Tree windbreaks in the wheatbelt

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Tree windbreaks in the wheatbelt
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By Robert Sudmeyer, David Bicknell and Neil Coles

September 2007

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Windbreaks can be combined with both crops and pasture
Summary

Windbreaks on wheatbelt farms should be regarded as insurance. They are most beneficial in years of extreme wind and harsh climate, but incur a cost in depressed production of crops or pasture immediately adjacent to them, as well as removing some land from production.

To maximise the benefits, land managers should aim to:

- Target the areas most at risk
- Plant windbreaks at right angles to the prevailing or most damaging winds
- Remember that longer, taller windbreaks shelter the widest areas
- Avoid gaps between or under trees
- Use dense plantings of low growing trees or shrubs to provide the best shelter for off-shears sheep or lambing ewes
- Use trees that provide commercial products
- Design windbreaks for a number of landcare benefits, such as water use and nature conservation.

To minimise competition with crops and pastures:

- Space windbreaks about 30 times the mature tree height (H) apart, but closer on areas with a high erosion risk
- Use narrow rather than wider belts of trees - three tree rows are usually adequate
- Deep rip along both sides of tree lines to minimise root competition with annual crops and pastures.

To maximise efficiency of windbreaks sheltering farm dams:

- Plant windbreaks in interlocking rows on two (typically the northern and eastern) sides of the dam to reduce evaporation during summer
- Plant windbreaks at least 3 H from the dam to reduce the impact of their roots
- If trees are planted closer to the dam, regular ripping of roots is recommended
- The entire area of the dam should be within 8-10 H of the windbreak. Using the smallest suitable tree species available to achieve this will minimise the area occupied by tree roots.
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Windbreak basics

Windbreaks comprising trees, or tree and shrub combinations, can offer many benefits on wheatbelt farms, particularly for protection of soil, stock, crops and pastures from damaging winds and erosion. Additional benefits include reduced evaporation from farm dams, reduced groundwater recharge, their use as nature conservation corridors and habitats, increased biodiversity including predators of crop and pasture pests, fire control, tree products and improved lifestyle and aesthetics.

In other areas and farming systems such as intensive horticulture, man-made windbreaks may be used, but their higher cost makes them unsuited for broadscale agriculture. Man-made windbreaks can be effective in reducing evaporative losses from farm dams in the short to medium-term but become costly if they are engineered to withstand strong winds or last a long time.

How windbreaks work

Windbreaks slow the wind by forcing airflow over the top of the barrier and slowing flow through the barrier. Windbreak height and wind direction determine the lateral extent of windspeed reductions. The distance downwind that windspeed is reduced is proportional to the height of the windbreak (H), so taller trees protect a wider area. To account for differences in height, distances from windbreaks are usually expressed as multiples of H. If the wind is at right angles (normal) to the windbreak, windspeed is reduced for 3-5 H upwind and 20 to 30 H downwind. This area of reduced windspeed downwind is called the sheltered zone (shown in Figure 1). As the wind angle decreases, the sheltered area also decreases.

Porosity, or ability of wind to flow through, rather than over, the windbreak determines how much windspeed is reduced. Windspeed is most reduced in the lee of dense windbreaks and less reduced in the lee of open (more porous) windbreaks. The greatest reductions in windspeed are usually found between 3 and 5 H downwind, with reductions greater than 20 per cent confined within 10 H. The sheltered zone can be further divided into two: the quiet zone within 10 H, where both windspeed and mixing of the air (turbulence) are reduced; and the wake zone between 8 and 20 H where windspeed is reduced but turbulence is increased (Figure 1). There are small reductions in windspeed between 20 and 30 H, and beyond 30 H, open conditions are resumed.

Figure 1. Air flow around a windbreak showing the extent of various microclimate zones in terms of multiples of windbreak height (H) - not drawn to scale
As wind meets a windbreak, air pressure is increased slightly on the upwind side and windspeed can actually increase as the higher pressure air forces its way around the ends or through gaps. This increase in windspeed is called jetting. Jetting is potentially more of a problem around dense windbreaks, which hold back more air, than porous windbreaks.

Reduced windspeed and turbulence alter the microclimate. In the quiet zone, evaporative demand is reduced and temperature increased during the day and decreased at night (see Figure 2). These changes generally benefit plant growth except when frost risk is increased, but the effect is quite small in WA. In the wake zone, windspeed is reduced but evaporative demand may increase, and temperatures are generally similar to open conditions.

![Figure 2. Idealised patterns of microclimate and crop productivity in the lee of windbreaks (after Marshall 1967)](image)

Around windbreaks there are two broad zones of crop and pasture response: a competition zone, in which yield is usually reduced, which extends 2-4 H from the trees; and a sheltered zone of unchanged or increased yield extending from the competition zone to at least 20 H downwind. The competition zone corresponds to the lateral extent of tree roots and is usually associated with reduced soil water, particularly in dry years. Competition can be minimised in many situations simply by root-pruning.

The magnitude of yield changes within the zones depends on the crops or pastures grown, the degree of shelter (windbreak orientation and structure), and site and climatic conditions.

The principal benefits of reducing windspeed are reduced soil erosion, plant damage and stock losses through wind chill. Wind chill decreases the apparent temperature of the air by about 1°C for every 5 km/hr that windspeed increases. Wind chill can distress or even kill stock, particularly when they are wet. With soil erosion, even small reductions in windspeed can reduce the erosivity considerably. For example, reducing windspeed by 20 per cent cuts erosivity by 36 per cent, and halving wind speed reduces erosivity by 75 per cent.

