Citrus Fact Sheet

CITTgroups AUSTRALIA

Windbreaks for Citrus

Citrus trees require a protected environment in order to produce high yields of top quality fruit. Wind protection may be provided in various ways – a row or rows of trees around the planting, single rows within the orchard, plantings of tall grasses between rows of newly planted trees, or construction of an artificial windbreak.

Types of Damage

The following are examples of the damage caused by wind:

- markedly reduced growth rates
- reduced yields
- root damage in young trees
- bark damage at ground level
- bent or fallen trees
- few or no fruit on the windward side
- lesions on the leaves and stems and fruit scarring
- limb breakage
- fallen fruit.

Some of these losses are readily measurable, while others do not become apparent until harvest. There are other invisible effects from wind, including increased evaporation and transpiration resulting from reduced relative humidity and temperatures, from excessive wind movement over the trees. The many surveys and quality control reports that have been produced over the years from packing sheds indicate that rind blemish accounts for most downgrading. Results from a case study following this report indicate that 75% of major blemishes and 87% of minor blemishes of navel oranges in Waikerie, South Australia in 2005 were due to wind damage.

The geographical location of the citrus planting will partly determine the type of windbreak required. Each citrus growing area and each planting will have specific windbreak requirements. For example, a planting close to the coast with constant multidirectional winds may require a substantial windbreak around and throughout the planting. However in drier

Photo 1:Windbreaks provide protection for trees and fruit resulting in reduced rind blemish.

inland areas windbreaks may only be required against the prevailing wind. Hot dry summer winds will measurably reduce the growth rate of young trees and tall grass windbreaks between each or every second row would benefit newly planted trees. Some varieties may also be adversely affected by living windbreaks. For example, in some subtropical areas it may be necessary to consider using artificial windbreaks because tall living windbreaks can cause shading and keep citrus foliage wet for too long. This applies when growing varieties that are susceptible to *Alternaria alternata* or Brown Spot. Mandarin varieties such as Murcott and Nova require good air movement for rapid drying (skirting, good air drainage, and no shade). In this instance if rind blemish is to be reduced then artificial white windbreak material should be considered.

Losses to blemish

Each year wind blemish causes a large percentage of otherwise perfect fruit to be downgraded to either second grade or rejected. In many years the large volume of seconds allows the price received for first grade fruit to be discounted.

The percentage of crops downgraded throughout Australia's citrus growing areas ranges from as low as 10% up to a massive 50% in some years (see case study). The real positive outcomes which can result from established windbreaks are fewer grade 2 fruit with a corresponding increase in Grade 1 and therefore increased returns. The less volume of Grade 2 on the market, the less likelihood there is of discounting Grade 1 prices.

When does wind blemish occur?

A high percentage of rind blemish on fruit is directly attributed to adverse wind events in the first six weeks after petal fall. However significant damage (95%) occurs within 12 weeks of petal fall. (Freeman, 1973). As soon as the petals fall and the small immature fruit is exposed, wind blemish to the rind can occur with any movement of leaves, branches, twigs, dead wood, thorns and even other fruit.

Leaf margins, particularly from hard old leaves are the main cause of this blemish. (Freeman, 1973). The surface of young fruitlets have irregularly raised ridges and bumps on which adjacent leaves tend to rub. The abrasion results in damage to the fruit skin, followed by the release of small quanties of oil on the fruit surface and then the production of repair tissue which becomes corky. Initially this corky material is raised and coarse in texture but eventually wears down to a finer texture usually creamy yellow in appearance. With fruit colour development the scar becomes buff coloured, but the final colour varies depending on the spray program used particularly the amount of copper used.

Other factors

While wind is responsible for the initial fruit blemish, two other factors can aggravate the

Photos 2 and 3: Wind scarring on fruit is a major cause of fruit downgrading.

problem. Poor pruning methods can increase blemish and copper sprays can darken blemish.

