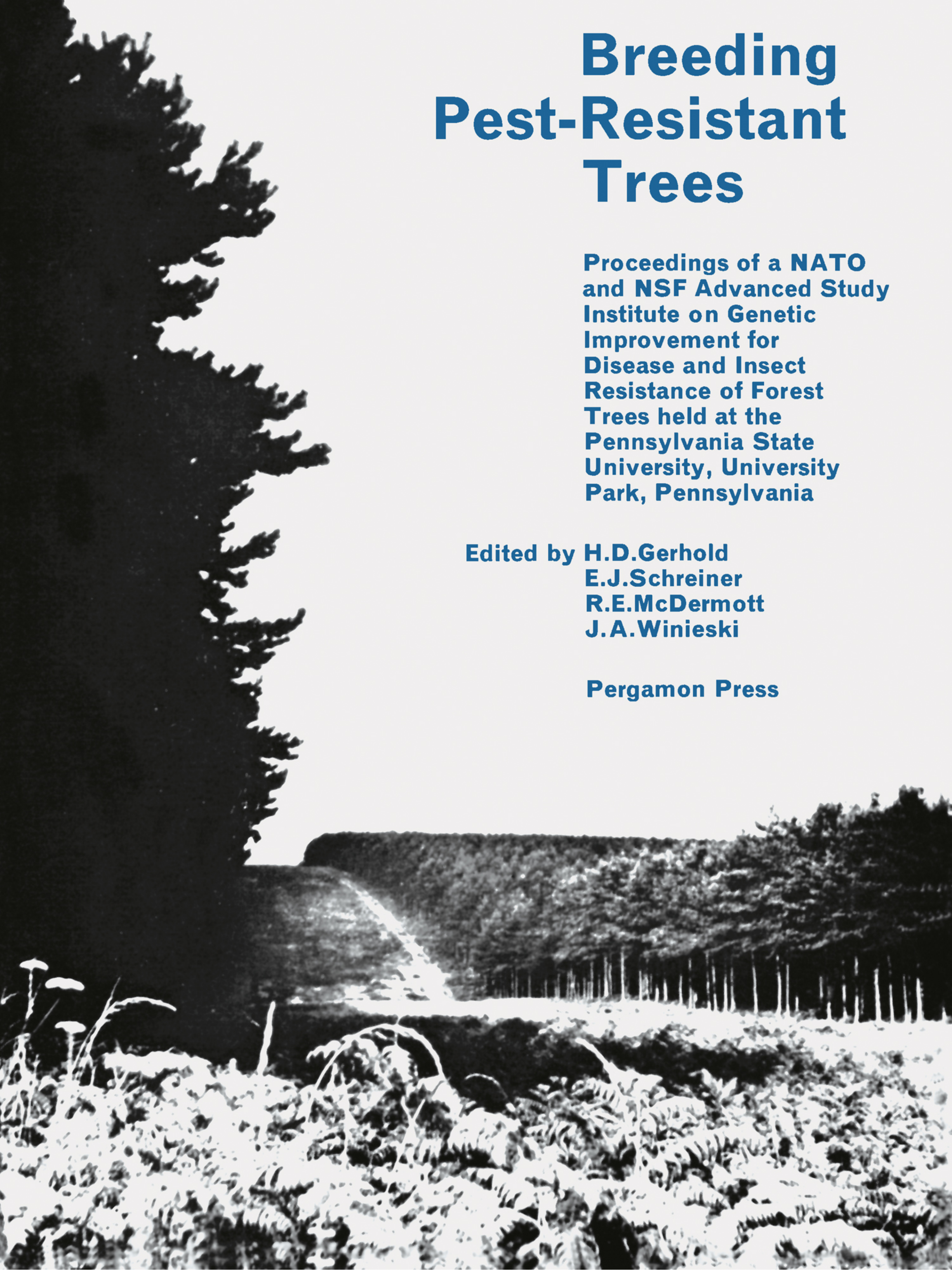

Breeding Pest-Resistant Trees

Proceedings of a NATO and NSF Advanced Study Institute on Genetic Improvement for Disease and Insect Resistance of Forest Trees held at the Pennsylvania State University, University Park, Pennsylvania

Edited by H.D.Gerhold
E.J.Schreiner
R.E.McDermott
J.A.Winieski

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BREEDING PEST-RESISTANT TREES

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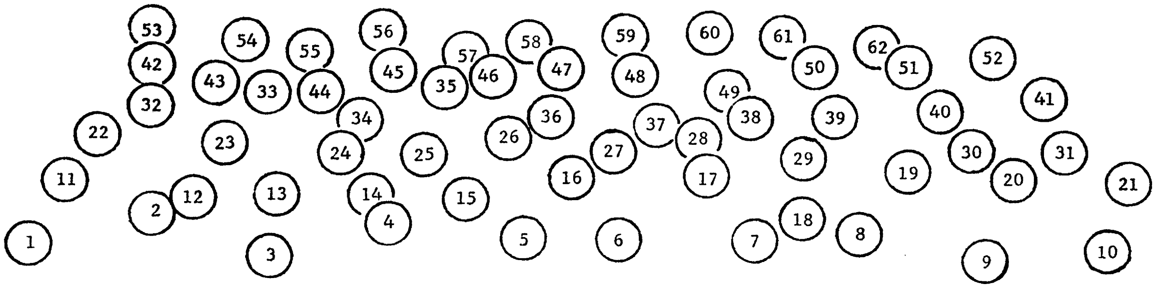