This bulletin contains information about windbreaks designed specifically to protect livestock, plants and soil, and reduce evaporation from dams.
Economic benefits of windbreaks

In WA, windbreaks have the greatest economic benefit in dry, windy years. In normal years, competition may result in a net loss of production, and in dry but non-erosive years, competition effects and yield improvements are likely to break-even. The greatest economic benefits are in areas that suffer from damaging winds and have small competition losses.

Critical factors that influence the economic benefit from tree windbreaks are:

- windiness at key times of the year
- exposure of the dam, crop or pasture
- exposure and erodibility of soil
- exposure of stock to climate extremes
- type of crop or pasture
- degree of competition between the windbreak and the adjacent crop or pasture.

The net economic value is calculated by subtracting all the costs from all the benefits over the life of the windbreak. These include the establishment costs, loss of production from the area directly occupied by the trees and the area of uncropped land immediately adjacent, reduced crop or pasture yields due to competition, and extra management required (e.g. ripping or pruning). The yield forgone on the land occupied by a windbreak can be minimised by making the windbreak as narrow as possible (three rows is usually adequate), by selecting tall trees to shelter a wider area, and by positioning windbreaks at least 30 H apart (closer on very erosion-prone areas).

Benefits include increased yields, reduced wind erosion, less evaporation from dams, and the value of any tree products. The degree and frequency of these benefits being realised depend on the season, site, and land use. There is good evidence in the south-east coastal region that pine windbreaks planted 25-35 H (450-650 m) apart are likely to return a net economic benefit if they protect crops from four to six damaging wind events over a 35-year life. The history of wind erosion in this region shows that this frequency is likely to be exceeded in many situations. Where wind damage is uncommon, windbreaks are unlikely to directly increase farm profitability because of the area occupied and competition losses.

The best method of minimising space and competition losses is to choose trees that produce a saleable commodity such as timber or provide ‘service’ benefits such as stock shelter, increased water-use for recharge management, or have nature conservation values (see Treenote 23).

Reducing evaporative losses also improves the reliability and efficiency of dams. A 20 per cent reduction in evaporative loss during summer will conserve as much as 600 cubic metres (600 kL) of water in the average farm dam. Any such reduction in the need for water carting within the farm or from external sources will provide significant cost and time benefits.

**Shelter for crops**

Windbreaks reduce evaporation from bare soil prior to germination and reduce wind damage immediately after germination (especially sandblasting). This leads to earlier and faster germination, and faster early growth. In extreme cases, windbreaks have reduced sandblasting damage for up to 30-40 H, beyond which crops were not worth harvesting despite being resown.
In dry windy years, the grain yield from sheltered crops can be significantly greater than unsheltered crops (see Table 1). In dry years without wind damage, increased yield in the sheltered zone will offset reduced yield in the competition zone so that net yield between 1 and 20 H is similar to that of unsheltered crops (Figure 3). In years of average or above-average rainfall and no wind damage, sheltered zone yield is largely unchanged and net yield between 1 and 20 H is less than that of unsheltered crops because of yield depression in the competition zone.

![Figure 3. Crop yield in the lee of windbreaks expressed as a percentage of yield outside the sheltered zone (results from 64 field years in Western Australia)](image)

Table 1: Comparison of sheltered and unsheltered crop yields for different seasons

<table>
<thead>
<tr>
<th>Season type</th>
<th>Yield change (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Competition zone</td>
<td>Sheltered zone</td>
</tr>
<tr>
<td>Normal</td>
<td>-27</td>
<td>+2</td>
</tr>
<tr>
<td>Dry</td>
<td>-35</td>
<td>+11</td>
</tr>
<tr>
<td>Dry + wind erosion</td>
<td>-?</td>
<td>+27</td>
</tr>
</tbody>
</table>

Legumes and canola are generally more responsive to shelter than cereals. This may be because they are slower to establish and their growing shoot apexes are at the top of the canopy, making them more sensitive to sandblasting damage.

**Reduced wind erosion**

Much of the agricultural area can suffer wind erosion. This causes soil movement and loss, and can lead to sandblasting of crops and pastures. The risk of crop or pasture losses depends on exposure to, duration and strength of strong winds, soil type, amount of anchored plant residues, soil moisture and crop stage. It usually takes the combination of several risk factors before severe damage occurs.

Soil erosion can cause financial losses through the loss of topsoil and subsequent agricultural productivity, damage to crops and pastures, and wind-blown sand and organic matter drifting over and into roads, fences, dams and yards as shown in Figure 4.
On loose, sandy soils, wind erosion will begin when the windspeed exceeds 30 km/h. The erosivity of the wind increases exponentially with speed. This means that winds of 60 km are four times more erosive than winds of 30 km/hr. So, even small reductions in windspeed, such as experienced 20-30 H from a windbreak, can have large erosion control benefits.

Maintaining adequate vegetation cover on susceptible soils should always be the first line of defence against erosion (Farmnotes 35/96 and 67/2002). However, windbreaks provide long-term protection across broad areas, and act as insurance in those areas where maintaining adequate annual vegetation cover is not always possible.

![Figure 4. Wind-blown sand trapped by a pine windbreak where the windward side suffered severe erosion and crop loss while downwind damage was negligible](image)

**Reduced evaporation from dams**

Water loss through evaporation from uncovered farm dams is a significant problem in dryland agricultural areas, particularly areas receiving less than 400 mm of annual rainfall. Typical evaporative losses range from 1 metre per year in the lower south west to 2.5 m in the north-eastern wheatbelt. These losses are most serious in low rainfall years when the typical depth of farm dams is less than 4.5 m.