Dead wood and long spindly fruit bearing wood resulting from poor pruning practices will increase the amount of blemish. Regular pruning is necessary to remove dead wood, reduce the length of bearing wood and let light into the tree to make inside buds fruitful. The removal of a central limb often achieves this purpose. Fruit protected inside the canopy usually has less wind blemish. In some areas the essential copper sprays used to control disease can darken the appearance of any blemish.

Benefits of windbreaks

From the published literature some of the quantifiable benefits of wind protection have included:

- Improved Grade 1 packouts. Grade 1 fruit was 67% in protected blocks with 40% in unprotected blocks (Revelant, 1987) and 53% in protected blocks with only 30% in unprotected blocks (Freeman, 1976).
- Improved yields due to increased fruit set and size. Yield increases of between 13% and 16% (Freeman, 1976).
- Increased tree canopy growth of between 8% and 12% (Freeman, 1976).

Some additional advantages of well designed windbreaks include:

- Reduced wind speed
- Reduced spray drift and improved spray coverage
- Reduced wind scarring of fruit
- Increased and earlier yields
- Reduced water loss from evaporation by up to 30%
- Reduced soil erosion
- Slightly higher temperatures in winter
- Reduced dust on plants, thereby increasing photosynthesis and reducing the damage caused by scale insects and mites
- Provides a habitat for insects and pollinators
- Provides protection from sun for harvested bins of fruit and for workers

Some disadvantages of living windbreaks include:

- Competition for moisture and nutrients if not managed properly
- Shading
- Material and labour costs
- Occupies valuable land
- Competes with crops for light
- Increased humidity which can slow drying times of foliage and fruit and may favour some fungal pathogens
- Requires valuable water
- Interferes with the movement of machinery
- Not able to be moved
- May act as a heat trap in summer
- In frost prone areas may dam cold or frosty air if not designed properly
- Trees blown over may cause damage
- Possible pest and disease buildup in a crop due to microclimate changes
- Tree seeds/flowers may attract unwanted bird species
- Trees may harbour pests
- Take five to 10 years to be fully effective.

When are windbreaks necessary?

Where wind blemish is responsible for more than 10% of fruit downgrading, and prevailing winds during the first 12 weeks after petal fall exceed 15 kilometres per hour, then serious thought should be given to providing wind protection. Winds stronger than 24kph will cause wind scarring. The minimum threshold for damage is 24kph for one hour (Andy Krajweski).

Whilst there are many good examples both in Australia and overseas of how windbreaks have markedly reduced rind blemish, the decision to install windbreaks needs to be practicable and economic. An analysis of the possible benefits and full cost of the required windbreak protection is recommended. You need to determine the amount of wind blemish that is acceptable in your operation in order to determine the need for primary and secondary windbreaks.

The loss of productive land and projected yield that is forgone for windbreaks should be added to the establishment and annual maintenance costs and equally the increased yield of better quality fruit attributable to the windbreak also needs to be included.

If windbreaks are required then the design, direction, length, depth, permeability, height and type of material (living or synthetic) needs to be thoroughly investigated. A deficiency in any of these areas would cause the structure to fail because the protection provided would be ineffective.

There is no 'one solution fits all' since all orchards are different. However there are some basic rules to follow, which may be varied to suit the particular orchard location and the type of wind events most likely to cause blemish.

Windbreaks, where possible should be designed into any new planting. Windbreaks must be fully costed to include deep ripping, weed control, irrigation, nutrition, canopy management or pruning and the area of productive land lost. Fencing to exclude stock also may be necessary. Failure to undertake these things will result in slow growth, and subsequent 'robbing' of the nutrition and water applied to adjacent rows of citrus trees.

Windbreak Design

Design the position of your windbreaks on paper first. Correcting mistakes on paper is much easier than waiting until after planting is complete. For a windbreak to be effective the following factors need to be addressed:

- Orientation
- Height
- Permeability
- Secondary breaks
- Length
- Traffic/access points
- Shape and width
- Suitable species
- Maintenance.

