FORESTRY COMMISSION

BULLETIN No. 7.

THE SILVER FIR CHERMES.

BY

R. NEIL CHRYSTAL, B.Sc. (Edin.).

LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE

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FOREWORD.

MUCH disappointment has been experienced in Great Britain during recent years owing to the destruction of young plantations of the common silver fir by *chermes*. The phenomenon appears to be comparatively new since there are many old trees of large dimensions to be found while a number of excellent middle-aged woods were felled during the war.

The Commissioners as well as many private owners of woodland for that reason have practically ceased from planting the tree and are experimenting with other species of silver fir, such as *Abies grandis*, which appear to be more resistant to the insect.

The common silver fir is not a tree to be abandoned lightly since there is ample evidence to show that its volume production is great, that its timber is of good quality when well grown and that it has a combination of excellent silvicultural characteristics which is not found in any other of the common conifers.

Mr. Chrystal's study of *chermes* on silver fir in Denmark has been carried out under the auspices of the Department of Scientific and Industrial Research. The insect has also been very destructive in that country, and the investigation suggests at least that it may be possible to grow the tree in favourable localities in Britain and to get existing plantations over the critical youthful stages at comparatively small cost.

R. L. ROBINSON,
Commissioner.

Forestry Commission,
22, Grosvenor Gardens,
London, S.W. 1.
January, 1926.

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THE SILVER FIR CHERMES.

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THE SILVER FIR CHERMES.

GENERAL INTRODUCTION.

The two species of silver fir *chermes* (*Dreyfusia*) which form the subject of this bulletin have been for many years recognised as serious enemies of silver fir (*Abies pectinata*) in Britain, and the damage caused to plantations by their attacks has been so wide-spread that of late years there has been an increasing reluctance on the part of foresters to plant silver fir.

In view of this fact, and also of the evident lack of accurate knowledge of the species as they occur in Britain, the author started an enquiry into the question in 1921, with the following main objects in view :—

(*a*) A study of the life-cycle of the species in Britain.
(*b*) A study of the relationship between the insect and its host tree, the silver fir, to ascertain how far the *chermes* was responsible for the death of the tree.
(*c*) Field studies upon the influence of silvicultural, soil and climatic conditions on *chermes* attack.

The main results achieved so far under (*a*) and (*b*) are dealt with in the following pages, but the author's chief object in presenting the bulletin at this time is to bring forward certain information collected by him during a visit to Denmark, made in June, 1924, for the purpose of studying the silver fir plantations there with reference to the *chermes*. These results are correlated here with an account of the silver firs in Britain, which is based upon such information as is at present available, in the hope that this bulletin, which must be regarded from the standpoint of British conditions as a preliminary contribution, may offer some suggestions for future work upon the problems arising out of the growing of silver fir in Britain.

GENERAL ACCOUNT OF THE CHIEF SPECIES OF SILVER FIR USED FOR FOREST PLANTING IN BRITAIN.

Three species of silver fir come under this heading :—*A. pectinata* D.C., *A. nobilis* Lind. and *A. grandis* Lind., each of which will be considered from the standpoint of its general distribution and occurrence in Britain, and in relation to the *chermes*.

Abies pectinata D.C.—The European Silver Fir.

Distribution.

A. pectinata is a native of the mountains of central and southern Europe, where it has an extensive but irregular distribution. It forms large forests in France, Germany and Switzerland, in which it occurs either pure, or in mixture with beech, spruce and Scots pine. Its maximum elevation is 6,000 feet in the region of the Pyrenees, and it occurs at least as far south as Corsica. In climatic requirements, fairly moist conditions suit the tree best, while as to temperature, owing to its susceptibility to late frosts, the colder aspects are more favourable to its growth than the warmer ones. As regards soil requirements, deep, moist, fertile soils are most desirable, but the tree appears to flourish on a wide variety of soil formations, being found on limestone in the Jura and in the Karst country of south-eastern Europe, and in the Vosges on a siliceous soil. Generally speaking, loam or heavy loam with a slight admixture of clay is the most suitable, while poor sandy soils, wet, peaty or sour soils are most unsuitable.

Growth in the British Isles.

A. pectinata was introduced into Britain about 1603, and since that period has been planted in all parts of the country both as a forest tree and for ornamental purposes. Elwes states* that it attains its maximum size in the south and west of England, Scotland and Ireland, where the climate is most unlike that of central Europe, being warmer in winter and cooler in summer, and showing an average rainfall of 60-80 inches, with occasional excess. He states that the tree grows to a considerable size in many places, but that its length of life in Britain is often shortened by the ill effects of drought and wind. In certain favourable places the tree regenerates freely, and several areas, notably Boynton, in Yorkshire, Auchendrane, Ayrshire, Scotland, and County Wexford, Ireland are mentioned by Elwes in this connection.

As regards the susceptibility of the tree to *chermes* attack, Elwes quotes the experience of Crozier in N.E. Scotland to show the extensive damage caused in young plantations by the insect. Dr. Malcolm Wilson states that in the Tay Valley silver fir is invariably attacked. Concerning the occurrence of *chermes* in England and Wales, Dr. Malcolm Wilson states that he has observed the *chermes* in the silver fir plantations at Lake Vyrnwy, North Wales, and Mr. Thomas Thomson, Lecturer in Forestry at the University of North Wales, Bangor, in *Notes on the Ceiriog Forestry Experimental Area*, 1922, p. 14, records the *chermes* as being particularly destructive to *A. pectinata*, which in his opinion suffers more severely from its attacks than do *A. grandis* and *A. nobilis*. All the evidence so far collected by

* Elwes and Henry, *Trees of Great Britain and Ireland*, vol. iv, p. 726.

the present author serves to confirm the statements made by Elwes and others, that the insect is a serious enemy to silver fir, and the author has himself studied the silver fir plantations at Inverliever, Argyllshire, where the *chermes* attack is very severe.

Data collected by the Forestry Commission.

Measurements were taken by the statistical parties engaged on a survey of the rate of growth of conifers,* but owing to the fact that silver fir has not been planted pure to any extent difficulty was experienced in finding many fully stocked sample plots.

In Scotland two subplots and four groups of this species were measured.

The subplots were both in Dinvin Wood, Dunskey Estate, Port Patrick, Wigtownshire, at an elevation of about 300 feet in a fully exposed situation, on a heavy clay loam over boulder till. The first was 55 years old with a volume† of 6,300 cubic feet per acre and the second 51 years old with a volume of 5,160 cubic feet per acre. The crowns were large, the wood having originally been a mixture with Scots pine. The crowns had been badly damaged, 40 to 50 per cent. being forked. The stocking was thin in the case of one of the subplots. *Chermes* was noted in both places.

A group was measured on the Minto Estate, Roxburghshire, at an elevation of 600 feet in full exposure. The trees were 60 years old and the wood was originally a mixture of Scots pine, larch and silver fir. The average height was about 65 feet. The soil was a clay loam on boulder till.

A group at Ardgour, Argyllshire, was measured at 300 feet elevation on shallow sandy loam over Moine Schist. The trees were well-grown in comparison with larch and Scots pine.

A group was located at Culquoich, Donside, at an elevation of 850 to 900 feet on a sandy loam over gneiss. These trees were over 95 years old and the height was about 85 feet. About 60 per cent. of the stems were badly forked, but the trees had been grown in mixture and were very scattered. They were healthy.

Another group was measured on the Balloch Hill, then belonging to the Seafield Estates, Banffshire, at an elevation of 700 feet and under full exposure. The soil was sandy with silt washed down from the hill by a stream. The silver fir were in mixture with spruce, larch and Scots pine. The age was 35 years and the average height was 53 feet, rather better than in other cases. The crowns were heavy but more restricted than in the above cases. Leaders had been repeatedly lost.