Windbreaks can reduce evaporation from farm dams by up to 30 per cent through reducing the windspeed and turbulence over the dam surface. Reductions of 20 per cent are commonly achieved for a variety of tree species and dam sizes (Farmnote 72/2002). This is significant considering that evaporation can reduce water depth by 1.5 m per each year in the medium and low rainfall areas. Reducing the windspeed across the surface of a dam reduces the size and number of waves generated on the water surface and therefore the amount of water in contact with the drier air. Combined with reduced turbulence, this limits the opportunity for evaporation.
**Stock shelter**

Windbreaks can benefit stock production in a number of ways. They can protect animals from extremes of hot and cold weather; pasture growing in shelterbelt systems benefits in similar ways to crops; and reduced soil erosion risk is a particular benefit in grazing systems given a single sheep can loosen up to a tonne of sandy soil a week during summer. In most years, reduced wind chill is unlikely to significantly improve the productivity of adult cattle or unshorn adult sheep. In these years the principal benefit is improved animal welfare through provision of shade and shelter. However, when stock are exposed to extreme weather events, reduced wind chill can be of considerable benefit.

Sheep in particular benefit from protection during wet or cold windy conditions because of their susceptibility to cold stress immediately after shearing and during lambing. Sheep and cattle are homeotherms - like us they have to maintain their body temperature within a narrow range. When experiencing hot or cold conditions, stock will expend energy to stay within that range. However, if stressed beyond a certain point animals will no longer be able to regulate temperature and die from hyperthermia (heat) or hypothermia (cold). For stock, the lower critical temperature (LCT) is the temperature below which energy has to be expended to maintain body temperature (see Table 2). Animals do this by burning body fat and increasing food intake. As wind speed increases, the LCT increases due to the effect of ‘wind chill’. The wind chill factor is a measure of how increasing windspeed increases the loss of body heat so that the apparent temperature of the air decreases as windspeed increases even though ambient temperature remains constant. This effect is more pronounced for wet and young stock which have much higher LCTs.

### Table 2: Lower critical temperatures for cattle and sheep on a maintenance diet and temperature at which newborn lambs become hypothermic

<table>
<thead>
<tr>
<th>Stock type</th>
<th>Dry Windspeed (km/hr)</th>
<th>Wet Windspeed (km/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Calves</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>Adult cattle, coat depth 3 cm</td>
<td>-7</td>
<td>3</td>
</tr>
<tr>
<td>Newborn lambs</td>
<td>22-37</td>
<td></td>
</tr>
<tr>
<td>Adult sheep, fleece 1 cm</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>Adult sheep, fleece 10 cm</td>
<td>-35</td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stock type</th>
<th>Dry Windspeed (km/hr)</th>
<th>Wet Windspeed (km/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 kg lamb</td>
<td>-32</td>
<td>-5</td>
</tr>
<tr>
<td>5 kg lamb</td>
<td>-69</td>
<td>-25</td>
</tr>
</tbody>
</table>

After Gregory (1995)

The other way windbreaks shelter stock is by providing shade. Cattle are more susceptible to heat stress than sheep due to their larger size, particularly if they are on high energy diets and in very good condition. Heat-stressed cattle will reduce feed intake, reduce milk production and exhibit reduced fertility. The generally mild climate of south-western WA means that heat stress is not a major factor affecting production, however it can occur and has been observed in cattle grazing pasture containing ryegrass ergot. Shade in feedlots in Victoria, NSW and Queensland has demonstrated some benefits.

The main benefit was observed before the stock acclimatised to the environment. Daily weight gain increased, however usually not enough to justify the cost of establishing the
shade (constructed shelters). However, the cattle used the shade, and welfare may again be the main benefit.

Over the last 25 years there have been at least six severe weather events that have led to major sheep losses in the South-West. The greatest losses from a single event occurred in 1982, when an estimated 100,000 sheep died. In excess of 40,000 sheep died in the Esperance region in 2007. Investigations following these and other events have shown a number of common factors:

- The damaging storms generally occurred during summer or autumn when animals were acclimatised to warm weather
- Storms were associated with a sudden drop in temperature, strong winds and heavy rain over a period of days
- Stock became saturated and remained wet for an extended period
- Recently shorn sheep (less than four weeks), lambs and animals in poor condition were most likely to die of hypothermia.

Examination of the effectiveness of windbreaks in reducing losses in these extreme conditions reveals mixed results. When susceptible animals are wet, even high levels of shelter may provide little protection against hypothermia. In this situation the best results are obtained by confining susceptible animals such as recently shorn sheep out of the rain in sheds. Where animals have sought shelter and have survived, the shelter has been of a type that provides maximum protection within a metre of the ground. This can be dense high stubbles or tall grasses and weeds. Losses are greatest where there is no low cover such as in pasture or low stubbles.

Windbreaks designed to protect crops and pastures will not give optimum stock protection from severe wind and rain events, consequently stock shelter requires some specific design considerations which are discussed below.

Sheep may benefit from extra shelter, particularly during severe weather events
Windbreak design to protect crops, pasture and soil

A windbreak’s effectiveness in providing shelter depends on its orientation to the wind, height, length, position in the landscape and structure. The ideal windbreak is a long, uniform, narrow belt of tall trees planted at right angles to the direction of damaging winds. In practice, the landscape, farming systems and overall farm plan will influence both placement and management of windbreaks.

Windbreaks are long-term structures, and planting layouts need to allow for changes to farming systems such as increasing machinery size, controlled traffic or raised beds. Complicated layouts often become impractical over time. As with any infrastructure, costs are involved: the initial establishment; the ongoing costs of the land taken out of production; and reduced production alongside the trees.