Orientation

In areas where the damaging wind direction is predictable during the critical 12 week period after petal fall, then the windbreak should be placed at right angles (perpendicular) to that direction. Placed in this position, protection is provided even when the wind shifts up to 30° from the perpendicular. The more the angle exceeds 30°, the less protection provided downwind of the 'break'. Length of the windbreak past the last tree is also a factor.

Where it is possible and practicable, main breaks should be north-south in direction to minimize shading. Property boundaries, topographical features and existing plantings will often prevent the ideal layout.

For those growing areas where there is a lot of variability in damaging winds, windbreaks need to be established along lines which provide the most protection. In countries such as New Zealand and South Africa, where there must be a packout of at least 70% export quality fruit, many growing areas require protection around the whole orchard, with additional internal windbreaks. Indeed, in windier areas, windbreak protected citrus blocks do not exceed two hectares. In South America internal windbreaks divide production units into 3-4 hectare blocks.

Height

The higher the windbreak, the greater the area protected. However **the effective height** of the windbreak is only the **height above the citrus trees**. For example, if citrus trees are 4.5 metres high and the windbreak is 16m high the effective height is 11.5m. Figure 1, *(not to scale)* gives a basic idea of distance and amount of protection from the break.

Most literature seems to indicate that the greatest wind speed reduction is in the 'quiet zone' or 'zone of protection' which extends for a distance

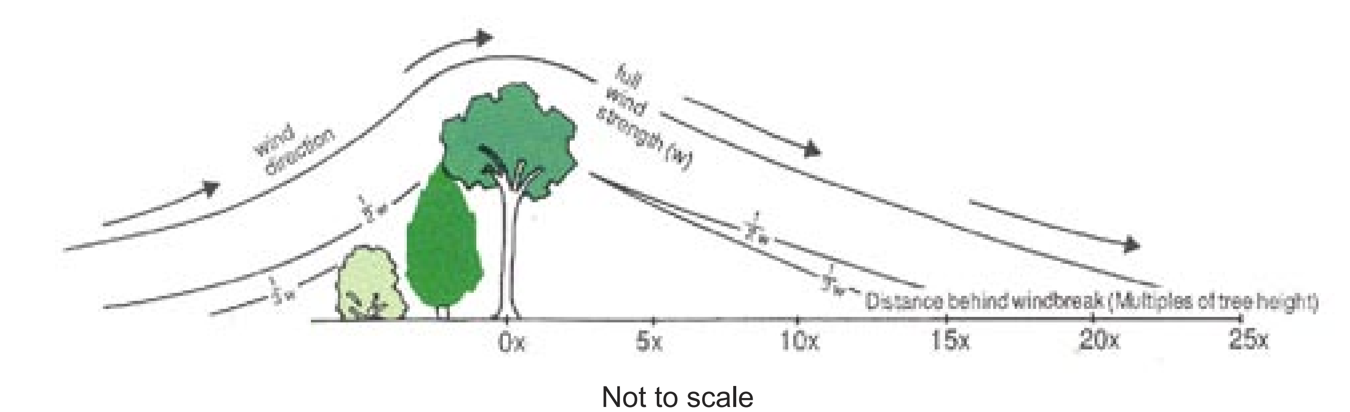

Figure 1: Conceptual presentation of the reduction in wind velocity provided by a windbreak. (Source: Designing Windbreaks for Farms. 1989. Line drawing by Shirley Turner)

of six times the effective height of the windbreak. However, some protection is provided for a distance of 10 times the effective height of the windbreak. The distance of protection will vary with topography. For example, it will be less if the land rises on the downward side and more if the ground slopes away.

The Zone of Protection = (Actual windbreak height – Crop height) x 6 – 10. For example, if the windbreak is 14m high and the citrus trees are 4m high then the best protection will extend for 60 – 100m *on the ground*.

In areas past this 'quiet zone' wind speed will increase until all the benefit from the windbreak ceases. Some literature suggests that some protection is provided for a distance of 30 times the effective windbreak height. Just how much wind blemish is sustained on fruit in trees beyond the 'quiet zone' has not been determined for citrus.

