Plantation disease and pest management in the next century

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ABSTRACT

The extensive development of plantation forestry in the tropics and Southern Hemisphere marks one of the great industrial successes of the 20th Century. Early experience led to the discovery that certain trees, although not particularly impressive in their areas of origin, can grow rapidly in exotic situations. More importantly, they are sufficiently genetically malleable to become outstanding plantation species through breeding. Perhaps the best examples of such trees are *Pinus radiata* and *Eucalyptus grandis*. By the early 1960's, diseases and pests were recognised as two of the most important threats to exotic plantation forestry. It was realised that separation of the crop from its natural enemies was responsible for the initial outstanding productivity of exotic plantation forestry. Gradually, new pathogens have been introduced in plantations in the tropics and Southern Hemisphere. The impact of these problems has been offset by new technologies that enhance the production of elite planting stock. During the course of the 21st Century, we will experience the emergence of many new strategies to cope with disease and insect pests in intensively managed and genetically modified plantations. The impact of DNA based technologies that enhance breeding will be one of the first developments, followed by the deployment of transgenic trees and microbes. The rapid emergence of DNA based technologies will bring tremendous opportunities to forestry, including its capacity to deal with pests and diseases. However, early experiences are likely to also be beset with problems. These will include a negative perception of transgenics by environmental action groups and the public. Successful forestry will, however, rest on persistence and patience while problems are addressed. Winning industries will be those that have harnessed new opportunities and that have developed the strategies to capitalise on these when concerns linked to safe deployment have been addressed.

INTRODUCTION

Exotic plantation forestry in the tropics and Southern Hemisphere rapidly developed in the 20th century. This was largely due to local requirements for timber and an emerging realisation of the negative consequences of logging native trees. Plantations of exotic trees, mainly pine, eucalypts and acacias, has continued to expand and today sustain huge industries. These industries do not only provide for local needs, but also form significant components of the international forestry business, particularly the paper and pulp industries (Sherry 1971, Gibson 1979, Turnbull 1991, Le Maitre 1998).

It is widely accepted that the success of exotic plantations in the Southern Hemisphere is closely linked to the separation of these plants from their wide array of important natural enemies (Bright 1998). While there are many hundreds of pests and diseases that damage pines, eucalypts and acacia in their native environment, relatively few of these have reached the trees in exotic plantation situations (Wylie and Peters 1993, Stone 1993, Neumann 1993, Bashford 1993, Phillips 1993, Abbot 1993, Wingfield 1990). Where such incursions have occurred, the consequences have been far reaching and the costs huge. In this sense, it seems reasonable to accept the view that pests and diseases pose one of the greatest threats to exotic plantation forestry in the tropics and Southern Hemisphere.

It is surprising how few pests and diseases have reached these exotic trees, although they are grown in plantations of largely genetically uniform stock. In the early years of plantation forestry little effort was apparently made to reduce the spread of pests and pathogens to new environments. There are two views pertaining to this situation. One is that it is merely a matter of time before damaging insects and diseases will emerge to make plantation forestry difficult, and in some parts even impossible to practice. An alternative view is that modern technology will make it possible to contain, or at least to effectively manage such incursions. In this paper, we consider these two possible scenarios.

APPEARANCE OF NEW PESTS AND DISEASES

While it is true that a relatively small number of pests and diseases have reached plantations of exotic trees in the Southern Hemisphere, this situation should not be misinterpreted. Pests and diseases have already had a very marked impact on plantation forestry in the Southern Hemisphere (Gibson 1979, Ivory 1987, Feirreira 1989, Wingfield *et al.* 1990, 1999). Indeed, in countries such as South Africa, diseases and insect pests have strongly influenced species that can be planted, as well as management practices (Gibson 1979, Zwolinski *et al.* 1990, Swart and Wingfield 1990, Wingfield 1991, Denison and Kietzka 1993). An example is the inability to plant *P. patula* or *P. radiata* in areas where hail associated Sphaeropsis blight caused by *Sphaeropsis sapinea* occurs (Swart *et al.* 1985).

Emerging evidence suggests strongly that new pests and pathogens are appearing in exotic plantations at an increasing rate. This is more obvious in countries with land borders, than island countries such as New Zealand and Australia. In South Africa alone, the three most serious pathogens of *Eucalyptus* were not known 10 years ago. Clearly, the ability to exclude pests and pathogens via quarantine is much easier where borders can be most effectively monitored. Yet even in these island countries, with quarantine regulations that are hugely impressive, introductions have occurred and this is a trend that is likely to continue.

The arrival of new pests and diseases must mean that plantation forestry in the tropics and Southern Hemisphere will become more challenging. The costs of producing timber will in all likelihood increase significantly. In some cases, it might even become impossible to grow certain species. This is further compounded by the fact that several indigenous insects have already become pests of these exotic plantation species. On the other hand, there are significant reasons to believe that contemporary forestry techniques and new technology will make it possible to deal with these problems. The remainder of this paper briefly outlines some strategies that will make it possible to continue with effective exotic plantation forestry despite the likely increase in pests and diseases.