Placing windbreaks adjacent to earthworks, roadways, laneways and roaded catchments will reduce the intrusion of trees onto arable land and minimise competition between the trees, crops and pastures. These placements may compromise effectiveness slightly, but will be a better whole-farm option in many cases.

Basic design considerations include orientation, length, spacing and place in the landscape.

**Orientation**

Windbreaks are most effective when they are at right angles to the wind. It is therefore important to know when winds are most damaging and the prevailing wind direction during those periods so you can plan accordingly. In Esperance for example, summer and autumn winds are dominated by strong afternoon sea breezes from the south-east (Figure 5); and in winter the strongest winds are pre-frontal winds from the north-west and west; while spring winds are dominated by westerlies in the morning and southerlies in the afternoons. This variability through the year means that while a particular windbreak can provide high levels of protection for some winds, it cannot protect against all (see Figure 6).

In the Esperance example, windbreaks oriented north-south or north-east to south-west provide the best protection against damaging winds. These orientations are also effective in protecting against problem winds in many wheatbelt areas. These winds are typically:

- Pre-frontal, northerly to westerly winds in autumn and early winter that erode bare soil and damage emerging crops and pasture
- Hot, dry spring and early summer winds from the north-east to south-east. These can cause flower abortion in lupins and other legumes, and wind erosion after harvest.

Windbreaks oriented north-south have the additional advantage of minimising shading (see Managing competition from windbreaks).

Where damaging winds come from different directions throughout the year and a high degree of protection is needed, windbreaks can be planted in a grid (perhaps along paddock boundaries as shown in Figure 7) to provide consistent shelter.
Figure 5. Proportion of time winds are stronger than 30 km/hr (capable of causing erosion) and their seasonal direction at Esperance.

Figure 6. Windspeed reductions between two pine windbreaks sited 450 m apart at Esperance.
Figure 7. Windbreaks planted on paddock boundaries can give protection from variable winds such as these pine windbreaks near Esperance (photo David Hall)

**Length, ends and gaps**

Windbreaks should be at least 20 times as long as they are high to maximise the protected area relative to jetting problems around the ends. Short isolated windbreaks shelter a relatively small area.

Jetting can cause erosion at the ends and access ways through windbreaks. The ideal system would be a network of windbreaks, with each end joining or butting into other windbreaks. Of course, this is not always possible and where windbreaks end or there are gateways, laneways and other planned gaps, there are several options:

- Site ends or gaps on heavier soil types to minimise erosion risk
- Incorporate remnant vegetation into windbreak ends
- When a gap is necessary, overlap the ends or run the gap at an angle through a section of wider windbreak
- Protect the soil surface in and near the gap from erosion; in gateways, this could mean surfacing with gravel or using stabilised earth or ending the windbreak at a gravelled roadway
- End a windbreak on the lee side of hills rather than the windward side
- Gradually increase the windbreak porosity and decrease height at ends by increasing tree spacing and using shorter trees. This gradually reduces the build-up of air pressure behind the windbreak and reduces jetting. In mature windbreaks this can be achieved by progressively removing some trees, pruning or coppicing.
**Spacing**

The distance between windbreaks will always be a compromise between minimising costs and facilitating farming operations, and providing adequate shelter. Increasing the spacing between windbreaks reduces costs, but also reduces the amount of shelter.

In most situations a spacing of 30-35 H between windbreaks is sufficient, where ‘H’ is the mature tree height. On very erosion-prone areas the spacing may have to be reduced to 20-25 H so that the area is sheltered as the trees grow. Where rapid wind protection is required, or in low rainfall areas where trees are slow growing, windbreaks can be planted at spacings of 10-12 H. As the trees approach their mature height every second windbreak can then be removed without compromising protection.

**Landscape considerations**

Landscape position and topography can change the degree of exposure, windspeed and direction.

Windspeed increases on the windward sides of hills. Upward slopes decrease the effective windbreak height and reduce the width of the protected area, so windbreaks need to be closer together. On lee slopes windspeed is reduced, and downward slope increases the effective windbreak height and the width of protection so windbreaks can be further apart. Siting a windbreak on the top of a rise or hill effectively increases its height and the area protected. However, caution needs to be exercised with steep hills as a windbreak on top may increase turbulence downwind.

Contour planting across slopes will intercept the downward flow of cold air and can increase the risk of frost. In frost-prone regions and low areas such as hollows, windbreaks need to have more gaps and lower porosity to 'spill' the cold air.

**Structure**

After orientation and layout have been decided, height and porosity are the main factors governing the magnitude and extent of windspeed reductions.

**Height**

Tall windbreaks maximise the distance protected and reduce the number required to protect a given area of land. Tall windbreaks therefore reduce planting and fencing costs, and the area directly occupied by the trees, relative to the area protected.

**Porosity**

The porosity of a windbreak determines how wind flows through it. Good windbreaks have uniform porosity from ground level to at least three-quarters of the tree height, and no gaps under or between trees. Windbreaks which are highly porous at the base (due to stock grazing or leaf loss) or which have vertical gaps (due to tree deaths or access ways), allow wind to jet through the gap as shown in Figure 8. This increased windspeed at ground level can cause erosion on susceptible soils within 1-2 H.