The question is *"how much wind blemish is sustainable for your orchard and how many windbreak rows do I need to achieve my goal?"* The answer to windbreak height and number of windbreaks required is answered in the following quote from the publication 'Trees for Shelter'.

"The National Windbreaks Program also investigated the effects of 'multiple windbreaks' i.e. several windbreaks planted parallel to one another and spaced either 6H or 12H apart (H represents the height of the windbreak). This mimics the plantings used in alley farming and kiwifruit vineyards. Multiple windbreaks were found to provide a high degree of 'regional' shelter, with each progressively reducing the wind speed such that the shelter behind a multiple array of windbreaks was greater than that for an individual windbreak."

Permeability

Another critical factor is permeability, or how much wind is let through. It appears that the ideal permeability is between 45% to 55%. A solid break that allows no wind through causes damaging turbulence on the side it is meant to protect (better to have no windbreak at all). In frost prone areas permeability is important as windbreaks can be responsible for damming cold or frosty air.

Note: The only way to maintain your windbreak at the correct permeability is to have a regular pruning or hedging program in place (at least

Photo 4: A row of Casuarinas that have been hedged to allow more air permeability and to promote more vertical growth as well as to stop encroachment onto public roads.

annually depending on species, age, distance planted and location). It is also important to prune on a slight angle, for example, the base of the trees should be wider than the top. This guarantees that the foliage at the bottom of the trees will receive adequate light in order to keep growing and therefore not lose lower branches creating open areas under the tree which will cause turbulence.

Figure 1 illustrates many of the suggestions contained in the literature. Severe wind events will reduce the protected area. The area of protection will vary on sloping land. Slopes facing the wind will need to have closer spaced breaks and on the opposite slope, breaks will need to be further apart.

Secondary breaks

Orchards may require secondary breaks for large blocks. The spacing of these secondary breaks will depend on the height of the primary break, the strength of the most damaging winds and the slope of the land. In addition, allowance in the cost needs to be made for modified protection at access points. Decisions need to be based on how much wind blemish is acceptable in your operation. A guide to the spacing of secondary breaks may be calculated from Figure 1 and also from the amount of blemish being sustained in trees further from the break. In South Africa, and some areas in Australia, three poplar trees have been used at the end of a row to decrease wind velocities when there is no room to put in a full windbreak and turning lane.

Length

Where only a single windbreak is required, the length of the break past the citrus block governs the amount of downwind protection. Wind will curl around the end of a break causing turbulence.

The recommendation is that the maximum length of a break should be12 times the mature height of the break. Connecting breaks to existing forest or shelter belts improves protection. If possible, work with neighbours if appropriate to plan mutually beneficial windbreaks.

Machinery access

The continuous nature of cultural activities in citrus orchards demands practicable access. It is critical that access through a windbreak does not allow the wind to funnel through and cause severe damage to adjacent trees. Access to all blocks within a protected orchard needs to be well planned. Several suggested ways to protect access areas are shown in Figure 2.

