Stopping Tree Decline in the Great Southern

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A conference to address the issues of declining tree health in Western Australia

CONFERENCE PROCEEDINGS

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Are fungi and viruses the cause of tree decline?

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SUMMARY

Trees altered by stress factors and subsequently invaded by opportunistic fungi or insects or both may exhibit essentially similar dieback-decline syndromes. In the wheat belt it is likely that clearing and subsequent changes in water tables, fertiliser usage, stocking, salinity, exposure to weather, aging and so on predispose trees to invasion. It is likely that attack by the opportunistic pathogens determines whether these stressed trees survive or succumb. These organisms of secondary action are probably and should be considered as significant components of host-stress-opportunist dieback-decline we are seeing in the lower south-west of Western Australia.

All plants actively invest nutrients and energy into protecting themselves from insects and pathogens. As resources decline due to continued stresses such as raised water tables, salinity, and herbicides their defenses will be weakened. Increased herbivory and invasion by pathogens often appear to be the cause of plant disease, when really they are a secondary (albeit final) consequence of stressful conditions.

DISCUSSION

A good knowledge of the biology of healthy trees is needed before any attempt can be made to identify the diseased conditions of trees in decline. Accurate diagnosis requires much information about the abnormal appearance (or symptoms) and the presence of pathogen structures or products (known as signs) on the host plant. It is reasonable to argue that we actually know very little about the biology of the trees in our landscape and that we still have much to learn and understand.

Tree decline is very widespread in the south-west of Western Australia. We see it along river valleys such as the Blackwood around Nannup, we see it along the coast in Tuart and other trees on the calcareous soils. Decline also occurs in higher rainfall areas such as round Pemberton, Augusta and across to Albany and then inland into the drier Great Southern. So it is affecting a wide range of tree species across a broad range of landscapes.

What I would like to do is approach the decline problem initially from the point of view of the tree in the landscape prior to our arrival. I will then look at how changing the landscape can and has predisposed trees to fungal and possibly viral attack.

I do this because it is important when making a diagnosis of tree diseases to have some information and understanding about the recent and past history of the environmental conditions and possible causes of disturbance around the trees.

PRIOR TO CLEARING

- Trees existed in-groups with a host of other plant species
- They had ectomycorrhizal and endomycorrhizal fungi associations
- There was balanced invertebrate and vertebrate fauna
- Deeper water table

POST CLEARING

- Trees now singly placed or in small groups in the landscape
- Loss in the diversity and abundance of beneficial mycorrhizal fungi
- Large shifts in fauna. For example, less habitat for birds that feed on insects or loss of fauna as food sources decline throughout the year.
- Rising water tables
- Problems associated with salinity
- Agricultural pressures (herbicides, fertilizers, high density stocking, ploughing disturbance.
- Poor recruitment of new plants.

So I have just introduced you to the concept of predisposition. Many important biotic diseases in trees are a result of changes in environmental conditions that can result in trees becoming predisposed to fungal pathogens and pests.

Now we come to the question that I have been asked to address "are fungi or viruses killing these trees"?

In the case of fungi we can readily isolate a range of fungi from diseased tissue associated with trunk and branch cankers and from necrotic leaves.

Many of the organisms we isolate are considered variously as opportunistic pathogens, secondary pathogens, saprogens, weak pathogens or facultative organisms but they are certainly not PRIMARY PATHOGENS. That is they are not able to cause disease in healthy, non-stressed plants (for example like *P. cinnamomi* does in banksia woodlands and heathlands). These 'opportunistic' fungi are present in the tree and are essentially contributing to the general decline of the tree and arguably could be the factor that is actually killing the tree. But they are 'opportunistic', they are there for a reason and they contribute to the decline of the tree and in some cases kill the tree because of other 'biotic' or 'abiotic' factors providing predisposition.

So what I am saying is that in some pest and disease systems, the pest or the pathogen is an opportunist that is innocuous until the plants are predisposed by salinity, heat, defoliation, mechanical or chemical damage etc. These fungi are present on healthy trees but do not become pathogens until the trees are stressed in some way.