Some further general observations may be of interest. In the Bellyhack Wood, Drummuir Estate, near Keith in

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* Forestry Commission, Bulletin No. 3.

† Volumes are expressed as quarter-girth measurements under bark.

Banffshire, Norway spruce and silver fir had been planted in mixture in two wet patches in a larch wood, on alluvial soil of some depth. The planting appears to have been in alternate lines. The age was about 50 years and most of the silver fir had died at a time when the trees were about 3 feet high, from some cause not recorded. The elevation was 900 feet and the growth of the surviving trees was similar to that of the Norway spruce.

In Skirrald's Wood on the Seafield Estates near Cullen, Banffshire, a mixture of silver fir with larch occurred, aged about 50 to 60 years. The soil was a good loam and both species were doing well. The silver fir appeared to be healthy.

One of the most interesting areas for silver fir is in the Lumsden district of Aberdeenshire. On Wester Clova Hill on the Kildrummy Estate, at an elevation of 1,300 to 1,400 feet, there is a considerable extent of this species. The soil is a shallow, rocky soil of a loamy nature over Andalusite Mica Schist. The age of the plantation is from 50 to 60 years. There have been many failures on the rocky slopes mostly due to damage by animals. The trees are healthy. Near here, along the burn in Glen Laff there is a row of healthy trees about 50 years old. The soil is shallow but the situation is sheltered.

On the Craig Estate near Lumsden, in Craig Den on old red sandstone loam, there were some very fine specimens of mature trees in mixture with beech.

Not far from Craig on Knockespock Estate on the north slope of the Correen Hills there are several enormous old silver firs. In the Den there were natural seedlings growing well and in good health.

At Tarland, on Deeside, there is an area of mature Scots pine underplanted with a species of silver fir. On the Birkhall Estate, near Ballater, there were numerous healthy trees on a good loamy soil in fair shelter.

In Kincardineshire, on the Netherley Estate near Stonehaven, there grew on a moist flat a successful mixture of silver fir and Norway spruce. The exposure was full and the growth of the two species was very similar.

On the Phesdo Estate near Laurencekirk, there are about 300 acres of Scots pine about 40 to 45 years old with isolated silver fir throughout. The exposure is full and the soil poor.

On the Kirkennan Estate, Kirkcudbrightshire, silver fir has been planted under oak and ash. *Chermes* is present and some trees are dead but the majority still seem to be healthy. This area is on a good loamy soil.

At Novar a few natural seedlings occur, and also at Dawyck, Peebles-shire.

In England and Wales two sample plots were measured, and in addition, 138 other stems in 25 woods in different parts of the country.

A plot at Stevenstone Park, Devonshire, at an elevation of 520 feet, in an exposed situation with a S.W. aspect, over a light

loam, was 42 years old. The mean height was 56 feet and the volume was 4,900 cubic feet per acre.

The second plot on the Endsleigh Estate, Cornwall, at an elevation of 500 feet, in a similar situation, over 24 inches of light loam, was 48 years old and had a mean height of 69 feet and a volume of 5,700 cubic feet.

The mean annual increments are well over 100 cubic feet per acre per annum, and the volumes are much greater than those given in Schlich's *Manual of Forestry*, Vol. III.

Of the 25 woods in which groups of trees were measured, 14 were in Norfolk, where there was good growth on the light sandy soils.

Individual stems of silver fir when compared with larch and Scots pine, grown in the same locality, showed much greater volumes at the same age. The average volume per tree of the silver fir was twice that of the larch and almost twice that of Scots pine. Further, the silver fir appears to be less subject to heart-rot on these soils than larch or spruce.

As regards Ireland the only detailed information obtained was for Black Wood, Ely Lodge, Fermanagh County. The elevation was 200–300 feet and the aspect was N.E., the soil being a deep, fresh loam. There were 180 trees per acre, 75 years of age with a mean height of 85 feet. The quarter-girth volume under bark was 16,050 cubic feet per acre.

Abies grandis Lindley—Giant Fir.

Distribution.

This species is a native of western North America, where it has a wide range, extending from Vancouver Island through Washington and Oregon to California. It is found growing from sea-level up to about 3,500 feet (Dallimore and Jackson, *Handbook of Coniferae*, p. 104).

Abies grandis was introduced to Britain about 1832, and since that time has grown in importance as a forest tree in this country. It has given good results in many parts of Scotland up to 1,200 feet elevation where annual growths of 12–15 inches are often found (Dallimore and Jackson, p. 104). The following account of the species in Scotland is given by Dr. Anderson.

A sample plot of *A. grandis* was established on the Novar Estate, Ross-shire, at an elevation of 250 feet in moderate shelter on sandy loam over glacial sand and gravel over boulder till on old red sandstone. The appearance of the wood is healthy, with no sign of *chermes*.

The planting was done in 1903 and the first measurement made in October, 1921, 18 years later. The data were then :— Age, 18. Stems per acre, 2,855. Height, 36 ft. Girth at breast-height, 13½ ins. Basal area, 278 sq. ft. True vol. (under bark) per acre, 3,895 cu. ft.

A second measurement was made in October 1923, and a light thinning carried out, when the data were :—Age, 20. Stems per acre, 1,820. Height, 43 ft. Girth, 16½ ins. Basal area, 271 sq. ft. True u.b.vol. per acre, 4,615 cu. ft. There were 1,035 stems removed in thinning with a volume of 225 cu. ft., making a total volume of 4,840 cu. ft. The mean annual increment for the two-year period was 472 cu. ft.

This wood shows that the volume production of *A. grandis* may be very high in this country.

There is an area in the Ruttel Wood on the Beaufort Estate, Beauly, Inverness-shire, which has no sign of *chermes*. It is still young.

In addition to the above, Dr. Anderson, in a previous letter to the author, gave the following additional records of plantations of *A. grandis* in Scotland :—

Kincardineshire—Fasque Estate. *A. grandis* mixed with Douglas fir. 20 years old. Healthy.

Perthshire—Buffalo Park, Murthly Estate. Small, pure patch of *A. grandis*. 20 years old. Healthy.

In Wales, Thomson (*Notes on Ceiriog Forestry Experimental Area*, Denbighshire, 1922), reporting on sample plots of this species, states that although in common with all silver fir this species grow slowly when young, the height-growth increases rapidly about the age of 12 years, and leaders of 18-24 inches are quite common. No trace of *chermes* was found by him on this species up to the age of 12 years.

Abies nobilis Lindley—Noble Fir.

Distribution.

This species forms large forests along the slopes of the Cascade Mountains of Washington and Oregon, and also occurs on the coast ranges of Washington, and the Siskiyou Mountains of California (Dallimore and Jackson, p. 115).

Abies nobilis was introduced into Britain in 1830 by Douglas. According to Dallimore and Jackson, it has attained considerable importance in Britain as an ornamental tree, and has also been planted as a forest tree ; in Scotland it occurs at elevations varying from 800-1,200 feet. These authors particularly remark upon the satisfactory growth of this species on the Ardverkie Estate of Sir John Ramsden in Inverness-shire, where it is said to be the most vigorous of the several kinds of coniferous trees grown (Dallimore and Jackson, p. 116). Dr. Anderson reports on the species in Scotland as follows :—

On the Craigo Estate in Forfarshire, there was in 1920 an extent of 6 to 8 acres of this species, 39 years old and about 50 feet high, planted at 15 to 20 feet apart. There were few failures, if any, and the trees were healthy. The soil was poor.

On Durris Estate, Kincardineshire, there is a plantation of about ¾ acre of *Abies nobilis* in which the trees are still healthy. They are not yet twenty years old.

On the Balmakewan Estate, near Marykirk in the same county, there is a plantation about 15 years old near the Home Farm, which was healthy in 1920.

There are healthy underplantings of this species under larch at Novar, and under birch scrub in Glenlonan, Argyllshire.