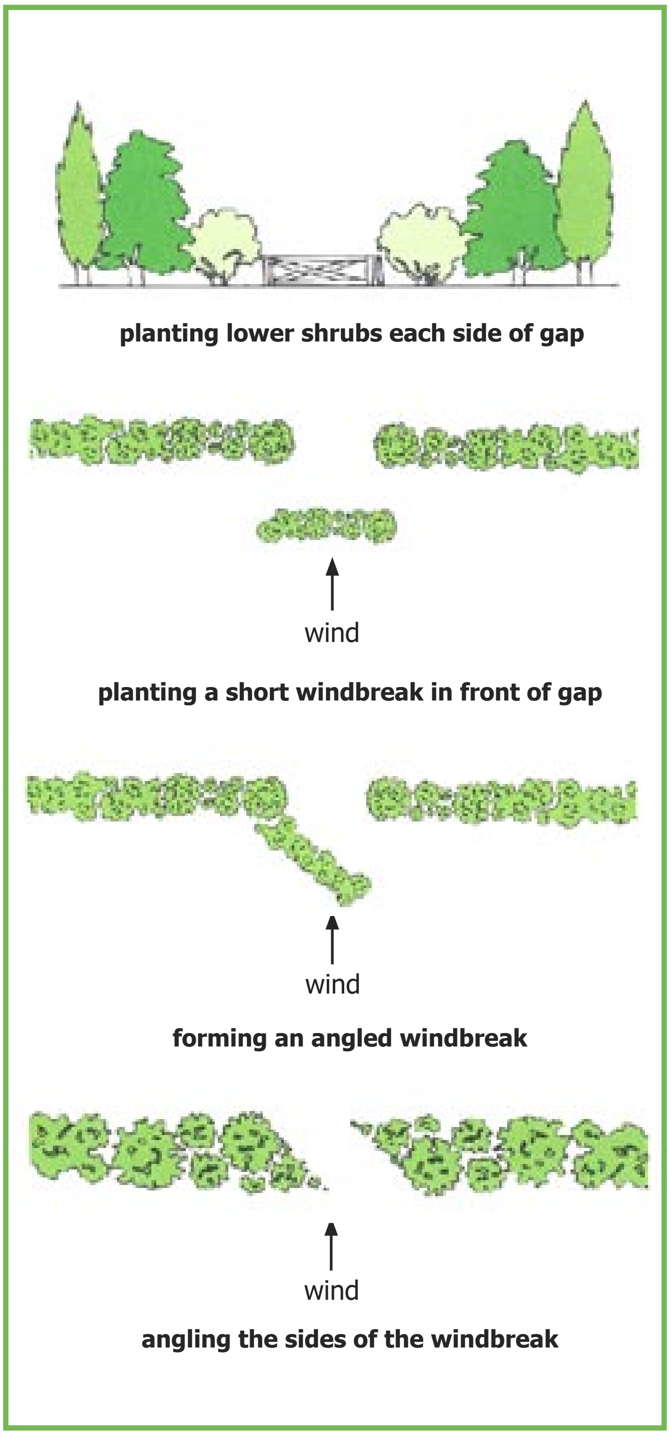

Figure 2: Possibilities for protecting machinery access points. (Source: Designing Windbreaks for Farms. 1989. Line drawing by Shirley Turner)

In frost prone areas planning is important as windbreaks can be responsible for damming cold or frosty air. This can result in frost damage to trees and fruit. The windbreak design needs to include an air drainage break in the lowest part of the protected block so cold dense air drains away from the crop.

Photo 5: Three Poplar trees are used at the end of tree rows in South Africa and some parts of Australia when there is not enough space for a full windbreak row.

Shape and width

Figure 1 indicates one type of windbreak, showing different sized trees, and indicating that the tallest tree does shed its lower branches when mature. This shedding of lower branches would leave a gaping hole if there were no lower storey tree protection. There are also many successful windbreaks using a single staggered row of trees that do not shed their lower branches if pruned correctly. Single rows of specific type bamboo breaks can also be used but these can grow into a dense stand and need thinning to allow for the required permeability. Which ever type is chosen, correct permeability is a major consideration.

Photo 6: A windbreak of mature Eucalypts inter-planted with bamboo to compensate for the loss of the Eucalypt's lower branches.

Suitable tree species

Throughout the citrus industry, many native and exotic species have been used as windbreaks. Some have been successful and others have not. There is no one species which fits all the needs of a windbreak tree, including: not losing lower branches, fast growing, non- invasive root system, cheap to buy, upright growth habit, tolerance to drought, salinity and water logging, tolerance to herbicides, immunity to pest and diseases, ability to be side trimmed, and many more.

In addition, the wide variations in the citrus growing environment in Australia does not allow for a situation where one group of species fits all orchards. Each State has lists of suitable species for different regions. There are a range of Eucalypts, Casuarinas, Pines, Cypress, Alders and Poplars that allow for a choice of several species to suit most situations.

The following comments regard the most commonly used species.

Native species

One of the main advantages of using native species is that they are adapted to the local soils and climate.