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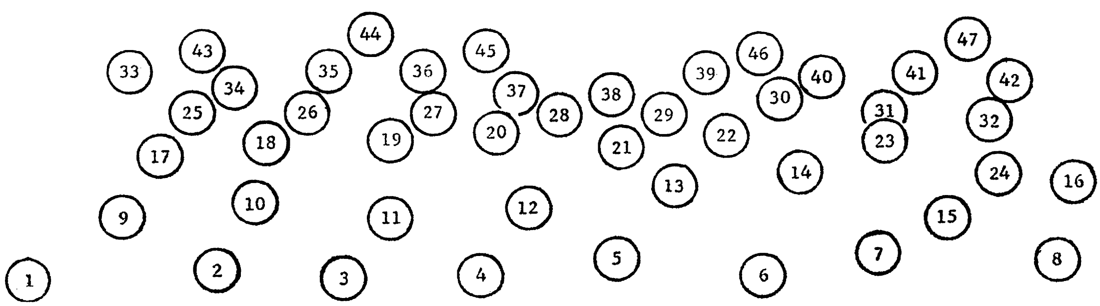

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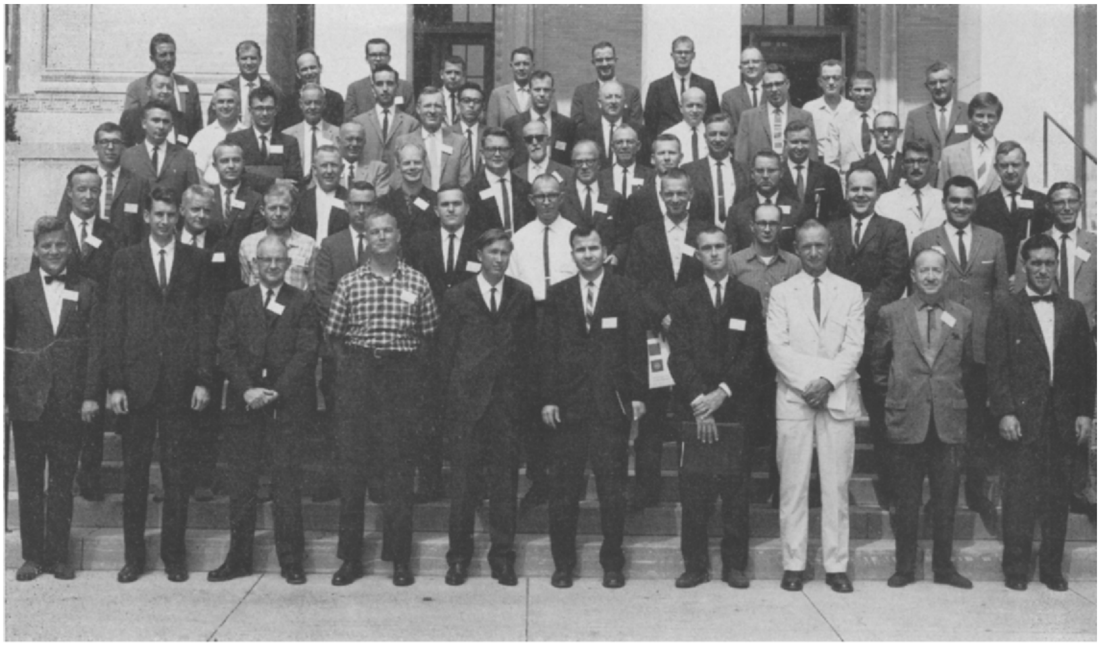

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Advanced Study Institute on

GENETIC IMPROVEMENT FOR DISEASE AND

INSECT RESISTANCE OF FOREST TREES

held at The Pennsylvania State University,

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August 30 to September 11, 1964

Edited by

H. D. GERHOLD E. J. SCHREINER

R. E. McDERMOTT J. A. WINIESKI

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CONTENTS

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EDITORS' PREFACE

PREPARATIONS which culminated in the Advanced Study Institute were started in February 1962. The Symposium Advisory Committee of The Pennsylvania State University's School of Forest Resources, consisting of W. T. Doolittle (U.S. Forest Service), A. R. Bond (Maryland Department of Forests and Parks), G. R. Moorhead (New Jersey Department of Conservation and Economic Development), and J. E. Ibberson (Pennsylvania Department of Forests and Waters), recommended that a symposium on forest genetics be organized. A Program Committee was appointed, consisting of the Editors, with E. J. Schreiner serving as chairman.