A young tree noted at Kinlochourn, where *A. pectinata* was attacked, was quite healthy.

Numerous examples of trees of middle-age occur up and down the west coast, notably at Benmore and near Gairloch in Western Ross. There is some evidence in such localities that this species would make a useful shelterbelt tree, especially on the loose moraine on the steep slopes of some hills.

In Wales, Thomson (*loc. cit.*) states that this species behaves in a similar manner to *A. grandis*, as regards rate of growth in youth. No *chermes* damage to the species was noted by him.

A. grandis and A. nobilis in Relation to Chermes Attack.

As the above observations upon these two species would seem to indicate, it is the experience of practical foresters that they are as a rule not subjected to the severe attacks of *chermes* in the same degree as is *A. pectinata.* It may, however, be stated that *A. grandis* and *A. nobilis* cannot be considered to be immune from attack for the following reasons :—

(*a*) In recent experiments conducted by the author at Kew, young trees of *A. grandis* were infected with *Dreyfusia nüsslini*, the young twig form of the silver fir *chermes*, with the result that gall swellings were formed on the young buds and stem nodes which resembled in every particular those caused by *D. piceæ*, the stem bark form, on *A. nobilis* and other species.

(*b*) *A. nobilis* frequently shows the young shoots galled and deformed as a result of *chermes* attack, and this form of damage to the tree in the opinion of Dallimore and Jackson, may lessen the usefulness of the species in the warmer parts of the country.

In the author's opinion, while there is no reason to suppose that the presence of *chermes* should deter foresters from planting these species, it is desirable that the above facts should be recorded, in order that due care may be exercised in the choice of planting sites, as well as in the selection of clean stock for planting, a subject which will be considered in greater detail in the last part of this bulletin.

THE SILVER FIR CHERMES, DREYFUSIA.

The genus Dreyfusia belongs to the family Chermesidae, insects which are well known as gall-makers on several species of *Picea* or spruce. The genus contains two so-called species, both of which occur on silver fir, and were separated by Börner in 1908 from an original single species. The original species was known as *Dreyfusia piceæ*, and Börner's division created a new species, *D. nüsslini*, retaining the old name *D. piceæ* for the second form. It may be mentioned at the outset that considerable difference of opinion exists as to the validity of Börner's species, some writers regarding the two as simply racial forms, but here the two species are recognised for the sake of convenience in description.

Dreyfusia nüsslini Börner. The Young Twig Form.

This species, in its complete life-cycle passes through a series of five generations, covering a period of two years and including two host trees. The cycle commences upon the oriental spruce, *Picea orientalis*, on which galls are formed, followed by the migration of winged forms to the silver fir, where they settle upon the needles of the younger shoots. These winged forms are the starting point of a series of wingless generations upon the silver fir, which alternate between the needles and the bark of the stem, these generations following one another throughout the summer. The development of the wingless generation on the silver fir in the early spring is accompanied by that of winged forms, which are, as in the case of the spruce, migrants, and destined to return to the oriental spruce, where later in the summer they produce a sexual generation of males and females, which, giving rise to the original gall-foundress in the late autumn, close the cycle.

This full life-cyele of *D. nüsslini* is usual upon the Continent under suitable conditions. In Britain, however, it is of rare occurrence, and the life-cycle is confined to the wingless generations on the fir which alternate between the needles and the bark of the young shoots and branches.

Dreyfusia piceæ (Ratz) Börner. The Stem-Bark Form.

This species, as it occurs in Britain, is also confined to wingless generations on the silver fir, and in general outline its life history resembles that of *D. nüsslini*. In structure, however, the young larvae differ considerably from those of *D. nüsslini*, and it was on this account that Börner separated the two species.

In natural habitat, the species also differs from *D. nüsslini* in the following particulars :—

(1) It concentrates more upon the older stems and branches of the silver fir, especially on those portions which are in deepest shade. The exact reasons for this aversion to light are unknown.

(2) On young trees, it concentrates more upon the buds and branch nodes, and causes a type of gall formation upon these which is not usually associated with *D. nüsslini.* This type of damage is often seen in species of Abies such as *A. nobilis, A. grandis, A. cephalonica* and others.

As a rule in Britain, no winged generation occurs in this species, but Marchal has described such a generation as occurring in France, which he named "*Alata non Migrans,*" owing to the fact that these forms passed from silver fir to silver fir, instead of migrating from silver fir to spruce. This generation has not so far been found in Britain.

Relation to the Forest.

Of the above species, *D. nüsslini* is for the forester by far the more important as it is undoubtedly to it that the chief damage to the silver fir in plantations is due, at least as far as Britain is concerned. Recent studies made by the author on the relationship of the insect to the silver fir have shown that it is the presence of large numbers of the *chermes* on the bark of the young terminal shoots and branches which cause the leaves to turn brown and die. The exact nature of the injury has now been studied, but a full account of the results obtained is too detailed to be given here, and the main conclusions arrived at are therefore summarised as follows :—Young trees of silver fir up to the age of 15–20 years can be killed by *chermes* attack, the death of the tree being due to the presence of great numbers of the *chermes* on the young shoots. The *chermes* pass their stylets or feeding tubes into the tissues in order to extract nourishment, and in so doing cause extensive interference with the xylem tracheids or water-conducting elements, not only in the main stem itself, but also in the leaf trace bundles. This interference with the conducting elements eventually causes complete stoppage of conduction, and those portions of the stem thus attacked die as a result.*

The above studies on the effects of *chermes* attack upon the silver fir have gone some way towards a solution of the question as to why plantations of silver fir in this country become unhealthy at a comparatively early age, but it was felt that other factors, such as soil requirements, climatic conditions, seed selection, etc., also entered into the question, and the visit to Denmark, now to be described, was undertaken to obtain data relative to these points, from a country in which, as in Britain, the silver fir is an introduced species, and where attacks by *chermes* were known

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*. R. N. Chrystal. *The genus Dreyfusia in Britain, and its relation to the silver fir.* Phil. Trans. Roy. Soc., Series B, vol. 214, pp. 29-61, 1925.

to be severe and had been studied by Professor Boas and others. The two main questions studied in Denmark were :—

(i) The cultivation of the silver fir there.
(ii) The relation of the *chermes* to the silver fir in the Danish forests.

The visit was made possible by the kindness of Professor J. E. V. Boas, Professor of Zoology at the Kgl. Veterinaer og Landbohöskole in Copenhagen, to whom the writer is in the first instance much indebted for advice and assistance. The tour, which started at Copenhagen, included most of the important areas where silver fir is being grown in Denmark, and the writer was also fortunate in meeting many of the chief foresters in the country and acquiring from them first-hand information of very considerable value.

THE SILVER FIR IN DENMARK.

The silver fir, *A. pectinata*, was first introduced into Denmark by the celebrated German forester Johann Georg von Langen in 1764. He started a plantation in the royal park of Jaegersborg near Copenhagen, the greater portion of which is still standing, and which was visited by the late H. J. Elwes in 1908, who referred to it as one of the most remarkable in Europe.* Since von Langen's time the tree has been introduced into all parts of the country, but only in two places, namely at Friisenborg in Jutland, and on the island of Bornholm has its cultivation extended over considerable areas.

Climate.

It is, generally speaking, considered that the region of southern Denmark is not cold enough for the silver fir. The species, however, prospers in Northern Zealand, on the plateaux of Bornholm, and at Langesö in the Island of Funen. A study of statistics representing the mean annual temperature and the average annual rainfall of all parts of the country over a period of 30 years, shows that a mean annual temperature of 42–44° F. combined with a mean annual rainfall of 23–28 inches represents the optimum climatic conditions for the growth of silver fir in Denmark. The climate of the above-mentioned localities where the silver fir grows well corresponds more or less closely with these figures, while in other places, *e.g.*, on the southern islands of Möen, Falster and S.W. Zealand there is a decided falling off in the vigour of the tree combined with susceptibility to severe *chermes* attack, the climatic conditions being more unfavourable.