STRATEGIES TO MINIMISE RISK

Diversity in planting stock

We believe that one of the key strategies to reduce dramatic losses will lie in the availability of sufficient diversity in planting stock to be able to absorb the losses linked to a significant pest or disease incursion. There can be no question that planting more than one species will provide a strong insurance against serious loss. In this case, planting of species representing unrelated genera is likely to be a more effective hedge against loss, than planting more than one species of the same genus.

The matter of planting more than one species as opposed to a single species is somewhat controversial. This is because some countries such as New Zealand have concentrated their forestry industry almost entirely on a single species, in this case *P. radiata* (Chou 1991). It is important to recognise that while the risks of this approach are high, the industry is in a position to contribute greater research funding to the improvement of that single species. Assuming that such funding is provided for long term improvement (including studies on resistance to diseases and pests; risk abatement strategies; improved quarantine; early detection and eradication of pests and diseases that might be important) the risks of single species forestry would presumably be considerably reduced. It is important to ensure that such funding is provided and also to ensure that it has a clear focus on disease and pest problems.

Contemporary horticultural techniques have made it possible to hybridise species of exotic plantation trees and to propagate such material, vegetatively. There are already many examples of hybrid species that have been used to reduce the impact of diseases. Good examples include avoidance of Cryphonectria canker caused by *Cryphonectria cubensis* through the deployment of select *E. grandis* hybrid clones (Hodges *et al.* 1976, Alfenas *et al.* 1983, Van Heerden 1999). Similarly, the impact of the serious coniothyrium canker caused by *Coniothyrium zuluense* in South Africa has been substantially reduced through the deployment of disease tolerant hybrids of *E. grandis* and other species in the Zululand forestry area (Denison and Kietzka 1993, Wingfield *et al.* 1997, Van Zyl *et al.* 1997). We believe that similar approaches will be used to reduce the damage due to pests and diseases on pines, eucalypts and acacias in the future.

Knowledge of the pests and pathogens

Avoidance strategies depend largely on a comprehensive understanding of the biology of pests and diseases. It is essential for forestry companies to invest significantly in projects geared to understand the biology, population genetics and epidemiology of important pests and pathogens. Knowledge pertaining to the biology of pests and diseases has a direct impact on silviculture practices, resistance programmes and quarantine measures. In this regard, our view is that in general relatively little effort has been made to obtain extended understanding of key pests and pathogens that damage plantations in the Southern Hemisphere.

Knowledge of the biology of pests and pathogens demands the attention of specialist entomologists and pathologists. These researchers should ideally work in collaboration with scientists with related fields of interest, including genetics, molecular biology, microbiology, botany, biochemistry etc. The support of such scientists will not effectively be mobilised if they are consulted only when problems appear and it is necessary for countries to develop rapid capacity in the field of forest pathology and entomology. It is our view that these fields have been significantly neglected in most Southern Hemisphere countries that have established significant forestry industries. This is unfortunate and the consequences are likely to be far reaching.

EMERGING MANAGEMENT TOOLS

Rapid screening techniques

If it is accepted that pests and pathogens will limit future plantation forestry. The ability to rapidly screen planting stock for tolerance to pests and diseases will be a major advantage. Such screening is already an integral component of most advanced breeding and selection programmes (Wells and Dinus 1978, Alfenas *et al.* 1983, Conradie *et al.* 1992, Denison and Kietzka 1993, Roux *et al.* 1999), but it tends to be a slow process, usually depending on natural pathogen inoculum or pathogen infestation.

Procedures for screening preferred planting stock for tolerance to pests and diseases are rapidly improving. This is a trend that will continue. Future improvements will be strongly linked to genome mapping and the discovery of genes linked to tolerance. For example, it is already possible to identify *P. taeda* and *P. elliottii* planting stock tolerant to Fusiform rust cased by *Cronartium quercuum* f.sp. *fusiforme* using molecular markers. This approach will clearly become much more refined in the future and it will be available for a wide range of pests and pathogens. It is our contention that successful forestry groups will rapidly recognise opportunities in this field and harness these to their advantage.

The ability to rapidly identify planting stock with genes linked to disease and insect tolerance, implies that it will be possible to overcome problems very early in the process of breeding and selection. Small plant samples will most likely yield the desired DNA to be able to predict many aspects of the likely performance of trees, long before they reach commercialisation. Thus, disease and pest problems will be less obscure and forest geneticists and breeders will have increasing control over these problems.

A crucial component in dealing with disease and pest problems is linked to a thorough understanding of the genetics, not only of the host plant, but also the insect or pathogen of interest. Molecular tools to measure diversity, and thus the pathogens capacity to adapt to management strategies, are emerging rapidly. We can thus expect that forest research teams will be able to include such knowledge into their tree improvement initiatives.