If we were to inoculate these opportunistic fungal pathogens into a healthy tree, these pathogens would be contained by the trees natural defense mechanisms. We would not see the symptoms we are currently seeing in the landscape develop, and over time it is likely that the necrotic tissue caused by us inserting the pathogen into the tree would be actually shed by the healthy tree. We

have actually done this with a number of potential fungal pathogens and in healthy vigorous trees we do not see disease develop. However, if we water stress or defoliate trees (to mimic insect attack) we can get cankers developing and death of the tree. However, it is important to point out that these experimental conditions are a simplification and are not taking into account other environmental or biological factors that could be contributing to tree decline in the south-west.

Let me come back to predisposition and consider that we have a complex system-driving decline. In order to get a handle on this complex system, plant pathologists use the DISEASE TRIANGLE when considering the causes of disease and also control.

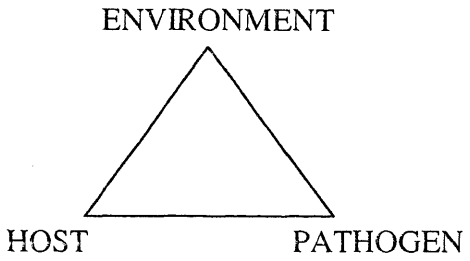
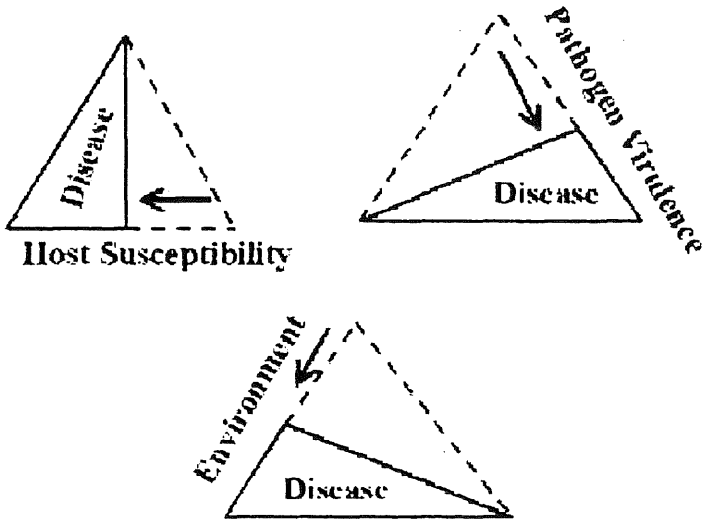


Figure 1. Illustration of Disease Triangle

The DISEASE TRIANGLE essentially incorporates the factors that affect the development and destructiveness of disease and these factors include the susceptibility of the host population, the virulence of the pathogen, and the environment favorable to the pathogen.



If the three sides of the equilateral triangle represent the maximum effect of each factor, then the area within the triangle represents the maximum severity of the disease. Reductions in host susceptibility, reductions in pathogen virulence or changes to less favorable environmental factors for the pathogen will reduce the severity of the disease as represented by the reductions in the areas of the triangles. It is unlikely that any one factor will be at its maximum in any disease situation. Not represented here is the effect of time on the severity of disease, the implications

being that the longer the interaction between the host and the pathogen, the more tissues of an individual tree or populations of trees will be affected.

The model demonstrates that complete host resistance, lack of pathogen virulence, or an environment in which the pathogen cannot grow or spread will eliminate disease. We obviously do not have this in the lower south-west of Western Australia.

PREDISPOSITION

Predisposition is 'to bring about susceptibility to infection'. Many organisms are able to invade tissues successfully only after those tissues have been altered or predisposed in some way. Stressed trees in the absence of attack by organisms usually recover once the stress abates. a most critical stage in the development of diebacks-declines is the point when invasion of vital tissues by secondary-action organisms is sufficient to impair recovery.

