DISEASE AS A CONSIDERATION IN THE THINNING OF CONIFEROUS FORESTS

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ABSTRACT
The consequences of thinning in coniferous forests are likely to differ according to the parasitic status, the life cycles and the mode of infection of pathogens. Each potential disease situation has to be considered individually before thinning regimes and intensities are recommended.

INTRODUCTION

Changes in environment and substrate which accompany the thinning of a closed forest stand will have a decided impact on microfloral species and populations. The type, season and intensity of thinning have pronounced effects on the incidence of non-parasitic diseases and injury, e.g. windthrow (Boyce, 1938). This paper focusses attention on the effect of thinning on microbial parasitic disease leaving the fields of generalised microbiological population changes and non-parasitic disease largely untouched.

Thinning is likely to have effects on each component of the disease induction triangle, viz. host, pathogen and environment, hence its effects are likely to be very variable. In the present state of knowledge it is possible to consider only some of the likely interactions resulting from thinning and suggest the application of these to individual circumstances.

DISCUSSION

Stand Vigour and Disease

The importance of maintaining stand vigour as a means of disease prevention has been stressed (Boyce, 1938; Peace, 1962). Overcrowding in stands of European larch has been claimed to predispose the stand to larch canker (Boyce, 1938). *Diplodia pinea* dieback and deaths associated with *Sirex noctilio* (Rawlings and Wilson, 1949) in *Pinus radiata* have been cited as examples of diseases associated with stands in an overcrowded, unhealthy condition. Much of the fundamental work on active host resistance to disease, e.g. phytoalexins (Cruickshank, 1963) supports the concept that high levels of active resistance in the individual host plant part are associated with high physiological activity. However, when this concept is expanded to cover whole plants or stands the association may be less clear. In stands of white pine affected by blister rust the most vigorous trees are the most severely attacked (Boyce, 1938). Vigorous trees generally carry more needles thus presenting more targets for infection. Unless the infected

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individuals have a high potential for an active disease resistance reaction, which is rare in natural white pine, they will become seriously diseased. Stand vigour and health are most likely to be closely correlated when the pathogens being considered are relatively weak, unspecialised, facultative parasites.

Thinning and the Reduction of the Level of Inoculum

The distance of a susceptible host from the nearest infected plant is a major parameter in a model used to describe disease risk with host-specific parasites (Chilvers and Brittain, 1972). Removal of diseased individuals by thinning has been advocated frequently as a means of disease control in forests (Smith, 1970). In eastern Massachusetts larch canker, an exotic disease in the United States, has been eradicated by the removal of diseased individuals in European larch plantations (Smith, 1970). In other cases, for example Dutch elm disease, where eradication programmes have not succeeded in the complete elimination of the pathogen the destruction of infected trees has led to a significant containment of diseases. However, this concept of disease control by inoculum reduction has to be extrapolated with caution.

In the southern pine plantations of the United States there is a local dictum, "Plant them close and keep them close", which has considerable evidence to support it. In dense stands of the southern pines needle infection by the causal organism of gall rust generally leads only to branch galls. The infected branches die very early under these stocking conditions thus reducing the possibility of the more damaging stem galls and cankers (Czabator, 1971). Thinning of rust-infected stands to remove all stem cankered trees undoubtedly reduces the amount of inoculum, at least temporarily (Dimond and Horsfall, 1960) and the use of thinning as a disease control measure in such stands had been advocated earlier (Lamb, 1937). However, it has been pointed out that even a light load of aeciospores to infect the alternate host (oaks) is likely to result in subsequent heavy secondary infections of the pines (Wakeley, 1954). Since thinning of the pines is likely to result in a rapid development of the oak understorey the level of inoculum for pine needle infection may be higher after thinning than before. The same reasoning has been applied to white pine stands infested by blister rust in areas where a regeneration of black currant is likely to follow thinning. Thinning as a disease control measure in stands infected by obligately heteroecious rusts is presently a very contentious issue. With the rare monoecious or more common facultatively heteroecious rusts reduction of inoculum level by removal of diseased individuals could be expected to have beneficial effects on disease incidence.

Thinning as a Factor Favouring Disease Incidence

Increase in the incidence of *Fomes annosus* root rot is associated with more intensive management of natural stands and the establishment and thinning of coniferous plantations in North America and Europe (Heather, 1967; Pratt, 1974). In Britain and North America the infection of freshly cut, coniferous stump surfaces by basidiospores following thinning has been demonstrated and is regarded as the most important source of subsequent infection of the roots of the remaining adjoining trees. The fungus spreads from the infected stumps to the roots of the standing crop by root grafts or close contacts (Risbeth, 1951a; Powers and Hodges, 1970). Factors which increase the area of fresh stump surface in a thinned stand, for example heavy thinning or removal of large trees, will generally be followed by heavier incidence of *F. annosus* root and butt rot (Risbeth, 1951b). The susceptibility of *Pinus sylvestris* plantations in East Anglia to *F. annosus* root rot following thinning decreased significantly with plantation age after 15 years (Risbeth, 1951b). Further, the susceptibility of stump surfaces to artificial inoculation with *F. annosus* decreased with time after felling; stumps being essentially resistant to infection after 3-4 weeks. This increasing resistance of stumps to infection with time after felling was attributed to stump colonisation by competing microorganisms, in particular *Peniophora gigantea.* Risbeth (1951b) has demonstrated also that the epiphytic growth of *F. annosus* along roots is more restricted in acid than in alkaline soils. This restriction is apparently due to the antagonism of root-surface fungi such as *Trichoderma viride.* In addition a more copious flow of resin, which appears to restrict the growth of the pathogen through coniferous roots, occurs in the roots of *P. sylvestris* infected by *F. annosus* in acid rather than in alkaline soils.