- ***Eucalypts***

Many Eucalypts lose their lower branches as they mature and so become less effective as single row windbreaks. When selecting Eucalypts species choose locally adapted species. On the central and north coast of New South Wales, a number of eucalypt species are used successfully as boundary windbreaks, including: tallow wood (Eucalyptus microcorys) and turpentine (Syncarpia glomerulifera). In central NSW, several species have shown promise including: Paddy's river box (E. macarthurii), narrow-leafed peppermint (E. radiata) and wattle-leaved peppermint (E. acaciiform). In the Riverina, one species has shown outstanding potential, E. platypus var platypus which is medium sized, retains its lower branches, is good on heavy soils, salt tolerant and can be hedged.

Photo 7 : A row of mature turpentines on the Central Coast of NSW (Syncarpia glomerulifera).

- ***Casuarinas (she-oaks)***

Casuarina and *Allocasuarina* species are both commonly known as she-oaks. They respond well to side pruning, maintaining an even permeability when regularly trimmed. These species are relatively fast growing after establishment in the first season. *Casuarinas* have been widely used in Australia, New Zealand and South Africa for horticultural windbreaks and are regarded as having most of the desirable qualities for windbreaks. *Casuarinas* are dioecious – that is, male and female flowers are produced on separate trees. In late spring the male trees sometimes appear to be dying because of the rusty coloured flowers produced on the ends of the needles. The female trees can sometimes produce large numbers of cones at the expense of foliage growth.

Photo 8: A young Casuarina windbreak

There are many species of casuarina with a wide range of growth habits and climatic adaptation. *Casuarina cunninghamiana*, or river she-oak, has proved to be the most adaptable to varying environments and the most suitable in tree form and development. Establishment and initial tree growth is dependent on the presence of an actinomycete organism *Frankia* in the soil, which stimulates the development of nitrogen producing nodules on the roots. *C. cunninghamiana* responds well to irrigation but is tolerant of some water stress. Trees will respond to fertilisers when the existing soil nutrition is poor, but moderate natural fertility is usually enough.

Late winter frosts can cause damage to the tips of the previous season's growth. Severe frosts, with temperatures less than -8°C may cause yellowing of foliage. Seedlings from a locally adapted seed source in the colder areas may reduce this problem. Pruning or trimming in late spring encourages a greater amount of young growth. This can be repeated every second year to maintain the best control over growth and windbreak porosity. In New South Wales coastal districts, both *C. glauca* (swamp oak) and *Allocasuarina littoralis* (forest oak) have been used successfully.

Despite the success of *Casuarinas*, some growers have experienced problems with poor growth and yellowing of the needles. Problems have included:

- poor growth in shallow soils with poor drainage (*C. glauca*, 'swamp oak' tolerates wet sites)
- *Phytophthora cinniamomi* root rot (often associated with poor drainage)
- herbicide damage – usually glyphosate on immature bark
- lack of the actinomycete organism (unusual)
- frost damage.

- ***Other native species***

The potential of other species is largely unknown for many districts. Melaleucas are ideal for small intensive enterprises and as understorey species, but in districts with a high risk of frost, Melaleucas can suffer from both winter and late spring frost damage on the new season's growth. Wattles are fast growing and produce a good hedge but they are generally short-lived. They are also a host for various tree borers. Hakeas (*Hakea saligna*) have been used in South Africa and respond well to hedging but can become too dense.

Exotic – evergreen
In the past various pines and cypresses have been used as windbreaks, including Pinus radiata (Radiata or Monterey pine) and P. elliottii (Slash pine). Although pines will grow fairly quickly and can tolerate drier and poorer growing conditions they have a number of drawbacks. As the trees age they become bare at the bottom and dead limbs can cause 'holes' in the breaks, they do not respond to hedging and are highly flammable. Cypresses are slow growing and tend to form a hedge which is usually too dense for efficient wind protection. Today these species are not normally recommended for windbreaks.