STRESS AND PREDISPOSITION

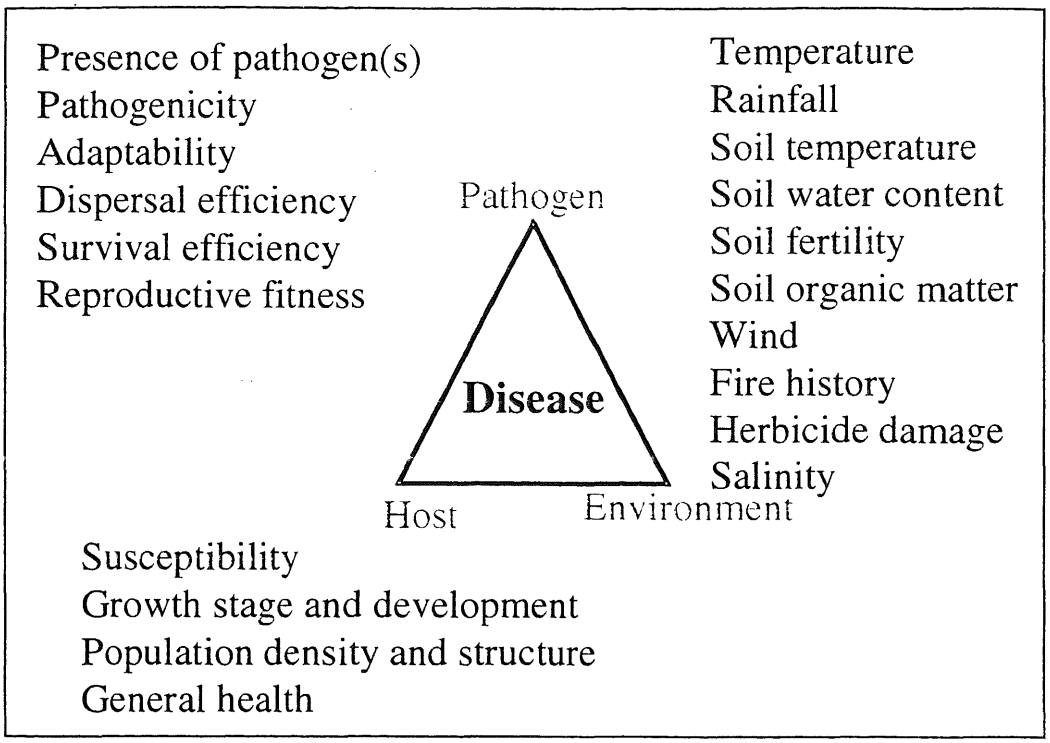
Each major stress factor associated with decline diseases will alter tree tissues in different ways. In many cases, neither the biochemical nor physiological changes in trees or their tissues wrought by stress events, nor the mechanisms responsible for lowered resistance are known. This is the case for eucalypt decline in the Great Southern and elsewhere.

SECONDARY ACTION ORGANISMS

Secondary action organisms include a wide variety of fungi and insects that can kill fine roots, buds and fine twigs, or bark and cambium or branches, stems and roots. While the invasion of many of these organisms can deliver the coup de grace following a given host/stress episode, certain ones have achieved notoriety because of their repeated association with one or more major decline diseases. Some might be specific to a plant host species or genus, others have a broad host-range.

WHAT ARE THE STRESSES LIKELY TO BE IN THE GREAT SOUTHERN?

The following Figure illustrates the types of factors that could be contributing to tree decline.



Drought

Extended drought can be a contributing factor to tree decline. It can influence the health of trees by loss of absorbing roots, which are really in the top 30 cm of soil. Once this soil dries, many absorbing roots dry out and die. Leaves and stems can also be damaged by drought conditions, especially where there is no water available for evaporative cooling and food production. Long drought periods can adversely affect trees, through the loss of stored carbohydrates and essential elements in woody tissues. As soon as stored foods near depletion, the trees will begin to prematurely defoliate. Clearing around a tree greatly increases drought. Lone trees experience higher winds at ground level and more sunshine. Therefore, evaporation is higher and they transpire more. Frost/cold effects are also more.

