Evaluating forest disease problems

G. DE BRIT[1]

ABSTRACT

This article is intended primarily for forest managers. It is suggested that forest managers may be somewhat reluctant in accepting the value of investment in forest disease prevention or control, because no positive effect on timber production is seen to derive from this type of investment. Economic evaluation of a disease, it is stressed, must be based on a thorough biological evaluation.

The article shows how two types of forest disease problems are evaluated: 1, an existing forest disease problem, and 2, a potential forest disease problem. *Rhizina undulata* is used as an example of the former situation, and *Fomes annosus* as an example of the latter situation.

INTRODUCTION

It is probably true to say that the major emphasis of any forest enterprise to-day is placed on increasing forest productivity. I am confining my remarks here to timber production and excluding consideration of other aspects of forest production such as amenity development and wild life management. Efforts to increase timber production in this direction are concerned with increasing the timber producing potential of forest land and of the trees which grow on forest land. Examples of forest management practices to achieve this end are drainage, control of competing vegetation, fertilization, thinning and species selection. All these factors operate in a positive way, i.e. they modify timber production. The change can be seen or measured. Measures aimed at preventing or controlling forest diseases do not operate in this way. They do not visibly increase timber production but safeguard existing and future production. This difference, I consider, can lead to reluctance in accepting the value of investment in tree disease prevention or control. It is perhaps necessary to examine this a little more closely. Should a forest manager invest in a positive production factor, e.g. fertilizing, he can measure an increase in production deriving from this investment. If, on the other hand, he invests money to prevent a forest disease situation becoming established he can not see any increase in timber production deriving from this investment. The benefit in this situation is the prevention of anticipated loss to existing or future production. My suggestion is that a forest manager will have more sympathy with the former type of investment. This is perhaps understandable, as an investment of the latter type will frequently leave a suspicion about its value, apart from the fact that it does not result in increased production.

The purpose of this article is to describe how forest disease problems are evaluated. I will indicate particularly how investment in prevention or control methods can be justified.

[1]Research Officer, Research Branch, Department of Lands (Forestry Division), Dublin.

DEFINING THE PROBLEM

There are two quite distinct aspects to be considered in defining the problem. The first concerns a tree disease problem which exists in the country. A forest manager will be aware of any significant problem which exists in his area. He may not be aware of the cause of the problem, but he will be aware of its effects. Communication between the forest manager and the forest pathologist will enable a reasonable assessment of the nature and scope of the problem. To illustrate the evaluation of this type of situation I will use the disease, group dying of conifers, caused by *Rhizina undulata.* The second aspect, which is particularly relevant to our situation in Ireland, involves the evaluation of potentially dangerous pathogens, especially those which are known to be damaging in other countries. To illustrate this aspect I will use *Fomes annosus* which causes butt and root rot of conifers.

DEALING WITH AN EXISTING FOREST DISEASE PROBLEM

Background

The disease, group dying of conifers, became apparent in Ireland in 1952. Murray (1954) had reported a similar condition in England. Briefly, it can be said that groups of trees in pole stage stands of a range of conifer species died. No explanation at that time could be offered to account for the occurrence.

Association with Rhizina undulata[1]

Mr. W. Shorten, who was Forester in Glendalough at that time, noticed a fungal fructification frequently associated with the groups of dead trees. McKay and Clear (1953), identified this fungus as *R. undulata.* The fungus was recoverable from affected trees, but attempts to inoculate healthy trees were unsuccessful.

Biological Evaluation

It seemed very likely then that *R. undulata* was the causal organism, but this could not be proved because of the failure to inoculate successfully healthy trees with the suspected pathogen. This point is of more than academic interest because failure to understand the mode of action of the pathogen renders impossible a logical preventive or control process.

It had been noticed in Ireland (de Brit and O'Carroll, 1967), and in England (Murray and Young, 1961), that fire sites were frequently associated with groups. These workers hypothesised

---

[1]*Rhizina inflata* is a synonom for *Rhizina undulata.*

that there was a relationship between the disease, fire sites and the fungus; by experiment they sought to demonstrate and explain this relationship. These experiments confirmed the relationship between the three factors but did not support the various hypotheses put forward to explain the relationship. Jalaluddin (1967) has since shown that germination of ascospores of *R. undulata* is stimulated by exposure to a high temperature, especially over the range 35-45° C, for certain periods. The fungus can then invade coniferous roots.