The subject matter was chosen with an awareness that very few intensive efforts to breed disease- and insect-resistant trees had been started, and even these were in their infancy; but that numerous scattered though related research projects were providing evidence of widespread interest and justification for starting new breeding projects. The Program Committee recognized a need for closer collaboration and improved communication among the geneticists, pathologists, entomologists, and foresters who shared this interest. The opinion prevailed that a week or two devoted to reviewing basic knowledge, philosophies of approach, and techniques would be timely and profitable.

It is our pleasure to acknowledge the generous support provided by the North Atlantic Treaty Organization and the National Science Foundation to cover administrative costs, and participants' travel and subsistence expenses. The international participation thus made possible was vital to the success of the Institute. We also wish to express our sincere thanks to the individuals and organizations who helped in many ways with the local arrangements and tours.

The papers and discussions contained herein are in the same sequence in which they occurred during the meeting. The first two days were joint sessions with the Northeastern Forest Tree Improvement Conference to hear résumés of research by geographic regions, and to visit examples of tree improvement work by The Pennsylvania Department of Forests and Waters and the U.S. Forest Service, and tree and trout improvement work by The Pennsylvania State University. The remainder of the meeting was interspersed with other scientific tours and social events designed to provide opportunities for improving professional communications and personal friendships.

May the scientific esteem and camaraderie that developed long be remembered in many lands!

HENRY D. GERHOLD
ERNST J. SCHREINER
ROBERT E. MCDERMOTT
JOHN A. WINIESKI

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PART I

RÉSUMÉS OF RESEARCH RELATED TO FOREST TREE PEST RESISTANCE, BY GEOGRAPHIC REGIONS

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STATUS AND TRENDS IN RESEARCH RELATED TO THE RESISTANCE OF FOREST TREES TO DISEASES IN NORTHERN EUROPE

ERIK BJÖRKMAN
Professor and Head, Department of Forest Botany, College of Forestry, Stockholm, Sweden

AT THE "World Consultation on Forest Genetics and Tree Improvement", arranged by FAO in Stockholm on August 23–30, 1963, a summary report was presented on "Forest tree breeding for resistance to diseases", including a discussion of principles concerning differences in resistance and the basis for resistance, as well as methods of investigation and genetic improvement of resistance (Björkman, 1964). Reports were also given at this session on "Improvement of disease resistance in *Populus*" (Schreiner, 1964) and on "Problems and progress in improvement of rust resistance in North American trees" (Bingham, 1964).

Therefore, a repetition of the statements in these reports does not seem to be necessary in the following description of the resistance research in northern Europe, nor to consider in detail individual approaches or methods. Instead, discussions of major disease problems and the current status of research on them have been briefly reviewed, based upon reports from forest tree breeders and forest pathologists in this area. Such reports have kindly been furnished by many North European research workers.* The reports have included:

1. A list of the diseases with which investigations have been completed, or are underway, concerning resistance to different diseases of forest tree progenies or provenances.
2. A list of the fungi considered to be most important as tree pathogens but not yet studied for resistance research, and
3. Comments about the possibilities to obtain resistance in various disease groups.

In the following a survey is given of the most important fungi met with in forestry practice, which affect trees and other plants in northern Europe, and which are being actively studied or are of major concern because of their potential threat.

* The names of the major contributors who have provided significant personal information to this report are italicized in the text when their statements appear.

DUTCH ELM DISEASE

Dutch elm disease caused by *Ceratocystis ulmi* (*Ophiostoma ulmi*) has spread over most of northern Europe during the last decades, and a great number of elms have been killed also in the Scandinavian countries (cf. Krstic, 1960, 1964). Studies of this disease have to a great extent been concentrated on the biology of the insect vectors *Scolytus laevis*, *S. scolytus*, and *S. multistriatus*. Comprehensive investigations have, however, been carried out also to control the disease by genetic methods. Tropical elms have been used in hybridization work, and different provenances and clones have been tested for resistance (cf. Heybroek; cf. Arisumi and Higgins, 1961). The most extensive resistance research with this disease in Europe has been carried out and is still continued in Holland (Heybroek, 1957, 1961, 1962, 1963.)

In England, Peace (1960) has reported elm disease to be less severe than earlier, which could possibly be ascribed to the fact that a certain selection may have taken place and the more resistant genotypes have survived. Another possibility is that variations in incidence of disease are related to variations in site conditions. In other north European countries the elm disease is of sporadic importance especially in parks, but very little research on resistance to the disease seems to have been carried out.

CANKERS ON BROADLEAVED TREES

In southern Europe the canker on poplars is a very important problem. As new poplars and poplar hybrids are introduced increasingly in northern

Europe, the cankers on these trees are of growing interest in this area.

