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Pacific sandalwood

Growers' guide for sandalwood production in the Pacific region

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Contents

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Acronyms and abbreviations

Term	Description
2CC	second cutting chips
DBH	diameter at breast height
DBHOB	diameter at breast height over bark

Units

Unit	Definition
cm	centimetre
cm AGL	centimetres above ground level
g	gram
ha	hectare
kg	kilogram
L	litre
m	metre
m^2	square metre
m AGL	metres above ground level
m ASL	metres above sea level
mm	millimetre
ppm	parts per million
t	tonne, metric tonne (1,000 kg)
°C	degree Celsius

7 Weeds

7.1 Importance of weed control

Every newly planted seedling requires a weed-free area of at least 1 m^2 for at least 3 years. The most common cause of plantation failure is inadequate weed control during the years of establishment. This means that labour inputs for weed control need to be considered in any new sandalwood planting.

There are three forms of effective weed control:

1. Manual pulling is used during the wet season, when conservation of soil moisture is not an issue.
2. Mechanical cutting ('brushing') with a bush knife is used during the dry season, when conservation of soil moisture is important (Figure 7.1).
3. Chemical control with grass-selective or contact/knockdown herbicides can be used if spray drift is adequately controlled. These types of herbicides are generally too expensive and inaccessible for smallholders. Systemic broad-spectrum herbicides (such as glyphosate) should not be used for any reason once the sandalwood has been planted because a systemic herbicide can move through the vascular system of the weeds and into the sandalwood through its haustoria, which can retard growth and potentially kill the sandalwood. Systemic herbicides can be used pre-planting to rid the planting site of weeds, but this should occur several weeks before planting.

Figure 7.1 Mechanical cutting (brushing) of Guinea grass (*Megathyrsus maximus*) with a bush knife

Several vines, locally known as rope weeds, are the most problematic for establishing sandalwood in Vanuatu. These vines include *Neonotonia wightii* (glycine), *Merremia peltata* (merremia and big leaf) and *Mikania micrantha* (mile-a-minute or American rope). These vines can be controlled by manual cutting, but do regrow rapidly (Figure 7.2).

Mechanical cutting of weeds

Soybean

Sandalwood thrive with good, weekly weed control

Merremia

Poorly controlled weeds have swamped any sign of sandalwood saplings

Mile-a-minute overrunning sandalwood

Figure 7.2 Vine weeds are particularly problematic if not regularly controlled by mechanical brushing. Vine weeds such as glycine, merremia and mile-a-minute have rapid growth and are particularly problematic

Singapore daisy (*Sphagneticola trilobata*) is a significant problem for sandalwood plantings in Vanuatu (Figure 7.3). The only way to deal with this weed is to prevent its entry into the plantation by immediate removal when observed. This weed is problematic for the following reasons:

- It significantly depresses the growth of many trees, including sandalwood, since it has an aggressive root system, which is mildly phytotoxic to other plants.
- It promotes a water saturated area around the base of the sandalwood that promotes fungi such as *Phellinus* spp. and *Phytophthora* spp.
- There is no effective method of control in sandalwood plantings. Manual removal is not sufficient to remove the weed as it grows back from any stem or root fragment that remains. It is possible to control Singapore daisy using metsulfuron-methyl, but this herbicide will also result in the death or significant deformation of the sandalwood trees.

Figure 7.3 Singapore daisy (*S. trilobata*) is a low-growing weed that depresses sandalwood growth and promotes stem rot

In Fiji and Tonga, *Spathodea campanulata* (African tulip tree) and *Tecoma stans* (yellow trumpetbush) are major weeds for sandalwood plantings. These two exotic woody weeds, both in family Bignoniaceae, provide intense competition and shade out sandalwood as well as being environmentally invasive, ecosystem transforming species. In Timor-Leste, Siam weed (*Chromolaena odorata*) is an invasive plant that can rapidly smother young tree plantings. In Papua New Guinea, kunai grass (*Imperata cylindrica*) is very hostile to sandalwood trees, owing to its aggressive root system and susceptibility to fire during the dry season.

7.2 Weed control – pulling and cutting

If manual weed control is used it is best to clean around the base of each tree every 2–4 weeks for the first 6–12 months.