Formulation of Preventive or Control Measures

The control of this disease lies obviously in the field of prevention, i.e. not lighting fires in pole stage coniferous stands. However, it would not have been possible to arrive at this simple solution if the biology of the pathogen and its relationship with its host and environment had not been worked out. Fires would continue to be lit. Everytime *R. undulata* ascospores were present where a fire was lit the disease could become established. At each such fire site more fructifications of *R. undulata* would be produced. This in turn would increase the risk of each subsequent fire initiating a new disease centre. Eventually a situation would be reached where everytime a fire was lighted a new disease centre would be initiated.

Economic Evaluation

No economic evaluation was made of this particular disease situation, because the implications were obvious, and the prevention costs negligible. Obvious damage was being done to valuable timber by tree mortality, although it should be pointed out that the timber was salvageable. Residual stands were rendered more liable to wind throw because of the disease, resulting in management and marketing problems and costs. Those portions of stands affected by the disease remained unproductive until the next rotation, perhaps 20 years away. As I have mentioned above, none of this was evaluated, but it would be interesting to determine, for academic reasons if no other, the monetary benefits accruing from this preventive measure.

In making an economic evaluation of the disease this is the situation against which the cost of preventive measures would need to be judged. As has been indicated above, with this particular disease such an analysis was not necessary because of the negligible cost of preventive methods. The point is emphasised to indicate the magnitude of the losses which are incurred in the absence of preventive measures.

DEALING WITH AN ANTICIPATED FOREST DISEASE PROBLEM

In dealing with the disease *group dying of conifers* it can be seen from a forest management or economic viewpoint to be a fairly simple problem to evaluate. The disease causes recognisable and measureable damage and the preventive measures are simple and non-costly. Not all disease situations are as simple as this. Many will require a careful economic evaluation of the damage and an equally careful economic evaluation of control or preventive methods. In saying this, I should point out that in describing *group dying of conifers* as a simple disease situation I do not intend to devalue the vital contribution made by various workers in elucidating the underlying causes of this disease. Without this work no simple answer would have been available. To underline this I can say that a thorough knowledge of any forest pathogen and its relationship with its host and the environment is necessary before consideration can be given to control or preventive measures.

Disease caused by *Fomes annosus* is not so easy to evaluate. It will be noticed that I have applied the term "anticipated" or "potential" threat to this pathogen. I do so in the knowledge that it is known to be present in many forests in this country and is considered a serious threat to timber production in certain areas. The greater proportion of our forests, however, have been established in relatively recent times and most of these forests have been established on sites which have not carried timber in historical time. As the pathogen is considered to be incapable of existing freely in soil outside a woody substrate, it can be assumed that these sites, at planting, are free of *F. annosus*. The problem is in predicting how the pathogen will behave in these new conifer forests.

Background

In continental Europe this disease has been known for a considerable period of time. European foresters and forest pathologists have concerned themselves with silvicultural and preventive methods to minimise the impact of the disease. In certain parts of North America *F. annosus* is considered to be indigenous, e.g. Washington, British Columbia, North Eastern United States, South Eastern United States. It is thought primarily to be a problem in managed coniferous plantations, Low and Gladman (1960) report Rennerfelt putting losses due to *F. annosus* in Sweden at £4 million per annum, losses due to decreased growth and windblow due to root rot not being taken into account. Low and Gladman (1960) report Zycha in Germany estimating a probable reduction in timber yield of between 10% and 15% per annum. In Denmark, Yde-Anderson (1962) reports that direct losses due to *F. annosus* amount to £300,000 per annum, and a further £200,000 is lost by such drawbacks as attend silviculture. Also in Denmark, Nannestad (1961) estimated in a Norway spruce plantation in Zeeland a reduction in annual profits due to *F. annosus* of ca.32% and a reduction in capital value of ca.47%. In England, Rishbeth

(1957) estimated an overall loss from killing by *F. annosus* at Thetford of about £1 per acre per annum. There is, therefore, considerable evidence of serious financial loss due to attack by *F. annosus*. Let us now consider some of the biological aspects of the pathogen.