A common fungus causing a serious disease on poplars in northern Europe is *Chondroplea populea* (*Dothichiza populea*, *Cryptodiaporthe populea*). The pathogen has been shown to attack various poplars in very different ways (Schönhar, 1960, 1963; Stefanov, 1957), apparently depending on occurrence or lack of fungistatic substance in the host's bark tissues (Loeschke and Butin, 1961). Most susceptible poplars belong to the *nigra* groups. As to the variability of the pathogen, Langner has reported remarkable differences in vegetative growth of cultures of two isolates of the fungus derived from *Populus nigra* and *Populus deltoides*, respectively, at the Institut für Forstgenetik und Forstpflanzenzüchtung in Schmalenbeck, Germany. Also at the Institut für Forstpflanzenkrankheiten in Hann.-Münden, Germany, extensive investigations are going on with *Chondroplea populea* (Zycha). A survey of recent results in this field is published by Donaubauer (1964b), where also experiments with environmental resistance (for example by fertilization) are reported.

Another disease intensively studied during recent years in Sweden is the *Valsa* (*Cytospora*) *nivea* canker on the so-called hybrid aspen (*Populus tremula* × *Populus tremuloides*). Chromatographic analyses have demonstrated that the "hybrid aspen" contains sucrose, which is absent in the parent species, and this circumstance has been correlated to the susceptibility to attack by certain strains of the fungus, able to split sucrose enzymatically (Persson-Hüppel, 1955; Hüppel, 1963). No damage has been found, however, on hybrid aspen by inoculation of other strains of *Valsa nivea* in eastern Germany (*Schönbach*).

A very severe canker in birch at the base of the stem, widespread in the northernmost parts of Europe, is caused by *Diaporthe aristata*. Certain susceptibility differences seem to occur in various birch provenances, but no resistance research has been done so far.

Other cankers on broadleaved trees of great importance for example in the United States, caused by species of *Hypoxylon*, *Nectria*, *Eutypella*, and other fungi, are not of great importance in Europe but are worth review as potential threats.

A severe disease in this group is the *Nectria galligena* canker on ash and other broadleaved trees in certain areas. No systematic research seems, however, to have been done about resistance.

The well-known fungus, *Endothia parasitica*, causing the chestnut blight, may also be mentioned here but is of only minor interest for northern Europe (cf. Gravatt, 1952). Very intensive research for resistance has been done in Yugoslavia and Switzerland.

Also bacterial canker of poplar, caused by *Aplanobacterium populi* is of great importance in northwestern Europe. Studies concerning resistance to this disease are at present being done in Germany (Zycha, Fröhlich), France (Ridé, 1958), Belgium (Grammont), Holland (de Lange and Kerling, 1962) and Great Britain (Phillips). Bacterial canker of ash, caused by *Pseudomonas fraxini*, can also be mentioned here. This bacterium is potentially dangerous to American species of ash.

CANKERS ON CONIFERS

In northern Europe the pine blister rust, caused by *Cronartium flaccidum* (*Peridermium pini*), is the most important canker on *Pinus silvestris*, the Scots pine. Through many earlier investigations, especially in Germany (for example Klebahn, 1924; Liese, 1936; Mülder, 1953; Bolland, 1957), it is proved that individual resistance exists. The age of the trees also seems to be of great importance. The resistance is greatest in small seedlings and in fully grown trees; developing trees show more susceptibility (Mülder, 1953). Systematic studies on the resistance to this disease in pine populations have not yet been carried out on a large scale but have recently started in Sweden in connection with progeny tests of *Pinus silvestris* plants from seed orchards.

White pine blister rust in *Pinus strobus*, introduced from America, is of great importance in Europe and has been very intensively studied, for example, by hybridization experiments at the Institut für Forstbotanik und Genetik in Hann.-Münden, Germany, and at the Institut für Forstpflanzenzüchtung, Graupa, East Germany (cf. Scholz, 1960). In comprehensive investigations on the resistance to the white pine blister rust fungus, *Cronartium ribicola* (*Peridermium strobi*), in the United States and Canada over 30 years (Riker, Heimburger, Patton, Hirt; see Bingham, 1964) several cases of resistance have been demonstrated, and resistant clones of *Pinus strobus* have been produced. Research along the same lines on the European *Cronartium flaccidum*, therefore, can be expected to be successful.

The pine twist rust, caused by *Melampsora pinitorqua*, is occasionally of importance as a canker pathogen on terminal shoots of *Pinus silvestris*. Normally the fungus causes some stem deformation but can also, especially in nurseries, kill young pine plants. The alternative host is aspen. This disease is very common in northern Europe and Asia but is not known to occur in America. It is of great interest that *Pinus contorta*—at least certain provenances—seems to be completely resistant to this fungus in Europe. Observations have been made especially in Germany and Sweden that various clones of *Pinus silvestris* are more or less resistant to this fungus (Rohmeder, 1954; Rennerfelt, 1954; Bergman, 1954; Klingström, 1963; Eklundh-Ehrenberg, 1963; and Schütt, 1964a). This disease is now included in the progeny test program in the Swedish forest tree breeding.