Vine weeds often need to be cut or pulled (depending on the season) on a fortnightly basis after seedlings have been planted. This weeding regime needs to be maintained for a number of years, until the trees begin to shade out the weeds. If the rope weeds are too big, they can only be cut. Only small rope plants can be pulled out easily in the wet season.

When vine weeds are a particular problem, the lower branches of the sandalwood may be pruned to 'lift' the crown of the tree away from the ground (Figure 7.4). This leaves only the trunk for the vine weeds to attach to. Although this might not reduce the frequency of weeding, it can help reduce the time spent weeding during a visit.

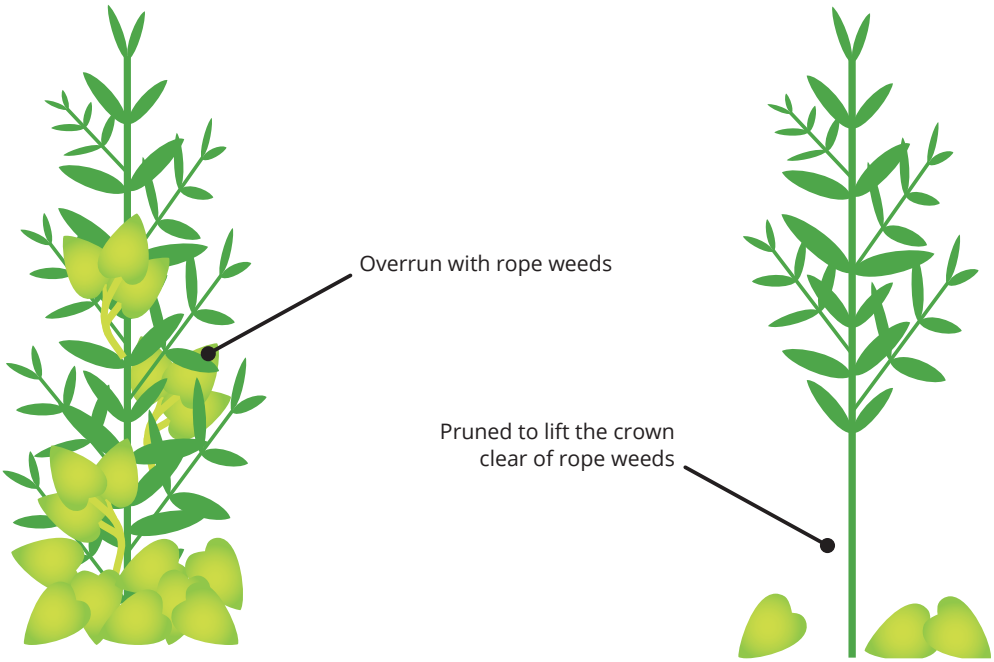

Figure 7.4 Method of trimming vine weeds and pruning lower branches of sandalwood to lift the crown of the tree away from the ground

7.3 Host competition

Sandalwood does not grow well under high competition for soil nutrients, water and light from other plants, including hosts.

Although hosts are necessary for good sandalwood growth, most can outcompete sandalwood if they are too dense or their growth is left unchecked.

Planting among weed thickets often leads to stunted sandalwood growth, with pronounced leaf yellowing (Figure 7.5).

Yellowing sandalwood in leucaena thicket

Crowded sandalwood surrounded by casuarina

Crowded sandalwood with too few hosts

Figure 7.5 Examples of crowded sandalwood and effect on plant health and growth

7.4 Sandalwood competition

Sandalwood growth is severely reduced when it is planted at a high density (spacings less than 3 m × 4 m). Although good early growth can be achieved at such densities, after 3–4 years growth will stagnate as a result of competition between sandalwood trees for soil nutrients, water and light. Figure 7.5 shows severe examples of the effects of high-density plantings. The trees in the top right image are limited by both the high planting density (1.5 m × 1.5 m) and the high number of host trees (*Casuarina* oak trees) planted around the sandalwood. The trees in the bottom image are 10 years of age; they are spindly because of a high planting density and lack of available long-term hosts.

8 Pests, diseases, and other problems for production

8.1 *Phellinus noxius*

Phellinus noxius is a fungal root infection (brown root rot) that has the potential to kill sandalwood seedlings and trees (Figure 8.1). The leaves of affected trees will rapidly turn from green to brown before dropping within a few weeks of showing the first symptoms. If the disease is present, a brown skin, which is the fruiting body of the fungus, can be seen at the base of the tree.