Biological Evaluation

F. annosus causes root rot and/or butt or stem decay over a wide range of coniferous species. The type and the severity of the damage caused being dependent on, among other things, the particular tree species involved. In general, pines are thought not to be affected to a significant degree by butt or stem rot. Damage to this genus is thought to be confined mainly to roots. The spruces, firs and larches are susceptible to butt or stem rot and root rot; once again there is considerable variation depending on the species. Western hemlock and western red cedar are both considered highly susceptible to butt or stem rot. These susceptibility indications are for the most part based purely on observation rather than on experimental work.

Distinction has been made here between *F. annosus* acting as a killing agent in pines and as a butt rot agent in butt rot susceptible species. The basis for this distinction is related to species susceptibility and resistance. This is an unclear field at present; for the purposes of this article it is sufficient to say that differences do exist between species, but that the reasons underlying these differences are not as yet fully understood.

Risbeth (1951) was the first to demonstrate the mode of infection. He showed that airborne basidiospores of the fungus could colonise freshly cut stump surfaces following thinning or felling. The fungus then grew into the stump body and eventually down to the stump roots. When an infected stump root comes in contact with a healthy root of a standing tree the pathogen could pass from the infected stump root to the healthy root. This is the main method by which healthy standing trees become infected. Further spread of the pathogen from this initial focus of infection is dependent on contact of infected roots with healthy roots. Other methods of infection, e.g. colonisation by basidiospores of damaged butts of standing trees, or brashing wounds, have been demonstrated, but these are considered to be of relatively little significance.

Rishbeth (1951b) working with Scots pine in East Anglia showed that damage due to *F. annosus* was considerably greater on sites which had formerly been used for agricultural purposes. He established a positive correlation between increasing pH and disease incidence. This work relates to *F. annosus* working as a killing agent in pine plantations. In tree species which are susceptible to butt or stem rot, sites with a former agricultural history and high soil pH are again considered to be significantly related to disease severity. However, considerable damage can be done on a wide range of mineral soil types of low pH. Such evidence as is available suggests that significant losses are not likely to be incurred on wet, acid, deep peats.

The reason for referring to this point here is to indicate the effect of site type on disease severity in the two susceptibility classes mentioned. In tree species which are susceptible to root rot but not to butt rot—pine species for example—the major disease effect is tree mortality. Tree mortality due to *F. annosus* of these species occurs only on sites which have high pH values and which favour transference of the fungus from infected to healthy roots. On other site types, ones for example with low pH values and which otherwise are unfavourable to the rapid transference of the fungus from infected to healthy roots, tree mortality does not occur. The disease may be present in standing trees but the incidence of root infection is not sufficiently high to cause tree mortality. With species which are susceptible to butt rot, site variation is not so critical; that is to say, on sites which favour disease development serious butt rot losses may be expected, but on sites which are less favourable to disease development significant losses may still be incurred. This is because root infections of standing trees, which would not be sufficient to cause mortality in butt rot resistant species, will cause stem decay in butt rot susceptible species.

Bearing in mind the soil types normally encountered in forest plantations in Ireland, and the major tree species planted, it seems likely that the pathogen's potential threat is as a butt rot agent. The effect of site variation on disease incidence and development has been mentioned above. I will enlarge a little on this now. The primary method of infection, as has been stated, is by infected stump roots coming in contact with healthy roots of standing trees, and the fungus transferring from the infected to the healthy root. The influence of site on the infection process is at the point of root contact. Assuming a susceptible host, it is thought that the main influence at the point of root contact is microbiological; that is to say, whether micro-organisms antagonistic or inhibitory to *F. annosus* are present or not. Whether these organisms are present or not is largely dependent on soil factors such as pH, moisture content, organic matter content and nutrient status. Many workers, including Rishbeth (1951b), Froelich et al. (1966) and Holmsgaard et alia (1968) have related various soil factors to disease severity. Most of these studies indicate disease severity to be correlated with one or more of the following factors: high soil pH, low soil moisture levels, low organic matter content increased sandiness of soil and former arable farm history. The precise role which these and other factors play in modifying the infectivity of the pathogen is not fully understood, but their effect on soil organisms which are antagonistic or inhibitory to *F. annosus* is considered to play a dominant role in influencing the infection process.

What is apparent from studies on the influence of site variation on disease severity is that *F. annosus* can cause significant damage over a wide range of site types. Based on present knowledge, it is possible to predict sites on which very heavy losses are likely to be incurred. There are, however, considerable gaps in knowledge concerning the behaviour of the pathogen on other site types. It will be necessary for us in Ireland to evaluate the disease based on information available in relation to species susceptibility and site variation.