Dasyscypha willkommii (*Trichoscyphella willkommii*) and other species of this genus often cause rather severe canker formation on north European conifers. The most important and most discussed canker occurs in larch and is formed by the species mentioned. *Larix leptolepis*, and to a certain extent also *Larix sibirica*, have for a long time been known to be more resistant than *Larix europaea*. Environmental factors, especially the moisture conditions, seem also to be of very great significance. The same is apparently the case for other *Dasyscypha* species, that cause cankers on *Pinus*, *Picea*, and *Abies*, and are favoured by dense stands. Investigations on resistance to *Dasyscypha* attacks in various larch provenances are at present carried out especially in England (*Phillips*) and Norway (*Robak*).

Damaging cankers on spruce and pine (*Pinus nigra*, *Pinus silvestris*) in northern Europe are caused by the *Ascomycete Scleroderris lagerbergii* (*Crumenula abietina*, *Crumenula pinea*). During recent years the attacks by this fungus on Scots pine have occasionally been very heavy, especially in nurseries in northern Sweden after a temporary thaw during the winter (Björkman, 1961, 1963a; Day and Barrett, 1963). In one nursery, 12 million plants were thus killed in one year (1958). The fungus is not known from America, and is therefore a potential threat to this continent. Preliminary field tests in northern Sweden have demonstrated that certain provenances of pine are more susceptible to attack by this fungus than others. In Austria the resistance to *Cenangium ferruginosum* on different provenances of *Pinus silvestris* and *P. nigra austriaca* has been investigated by Donaubauer.

Phacidiopycnis pseudotsugae (*Phomopsis pseudotsugae* and *Phomopsis strobi*; perfect stage: *Phacidiella coniferarum*) is known in northern Europe as a bark fungus especially on Douglas fir and larch species (Zycha, 1952). The fungus is normally of a certain importance only in nurseries. Sometimes there is an association between frost injury and colonization—by *Phomopsis pseudotsugae* (*Day*). Some observations indicate a probable resistance to the fungus.

LEAF DISEASES OF BROADLEAVED TREES

Rust fungi on forest tree leaves are very common in northern Europe but normally of very little importance as they develop mostly at the end of the vegetative period. One exception can, however, be mentioned. *Melampsoridium betulinum* causes yellowing of leaves early in July and often kills young birch plants. *Betula pubescens* is as a rule more susceptible than *Betula verrucosa*, but individual variations also occur. At the Forest Tree Breeding Station in Ekebo in southern Sweden highly resistant *Betula pubescens* progenies have been produced. Resistance to other leaf rust fungi has also been demonstrated to exist, for example, to *Melampsora larici-populina* (van der Meiden and van Vloten, 1959; van der Meiden and Kolster, 1961, 1963), to *Melampsora allii-populina* (Donaubauer, 1963a) and to *Melampsora pinitorqua* (Regler, 1957).

Donaubauer (1964a) has demonstrated clear differences in resistance to *Septotinia populiperda* among 42 individual poplar clones artificially infected with this fungus in Austria (cf. Schwenke, 1960).

It has also been proved that there is a difference in resistance to *Venturia tremulae* (*Pollaccia radiosa*) among different poplar clones (for example at the Institut für Forstpflanzenzüchtung Graupa, and the Forschungsinstitut für Pappelwirtschaft, Hann. Münden).

The powdery mildew fungus, *Microsphaera alphitoides* (*Microsphaera quercina*), on white and red oak seems now to be acclimatized in many north

European countries and can under certain conditions, sometimes after frost damage, cause great damage in nurseries and young oak stands. In analogy with other experiences with powdery mildew fungi of importance in horticulture, breeding for resistance would be expected to be successful, but so far no positive results seem to have been obtained (Rack, 1957).

NEEDLE DISEASES OF CONIFEROUS TREES

A much studied disease on forest tree needles is the pine needle cast in Scots pine, caused by *Lophodermium pinastri*. This fungus is a typical facultative, respectively a weak, parasite (Rack, 1959), and very much dependent on environmental factors for effective attacks. Like many facultative parasites, this fungus attacks various provenances of the host tree with different intensity. Comprehensive investigations have been carried out on this problem in many countries, for example, Germany, Austria, Holland, Norway. Dengler (1955) found that a Finnish provenance of Scots pine was much more resistant to *Lophodermium pinastri* than a German provenance (Mark Brandenburg), and Troeger (1960a and b) showed that clear resistance differences exist among German pine provenances. Schütt (1957a and b, 1960, 1964b and c) has also demonstrated the occurrence of distinctly individual differences, and has conducted extensive provenance experiments with *Pinus silvestris* containing twenty seed origins planted out on ten locations in Germany. From these inoculation experiments it was clearly demonstrated that the Norwegian west coast provenance was more resistant than provenances from middle Europe. In spite of the fact that *Lophodermium pinastri* has been studied very intensively as an important destroyer of pine plants, especially in nurseries and young plantations (cf. Jahnel, 1953; Jahnel and Junghans, 1958; Rack, 1963), the biology of the fungus still includes many unsolved problems (cf. Hattemer, 1964). In certain areas the fungus occurs practically only as a saprophyte, but in others as a severe parasite. Chemical control is possible (Rack, 1958) but not always feasible in practice. The recent breeding work gives, however, hope of success for genetic control of the attacks by this fungus.