Biological control - advanced approaches

In most situations, chemical control of forest pests and diseases, has the limitation of being costly and environmentally undesirable. On the other hand, biological control offers many positive opportunities. Ironically, the current principals and criteria of the Forestry Stewardship Council (FSC) legislate against biological control. This is a situation that needs careful and urgent review.

There are many examples of highly successful biological control of insect pests in forest plantation situations. Damage caused by many pests in plantations of *Eucalyptus* and *Pinus* in the Southern Hemisphere has been effectively reduced. One of the best-documented examples in *Eucalyptus* is that of the biological control of the eucalyptus snout beetle, *Gonipterus scutellatus*, which to our knowledge was the first example of biological control of plantation pests (Tooke 1955). Likewise, biological control of the Sirex wood wasp (*Sirex noctilio*) has been highly effective in Australia, New Zealand and elsewhere in the Southern Hemisphere (Bedding 1995, Haugen 1990, Neumann *et al.* 1987, Taylor 1978, Tribe 1995).

Biological control of pathogens has been less successful than it has for insects. Other than in nursery situations, there are few examples where biological control has been used to reduce the impact of forest plantation pathogens. The best example is for root disease caused by *Heterobasidion annosum* in the Northern Hemisphere (Hodges 1969, Webb *et al* 1981, Hansen and Lewis 1997). Here freshly cut stumps are the major infection sites, and inoculating them with spores of the saprophytic basidiomycete *Phlebiopsis gigantea* (Greig 1976, Rishbeth 1979, Hansen and Lewis 1997) can effectively protect these stumps.

As yet, we are aware of no examples of effective biological control of stem canker and foliage diseases of plantation forest trees. However, we believe that this is an area of great opportunity. Amongst the natural enemies of fungi are viruses. These mycoviruses are generally of a double stranded RNA (dsRNA) nature and may result in reduced virulence of its fungal host (Van Alfen *et al.* 1975, Day *et al* 1977, Elliston 1981, Choi and Nuss 1992). Knowledge pertaining to these viruses is emerging, although perhaps not sufficiently rapidly. Recent research has shown that mycoviruses can be transferred amongst species of fungal pathogens (Choi and Nuss 1992, Chen *et al.* 1996). This advance should herald a new era in the biological control of forest pathogens. Likewise, and expanded understanding of the barriers to the transfer of mycoviruses between genetic entities of pathogens will enhance opportunities to utilise these factors in disease management.

Transgenic trees

A comprehensive treatment of the rapidly emerging field of transgenics in forestry is beyond the scope of this paper. However, it must be recognised that the technology to move genes between trees, and from other organisms to trees will provide huge opportunities to reduce the impact of diseases and insect pests.

The so-called BT or *Bacillus thuringiensis* genes have already been shown to be effective in reducing insect feeding on forest trees (Shields 1987, Vaeck *et al.*, 1987). Likewise genes involved in disease resistance have been identified and tested for their efficacy in tree crops. There can be little question that many new genes linked to disease and insect tolerance will be identified in the future and these will represent powerful tools for future forestry.

The era of genetic modification of plants via transgenics is new. Currently there is much concern from environmental interest groups, and from the public regarding the safety of transgenic plants. These concerns must also be those of scientists working in the field of molecular genetics, and they must be taken seriously. Nonetheless, we have little doubt that safety issues will be addressed and techniques to ensure the safe deployment of transgenic trees will emerge in the relatively near future. If our prediction is correct, there can be little doubt that transgenic trees will emerge as a major development, particularly in exotic plantation forestry. As diseases and insect pests become increasingly difficult to contend with, it is our view that transgenic trees are likely to provide the solution to these problems. This will be similar to the impact that hybridisation and vegetative propagation has had on plantation forestry during the course of the last two decades.

CONCLUSIONS

The tremendous success of plantation forestry in the tropics and Southern Hemisphere is closely linked to the fact that trees have been separated from their natural enemies. This situation has gradually changed and there is good evidence to show that damage by diseases and insects are increasing markedly. New introductions of pests and diseases also appear to be increasing and there is every indication that this is a trend that will continue in the future. It would be foolhardy to believe that plantation forestry will be easier or less costly in the future.

Together with the increasing damage to plantations due to pests and diseases, new technologies are emerging that should make it possible to deal with these problems. In this regard, breeding techniques and particularly the techniques to select and deploy species hybrids has already made it possible to reduce the impact of pests and diseases. Additional opportunities lie in a wide array of advanced technologies that are rapidly becoming available to forestry. Utilisation of these opportunities should ensure growth and future sustainability of exotic plantation forestry. Forestry organisations that do not enter this new area of technological advancement are likely to fail due to the impact of pests and diseases.

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