The disease is spread through the root systems of affected trees, and infection can therefore rapidly spread to other trees in a plantation.

Figure 8.1 Examples of *P. noxius* infection in sandalwood trees: (left page) brown root rot at the base of a sandalwood trunk, and (above) *Phellinus*-infected sandalwood losing its leaves

8.1.1 *Phellinus* prevention

The best way to control *Phellinus* is to prevent infection by:

- avoiding planting in areas where the disease is already established
- selecting a site that is free draining and on a slight slope; waterlogged soil promotes the growth of the fungus
- removing all living stumps when clearing a new site, because living stumps and roots are the most likely sites for *Phellinus* spores to establish a new colony; stumps should be burned to ensure that they are completely dead
- allowing a short period of fallow after clearing, or ensuring that the refuse and roots of old trees that may harbour *Phellinus* have decomposed
- planting herbaceous plants adjacent to each sandalwood tree (e.g. *Euphorbia tithymaloides* (vinil), and *Cordyline fruticosa* (cordyline or nangaria) are said to help prevent the spread of infection, although it is not known how)
- avoiding unnecessarily cutting into the sandalwood tree with a bush knife
- pruning during dry conditions to limit the chance of infection of cut stems and to help the rapid healing of the wound (because sandalwood grows rapidly during the dry season)
- avoiding movement of infected plants into the sandalwood plantation.

8.1.2 *Phellinus* control

Controlling *Phellinus* can be difficult. When a tree becomes infected by the fungus, it is important to reduce its spread to other trees in the plantation by:

- reducing the number of people walking around and touching the affected areas of the tree and then touching other (healthy) trees without washing their hands and feet with soap and water
- removing and burning any fallen branches from the plantation
- cutting a wide circle (5–10 m diameter) around the affected tree with a spade to cut the roots
- disinfecting any tools used on an infected tree by washing them with soap and water, and then placing them in a fire or boiling water before using them on a healthy tree.

At the first sign of symptoms, such as drying leaves, some growers believe that the following control methods help reduce the spread of infection:

- Plant herbaceous plants adjacent to each sandalwood tree (e.g. devil's backbone, cordyline).
- Excavate a hole around the trunk of the affected sandalwood tree and place plenty of cut bush lemons in the immediate root zone, as is done in coffee production in Tanna.

If a tree is killed by *Phellinus*, it remains a source of infection for other trees. The dead tree needs to be burned on site to kill any disease remaining in the wood and soil. It is also important to dig and break the roots to reduce movement of the fungus along the roots to other trees in the plantation. Mature trees may be salvaged for their heartwood, although often the disease reduces the quality (see Section 11.3).

8.2 Leaf blackspot

Blackspot is a fungal disease that affects the leaves of sandalwood, particularly in saplings (Figure 8.2). Although blackspot will not usually kill a tree, it is an indication that conditions are too humid for sandalwood. Blackspot can appear intermittently, and its presence will depend on seasonal environmental variation. If blackspot is persistent for most of the year, this is a good indication that the climate is not ideal for growing sandalwood. The effect of blackspot on growth rates and heartwood formation is not known.

Figure 8.2 Leaf blackspot on sandalwood

8.3 Seedling wilt, damping off and dieback

The mortality of young sandalwood seedlings under nursery conditions due to disease is widespread in Timor-Leste and may occur elsewhere in the Pacific. Symptoms include seedling wilt, leaf lesions, stem girdling and ultimately dieback. These diseases cause significant seedling mortality of up to 80–90% (Figure 8.3), particularly under wet and humid conditions.

The canopy of the seedlings displays three distinct symptoms:

1. girdling wound or lesions on the stem (Figure 8.4)
2. leaf wilt/lesions and damping off (Figure 8.5)
3. stem girdling and dieback.