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* Elwes and Henry, *Trees of Great Britain and Ireland*, vol. iv, p. 725 (1909).

Soil Conditions.

A permeable sandy clay soil, such as is suitable for beech, is considered most favourable for the silver fir. This condition is well seen on the island of Bornholm, where on a granite formation, unique as far as Denmark is concerned, a sandy loam soil combined with a little clay is produced, which seems to suit the tree, better than almost any other soil in Denmark. Wet soils, thin, sandy soils, or soils in which the acidity is high are considered quite unsuitable. This was well illustrated on some of the areas visited near Copenhagen, where poor soil conditions are correlated with severe insect damage to the trees, and other data were collected regarding areas where in wet soils the trees have likewise succumbed to insect attack.

Cultivation.

Under this heading, the first subject to be considered is undoubtedly the question of seed selection, which Professor Oppermann, one of the leading forest authorities in Denmark, considers as of prime importance in the cultivation of exotic species. So far, very little research has been done on this question in Denmark in the case of silver fir, but the following points are of interest. The first seed sown by von Langen in Denmark came from the Thuringer Wald, and this strain has proved more suited to the Danish conditions than seed obtained from the Tyrol. This is shown by the fact that at Dyrhaven where von Langen's first trees were planted, and also in the Folehave forest a few miles away, two generations directly descended from the original Thuringer stock are to be seen as tall, well-grown, healthy trees indicating the suitability of the climate and soil to their needs.

Furthermore, seed from the original trees planted by von Langen was also used to form the plantations on the island of Bornholm, where, started in 1815, the trees of this stock have now reached their third generation, having been naturally regenerated or artificially planted. Further evidence of the importance of seed selection was obtained at Friisenborg, where it appears that seed obtained from the south of France (Jura) has proved unsuited to the conditions there. For this two reasons are given : (*a*) the autumn growth is too prolonged, and (*b*) the buds develop too early in the spring and therefore suffer severely from frost.

Distribution and Silvicultural Treatment.

As regards the oldest stands, Friisenborg and Bornholm provide the only examples approaching the original plantations of von Langen in age. In the former locality the oldest plantation, which is 100 years old, shows an average height of 112 feet and measures 11,400 cubic feet per acre. The largest single specimen is 124 feet in height, and has a content of 525 cubic feet (Fig. 1).

On the island of Bornholm the oldest stands formed in 1815, are situated on the central plateau of Almindingen, 300 feet above sea level (Fig. 2). In point of size these trees compare less favourably with those on the Zealand and Friisenborg areas, the stand having been very much under-thinned, as may be seen by the thin and lanky stems of many of the trees now. Recent attempts have been made by Skovrider Bramsen to thin out, but this is an operation which necessitates great care, and even now in its beginning has already allowed the wind a chance to begin its ravages on the remaining none too well-rooted trees. Examination of felled stems showed also that as a result of under-thinning the increment of late years had fallen considerably. The remainder of the silver fir stands in Denmark range between the ages of 4–60 years, Friisenborg and Bornholm being the most extensive areas. On Bornholm the acreage under silver fir, including the oldest stands is 976 acres, of which only 25 acres are over 100 years old, the remainder ranging from 4–30 years. Oppermann states that the silver fir cultivation on Bornholm has attained more considerable proportions than in any other part of Denmark to which it has been introduced. This he explains as being due to the absence of deer in the island, which in this respect is favoured as compared with the rest of Denmark where deer are present in abundance everywhere.

At Friisenborg the conditions have not proved so favourable to the tree as on Bornholm, chiefly owing to the presence of the silver fir *chermes*. In consequence of this, Friisenborg must be considered separately and is dealt with later. Other smaller areas throughout the country such as Holte near Copenhagen, and Langesö in Funen, are also discussed in connection with their relations to the *chermes* attack.

Silviculture.

Since its first introduction, the culture of the silver fir has been extended both by planting and also by natural regeneration. These may be considered separately :—

Planting.—In the past one of the principal uses for silver fir was as a substitute for spruce in areas where the fungus *Trametes* was present, the silver fir being considered less liable to attack. Such plantations are to be seen in the Rude Skov near Copenhagen, but here the poverty of the soil is such that the replacement of spruce by silver fir is, to say the least, questionable. Recently, and especially on areas where frost damage is to be feared, the silver fir has been grown under " Overholders," and good examples of such plantations were seen on Bornholm. These were started in 1866, the land being originally under heather (*Calluna vulgaris*), which was burnt off, Scots pine and larch being sown. This heath soil is of good quality, well drained, and non-acid, and its preparation for planting was rapidly and cheaply effected. The silver fir were planted about thirty

years after the first crop of pine and larch was sown. Several plantations of this type were seen, the oldest silver firs being 30 years. They were found to develop more rapidly than the naturally regenerated silver fir and thinnings were made regularly every three years after the age of 20 years. Scots pine, larch and birch are used almost exclusively as "Overholders," with an occasional spruce here and there, but the spruce is not favoured owing to its liability to windfall. Young plantations were seen in which the silver fir are from 4-10 years old, and which were planted 4 feet apart and 3 feet 3 inches between the rows. The removal of the overholders begins about the age of 15 years, the process being gradual, those in the low-lying places being dealt with last to avoid frost injury (Fig. 3).

Natural Regeneration.—The largest areas of natural regeneration were seen on Bornholm, and are about 30 years old. They have just been thinned and, as the photograph (Fig. 4) shows, were originally very dense. Great density has produced clean-boled trees of a generally good shape, and this in the opinion of Skovrider Bramsen, with whom the writer visited the area, represents the ideal treatment, which is to start with a close stand, to begin thinning about the age of 20 years, and then to thin regularly at intervals determined by the formula—

$$\frac{\text{Age of stand}}{10}$$

Natural regeneration was common throughout most of the areas visited, being especially abundant at Langesö in Funen (Figs. 5, 6), and fairly extensive even on unfavourable areas at Holte near Copenhagen. The occurrence of natural regeneration on these areas is interesting, and indicates that the failure of the trees there is not to be ascribed wholly to the fact that they are being planted outside their proper climatic zone. Other conditions, such as depth and type of soil, are at variance with the optimum requirements of the tree, and the relation of these to the *chermes* attack must be carefully considered.

Yield.

While, at the present time, the silver fir cannot be said to take an important place as regards yield among Denmark's coniferous woods, we have already seen that considerable areas have been planted with this species, and the work of Oppermann* on Bornholm has shown its undoubted possibilities. In his recent article on the silver fir of Bornholm, Oppermann has collected and discussed sample-plot researches extending over a period of 40 years, and has drawn the conclusion that the climatic and soil conditions of Bornholm will produce a rate of growth in the silver fir which will be hardly less than that which obtains

* Oppermann, *Le Sapin pectiné à l'île de Bornholm*, 1912.

in the more southerly countries of Europe. Other sample plots at Friisenborg have also shown that the silver fir in rate of growth compares favourably with the spruce, and gives much promise of being a useful species, although against this we have to place the disadvantage of its liability to *chermes* attack, the extent and effects of which are considerable.

At the present time, *Abies pectinata* forms 90 per cent. of the total silver fir stand in Denmark, but in some places, notably, at Langesö in Funen, and Friisenborg, a number of other species are being planted. At Friisenborg, *A. grandis* is being made the subject of sample plot studies by Professor Oppermann, and one such plantation, 26 years old, was seen there. This plantation is doing well, and has never suffered from *chermes*, but is liable to suffer from exposure to storm winds from the north-west. No indication of the presence of *chermes* on *A. grandis* was found there.