Stock grazing increases evaporation from soil by removing ground cover. This leads to higher temperatures and greater water loss. Stock compact the soil, reduce water infiltration and cause more runoff. They also cause loss of microorganisms and damage to fine feeder roots, which further stresses trees. As soil nutrient levels increase so does those of the leaves, they become more palatable to insects. Insect attack tends to be sporadic but intense. This damage provides entry point to fungal pathogens and opportunists. If this process continues over a number of years we get decline and possibly death.

Waterlogging

In Western Australia in addition to long periods of dry we also see waterlogging occurring. This is a result of clearing, duplex soils and land practices. Waterlogging for even short periods of time can result in the death of feeder roots and tap roots. This death of roots can help exacerbate the effects of drought. Excessive water will also predispose roots to opportunistic soil borne plant pathogens that can further exacerbate the decline a result of reduced water uptake and nutrient acquisition. Waterlogging will reduce the effectiveness and abundance of ectomycorrhizal fungi.

Salinity

Salt stresses trees by drawing water out of their cells osmotically. Plants respond by increasing the concentration of protective solutes inside cells, usually sugars and protein. Unfortunately, this makes the leaves more nutritious. As the leaves contain more sugar, they are more nutritious and consequently more attractive to insects. We might think then that the cause of the problem is an outbreak of insects, when really it is salt stress that is really the problem. Saline soils will also cause root necrosis and subsequent decline in the uptake of water and nutrients.

Mechanical Injury

Excessive grazing, stock standing under trees for shade disturbs soil via breaking up soil, compaction which in turn leads to root loss, reduced water infiltration and aeration of soil. Animals remove bark (especially horses), and cultivation around trees disturbs soil and roots.

Chemical Injury

Herbicides around trees can lead to root death or death of fungal symbionts which leads to decline. Fertilisers change the pH of soil, effect the uptake of certain trace elements and macro-nutrients and can influence mycorrhizal function and diversity.

Pests

All of the above stresses will weaken trees and predispose them to pest organisms.

- Tree cankers
- Twig cankers
- Leaf spots

Decline Management

What we have in our paddocks, along road verges and in patchy remnant vegetation are trees left behind after clearing and various people driven management practices. We have removed the supporting vegetation surrounding these trees. We have radically changed the environment with our rural management practices. With this management, we have removed birds, insects, animals etc involved in predation (birds that eat insect pests, insects that eat other insects and so on), pollination, dispersal etc. We have essentially presented the trees growing in our paddocks with a huge range of predisposing stress factors or a huge range of stress factors. The tree does not die immediately, it does not even immediately show symptoms. It might take years before symptoms

start to show and many more years before the tree looks really awful and then a few more years before it dies.

We are left with individual trees standing in an environment that is now totally changed, these include:

- Changed water tables
- Drought and temporary waterlogging
- Increasing salinity (salinity can be a result as well as a cause of tree decline)
- Changed micro-climate
- Increased soil temperatures
- Changing pH as a result of fertilisers
- Herbicide usage
- Aging trees which are not being replaced
- Compaction

So we now have a tree growing in an environment to which it was never really adapted. It is stressed. These stresses all reduce the tree's defenses that make it more vulnerable to another stress agent that accelerates the decline.

Often the predisposing factor is non-living, or abiotic, while the contributing factor may be abiotic or biotic (there may also be more than one predisposing factor and contributing factor). The question in many cases is not what is the causal agent but how many are there.

The key to good health is tree vigour. Provide a site that is suitable for the species involved.

LET'S FOLLOW WHAT HAPPENS WITH STRESS

1.) Healthy Trees + stress → Altered trees (tissues) (dieback/decline begins)
2.) Altered trees + more stress --→ Trees (tissues) altered further (dieback/decline continues)
3.) Severely altered trees (tissues) + more stress → Tree altered further (continued dieback/decline)
4.) Severely altered trees (tissues) + secondary organisms → Trees (tissues) invaded
invade and act on tree loose ability to respond to improved conditions, decline, and possibly die.

after Manion 1981

1). Dieback of trees or tissues often results from the effects of stress factor(s) alone. With abatement of the stress, and in the absence of significant colonisers by opportunistic pathogens or secondary insects, dieback ceases and trees recover. The dieback phase can be viewed as a survival mechanism whereby the tree adjusts to its recently encountered adverse environment.