Figure 8.3 Significant seedling losses associated with seedling wilt disease in Timor-Leste

Figure 8.4 Stem lesion symptoms causing girdling and leaf drop above the lesion area

Figure 8.5 Leaf wilt and lesions observed on young sandalwood seedlings

The following conditions are likely to promote onset and development of fungal disease:

- Persistent rain and associated leaf wetness. The number of consecutive rain days can be more important than the total level of precipitation.
- Heavy shade trees adjacent to the nursery area, and/or the combination of heavy cloud and shade cloth.
- Close spacing of the sandalwood seedlings reducing air flow, raising humidity and facilitating disease transfer.
- The growth and abundance of pot hosts growing and outcompeting the sandalwood. This has three effects:
  - raising humidity and reducing air flow among the seedlings
  - providing an alternative host for the disease
  - reducing the vigour of the sandalwood. It is important to note that despite being a root parasite, young sandalwood can be outcompeted by its host.

8.3.1 Cultural methods of control

The onset of fungal disease can be reduced by:

- using clean and disease-free potting media/topsoil
- using well-drained potting media to reduce waterlogging
- growing seedlings on raised benches or a free-draining substrate (rocks)
- surface sterilising seeds prior to sowing.

The incidence of the disease may be limited by the following cultural practices:

- Prune the pot hosts to reduce humidity and increase air flow.
- Remove all dead plants from the nursery.
- Isolate any sick plants in a dedicated and separate area in the nursery.
- Remove any dead or affected leaves in the nursery.
- Reduce plant density by spacing the seedlings more widely.
- Sort seedlings based on size and health.
- Increase available light in the nursery area to help improve sandalwood growth and reduce humidity.
- Increase air flow in the nursery to reduce humidity.
- Water seedlings on demand (according to seedling needs) rather than a regular schedule.
- If possible, limit leaf wetness by growing under clear polythene plastic.

8.4 Sap-sucking and defoliating insects

Various sap-sucking insects occur on sandalwood trees, including mealy bugs and aphids (order Hemiptera), and beetle borers (order Coleoptera) (Figure 8.6). These insects are abundant in some localised areas and at particular times of the year, but none is considered to be a serious pest of sandalwood. These insects are more common on weaker or stressed saplings, and rarely occur on vigorously growing trees.

The best method of controlling these pests is to ensure that the sandalwood trees are planted in an appropriate site, with good weed control. Such practices will help to promote tree vigour and ensure that these pests do not become a problem.

Mealy bugs and aphids have been controlled using white oil pesticide; however, the spray should be applied only to the pest (broadcast spraying should not be used), to avoid killing non-target beneficial insects.

Some insects, such as ladybirds (order Coleoptera, family Coccinellidae), can be effective predators of mealy bugs and aphids, and their presence in the plantation should be promoted.

Trees infested with mealy bugs or aphids are often covered in sticky honeydew, which is a sweet by-product of feeding. This honeydew can promote the growth of blackspot, and infestations of ants seeking the available sugars.

Young sandalwood seedlings can also be susceptible to defoliating insects such as locusts and caterpillars. While these pests are not necessarily a widespread problem, an isolated outbreak can potentially destroy a young planting of up to 2 years of age. These pests can be controlled through manual removal, particularly at the early stages of infestation. If the pest population begins to build up, then an application of chemical insecticides may be necessary to gain control.

Figure 8.6 Mealy bugs (left) and borer beetles (right) can cause harm to young sandalwood seedlings

8.5 Pot host field issues

Sandalwood performs best when the pot host (*Alternanthera*) persists in the field for 1–2 years. Under wet-season conditions it is important to monitor and cut / pull back the pot host growing around the stem of the young sandalwood trees. The two main reasons for this are: (1) the pot host can sometimes fasten/wrap around the stem of the sandalwood and cause rotting and partial or full ringbarking; and (2) in some areas of Timor-Leste the pot host can harbour a snail that can consume the outer bark of the sandalwood (Figure 8.7). Both these problems can cause seedling mortality and are promoted during high rainfall and dense growth of the pot host around the stem. This can be easily rectified by cutting or pulling back the *Alternanthera* from around the sandalwood stem.