A. nobilis has also been planted at Friisenborg, and the plantations range in age from 4 to 20 years, the oldest having been recently thinned for the first time. According to Moldenhawer, wide planting (4 feet by 4 feet) will produce very pyramidal-shaped stems in youth, which, however, is rectified later in life, but if the distance between the plants is reduced to 3 feet by 3 feet, or 3 feet 6 inches by 3 feet 6 inches, the shape of the stem always remains cylindrical. Young plantations in the open suffer from frost in May and June, but do very well under a shelter wood of birch and *Alnus incana*. When planted on areas previously occupied by spruce, which has suffered from *Fomes annosus*, many plants are killed by the fungus, the attack lasting over a period of years. At Langesö, two stands of *A. grandis* were seen, of which the older, 43 years, showed an average diameter at breast height of 17 inches, and an average height of 80 feet (Fig. 7). This stand showed particularly good growth, one cut stem showing an average annual diameter increment of ·5 inches. Two stands of *A. Nordmanniana* were also visited here, and appeared to be doing very well. But perhaps the most interesting stand was one of *A. concolor* (Fig. 8), 46 years old, which showed an average diameter at breast-height of 16·5 inches and an average height of 66-68 feet. On none of these species were there any signs of *chermes* damage, and this is especially interesting in the case of *A. Nordmanniana*, which is not immune from *chermes* in other parts of Denmark, and thus furnishes further confirmation of the suitability of the conditions at Langesö for its growth.

THE SILVER FIR CHERMES IN DENMARK.

The biology of this insect under Danish conditions has been studied by Boas in much detail for a number of years, and the main points of the life-history agree in every way with the results of our studies of the insect in Britain. Normally, there

s no gall generation on the oriental spruce in Denmark, that tree being of very rare occurrence, and Boas has not succeeded in producing this generation experimentally. Winged forms do appear on the fir in spring, but, as in Britain, they are sexuparae in tendency and apparently die off for lack of a spruce host. No winged generation migrating from one silver fir to another has been found so far, although the possibility of its occurrence is not entirely ruled out. As regards the two species of *Dreſusia* separated by Börner, viz., *D. nüsslini*, the young twig form, and *D. piceæ*, the stem form, Boas regards these as racial forms, and not as true species. This view, which has a considerable body of *prima facie* evidence to support it, seems more readily acceptable when one has seen the close proximity in which the two forms are to be found upon the same tree in Denmark.

Abundant proof of the injury to silver fir caused by *chermes* was afforded by the study of the Danish plantations, and the first very striking observation made was the correlation between poor soil and severity of infestation. This was very marked in the forests round Holte, near Copenhagen, where the silver fir growing in a poor soil were severely attacked.

These areas consist for the most part of very poor sandy soil, which in places where the silver fir is planted is very acid, forming heathery moorland, where in certain cases chalk is artificially added previous to planting to neutralise the acidity. These soil conditions, together with the fact that this region is probably not climatically suitable for silver fir, are responsible for its poor growth. As a result of this, the *chermes* is very injurious and the young stands have the same appearance as those to be seen at Inverliever, in Scotland. On many of the young trees the *chermes* has already got the upper hand and the trees are dying (Fig. 9). Severity of attack, however, varies greatly in different parts of the same plantation, and even in the case of single trees standing adjacent to one another. This feature is very striking. The trees were making valiant efforts to restore their lost branches by vigorous production of side shoots and shoots from accessory buds, the multiplication of these causing curious abnormalities in many cases.

In those places where the soil was rather better, a little clay being present, the silver fir had to some extent recovered, and in the older stands it was observed that the *chermes* was not prevalent on the tops, the trees having, so to speak, grown away from it. This was attributed to the effect of light and consequent vigour of growth and, as will be seen later, the operation of thinning has much to do with this improvement in the health of the trees.

In this forest, owing to the prevalence of the fungus *Trametes*, the silver fir has been planted in pure stands, following spruce and, so far as one was able to ascertain, no particular care has been taken to plant only clean stock free from *chermes*. It is probable that this stock was the original source of infestation

by the *chermes* which has spread further and increased naturally.

At Friisenborg, again, there was evidence of severe attacks in the past, although this area is undoubtedly much more favourable for silver fir than the Copenhagen district and in addition the energetic protective measures employed by Overförster Moldenhawer had removed the worst signs of damage. On the other hand, at Langesö and on Bornholm, areas which are probably the most favourable for silver fir in Denmark, one found silver fir of all ages and species growing well, and the *chermes*, while certainly present here and there, was reduced to a negligible quantity. These personal observations were supplemented by reports from other areas where on poor soil or badly drained areas the condition of the silver fir was similar to that prevailing at Holte. In the young stands the damage was caused by the young twig form, *D. nüsslini*, but at Friisenborg the older trees also suffered from the attacks of the stem form, which in very severe cases caused death, while general weakening of the stem and poor growth were invariable. This type of damage is not familiar in Britain where older woods of silver fir are of rare occurrence. Many examples of the above damage were seen at Friisenborg, of which the following are the salient features: The attack on the stem may extend up to a height of 30 feet. The presence of the insects causes little pustular swellings to rise on the bark, the first effect being total or partial killing of the cambial layer. Should the attack be sufficiently severe, the tree will succumb after some years and the bark will split in a longitudinal direction (Fig. 10). Should the attack be arrested, however, either by natural or artificial means, a new bark arises under the old one; this was constantly observed at Friisenborg and the coarser texture of this new protective layer is believed to be a protection against further injury. A remarkable feature of the attack is the occurrence during and subsequent to it of several species of unicellular *Algae*, which persist as a feature on such trees even after the *chermes* has disappeared. Their relation to the *chermes* attack, if any, has not so far been satisfactorily determined.

We now come to the important question as to how the *chermes* attack may spread from one tree to the other in plantations, and in this connection the Danish forests provided conclusive proof that the *chermes* does spread naturally in plantations. This was shown by the fact that in many places the insects were found present on natural regenerations of all ages, from tiny seedling plants to trees 8 to 10 feet in height. This fact is only to be explained in two ways, viz., either Boas' theory is correct that *D. nüsslini* and *D. piceæ* are racial forms, and in that case the existence of a winged form migrating from fir to fir may be supposed to occur from time to time, and thus spread infection; or the spread may be due to wind, birds or other animals. Wind carriage has already been shown to occur in the case of the Douglas fir *chermes*, *C. cooleyi*, causing infection of even very

small seedlings, and there is every reason to suppose that in Denmark it plays a large part in the distribution of *Dreyfusia* and may even be the most common means of spread.

THE CONTROL OF CHERMES IN DENMARK.

The district of Friisenborg provides what is, as far as I know, a unique example of artificial control of *chermes* in plantations by spraying. Here the younger stands, which vary from 10 to 15 years up to 35 to 40 years old, have in the past suffered and still do suffer severely in places from the attacks of *chermes*, but owing to the extensive control operations carried out by Overförster Moldenhawer, the state of the trees is now in most cases very satisfactory. The causes underlying the prevalence of *chermes* there are not so far clearly known. Compared with other parts of Denmark the soil and climate would seem to be well adapted for the tree, but it has been suggested that the question of the origin of the seed may play a part in the problem, and that so far the ideal type of tree for this area may not have been employed in planting. Be that as it may, however, one thing is certain, namely, that Friisenborg is a most interesting and instructive area from the *chermes* point of view, for the following reasons :—

(1) Overförster Moldenhawer has for the past 20 years and more instituted a regular campaign against the insect by means of spraying, in stands of all ages.
(2) He has also shown that regular thinning has much to do with the lessening of *chermes* attacks in plantations, and he believes this can in certain cases cause a complete cessation of an outbreak.

Spraying.