An example of how jetting increases windspeed is shown in Figure 8. The unfenced tuart windbreak is one-row wide and 15 m tall with no foliage at ground level which allowed jetting under the trees, thus increasing windspeed. The fenced acacia windbreak is four-rows wide and 3 m tall with foliage to ground level and is much more effective in reducing windspeed close to the windbreak.
Dense windbreaks (in lower rainfall areas achieved with multi-row tree belts) allow less air flow and so reduce windspeed more than permeable ones. Permeability is relatively unimportant for erosion control, as even small reductions in windspeed reduce erosivity substantially. As long as there are no gaps, one to three-row windbreaks or open remnants of mallee vegetation can perform as well as wider dense windbreaks. However, dense windbreaks are required if the aim is to alter microclimate in the sheltered zone.

**Figure 8.** Comparison of an acacia windbreak with uniform porosity from ground to 2-3 H and a tuart windbreak that has high porosity near ground due to grazing and leaf shedding (after Bird et al. 1992)

**Evaporative losses from farm dams**

A simple way to protect a farm dam is illustrated in Figure 9 with a windbreak grown on two sides to provide shelter and reduce evaporation.

**Figure 9.** a) Dam protected from summer north-easterly winds by windbreak on two sides; b) plan view showing tree spacing for a two-row windbreak
The aim with this type of windbreak is to reduce windspeed as much as possible in the quiet zone, so the windbreak should be as dense as possible. This can be achieved by selecting appropriate species, planting trees close together and using at least three rows. Fencing will encourage retention of vegetation at ground level and prevent jetting. If the trees are to be left unfenced (perhaps to provide shade for stock) it will be necessary to plant the windbreak at least 4 H from the dam so that air jetting under the trees dissipates in the quiet zone before reaching the dam.

The entire area of the dam should lie within the quiet zone, i.e. within 8-10 H. Further from the windbreak, the dam will be in the more turbulent wake zone where evaporation can actually be increased. The ratio of tree height to dam width is given in Figure 10.

![Figure 10. Minimum windbreak height required with square dams for artificial windbreaks and trees placed twice and five times tree heights from the dam](image)

Windbreak trees will use water from the dam if they are too close, so it is important that they are planted at least 3 H away. Regular root-pruning (see below) should be considered to ensure roots don’t access the dam and to encourage pasture growth near the trees.

Man-made windbreaks can also be effective in reducing evaporation, and have the advantage of working immediately without the problems associated with tree roots. However, artificial barriers may need to be constructed to withstand strong winds which can add to the installation costs and may have a shorter working life than trees.
Protection for stock

The most effective and efficient livestock shelters confine vulnerable animals to a relatively small area that provides high levels of shelter across the entire paddock. This means that the animals do not have to actively seek shelter should they be faced with an extreme weather event.

For maximum protection, stock shelter paddocks should be dry (i.e. not prone to flooding or waterlogging) and have dense, closely-spaced windbreaks that reduce windspeed as much as possible. It is particularly important that the windbreaks do not cause jetting. To prevent this, use dense low growing trees or shrubs that retain foliage to ground level or even rank tussock grasses planted in strips or randomly between the tree rows.

Very dense L-shaped windbreaks have been used in paddock corners, but to be effective they rely on the sheep actively seeking shelter, which doesn’t always happen, particularly with lambing ewes. In extreme conditions, tree shelter may not be sufficient to protect sheep totally, but could reduce losses.

Cattle benefit from shade in hot areas. Shade can be provided by windbreaks if the cattle have access to the area under the trees, but this will compromise the windbreak’s ability to reduce windspeed.
Choosing the right tree species

Trees and shrubs should be adapted to the site. They should also be tall, fast growing and able to retain foliage to ground level. Soil, climate and planting conditions at a given site should determine the species chosen and the subsequent survival, growth rate and height of the mature trees. Site preparation and the establishment technique are also important.

Windbreaks are expected to last several decades, so choose species that have suitable longevity and tolerance of conditions expected over that period. This includes ability to withstand severe events such as drought, waterlogging, frosts or high temperatures.

We recommend that managers use local experience and specialist advice wherever they can. Local tree nurseries, natural resource management officers, private forestry committees and the Forest Products Commission are all good sources of information. Publications such as Farmnotes and TreeNotes (available from DAFWA) and software programs can help select species for windbreaks, commercial harvesting and nature conservation corridors.

Some suitable species are suggested in Table 3, but local knowledge is very important and other species could work just as well in particular situations.

In summary:

- Choose species that are well adapted to the site conditions, grow rapidly and will survive long-term.
- Plant at least three tree rows as insurance against seedling or mature plant deaths. Small gaps will usually be filled as the trees mature. Larger gaps in recently planted windbreaks may need replanting, and this should be done as soon as possible to avoid competition with the older trees.
- If planting only one or two-row windbreaks is unavoidable, reduce the spacing between trees to achieve quicker closure of the canopy and to insure against gaps. Choose species that retain foliage close to ground level.
- Many species are suitable for windbreaks, especially in combination with others to get suitable porosity and eliminate gaps. A common technique is to use one or more rows of tall, fast growing trees combined with an outer row of dense shrubs to give a tall windbreak with good protection at ground level. As windbreaks are usually long enough to cover several soil types and landscape conditions, it is often necessary to change the species along the length.
- Gaps at the base can be avoided by fencing to exclude stock and planting an outside row to shrubs or even tall tussock grass species which maintain foliage at ground level. Pines will retain foliage to ground level if fenced, but many eucalypts lose lower foliage and branches as they mature. For existing windbreaks, it may be possible to add another row of shrubs or more suitable tree species. Coppicing is an option for some species; trees are cut at ground level and the regrowth provides foliage near the ground for many years.
Table 3: Some recommended tree species for windbreaks