Figure 8.7 Bark damage due to pot host wrapping and rotting around the stem (left) and snail (inset right) caused bark damage of young seedling (right). Both these sources of damage can cause seedling mortality in the field

Photos: Luis Almeida

8.6 Leaf galling

Leaf gall is a serious pest of sandalwood trees and can cause significant loss of health and vigour (Figure 8.8). Leaf galling is a particular problem in Timor-Leste and is found throughout the country. The galls are caused by the larvae of an (as yet) unidentified fly or wasp. The larvae consume the leaves causing severe deformation. Young shoots are the most affected by this problem, which can cause a complete loss of growth in that season. The scale of the problems is determined by the severity of infestation. Little is known about this pest and methods of control, but at this stage it appears that stressed trees are more susceptible to leaf gall. Leaf gall often facilitates secondary infection of white scale (Figure 8.9). Further research is required to identify the insect pest and determine methods for management and control.

Figure 8.8 Leaf galling insects affect the leaves (left) and new shoots (right) of sandalwood in Timor. The galling is often followed by infestation of white leaf scale (right)

Figure 8.9 Leaf scale insects can be prevalent in some areas

8.7 Web-forming, leaf-eating caterpillars

Sandalwood trees in Timor-Leste are susceptible to defoliation caused by a caterpillar that forms large colonies within a silken web nest (Figure 8.10). While these colonies can be found on large mature trees, they don't appear to cause significant damage. However, they can completely defoliate young (1–3 years) sandalwood trees in a plantation. This can reduce the health and vigour of the trees and repeated defoliation can result in tree death. Control of this pest is therefore recommended by targeting the colony through physical removal, pesticide treatment or flame treatment.

Figure 8.10 Web-forming, leaf-eating caterpillars form colonies on the bark of mature trees. They eat sandalwood leaves (left) and under some conditions defoliate young, planted trees (right)

Photos: Luis Almeida

8.8 Grazing and browsing animals

The leaves of all young sandalwood species are highly palatable to a range of grazing animals. Both feral and village animals can graze young saplings and severely reduce the chance of plant survival (Figure 8.11). Sandalwood trees may need to be at least 5 years old before they can tolerate animal grazing. This is particularly a problem in some areas of Timor-Leste and Indonesia where there is an abundance of grazing animals in the community including goats, cattle and horses. In Papua New Guinea and Vanuatu, pigs (both wild and domestic) can be particularly problematic when sandalwood is planted in association with root vegetables. When pigs dig to seek out the root crops they will uproot and/or disturb any young sandalwood seedlings and cause significant losses.

The only effective method of controlling cattle grazing is to exclude animals from the planting. This can be done by tethering, installing tree guards or fencing the plantation. Without such control, animal grazing can completely destroy a young sandalwood plantation. In areas where pigs are a concern, the exclusion of companion root crops can limit issues with pigs.

Figure 8.11 Grazing animals can cause significant damage to young sandalwood trees

8.9 Seed predation by birds

The sweet flesh of sandalwood fruit is a prized food for many types of birds. Fruit consumption by birds limits the amount of seed that can be collected for planting or sale. The problem is more pronounced where trees are isolated, because birds are left undisturbed for long periods and it is difficult for a farmer to collect seeds regularly.

Positioning new plantings close to village or garden areas will help the farmer maintain the trees and limit seed loss from consumption by birds.

A sandalwood tree that is a particularly valuable source of seeds may be protected by using a net over its canopy or branches. Another method, which has a limited effect, is hanging shiny objects in the branches of the tree to distract and frighten the birds. Scarecrows can also be effective. However, many birds are quick to see through these tricks, so it is important to place these objects in the plantation only as the seeds mature and quickly remove them after the farmer has finished harvesting the seeds.

8.10 Waterlogging and/or high watertable

All sandalwood species are intolerant of waterlogging and will become yellow and stunted under such conditions. Sandalwood growing on sites with a high water table will grow well in the first few years, but growth will gradually decline, leaves will become yellow, and the tree will become more susceptible to pests and disease. Sandalwood tends to grow best when there is a distinct dry period at some time during the year.

8.11 Fire

Sandalwood does not tolerate fire and will die even when exposed to a low-intensity fire (Figure 8.12). The most susceptible species include *S. album*, *S. yasi* and *S. austrocaledonicum*. *S. macgregorii* and *S. lanceolatum* have thicker bark and have a moderate tolerance to low-intensity fires. Fuel loads in sandalwood smallholdings should be kept to a minimum by removing grass and woody debris from the site. During dry periods, care should be taken to limit people lighting fires close to and upwind of the sandalwood plantation. In Papua New Guinea where sandalwood is planted into kunai grasslands, the risk of fire is very high. Kunai needs to be eliminated from the site prior to planting either through ploughing and/or herbicide. Firebreaks surrounding the sandalwood plantation need to be maintained throughout the dry season. Green firebreaks may also be considered by planting species such as noni (*Morinda citrifolia*) or mango (*Mangifera indica*) and maintaining a debris-free ground layer.