Formulation of Preventive or Control Measures

Rishbeth (1959a), who worked out the mode of infection, suggested a disease prevention method based on this knowledge. He argued that if colonisation of freshly cut stump surfaces by airborne basidiospores is the primary factor in the infection process, then prevention of this should prevent infection of healthy standing trees. He achieved this by treating the freshly cut stump surfaces with cresote. Cresote is toxic to *F. annosus* spores, so that basidiospores landing on stump surfaces treated with creosote failed to germinate and colonise the stumps. The pathogen could not, therefore, proceed further. Experiments have shown that treatment of stump surfaces with creosote significantly decreases the incidence of the disease when compared with control areas with no creosote stump treatment.

The principle of stump protection having been worked out, Rishbeth (1959b, 1963) and many other workers including Yde-Andersen (1967), and Driver (1963) have sought to refine the technique. Creosote had certain disadvantages as a stump protectant. Its composition could be variable, the component toxic to *F. annosus* could, therefore, also vary. It is toxic to a wide range of wood colonising saprophytic organisms. This means that stumps treated with creosote are not decayed rapidly, but remain potentially liable to colonisation by *F. annosus* for a much longer period than untreated stumps. Thus, subsequent damage to a creosote-treated stump, during extraction operations for example, can lead to a breakdown in protection. This disadvantage can be important in another way. In areas where *F. annosus* is already present, and spread of the disease is taking place by root contact between infected and healthy roots, stumps which have been treated with creosote are liable to become infected below ground by root contact. The fungus can obtain complete possession of such a stump without competition from saprophytes from above. Further below-ground spread of the pathogen by root contact can develop from this new infection location. A final disadvantage of creosote is that it does not penetrate appreciably into the stump body. This makes timing of the creosote application critical. If a *F. annosus* basidiospore lands on a freshly cut stump surface, germinates and grows into the stump body, it will very quickly be away from the influence of the creosote. Creosote, to be effective, needs to be applied to the cut stump surface immediately after felling.

The disadvantages encountered with creosote indicate in a negative way what properties a good chemical stump protectant should have. It should be of constant composition. It should be capable of penetrating well into the stump body in order to make the timing of application less critical; it should be selectively toxic, ideally toxic only to *F. annosus* but allowing other organisms to cause rapid breakdown of the stump. This would reduce the risk of subsequent stump damage causing a breakdown in protection, and would protect more adequately already infected stands.

Many chemicals have been screened as possible stump protectants and quite a few promising protectants have emerged. These have been evaluated under field conditions in many countries. Some are currently being used in general forest management. None of the protectants evaluated so far could be described as perfect, but many are considerably more efficient than the pioneer protectant, creosote. It is not necessary here to trace the development of these stump protectants, nor to describe the advantages and disadvantages of individual protectants. It is sufficient to note that in England sodium nitrite has emerged as the most efficient chemical stump protectant evaluated so far, and in the United States boron based chemicals are proving satisfactory stump protectants. It will be necessary to test the efficiency of the more promising protectants under Irish conditions.

It has been stated that one of the main properties which a chemical stump protectant should possess is selective toxicity to stump colonising organisms. Ideally a protectant should be toxic only to *F. annosus* allowing other organisms to cause a rapid breakdown of the stump. This has lead to an examination of the possibilities of biological control. Basically, the idea is to inoculate stumps after felling with organisms which will quickly colonise the stump, are non-pathogenic, and compete successfully with *F. annosus*. This method of prevention or control is more efficient than chemical stump protectants if a suitable organism can be found. All the criterion for a good stump protectant enumerated earlier are achieved. There are a couple of additional benefits deriving from biological stump protection. Inoculation of freshly cut stump surfaces with organisms which compete with *F. annosus* increases the level of natural control exerted by these organisms. Potential hazards associated with the use of chemical stump protectants are eliminated.

Rishbeth (1963) has done the pioneering work in this field. He has developed the use of a fungus *Peniophora gigantea* for pine species. Efforts are being directed in many countries to determine suitable stump colonisers for other tree species; of particular interest to us in Ireland will be the finding a suitable stump coloniser for Sitka spruce.