<table>
<thead>
<tr>
<th>Species</th>
<th>Minimum rainfall (mm)</th>
<th>Preferred soil type</th>
<th>Mature height (m)</th>
<th>Growth rate</th>
<th>Retains lower branches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia acuminata (raspberry jam)</td>
<td>450</td>
<td>C, Cl, G</td>
<td>3-5</td>
<td>M</td>
<td>Y</td>
</tr>
<tr>
<td>A. cyclops (WA coastal wattle)</td>
<td>450</td>
<td>C, Cl, G</td>
<td>3</td>
<td>F</td>
<td>Y</td>
</tr>
<tr>
<td>A. saligna (golden wreath wattle)</td>
<td>474</td>
<td>C, S</td>
<td>3-5</td>
<td>F</td>
<td>Y</td>
</tr>
<tr>
<td>Casuarina obesa (swamp sheoak)</td>
<td>400</td>
<td>C, Cl, S, W</td>
<td>5-10</td>
<td>M</td>
<td>Y</td>
</tr>
<tr>
<td>Chamaecytisus proliferus var. palmensis (tagastaste)</td>
<td>400</td>
<td>S</td>
<td>3-6</td>
<td>F</td>
<td>Y</td>
</tr>
<tr>
<td>Corymbia maculata (spotted gum)</td>
<td>500</td>
<td>Cl, G, S</td>
<td>20-30</td>
<td>M</td>
<td>N</td>
</tr>
<tr>
<td>Eucalyptus angustissima</td>
<td>350</td>
<td>S, W</td>
<td>6-10</td>
<td>S</td>
<td>Y</td>
</tr>
<tr>
<td>E. camaldulensis (river gum)</td>
<td>450</td>
<td>Cl, G, S, W</td>
<td>20-30</td>
<td>M</td>
<td>N</td>
</tr>
<tr>
<td>E. cladocalyx (sugar gum)</td>
<td>450</td>
<td>S, G, W</td>
<td>20-30</td>
<td>M</td>
<td>N</td>
</tr>
<tr>
<td>E. conferruminata (Bald Island marlock)</td>
<td>450</td>
<td>Cl, G, S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. cornuta (yate)</td>
<td>500</td>
<td>C, Cl, S, W</td>
<td>10-20</td>
<td>M</td>
<td>Y</td>
</tr>
<tr>
<td>E. globulus (Tasmanian blue gum)</td>
<td>600</td>
<td>Cl, G, S</td>
<td>20-30</td>
<td>F</td>
<td>Y</td>
</tr>
<tr>
<td>E. gomphocephala (tuart)</td>
<td>400</td>
<td>C, G, S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. leucoxylon (SA blue gum)</td>
<td>500</td>
<td>C, Cl, G, S</td>
<td>10-20</td>
<td>M</td>
<td>N</td>
</tr>
<tr>
<td>E. loxophleba (York gum)</td>
<td>400</td>
<td>Cl, S</td>
<td>8-20</td>
<td>M</td>
<td>N</td>
</tr>
<tr>
<td>E. loxophleba ssp. lissophloia</td>
<td>350</td>
<td>S, Cl</td>
<td>6-12</td>
<td>M</td>
<td>N</td>
</tr>
<tr>
<td>E. occidentalis (swamp yate)</td>
<td>425</td>
<td>Cl, S, G, W</td>
<td>15-20</td>
<td>F</td>
<td>N</td>
</tr>
<tr>
<td>E. platypus (moort)</td>
<td>350</td>
<td>Cl, G, S</td>
<td>3-8</td>
<td>M</td>
<td>Y</td>
</tr>
<tr>
<td>E. plenissima</td>
<td>300</td>
<td>S, G</td>
<td>6-10</td>
<td>S</td>
<td>Y</td>
</tr>
<tr>
<td>E. polybractea (blue mallee)</td>
<td>400</td>
<td>Cl</td>
<td>10-15</td>
<td>M</td>
<td>N</td>
</tr>
<tr>
<td>E. spathulata (swamp mallet)</td>
<td>375</td>
<td>C, Cl, S, W</td>
<td>6-10</td>
<td>F</td>
<td>Y</td>
</tr>
<tr>
<td>Hakea laurina (pin cushion hakea)</td>
<td>425</td>
<td>C, G, S</td>
<td>2-4</td>
<td>M</td>
<td>Y</td>
</tr>
<tr>
<td>Pinus pinaster (maritime pine)</td>
<td>400</td>
<td>S</td>
<td>15-25</td>
<td>M</td>
<td>Y</td>
</tr>
<tr>
<td>P. halepensis (Aleppo pine)</td>
<td>400</td>
<td>S</td>
<td>10-20</td>
<td>S</td>
<td>N</td>
</tr>
</tbody>
</table>

1 C = calcareous; Cl = clay; G = gravel; S = sand; W = waterlogged periodically
2 F = fast growing; M = medium; S = slow

**Fencing and maintenance**

Primary windbreaks should have livestock excluded permanently. This will help preserve foliage close to the ground, and reduce bare and loose soil in any gaps. Fencing can be reduced by planting around existing paddock boundaries and laneways. On properties without livestock, fencing is not required.

Once the windbreak trees are established, weed build-up is rarely a problem, and needs no special management. In fact, erosion damage from bare soil around windbreaks is more likely. Consequently, fire risk from grass and other weeds is negligible and windbreaks act to slow windspeed and the spread of fires.