Figure 8.12 Sandalwood grows in areas that are susceptible to fire in the dry season (left). The trees have limited tolerance to fire and are killed from exposure (right)

8.12 Cyclones

Ideally, sandalwood plantings should be established in areas with good wind protection, to limit the damage caused by cyclones (Figure 8.13). The use of windbreak trees known to be tolerant to high winds, such as *Casuarina equisetifolia*, can reduce the wind speed in sandalwood plantations. Sandalwood trees tend to break under cyclonic winds but can recover through new growth from the damaged stem. Trees with broken trunks should be pruned with a saw to give a good clean cut to prevent water entry and rotting of the main stem. There is evidence that the native Pacific species (*S. yasi*, *S. austrocaledonicum* and *S. lanceolatum*) may be more cyclone resistant than species such as *S. album* and *S. macgregorii*. Sandalwood trees tend to be windblown in deep fertile soils with high rainfall and a high water table. In such locations, sandalwood trees don't generally establish deep enough root systems to anchor themselves. Windblown sandalwood can recover through a process of gradual lifting and propping over several months. A tree managed in this way will re-establish its canopy and root system. Cyclones can cause the formation of 'waterwood' (see Section 11.3) at the expense of high-value heartwood. More research is required to determine if waterwood can further develop into true heartwood over time.

Figure 8.13 Cyclone damaged sandalwood trees: *S. yasi* (left) and *S. austrocaledonicum* (centre and right)

8.13 Sun scorch

Sun scorch is a problem in environments where there is not adequate shading and the trees and their main stems are exposed to the full sun (Figure 8.14). It can be promoted when the sun's heat is reflected on dark and bare soil where there is also a lack of ground vegetation or mulch. Sun scorch exposes the inner heartwood, making it more susceptible to other diseases (see Section 8.16).

Figure 8.14 Sun scorch is often found on the sides of trees exposed to hot sun

8.14 Bark slash

Bark slash wounds (Figure 8.15) are typically made using a bush knife, either indiscriminately (vandalism) or systematically (marking ownership). Bark slash is more commonly encountered in areas of high foot traffic (vandalism) or where people seek to mark ownership of the tree to limit theft. The effect of bark slashing on tree health and vigour depends upon severity, and in some villages this practice has been banned.

Figure 8.15 Systematic slashing of the bark as a way to mark ownership of or vandalise other trees. The effect of this damage to the bark on tree health and vigour depends upon the severity of application

8.15 Heartwood check damage

Heartwood checking is damage caused by people cutting into the main stem to check for heartwood development (Figure 8.16). This technique causes significant damage to the tree through the following:

- reduces growth by severing the vascular tissues that connect the roots and the leaves
- creates a wound for entry of pathogens and wood rotting fungi
- introduces a weakness to the trunk, making it more susceptible to being broken in strong winds.

If it is necessary to check the tree for heartwood development, this should be done by making small cuts in the branches and/or roots. While these methods have similar issues to heartwood checking in the main stem, it is less invasive. Alternatively, a small drill bit (6 mm) can be used to drill into the tree and the wood shavings can be collected and checked for the presence and depth of heartwood. The intensity of heartwood fragrance can be used by skilled practitioners to understand the maturity of the heartwood. While drilling has issues with insects and other pathogens gaining entry to the hole, in a vigorous tree the bark can quickly grow over the wound.

Figure 8.16 Examples of severe heartwood check damage

8.16 Heartwood rot

Fungi, bacteria and other pathogens can cause the heartwood of sandalwood trees to rot. They enter through wounds or damage where the heartwood is exposed (e.g. broken off branches in a storm). Trees are more susceptible to this if they are stressed. Fungal fruiting bodies on the bole are a sign that the tree is infected (Figure 8.17 left) and over time they can cause tree mortality (Figure 8.17 right).

Figure 8.17 Over time heartwood rot in sandalwood (left) can cause tree mortality (right)


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