The spray used is a solution of Lysol 3–5 per cent., and all the work has been done with small knapsack sprayers, which seems at first incredible, when one sees the areas involved. The young twig form (*D. nüsslini*) is sprayed just after the opening of the buds in spring and spraying is repeated at intervals throughout the summer, every time attacked trees are located. Owing to the fact that attacks begin sporadically, successful control involves careful inspection on the part of the forester to locate the affected area and destroy the insects in the beginning. Young plants bought from other places are often found to be infected when received and these are at once destroyed. The stem bark form (*D. piceæ*) is dealt with in a similar manner to the young twig form, the same strength of spray being used in both cases.

In Moldenhawer's opinion, close watch must be kept and the necessary spraying must be carried out in the plantations every spring and summer throughout their life. The cost of

spraying for the young twig form differs greatly in proportion to the intensity of infestation. As a rule the cost of spraying and inspection of plantations ranges from 1s. 6d. to 6s. per acre yearly.

In the case of the stem-bark form spraying has been expensive on several occasions owing to the fact that the true menace of the attack was not realised in time. In these cases the cost of treatment ranged from 15s. to 30s. per acre yearly, but Moldenhawer considers that this cost can be very much reduced by careful inspection and timely treatment.

The cost of this treatment has been objected to by some authorities in Denmark, but in Overförster Moldenhawer's opinion the results obtained have warranted the expense. Many examples of sprayed plantations were seen, figures 11 and 12 showing one such example which is fairly typical of many others. The area is one of Douglas fir and silver fir, 39 years old, originally planted 3 feet apart. It was so severely attacked by *chermes* in 1903 that Boas when visiting the area declared that it could never form a stand. It was sprayed at this time and the attack checked, but was again attacked in 1918 by the stem-bark form, the majority of the trees being white with *chermes*. In the 1918 outbreak, the attack began in certain belts and then gradually spread all over, covering the stems up to a height of about 26 feet. The total area affected was 7½ acres. The present condition of the stand is eminently satisfactory as the photographs indicate, the *chermes* attack has entirely subsided, and the increment of the trees is good. In other plantations visited the general control procedure was similar to that just described, spraying having been carried on in some cases over a period of 4–5 years, accompanied by thinnings at regular intervals. This treatment was particularly striking in its results on one plantation, 35 years old, where an area of 60–70 acres badly affected in youth is now doing well. Of the younger woods, figure 13 of a young plantation of *A. Nordmanniana*, 15 years old, provides a good example of an area which is now being treated. Here the attack became severe a few years ago and spraying was completed last year. Near this place there were some other trees of the same species which had been sprayed a few years previously, when about the same height (8–10 feet) as the plantation in question. Since then the height-growth put on by these trees has been remarkable and provides an excellent example of the immediate benefits arising out of this treatment.

Thinning and other Silvicultural Measures.

The first thinnings are made at the age of 20 years; this is general throughout the country. At Friisenborg subsequent regular thinnings are made at intervals of two years. The influence of regular thinnings on the *chermes* attack is very remarkable, and one saw several places where a marked improvement

in the health of a stand had been effected by thinnings alone, without any recourse to spraying. Fig. 14 shows a typical example of such a plantation, 45 years old, which, although heavily attacked by the stem-bark form of the *chermes* after the first thinning, has, under the influences of subsequent heavy thinnings made at intervals of 2-3 years, completely thrown off the attack of the insect. This phenomenon is due probably to two causes, *e.g.*, the beneficial effect on the tree of increased light, and the unfavourable effect of light, so far unexplained,* on the development of the *chermes*.

The first thinnings tend to show a temporary increase in the *chermes* attack, but subsequently, as the thinnings become heavier, the *chermes* gradually disappears. Great attention is also paid to proper drainage in the stands, and this measure must have much to do with their welfare.

GENERAL DISCUSSION OF THE DANISH RESULTS IN RELATION TO BRITISH CONDITIONS.

The main conclusions arrived at as a result of the Danish tour, with respect to the silver fir *chermes* problem in Denmark, may be summarised as follows :—

(*a*) The silver fir *chermes* is a severe pest of silver fir in Denmark, both the young twig form (*D. nüsslini*) and the stem bark form (*D. piceæ*) causing injury. The incidence of *chermes* attack, however, has been shown to be directly connected with a complex of factors, which include climatic conditions, soil conditions and type of tree used. Thus the regions of Langesö and Bornholm afford examples of areas where the combination of the above factors is suitable to the tree, which is doing well there, despite the presence of *chermes*, which does occur in small numbers, but is not a menace to the tree. On other areas, however, such as at Holte near Copenhagen, and Friisenborg in Jutland, where the conditions are not so favourable, the *chermes* attack assumes serious proportions.

(*b*) The importance of planting clean stock was also brought out during the Danish tour, as it was found that the *chermes* does spread from one tree to another in plantations, probably by wind or animal agency.

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* One possible explanation of the effect which light has in reducing an infestation is that light seems to favour development of winged forms which are abortive in the absence of oriental spruce, or, if that is present, owing to the failure of the sexual generation. Thus, if 40 per cent. of the *chermes* present in spring develop into sexuparæ the infestation is reduced to that extent. This, however, needs confirmation.

(*c*) Artificial control by spraying has been demonstrated at Friisenborg to be a successful method of *chermes* control. Along with this, sylvicultural measures, such as regular thinnings of the stand have been shown to have a marked effect upon the intensity of attack by *Dreyfusia.*

In Britain the main results of the work so far carried out can be stated as follows :—

(*a*) The life cycle of the *chermes* has been studied and compared very closely with that found by Boas in Denmark.

(*b*) The laboratory investigation conducted by the author on the relation of the *chermes* to the silver fir has supplied clear proofs that these insects are a prime cause of the death of silver firs quite apart from soil or climatic factors or of the attacks of fungi such as *Rehmiellopsis.*

(*c*) From the standpoint of the forester, the evidence so far available points to the fact that in the past at any rate the species *A. pectinata* and *A. Nordmanniana* have in the majority of cases been very severely attacked, and in many places killed out by the insect. This, however, has not been the case in every instance, and reference to Dr. Anderson's report furnishes evidence that in certain parts of N.E. Scotland *A. pectinata* is doing well in plantations, favourable soil and climate being probably the cause of this. Additional evidence in support of the contention that silver fir does survive in certain localities, and grows to large dimensions, is indicated by the occurrence of fine old trees of the species which are to be found in isolated positions all over the country.

Despite this fact, however, one thing is quite clear, namely, that in Britain the growing of *A. pectinata* can only be accomplished successfully in the majority of cases by taking due precautions both in the nursery and also in the young plantations, and we may now proceed to consider this question in detail.

The Introduction and Spread of Chermes in Britain.

In the first place we must assume that the insect was introduced to this country on nursery stock from abroad, and that since that time it has been spread throughout the country from nursery to nursery, and so to the plantations. As to the means of spread, both in the nursery and also in plantations, the author is convinced that in Britain the insect only rarely produces winged generations which could carry infection from tree to tree, and that even if these do occur, the winged forms are migratory to the

oriental spruce, which is a relatively rare species in Britain, and upon which tree alone they can successfully settle. Spread is therefore limited to wind and animal agencies as has already been shown to be the case in Denmark. It cannot be too strongly urged here that there is no basis for comparison between the spread of the *chermes* and that of such a fungus as the White Pine Blister Rust. In the case of the fungus, the recognised secondary host plant, the currant (*Ribes*) is, when present, the medium by which spread takes place, while in the *chermes* as already stated the alternate host is in 90 per cent. of cases absent.