Fencing should be no closer to the tree lines than the near-mature canopy spread. If closer, fencing may be damaged by foliage pressure, falling branches and stock trying to graze foliage. Management (see below) such as root-pruning may be necessary to reduce competition between trees and crops or pasture, and reduce the area of bare soil alongside the trees.
Managing competition from windbreaks

Farmers can reduce competition effects between tree windbreaks and adjacent crops and pastures by:

- Reducing the amount of tree-crop interface (wider windbreak spacings and reduced tree distribution)
- Planting more competitive crops and pastures (mainly perennial pastures)
- Reducing tree competitiveness (root-pruning, thinning, pruning, aligning north-south).

Options chosen should depend on the economic value of the tree and crop products and the value put on other tree benefits such as shelter and reduced groundwater recharge, and competition costs. The cost of competition to the adjacent crop or pasture depends on the area directly occupied by trees, the uncropped area immediately adjacent, and the competition zone where tree and crops or pasture compete for water, light and nutrients (resources).

Lateral tree roots cause most competition losses by extracting soil moisture. Crop and pasture growth generally declines as trees grow older and taller and their roots spread further. The relative effect of above-ground (shading) and below-ground (nutrient and water) competition from trees depends on the crop type, site and climate. In medium and low rainfall areas, drier soil near trees is the limiting factor for growth in most years.

The area occupied by trees and the competition zone are determined when setting the width and number of windbreaks. As shown in Figure 11, the area of the competition zone increases as trees are more dispersed across a paddock. Block plantings have the smallest competition zone and close-spaced alleys the most, although the area occupied by trees can be similar. The aim should be to minimise the competition zone while still achieving planting goals. For example, tall windbreak trees shelter a wider area than short trees and a block planting may be easier to manage for timber production than a narrow belt.

Farmers should consider managing competition for resources. Two principal advantages are improved crop and pasture productivity, and more ground cover beside trees reducing wind erosion risk on lighter soils. Disadvantages include slower tree growth, reduced tree water use and possibly increased groundwater recharge, the cost of pruning or cutting trees and reduced shelter from the trees.

The costs of not managing competition can be significant. Crop yield or pasture growth can be reduced up to 30 m from tall trees. Typically growth is reduced for 1.5-2 H, but up to 4 H around mallees. Mean crop and pasture yield within the planted competition zone ranges between 50 and 79 per cent of yield outside the competition zone. This means that returns from crop and pasture can be less than input costs for a distance of 5-20 m (0.5-2 H) from larger trees and 8-10 m (3-4 H) from mallees.
Agricultural production losses within the competition zone can be reduced in several ways, listed below in declining order of practicality and effectiveness:

- severing lateral tree roots (root-pruning)
- planting more competitive perennial pastures alongside the trees
- reducing above-ground biomass of trees by pruning and thinning (as in a silvicultural regime) or coppicing (as in harvesting oil mallees)
- orienting windbreaks north-south to minimise shading.

Each of these is discussed below.

![Figure 11. Length of the tree-crop interface increases as trees are more dispersed (from Abel et al. 1997)](image)

**Root-pruning**

Root-pruning is the easiest and most effective method of reducing competition in many situations (Figure 12). Root-pruning is best done using either a three-point linkage mounted or trailed ripper and is most effective where lateral roots are confined within 70-80 cm of the surface by subsoil clay. If possible, ripping should extend into the clay so that all lateral roots are cut. Uncut roots below the rip line continue to grow and subsequent ripping becomes
less effective. This makes root-pruning on deep sands ineffective over time. Ripping can be done at any time that fits in with other farm activities, however it is best when soil is moist as this reduces stress on the trees and facilitates penetration of the ripper.

Ideally, root-pruning should begin before the trees develop extensive lateral roots. This may mean beginning when they are about five years old. Aim to prune the trees at a distance of about half their height from the stem. If trees are pruned regularly, the rip line can be maintained 5 m from the stem as the trees grow taller. Caution needs to be exercised in pruning large mature trees for the first time although experience has shown that root-pruning at least 5 m from the stems will not kill them.

The timing between ripping operations will depend on tree vigour and the speed at which the roots regrow. A two to three-year interval is sufficient in most cases, but a one-year interval may be necessary for mallees which can regrow vigorously.

![Image](85x355 to 544x583)

**Figure 12.** Impact of root-pruning beside a pine windbreak where crop grew within 5 m of the trees when root-pruned, but not within 15 m of unpruned trees

**Using perennial pastures**

Perennial species such as tall wheatgrass, veldt grass, Rhodes grass and consol lovegrass are more competitive with trees than annual crops and pastures because of their deeper and denser root systems.

Ideally, perennial pasture and trees should be established at the same time. Kikuyu runners will spread slowly into the competition zone alongside mature trees, but lucerne establishment and subsequent growth has been poor when sown into dry soil near established trees.

Perennial grasses reduce tree root density and extent more than annual pastures, and so reduce tree water use and growth. This could significantly reduce tree growth if grasses spread into the tree belt and may have economic implications where trees are grown for commercial products.
Coppicing and thinning trees

Coppicing or thinning trees reduces competition by reducing tree demand for water and can result in dramatic reductions in improvements in crop and pasture growth, even in deep sands where root-pruning is ineffective (Figure 13). Ideally, coppicing and thinning operations will be part of a commercial agroforestry system. Harvesting biomass from oil mallees (coppicing) could be expected every three to five years depending on growth rates, while selective thinning would occur two to three times over a 30-40 year sawlog rotation. It is unlikely that selective thinning of tree stands would be economically viable unless they provided a commercial product.

Figure 13. Closer unthinned trees (800 stems/ha) had little pasture growing within 18 m, but where trees had been thinned to 125 stems/ha the pasture grew to within 5 m

Where mallees are not harvested commercially, farmers can cut them by engaging a contractor with a hedge or tagasaste cutter. This operation would have to begin while the branch size can be handled by the cutter. Where mallees grow well, they recover very quickly from coppicing or root-pruning, and these operations are best alternated every year.