I have gone to some lengths to describe what is known concerning the biology of this pathogen. I have also indicated aspects of the disease which are as yet not fully understood. Finally, I covered preventive or controls methods being developed or employed in other countries. It is now necessary to evaluate the damage potential of the pathogen in Ireland and relate this to prevention or control costs.

Economic Evaluation

I have said that *F. annosus* is known to occur over a wide variety of locations and sites in the country. In only one instance (O'Carroll and O Muirgheasa, 1963) has a precise measurement of the losses incurred been worked out. Many of the tree species which we plant are known to be susceptible to attack by *F. annosus,* both from observation within the country and from experience in other countries. Many forest site types within the country are potentially capable of allowing significant disease development. This comment is based on work carried out in other countries, and on limited observational work within this country. A significant proportion of our forests are established on deep wet acid peats. Present knowledge suggests that these will be low risk sites.

In summary, it can be said that no large scale *F. annosus* problem exists at present in our forests. Enough is known concerning site types, species composition and incidence of the pathogen, relating to the accumulated knowledge of its behaviour, to suggest that it is a potential threat to timber production in certain areas but not in others. What is lacking is precise information in our situation. It is necessary, therefore, for us to determine accurately what impact the disease has on our major tree species on our major site types. Information of this sort can be obtained only by careful observation and experimentation. The nature of this disease dictates that much of this work will be carried out over a long period. Consequently, the necessary data on which to base a realistic economic evaluation will not be available for some considerable time. Preventive or control measures are carried out now on the assumption that the disease does or will cause intolerable damage. It is necessary to confirm or invalidate this assumption by investigation as described above. It is not possible to evaluate the cost of preventive measures without data on the effect on timber production of the disease. The assumption that the disease is potentially damaging is an interim decision or evaluation based on the available knowledge both within and outside the country. It may or may not be a valid assumption. If it is shown to be valid, the cost of preventive or control measures can be balanced against known loss figures and a decision to continue or discontinue control measures taken. If the assumption is shown to be invalid, control measures can be discontinued. This error of judgment will mean bearing the cost of the control measures during the period in which the assumption was in operation. If, however, it was decided not to implement control measures a different situation arises. Firstly, it may be shown that the pathogen does not in fact cause serious damage, in which case the decision not to carry out control measures is shown to be correct and there will be no change in policy. The alternative situation is that the pathogen does cause significant damage. This error of judgment is likely to be considerably more costly than the first error. It has been stated that the length of time necessary to evaluate the impact of the disease would be lengthy, perhaps 20 years or more. During this period no stump protection would have been carried out and large areas of forests would have become infected with *F. annosus*. A situation very much akin to closing the stable door after the horse has gone would exist. A forest disease problem of considerable importance would have developed which would affect timber production and management practices, not just in the present rotation, but also in succeeding rotations.

This is the reason why stump protection measures are adopted now without a full appreciation of the pathogen's potential. It is a considered policy based on the pathogen's known and potential impact in other countries, and on an assessment of its potential in our environment. The cost of this protection measure has to be borne until sufficient data becomes available to allow a final decision to be made. The implications of a judgment error in this situation are minimal when considered against the consequences of the other judgment error.

CONCLUSIONS

I started this article by suggesting that because tree disease prevention or control does not visibly increase forest production, a certain reluctance in accepting the value of an investment in prevention or control measures might exist. I have attempted to assuage this assumed reluctance by examining in some detail two disease situations. I consider this to be relevant because it shows the basis on which an investment of this sort is deemed necessary or not.

In the first situation, that of an existing forest disease problem (*group dying of conifers*), it is perhaps easier to appreciate the value of a prevention or control investment. The disease causes recognisable damage to existing production. The forest manager will be very anxious to obtain a solution to this problem. He will be prepared to invest money to safeguard his existing and future productions from this disease. The second situation is somewhat different (*Fomes annosus* butt and root rot). No disease situation has developed. The threat to timber production is potential, not existing. Investment in prevention or control measures in this situation, as I have described, may be shown to be unnecessary, but, as I have also described, it may prove to be essential. It follows, I think, that a very careful evaluation of the biology of the particular pathogen involved, in this case *F. annosus,* and its relationship to its hosts and environment is vital if a sound appraisal of the threat is to be made. Careful consideration will also have to be given to the magnitude of the potential threat. That is to say, assuming the worst, how big an impact on timber production could the pathogen make? This type of control investment may be considered as a form of insurance, an insurance designed to protect the larger total investment in timber production, present and future, from specified, evaluated, potential pathogens.