Clearly then in order to infect a plantation the insect must either be already present on the young trees when planted, or else it must be introduced at a later period, through the agency of wind or animals from nearby infected areas. The first point of importance therefore in any future attempt to establish silver fir plantations in Britain should be the production of clean nursery stock. This is not a simple matter, as the *chermes* are small and difficult to detect, and may easily be overlooked upon plants which are being sent out into plantations. The only sure way of raising clean stock is to grow it from seed in an isolated place, *i.e.*, away from all other silver fir, and never to risk infection by bringing in other plants the origin of which is unknown. So far as the author is aware no experiments along these lines have as yet been tried in this country, and a preliminary series on a small scale would undoubtedly yield valuable data on the vital question as to whether or not clean silver fir can be grown for planting, and whether after planting it can be kept clean in the plantation. The only information available regarding isolated plantations of silver fir is contained in the following report by Dr. Anderson on two plantations at Glen Quoich and Kinlochourn, Inverness-shire, Scotland.

The *Abies pectinata* at Glen Quoich covers roughly one-tenth to one-fifth of an acre all told, though not in one compact block. In age the trees appear to be between 20 and 100 years. The top soil is a somewhat thin peaty loam over a clay loam over what appears to be a rock outcrop with patches of morainic drift. The elevation is 600 feet and the locality is in moderate shelter. The height of the trees is about 80 feet. The stems are much covered with mosses, etc., and show no sign of the bark *chermes*. The foliage appeared to be healthy and one recently blown tree had no sign of disease.

At Kinlochourn at an elevation of about 100 feet there is a mixed plantation of 30–40 years of age consisting mainly of Corsican pine with some *Abies pectinata* and other species. The trees are growing on pockets of rather heavy soil over gneissose rock which frequently outcrops. The herbage is strong Calluna, 2–3 feet high, with mosses, Molinia, etc. Many of the trees show evidence of damage and *chermes* is present on the silver fir. The climate is mild in winter and the soil does not appear to be very favourable.

Both these plantations are very isolated but in the first case the climate is more severe and the trees are older, while in the second case the climate is milder and the trees are younger. In the above cases of course, as no data are available giving the origin of the silver fir planted, which in the case of the infected plantation at Kinlochourn were almost certainly infected when planted, these areas do not meet the requirements of experimental plantations on the lines already laid down, but they do however show interesting comparisons in climate and soil conditions.

A further line of research bearing upon the question of clean stock production is the question of seed selection, the importance of which is being more and more realised by foresters both at home and abroad, and a study of this in the case of silver fir would be invaluable.

Control Measures.

The Young Twig Form—Dreyfusia nüsslini.

The success which has attended the spraying operations at Friisenborg may be due, in the author's opinion, to the following considerations.

It is now evident that the *chermes*, in order to become a serious enemy in any silver fir plantation, requires to be present in considerable numbers over a large proportion of the area. Even then its activities are comparatively slow in causing vital injury to the trees.

In practice it is not found that the whole area is attacked at once, but that the attack begins in patches and only spreads slowly throughout the area. If, therefore, spraying is begun in good time and thoroughly carried out, the *chermes* population, which takes some years to reach dangerous proportions, is severely reduced in numbers and the heavy drain upon the young trees is largely arrested. Freed from this weakening influence the latter can now proceed to recuperate, their leading shoots get a chance to develop, and after a short time the height-growth should be restored to normal.

The result is that in a few years the trees are of such a height that the conditions of light and probably also of temperature in the crowns of the trees are no longer suited to the *chermes*, which will confine its attacks to the lower branches, where the damage is negligible.

The Stem Form—Dreyfusia piceæ.

This form is, as we have seen, responsible for the attack on older stems. At Friisenborg its attacks are said to become serious about the age of 20 years (Fig. 15). This is, probably, also the result of a gradual increase in number on the part of

the insect, which up to now has been free to develop under favourable conditions of shade and temperature. Light is believed to be a very important factor, both for *Dreyfusia* and also for *chermes cooleyi*. It has been noticed that the insects show a marked tendency to turn away from the light. On young trees the concentration of the *chermes* is on the under sides of the side branches and on the most shaded portions of the vertical ones ; on older trees the stem-bark form only reaches a certain height, above which it is probable that the light conditions are unfavourable and this may explain the fact that heavy thinning, which means increase of light in the stand, has the effect of reducing the *chermes* in numbers.

The Attack on Older Stems.

It is the opinion of Overförster Moldenhawer and others that the attack of the stem form can cause the death of the tree but so far we have little knowledge as to the means by which this is brought about. In fatal cases it is probable that serious injury has been done to the cambial region and has been spread over such an area as to render recovery impossible, but, in many cases, it is evident that the cambial layer has only been temporarily disorganised, as is shown by the formation of a new bark, which is formed, it is supposed, to protect the tree from further injury in that region. This may be due to the fact that the new bark cells laid down offer an effectual barrier to the insect's feeding tube, and Zweigelt, in his work on the feeding of Aphids, states that in rose plants such protective zones of cells do occur and offer a barrier to further attack. It is probable then that the attack on the older stems requires a considerable period to reach serious proportions and timely spraying would have a good effect. This would probably also be permanent, as by the time the *chermes* population had again become numerous, thinnings would have begun and would act as an additional check upon their increase.

Furthermore, with increasing age, the thickening of the bark and perhaps also its structural changes, have the effect of preventing renewed attacks, at any rate on a large scale.

While, therefore, it is evident that in young plantations severely attacked by *chermes*, spraying is an effective and necessary operation especially if accompanied by measures of soil improvement such as drainage, etc., where necessary, and will save the trees from disaster at a critical time, it is considered that as regards older trees, the information we possess concerning the stem form is insufficient to indicate whether or not the expense of spraying is justifiable. In some cases at Friisenborg it would appear that regular thinnings alone have been sufficient to keep the insect in check. If, however, timely spraying is resorted to, it cannot fail to be of good effect, and the question of its application is one of financial profit or loss.

As regards thinning operations in relation to *chermes* control, the time for these has not arrived in the case of the silver fir in Britain. While it may be questionable as to how far our forestry practice will permit of the intensive system of thinnings customary in Denmark, it is a point of attack which should be borne in mind, and the application of which might be extended to other coniferous species, such as larch and Douglas fir, in the event of severe attacks by *chermes* in older woods.

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FIG. 1.—Old silver fir, Friisenborg.

FIG. 2.—Old silver fir, Bornholm, with natural regeneration.

FIG. 3.—*A. pectinata*. Young plantation established under overholders of larch and Scots pine. Rö Forest, Bornholm.

FIG. 4.—*A. pectinata*. Natural regeneration, after thinning, Bornholm.

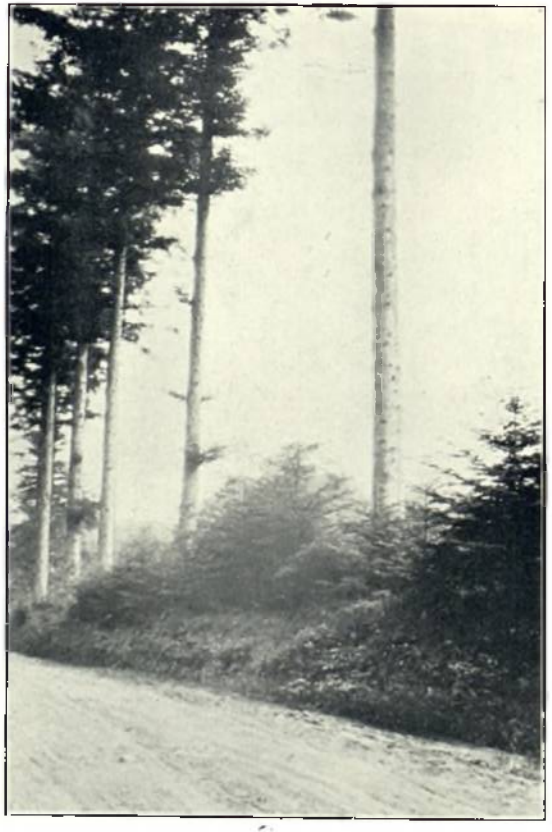


FIG. 5.—Old silver fir, Langesö, with natural regeneration.

FIG. 6.—*A. pectinata*. Natural regeneration, Langesö.