Orientation to reduce shading

As a general rule, competition for soil moisture has more effect on crop and pasture growth than shading near trees in medium and low rainfall areas. Even with root-pruning it is very difficult to reduce tree competition for water to the point where shade is more limiting to crop growth than water. Therefore it is recommended that windbreaks are oriented primarily to protect against damaging winds, rather than to minimise shading. Fortunately, north-south oriented windbreaks minimise shading and provide excellent shelter from damaging winds across much of the agricultural area.
Economics of competition management

Root-pruning is the easiest competition management to apply to existing windbreaks, and is consequently the most widely practised. Root-pruning increased the annual return from crops on both sides of a radiata pine windbreak by $548/km of tree line/year in the Esperance region (see Table 4, site 1). Note that competition management can also decrease returns if root-pruning increases waterlogging (Table 4, site 5), or at low productivity sites where the costs outweigh increased agricultural returns (Table 4, site 7). Competition management will also reduce tree water-use and may increase groundwater recharge (root-pruning reduced the water-use of the radiata pine windbreak by 61 per cent and oil mallees by 22 per cent). It is difficult to put an economic value on these tree services, but they should be considered when undertaking competition management.

While the economic case for managing competition is reasonably clear when trees don’t produce a commercial product, it is more complicated when the trees will be harvested at some future point. In medium rainfall environments, edge trees can grow at two to three times the rate of inner trees so root-pruning can significantly reduce growth rates (see Table 5). This has a particularly severe impact on the economics of mallee-based agroforestry where the trees are grown in two-row hedges and are all effectively edge trees.

Table 4: Increase in annual equivalent return from crops and pasture within the competition zone of trees with treatments applied to both sides of tree line

<table>
<thead>
<tr>
<th>Site</th>
<th>Tree layout</th>
<th>Annual rainfall (mm)</th>
<th>Increase (compared with no action) in annual equivalent return due to management of competition ($/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Root-pruned every 3 years</td>
</tr>
<tr>
<td>1</td>
<td>Pine windbreak</td>
<td>500</td>
<td>303</td>
</tr>
<tr>
<td>2</td>
<td>Pine windbreak</td>
<td>475</td>
<td>96</td>
</tr>
<tr>
<td>3</td>
<td>Blue gum timber belt</td>
<td>475</td>
<td>194</td>
</tr>
<tr>
<td>4</td>
<td>Blue gum timber belt</td>
<td>525</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Eucalypt windbreak</td>
<td>496</td>
<td>-2</td>
</tr>
<tr>
<td>6</td>
<td>Mallee belt</td>
<td>386</td>
<td>54</td>
</tr>
<tr>
<td>7</td>
<td>Mallee belt</td>
<td>342</td>
<td>26</td>
</tr>
<tr>
<td>8</td>
<td>Remnant mallee</td>
<td>342</td>
<td>158</td>
</tr>
</tbody>
</table>

When management reduces the growth of windbreak trees it also reduces the area sheltered. If windbreaks are planted to protect a very erosion-prone area, and are going to be root-pruned, it may be worth reducing the spacing between windbreaks to compensate for reduced growth rates. The increased area occupied by the trees may offset any production benefits next to them.

A benefit of root-pruning windbreaks on light sandy soils is that increased crop and pasture growth will reduce the erosion risk from bare soil adjacent to the trees.
### Table 5: Effect of competition management on edge tree growth compared with unmanaged trees

<table>
<thead>
<tr>
<th>Site</th>
<th>Tree species</th>
<th>Root-pruned every 3 years</th>
<th>Root-pruned annually</th>
<th>Coppiced</th>
<th>Coppiced and root-pruned</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Radiata pine</td>
<td>57</td>
<td>57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Radiata pine</td>
<td>70</td>
<td>66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Blue gum</td>
<td></td>
<td>87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Mixed eucalypts</td>
<td>79</td>
<td>88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Oil mallee</td>
<td>65</td>
<td>60</td>
<td>39</td>
<td>26</td>
</tr>
<tr>
<td>7</td>
<td>Oil mallee</td>
<td>75</td>
<td>47</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Oil mallee</td>
<td>75</td>
<td>72</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Oil mallee can serve a dual purpose of reducing watertables and acting as windbreaks*
Further reading

**TreeNotes**

A series of TreeNotes was produced by the Department of Agriculture and CALM in the late 1990s. They are no longer being reprinted but some hard copies may be available from district offices and on agency websites.

- No. 17: Tree planting - in the medium and high rainfall zone of Western Australia
- No. 22: Windbreak design and management in the greater than 450 mm rainfall zone of Western Australia
- No. 23: Timber production from windbreaks in the greater than 450 mm rainfall zone of Western Australia

**Farmnotes**

Various Farmnotes produced by the Department of Agriculture and Food are available at district offices and the website at www.agric.wa.gov.au

- No. 36/1998: Site assessment for successful revegetation for agricultural areas with less than 600 mm rainfall
- No. 37/1998: Site preparation for successful revegetation for agricultural areas with less than 600 mm rainfall
- No. 47/1998: Weed control for successful revegetation for agricultural regions with less than 600 mm rainfall
- No. 43/1999: Windbreaks for horticulture on the Swan Coastal Plain
- No. 72/2002: Using windbreaks to reduce evaporation from farm dams
- No. 67/2002: Amount of stubble needed to reduce wind erosion

**Other publications**