2). Stress alone, if sufficiently severe, prolonged or repeated can cause continued or repeated dieback and even death. There are lots of examples of tree mortality following unusually severe and prolonged drought periods, or episodes of severe defoliation, especially if repeated, perhaps

in the same growing season. When drought and defoliation occur together or in sequence, mortality may be high.

3). Usually, the decline phase, wherein vitality lessens and trees succumb, is the consequence of organism invasion of stress-altered tissues. Recovery from this phase, which is less likely to occur with abatement of stress, depends on many factors including the condition of the tree, the tissue types invaded, the relative aggressiveness of the organisms and the degree of invasion.

4) Where and when the dieback phase occurs is closely related to where and when the triggering stress(es) occurs.

Partitioning the developmental phases of these diseases into separate phases that encompass one or more stages of stress and host response followed by debilitating and often mortality-causing attacks of opportunistic /saprogenic organisms provides a framework to aid in disease diagnosis and study. It also serves to emphasize the chronological ordering of the stress-host change-opportunistic pathogen relationship. In reality these relationships are continuums of interactions reflecting physiological and morphological host responses to a variable suite of shifting environmental stresses exacerbated by invasion of an opportunistic organism complex.

The chronological 'positioning' of attacks by opportunistic pathogen secondary to the stress events, together with their often great diversity in number and kind, has led many pathologists to discount opportunistic pathogen as important contributors/components of dieback-decline diseases.

To accept opportunistic pathogens as important components of causal complexes in decline diseases may require re-examining concepts of a) host predisposition and b) the effects of stress relative to the role and consequence of secondary pathogens.

MANAGEMENT OF DECLINES

- Understand the predisposing factors and interactions with the fungi/insects involved in finishing 'off the job'.
- Manage these factors
- Look/select for resistant or tolerant species or genotypes of trees. It would appear to be futile to try and re-establish local genotypes that have not adapted to the changed rural environment.
- In new plantings maintain high levels of genetic variability so there is potential to cope with diverse stress factors at a site.

QUESTIONS AND ANSWERS WITH REGARD TO TREE DECLINE

So we know fungi are attacking our trees and they are likely to be causing the coup de grace. Can we spray it? Costs would be detrimental, the cause is likely to be due to a group of taxonomically diverse range of fungi, each group requiring different fungicides. If they did work, it is very likely to be only temporary, as the abiotic stresses/insects etc will do the job anyway.

If a tree is in decline, do we use the same species in our revegetation programmes? I do not see any reason not to, as there is no evidence of primary pathogens. However, we need to remove the stresses that will predispose the new trees to insect and pathogen attack.

If one patch of bush has dieback and another not-should we still connect them with vegetation corridors? Probably no harm in doing so. Again we need to consider the predisposing factors and try and suppress or reduce the impact of these in any activities that are undertaken.

Do we collect seed from the area? I do not see too much harm in doing so. It is possible seed will be contaminated with the opportunistic fungi. If they are sown under optimal conditions it is unlikely that death will result. Try collecting seed from plants that appear to be healthy or not adversely influenced by decline, hopefully these will be more tolerant of the predisposing factors.

Can we use the dead wood from 'dieback' trees for fence posts? Yes and no. If *Armillaria* is present in the tree I would definitely say not. Otherwise okay.

We have to be looking for answers on more of a regional basis of ecosystem health and restoration. This would take into account all of the many changes we have made since we 'developed' our landscape, and try to restore the balance to something like that prior to our activities. There are obviously many social and economic considerations to be made in such an approach. But until we start to consider change at this level, I strongly believe decline is inevitable and will continue to have a considerable impact on our landscape.