Another pine needle fungus is *Phacidium infestans*, causing the typical snow blight on plants in areas where deep snow occurs in the winter. The fungus is common in the northern parts of Europe and Asia (*Pinus silvestris*), and also in the Alps, where it is a serious threat to the pine (*Pinus cembra*) regeneration (cf. Petrak, 1955; Donaubauer, 1963b), and in the Ural Mountains. The fungus is a strong parasite and attacks all snow-covered pine needles which are 15–20 cm from the infection point (Björkman, 1948). The fungus is, however, a typical facultative parasite developing sporophores (apothecia) in dead needles. Observations by Schotte (1923) indicate that the southern provenances of Scots pine are much more heavily attacked than northern provenances. This has recently been confirmed experimentally by artificial inoculation of pine plants under the same environmental conditions in northern Sweden (Björkman, 1963b). No full resistance has so far been attained, but there is hope for increasing progress through tree breeding, for example, by crossing various pine provenances. Spruce and fir plants are not attacked by *Phacidium infestans*. In Canada and the northern United States such plants are attacked by other *Phacidium* species (Reid and Cain, 1962), causing a snow blight.

Among other needle diseases on north European forest trees the following can especially be mentioned.

Herpotrichia species can be very dangerous to young spruce plants in areas with deep snow cover, such as occurs during the winter in the Scandinavian countries and in the Alps. In Switzerland at the Eidg. Anstalt für das forstliche Versuchswesen in Zürich (*Bazzigher*), *Herpotrichia juniperi* and *Herpotrichia coulteri* are being studied as to resistance of the host plants.

Hypodermella sulcigena on pine and *Hypodermella macrospora* on spruce are other fungi known to attack various tree individuals to different degrees. As they are normally of not so great importance in forestry, they have not as yet been intensively investigated as to the nature of the resistance.

Meria laricina causes the needle blight of larch, especially on provenances from high altitudes when cultivated at lower elevations. It has been found that the Japanese larch (*Larix leptolepis*) is more resistant than European larch, but resistant individuals of European larch do exist (Kiellander, 1950; Langner, 1952).

Rhabdocline pseudotsugae and *Phaeocryptopus* (*Adelopus*) *gäumanni* are two needle-cast fungi on Douglas fir (*Pseudotsuga menziesii*) reported to have caused very severe attacks in stands in northern Europe, sometimes in combination with heavy frost damage. Thus very severe attacks by *Phaeocryptopus* were reported from Denmark after the very cold winters of 1940 and 1941. The *viridis* form of Douglas fir is, as a rule, most resistant to these fungi, but as it is a coast form in its native country, it is very susceptible to frost. The *glauca* and *caesia* forms of Douglas fir have been found to be less resistant to the fungi when cultivated in Europe. Through very extensive breeding research, especially with *Rhabdocline* in Germany (*Zycha*), more resistant individuals have been found (cf. Liese, 1935). Therefore, the tree breeding research seems to have a good chance to be successful in eliminating the occasionally very severe attacks by *Rhabdocline* and *Phaeocryptopus*. The culture of Douglas fir in northern Europe could then be increased to a great extent.

Didymascella (*Keithia*) *thujina* occurs chiefly on *Thuja plicata*, but can also cause rather severe attacks on *Thuja occidentalis* in nurseries. Soegaard (1956) has found the hybrid *Thuja plicata* × *Thuja standishii* to be resistant in Denmark. He also reported the attacks by the fungus to be more severe on seedlings than on cuttings from the mother tree. The same problem has also been investigated in England (*Phillips*).

The damping-off fungi belonging to such genera as *Fusarium*, *Phytophthora*, *Pythium*, *Mucor*, and also the very common *Botrytis cinerea* (cf. Zycha, 1962), play an important role in nurseries. Chemical soil treatment is still the common method to control these attacks, but resistance research is also desirable in this case.

HEART ROTS AND RELATED ROOT ROTS

Rot fungi cause enormous losses in forestry every year. The control of these attacks is, however, only possible to a very limited extent through certain cutting methods and treatment of stumps. The rot fungus of the greatest economic importance in northern Europe is *Fomes annosus* (*Trametes radiciperda*), occurring in many forest trees, especially spruce and pine.

When the fungus causes a heart rot in the trunk and mainly invades dead tissues, as in different species of spruce (of greatest importance in *Picea abies*), the chance for obtaining resistance through breeding methods does not seem to be as good as for living tissues. The possibility for changing or introducing toxic substances in the heartwood by crossings or other genetic methods should, however, be intensively investigated.

When the fungus occurs as a typical parasite, as in pine (of greatest importance in *Pinus silvestris*), and kills the living cambial tissues, the chance seems to be much greater for success. A very comprehensive research program in this field is justified. The fact that young trees of Scots pine seem to be more susceptible to attack by *Fomes annosus* than old trees seems to give a certain indication of different conditions in the host related to fungal attacks.