The stumps of Scots pine show a seasonal variation in susceptibility to infection by *F. annosus* (Risbeth, 1951b). In central Europe stumps from fellings made in winter and spring were free from natural infection by *F. annosus.* This is probably associated with the effect of the environment on fruiting of the pathogen (Manka *et al.,* 1972). These authors also demonstrated that while artificial inoculations of stumps were successful in all seasons they were especially effective under their conditions in summer and autumn and only occurred in winter if the stumps were covered with paper bags after inoculation. By contrast avoidance of root rot by thinning only in summer in the southern pine plantations has been advocated (Driver and Ginns, 1964). Temperatures of stump surfaces during summer in the southern States are unfavourable to spore germination and subsequent growth.

The painting of the surfaces of stumps of felled trees with creosote (Risbeth, 1951b), urea (Greig, 1974), borax (Hodges, 1974), zinc chloride and ammate (Morrison, 1974) has been adopted to prevent stump colonisation by *F. annosus* (Myren and Punter, 1972). Studies are in progress on biological control of *F. annosus* root rot by manipulation of the environment to favour the colonisation of stumps by the competing saprophyte *Peniophora gigantea* (Blakeslee and Stambaugh, 1974).

Research on *F. annosus* root rot probably has application to many other root rots of coniferous and hardwood forests, particularly to those caused by basidiomycetes with a generally similar epidemiology.

The importance of broken branches, stem and butt wounds as sites for the entry of stain and decay organisms has been emphasised in both hardwoods (Shigo and Larsen, 1969) and conifers (Boyce, 1938; Buckland *et al.,* 1949).

In general small wounds in conifers are quickly covered by resin which acts as a protective barrier against the entrance of stain and decay-causing organisms. Large butt wounds, for example those over one square foot in area, are particularly important because degrade in this area causes loss of the most valuable portion of the log. The larger the surface area of the wound and the closer it is to the ground the greater the likely level of subsequent decay in western hemlock and Douglas fir (Hunt and Krueger, 1962). In this regard damage caused during the skidding of logs after thinning has been most significant in the subsequent decay of hemlock and Sitka spruce

(Shea, 1960). In the latter study the number of scars was independent of thinning intensity but in contrast Wright and Issacs (1956) demonstrated that the percentage of remaining trees containing decay following wounding was higher in lightly thinned areas.

A preliminary study of the defect associated with logging scars in a 27-year-old *P. radiata* stand in the A.C.T. was carried out in 1968. The stand had been thinned on three occasions for cordwood, the most recent thinning eight years previously. Twenty scarred trees were selected, felled and the extent of the wounds and the defects associated with the scarring recorded (Johnston, 1968). The study generally confirmed overseas observations on the importance of scar size and position in subsequent defect. However, the extent of the defects and the defect volume resulting were low by comparison with records from studies in the United States. Two of the organisms regarded as causing major decay of conifers in the American studies, *Fomes pini* and *Polyporus tomentosus,* have not been recorded from the study area. In addition the scars penetrated only shallowly into the wide sapwood which in the standing tree is likely to have a higher decay resistance than the heartwood. If the damaged trees remained standing sufficiently long for heartwood formation to approach the damaged zone subsequent decay development could be much more rapid.

CONCLUSION

Potential for disease induction is likely to receive increasing consideration in thinning regimes and practices in coniferous plantations in the future. The disease potential/thinning interaction is obviously very complex. A general maxim such as "thinning to maintain vigorous growth will result in minimal disease" is no longer adequate. Proposals for thinning must take account of their influence on disease potential in each individual situation.

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THE KAINGAROA GROWTH MODEL FOR RADIATA PINE AND ITS IMPLICATIONS FOR MAXIMUM VOLUME PRODUCTION

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ABSTRACT

The continuing controversy with regard to the relative merits of heavy-early non-commercial thinning, and the more conventional regimes employing one or more productive thinnings, has been based predominantly on economic argument. Little consideration has been given to their relative performance in terms of yield. This is due to the absence of extended measurement of severely thinned stands and to the restricted relevance of currently available growth models.

The paper describes the work being undertaken to derive a growth model for radiata pine from Kaingaroa growth plot data. While this study has not yet been completed an interim growth model has been derived. Preliminary checking has shown it to be reasonably accurate and unbiased when applied to a wide range of management practice and it has been used to derive criteria for the production of maximum yield.

Analysis of stand simulations has shown that in stands with low initial stockings, or in heavily thinned stands, short rotations will sacrifice volume production and that this loss is increased as site index decreases. It demonstrates that the reaction directly attributable to a thinning is relatively small, and that a wide range of management practice results in very little variation in total volume production. To obtain optimum yield, low initial stocking or very early thinning to waste is required on good sites (where Mean Top Height at age 20 exceeds 30 metres). On poorer sites and for short rotations (less than 30 years) pulpwood regimes with high stockings producing small piece size may be most productive, while a series of very light production thinnings may produce optimum total volume production on poor sites.

The above abstract is for the paper tabled at the meeting. However, the paper is presently under revision, and the editor expects it will appear in the subsequent issue (Volume 6, number 3) of this Journal.

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