FIG. 10.—*A. pectinata*, Friisenborg. Bark of old tree, killed by *D. piceæ*.

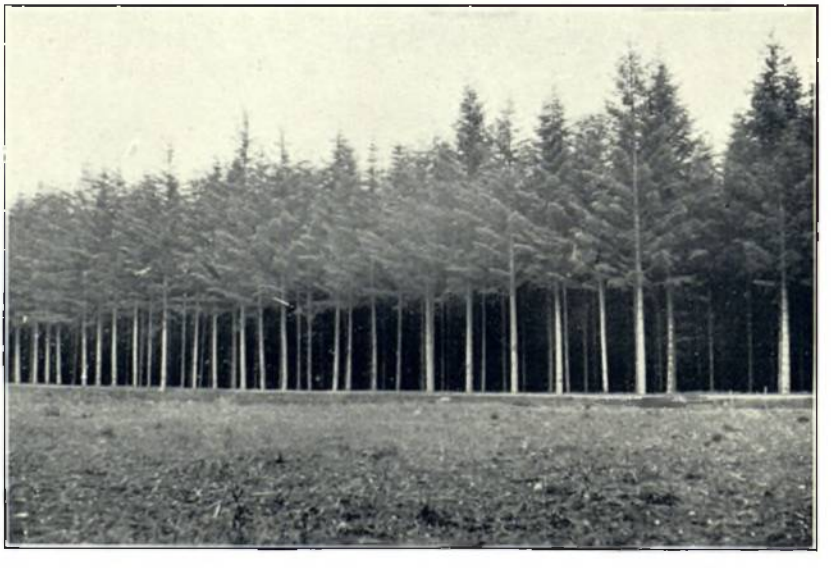


FIG. 11.—*A. pectinata*, Friisenborg. (*See* text, p. 21.)

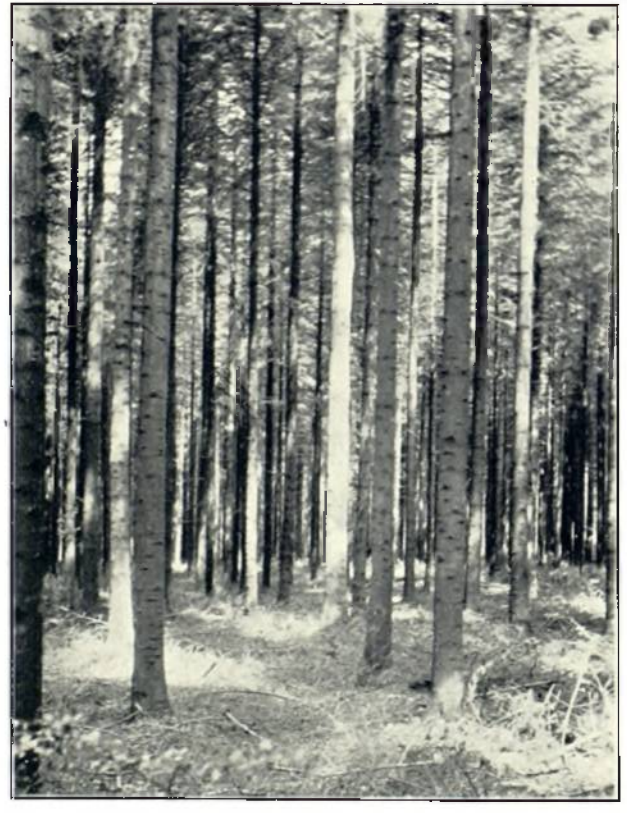
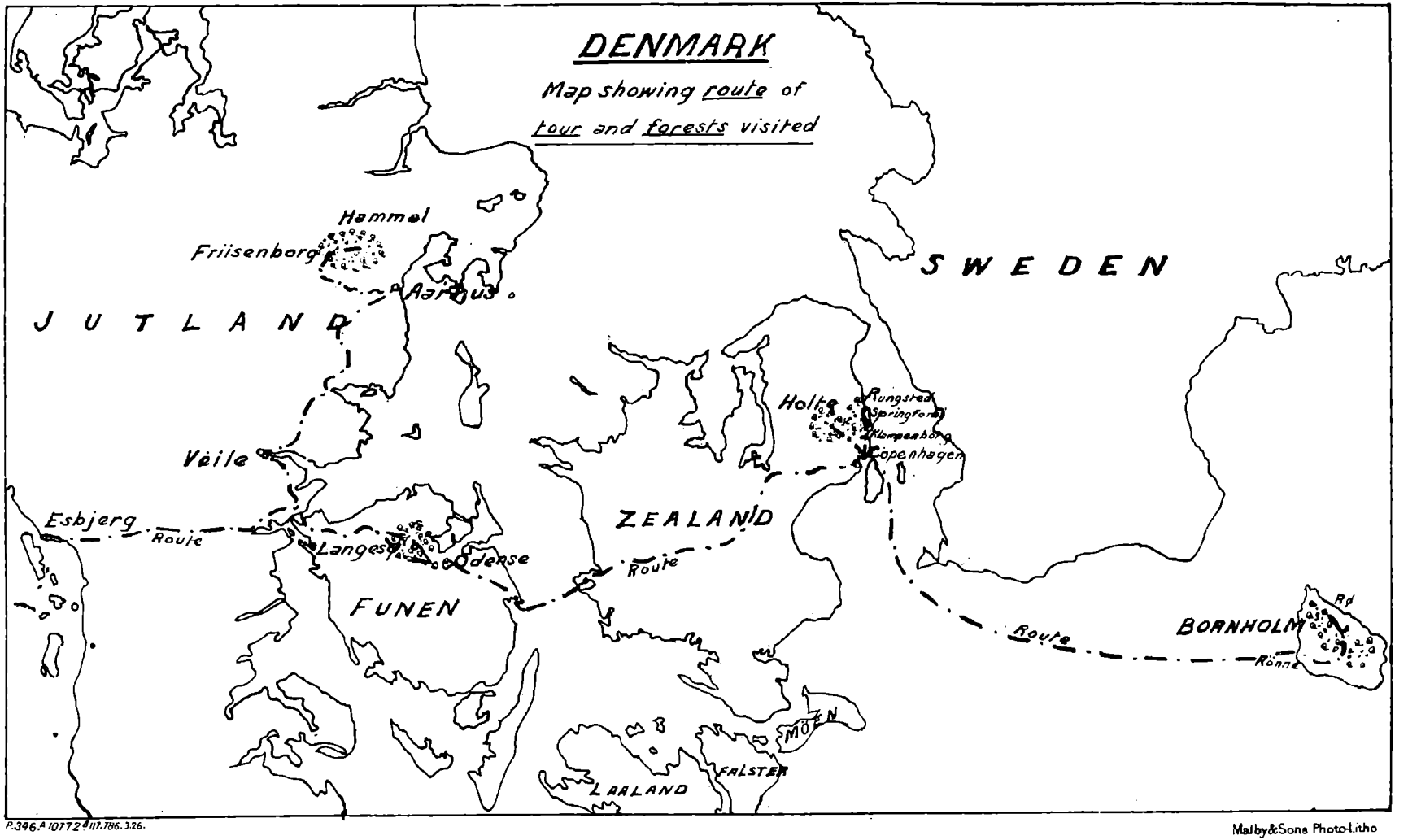


FIG. 12.—*A. pectinata*, Friisenborg. (*See* text, p. 21.)

FIG. 13.—*A. Nordmanniana*. Young plantation severely attacked by Dreyfusia. One year after being sprayed, trees recovering.

FIG. 14.—*A. pectinata*, 45 years old, Friisenborg. (*See* text, p. 22.)

FIG. 15.—*A. pectinata*, *Dreyfusia piceæ* (Stem-bark form). On older trees commencement of attack. Friisenborg.



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