The same as about *Fomes annosus* can also in principle be said about many other rot fungi, for example *Armillaria mellea* and *Rhizina inflata*, which are also widespread and sometimes of great economic importance.

The major diseases in forest trees occurring in northern Europe and listed above can, in principle, be grouped into three categories of probability of success in breeding for resistance.

1. Attacks by *obligate parasites* such as *rust fungi* and *powdery mildew fungi* have often illustrated the existence of resistance to the disease in certain clones or individuals. The chance for success in such cases seems therefore to be good. Very successful intensive research has been carried out or is in progress with rust fungi, especially *Cronartium ribicola*, *Cronartium flaccidum*, and *Melampsora* species. Studies on resistance to the powdery mildew fungi, however, seem to have yielded no positive results in forest tree breeding so far.

2. Attacks by *facultative parasites* are very often limited to certain provenances. Some individual resistance has also been found in a few cases. Therefore, the chance for successful breeding for resistance seems to be good. If the fungi are weak parasites, their attack seems, to a great extent, to be more dependent on environmental factors than on genetic differences of the host. Such factors are drought in the soil or in the plant tissues, frost, relative humidity, nutrition in the soil, light, extremes in elevation, silvicultural practices, bark cracking, age of trees. Examples of such fungi are

Phacidium infestans, *Lophodermium pinastri*, *Scleroderris lagerbergii*, *Dasyscypha* species, *Valsa nivea*.

3. The chance for successful breeding for resistance to attacks by *rot fungi in living trees* is unknown.

FUNGI OF POTENTIAL THREAT IN NORTHERN EUROPE

Among fungi of a potential hazard to the forests of northern Europe, not yet introduced but known as dangerous pathogens in America, can be mentioned: *Ceratocystis fagacearum* (oak wilt), *Septoria musiva* (*Septoria* canker on *Populus*), *Hypoxylon pruinatum* (*Hypoxylon* canker on *Populus*), *Cronartium fusiforme* (southern fusiform rust on pine and oak), *Cronartium harknessii* (western gall rust or gate rust, apparently especially dangerous on Scots pine), *Morsus ulmi* (phloem necrosis on elm). The list could be lengthened by many fungi from Asia (cf. Riker, 1954, 1960; Peace, 1962; Imazeki, 1962; Krstic, 1964).

The occurrence of different biotypes or strains of the parasitical fungi or the possibility of less resistance to a disease in one climate type than in another must also be considered (Spaulding, 1956, 1961).

A close cooperation among forest pathologists (cf. Hansbrough, 1963) and forest tree breeders in the world will be necessary to obtain real progress in the control of forest tree diseases.

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SUMMARY OF RESEARCH CONCERNING DISEASE RESISTANCE CARRIED OUT IN SOUTHERN EUROPE

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THE continuously increasing need of wood has been a strong incentive for the widespread planting of fast-growing autochthonous and exotic species in southern Europe. The large extent of such (often single-clone) forest plantations, sometimes established under unfavorable ecological conditions, has caused phytopathological problems to arise and become more serious year after year.

Since mechanical and chemical measures are not sufficient for economical control of the pests of forest trees, breeding for insect and disease resistance has become an essential task, and in many cases is the key solution of modern forestry in those countries of southern Europe where stronger menaces are to be feared from several diseases.

On the other hand, it is well known that pathogens are liable to form races and strains with a different infection potential. It may thus happen that selections produced through breeding may become susceptible to disease. For this reason the virulence of pathogens and the susceptibility of bred selections should be constantly checked.

This summary deals essentially with the problems concerning the disease resistance in cultivated, fast-growing species, and through lack of information gives only a little attention in this respect to traditional Mediterranean trees.

OAK

The available information about disease behavior of the *Quercus* species which are typical representatives of the Mediterranean flora is very poor. For instance, no research work is known to have been carried out in southern Europe on the genetic improvement of disease resistance in *Q. ilex*. In his quite complete monograph of this species, Ruperez (1957) merely lists the fungi inhabiting it without any comment.

Some more extended information is available on the diseases of *Q. suber* which have been studied in Sardinia since 1953 by F. Marras. The published papers by this author (1963, 1964) deal with the diseases caused by: *Microsphaera alphitoides* Griff. et Maubl.,* *Elsinöe quercus-ilicis* (Arn.) Jenk. et Goid., *Cronartium quercus* (Brond.) Schroet., *Dendrophoma myriadea* (Pr.) Sacc., *Phlaeospora ilicina* Sacc., *Discula quercina* (West.) v. Arx, *Septogloeum dryophilum* Marras, *Coryneum foliicolum* Fuck., *Cystodendron dryophilum*, and *Morenoella quercina* (Ell. et Mart.) Theissen.