Both of the diseases considered lend themselves to preventive rather than control methods. This is because an understanding of the biology of the pathogens indicated methods of preventing the diseases becoming established. With forest diseases it is undoubtedly true to say that prevention is better than cure. It is invariably difficult and costly to control an established forest disease situation. More and more I consider that, in forest tree disease research, efforts will be aimed at prevention rather than at direct control. It is not appropriate to consider in detail this subject in this article. I mention it here because I think it can influence a forest manager's thinking on investment in forest disease control. If the future holds prevention rather than control, as is the case with both *R. undulata* and *F. annosus* then forest managers will not see many disease problems in their plantations. This gets me back to my original supposition. Does the forest manager consider he is getting value for the money he has invested? The purpose of this article has been an attempt to show that he does.

LITERATURE CITED

de Brit, G. and O'Carroll, N. (1967)
Group dying of Sitka spruce and its relationship with *Rhizina undulata* and fire sites. Papers XIV I.U.F.R.O. Congress, Vol. V, Munich.

Driver, C. H. (1963)
*Effect of certain chemical treatments on colonisation of slash pine stumps by *Fomes annosus*. Plant Dis. Rep. 47: 569-571.

Froelich, R. C., Dell, T. R. and Walkinshaw, C. H. (1966)
Soil factors associated with *Fomes annosus* in the Gulf States. For Sci. 12: 356-361.

Holmsgaard, E., Neckelmann, J., Olsen, H. C. and Paludan, Fr. (1968)
[On the dependence of butt rot on soil conditions and silvicultural methods of spruce planting in Jutland heath areas.] Forstl. Forsogsv. Danm. 30: 187-407.

Jalaluddin, M. (1967)
Studies on *Rhizina undulata*. 1. Mycelial growth and ascospore germination. Trans. Br. Mycol. Soc. 50: 449-459.

Low, J. D. and Gladman R. J. (1960)
Fomes annosus in Great Britain. F.C. Forest Record No. 41. H.M.S.O., London.

McKay, R. and Clear, T. (1953)
Association of *Rhizina inflata* with group dying of Sitka spruce. Irish Forestry. 10: 58-59.

Murray, J. S. (1954)
Two diseases of spruce under investigation in Great Britain. Forestry, 27: 54-62.

Murray, J. S. and Young, C. W. T. (1961)
Group dying of conifers. F.C. Forest Record No. 46, H.M.S.O., London.

O'Carroll, N. and O'Muirgheasa, N. (1963)
The estimation of heart rot in standing trees: a note. Irish Forestry 20: 16-17.

Nannestad, L. (1961)
*[The importance of attack by *Fomes annosus* in the economics of spruce growing in a forest district in Zeeland.] Dansk. Skogforen. Tidskr. 46.

Rishbeth, J. (1951a)
Observations on the biology of *Fomes annosus* with particular reference to East Anglian pine plantations. II. Spore production, stump infection, and saprophytic activity in stumps. Ann. Bot. N.S. 15, 1-21.

Rishbeth, J. (1951b)
Observations on the biology of *Fomes annosus* with particular reference to East Anglian pine plantations. III. Natural and experimental infection of pines, and some factors affecting the disease. Ann. Bot. N.S. 15, 221-246.

Rishbeth, J. (1957)
Some further observations on *Fomes annosus* Fr., Forestry 30: 69-89.

Rishbeth, J. (1959a)
Stump protection against *Fomes annosus*. I, Treatment with creosote. Ann. Appl. Biol., 47: 519-528.

Rishbeth, J. (1959b)
Stump protection against *Fomes annosus*. III. Inoculation with *Peniophora gigantea*. Ann. Appl. Biol. 52: 63-77. 529-541.

Rishbeth, J. (1963)
Stump protection against *Fomes annosus*. III. Inoculation with *Peniophora gigantea*. Ann. Appl. Biol. 52: 63-77.

Yde-Andersen, A. (1962)
Conference and study tour on *Fomes annosus*, Scotland 1960, I.U.F.R.O. Section 24, Florence.

Yde-Andersen, A. (1967)
Stump protection in conifer stands. Papers XIV, I.U.F.R.O. Congress, Vol. V., Munich.

*Abstract only referred to.

References in brackets are translations of the original titles.