For each of the above-mentioned diseases he gives the description of the symptoms and of the causal pathogen, relates the ecological conditions favorable for infection and, in some instances, gives some information about biological specialization of the fungus and the resistance or susceptibility of different *Quercus* species.

Special attention has been given to powdery mildew (*Microsphaera alphitoides*). Concerning the reaction to this disease, Georgescu *et al.* (1957) in Roumania arranged the *Quercus* species as follows:

Susceptible: *Q. farnetto, Q. robur, Q. pedunculiflora, Q. pubescens, Q. virgiliana, Q. polycarpa, Q. dalechampii, Q. petrea, Q. cerris;*
Resistant: *Q. alba* and *Q. dentata;*
Immune: *Q. macranthera, Q. macrocarpa, Q. palustris, Q. borealis.*

Both Georgescu and Marras point out the importance that conditions associated with time and place have on the severity of the disease. This could explain the different degrees of susceptibility quoted by different authors in some European oaks. No information is given about specialization of the fungus.

It must be noted that in the last decades a decreasing severity of the disease has been observed

* According to Marras this species differs clearly from the congeneric American species: *M. densissima* (Schrein.) Cke. et Peck, *M. abbreviata* Peck, and *M. extense* Cke et Peck.

in southern Europe. Raimond (1927) thinks this may be explained as a consequence of biological equilibrium which might have become established between host and pathogen through a still unknown mechanism.

CHESTNUT

The most important diseases of the chestnut in southern Europe are ink-disease and blight.

Considerable research was carried out in Italy and France before World War II (see Fenaroli, 1945), especially by Petri and Pavari and their co-workers, in order to test the reaction of several species of *Castanea* to the ink-disease. At first, research workers thought that the problem could be solved by grafting scions of *C. sativa* on stocks of resistant species, but this approach was given up because of grafting incompatibility. New attempts have been made to introduce resistant Asiatic and American species that keep their resistance characteristics in Europe. They did not solve the problem because they grew well under good climatic and soil conditions but failed to grow in the poor soils where chestnut tree culture is generally located in southern Europe. In addition, *C. dentata* showed high susceptibility to *Endothia parasitica* which meanwhile had reached southern Europe.

Despite the economic importance of the problem in the Mediterranean area, special breeding work for resistance to ink-disease has been neglected here. As an interesting beginning, one should mention the clone M15, a Japanese × European hybrid selected in France, which has been shown to be resistant to this disease under artificial inoculation (Grant and Sauret, 1961, quoted by Kristic, 1963) and has given promise for indirect control of the causal organism.

Attempts at obtaining ink-disease resistant strains are now carried out at Centro de Estudos do Castanheiro, Alcobaca, Portugal (Azevedo, Personal correspondence).

A number of experiments were carried out in southern Europe, especially in Italy by Biraghi (1951), in order to test the blight behavior of populations of *C. sativa*, *C. dentata*, *C. mollissima*, *C. crenata*, and *C. koraiensis*. In 1951 more than 10,000 seedlings were artificially inoculated. *C. dentata* proved to be extremely susceptible, while some *C. sativa* seedlings were fairly resistant and *C. mollissima* was quite resistant. The reasons mentioned under the discussion of ink-disease did not allow these selections to spread in Italy. On the other hand, Biraghi (1951, 1963) remarked that sprouts from seriously blight-damaged chestnut trees somehow have a high resistance to the blight, in some cases remaining alive for 25 years. This sprout resistance seems to be of general occurrence, so that there seems to be no longer a need for continuation of blight-resistance breeding in Italy.

Furthermore, the chestnut tree is losing the importance it had years ago because fruit picking is becoming less and less convenient and the use of its bark and timber by the tanning industry is steadily decreasing.

ELM

The most important disease of elm in southern Europe is the Dutch disease caused by *Ceratocystis ulmi*. Much research is aimed at the control of the insects by which the disease is carried (*Scolytus*, etc.) and the development of chemotherapeutants that act against the fungus itself. But breeding for resistance remains of primary importance, and use is being made of the wide variation in susceptibility within some species, as well as of the high degree of crossability between the species.

It is beyond the limits of this summary to relate the very important work carried out in the Netherlands (Went, 1954; Heybroek, 1957, etc.) to obtain resistant elms with good growth-habit.

In Italy (see Goidanich, 1936), where the damage of the disease was particularly serious on elms employed as vine supports, Siberian elm (*Ulmus pumila* var. *pinnata ramosa*)—which under southern Europe climatic conditions is not subject to *Nectria* attacks that elsewhere have been very dangerous to the young plants—was introduced more than 20 years ago. Subsequently it was replaced by some strains of *U. foliacea* from Spain and by the well-known Buisman elm from Holland. Some interest is now also directed to some selections of *U. campestris* and to some *U. campestris* × *U. pumila* hybrids which combine disease resistance with useful characteristics from an agricultural point of view. It has to be remarked that some strains of *U. campestris* from southern Italy, although easily infected by the fungus, show a considerable resistance to the disease which progresses slowly. An explanation of this fact may be found in the xerophytic habit of these trees which might