Exotic – deciduous
The three main deciduous groups used include Populus (poplars), Salix (willows) and Alnus (alders). All are moderate to fast growing, and respond well to intensive management and side trimming. The willows are especially fire tolerant. The main disadvantage with deciduous species is the loss of wind protection in winter when the trees are bare. All three species are susceptible to silver leaf fungus and should not be used in areas growing stone and pome fruit.

Hybrid Willows
Rapid growing hybrid willows were introduced into Australia in 1980. They were easy to propagate, grew rapidly and were free of rust and many plantings were established. There are many clones of willow and they differ in their tolerance to pests, disease and water stress. The potential 'weed' status of willows is currently under investigation and hybrid willows are not being generally recommended. Plantings of willows should be limited to male clones (NZ1002 and NZ1184) and no trees should be planted near watercourses. Ensure the reliability of nursery stock and do not buy 'hybrid willows' but specify the clone by name and number.

- ***Alders***

Alders (*Alnus species*) are slower growing, deep rooted and can utilise lower water tables in heavier soils. They perform best in their native conditions of cool, moist temperate regions and are limited to good soils in the cooler districts. There are a number of species some of which are still being evaluated.

Grasses

Various grasses have been used as short-term windbreaks for protection of young trees whilst the main windbreak is established and they are also used between tree rows. One of the most notable of these is barner grass (Pennisetum sp. a tall growing strain of elephant grass) which has been used on the central and north coast of New South Wales, Queensland and some of the warmer inland districts. This grass is a vigorous perennial that can grow up to 3m tall. It is robust and has provided

Photo 9: Sudax used as a temporary windbreak for young trees.

Photo 10: Barner grass used as a temporary windbreak.

a rapid-growing thick shelter, however it is very flammable. Some bamboos such as Bambuso oldhami can create a similar or larger windbreak but these have not been accepted commercially.

Barner grass and bamboos are equally competitive and difficult to eradicate once established, creating a potential weed problem especially in tropical and subtropical areas. Various annual cereal grass species such as hybrid sorghums and Sudax can provide good protection to young trees. The hybrid sorghum 'Jumbo graze' can reach up to 3 m and will not reseed.

Tree spacing

Traditional spacings of three to four metres between windbreak trees are too wide for wind protection early in the life of the planting, particularly when single row plantings are used. A one to two metre spacing has proved satisfactory in Australia, New Zealand and Europe for many of the recommended windbreak trees, such as the deciduous and Casuarina species, but not for eucalypts. For boundary windbreaks, wider spacings can be used particularly with multiple row plantings, with each row offset to cover the gaps in the adjacent row. Farm Trees Booklet No. 5, *Designing Windbreaks for Farms*, has more details.

Problems

Windbreaks are designed to overcome problems, but in some cases they can create them.

• ***Will windbreak trees block pipes and drains?*** Willows in particular have a reputation for blocking and breaking drains. Various species can also cause problems with pipes. Avoid planting species such as willows within 40 to 50m of pipes. Ripping to a depth of 0.75 to 1.0m at about 1.5m on either side of the windbreak will reduce roots moving into the crop. Only rip one side each season to prevent creating unstable trees with poor anchorage. Ripping should not be carried out on species that sucker as disturbing the roots increases suckering.

• ***Do windbreaks compete with the crop?*** Windbreaks can compete with the crop for light, space, water and fertiliser. Shading can specifically reduce fruit quality, flower bud formation and crop yield. A north-south orientation for the windbreak rows will help overcome this problem by giving the adjacent crop rows direct sunlight for at least part of the day. Where the north-south orientation is not possible, the effects of shading must be accepted or the distance between the crop and the windbreak increased. The level of competition will depend on species planted, soil type, amount of water and nutrients applied, distance planted from the crop, final windbreak height, and frequency of pruning. Regular maintenance is critical.

Photo 11: Windbreak trees provide protection but they cause shading. Orientate your windbreak trees in a north-south direction when possible to reduce shading.

Establishment and Management

Establishment

Perimeter windbreaks with suitable access points should be established at least 12 months prior to planting the citrus trees. They require as much care and attention as the young citrus trees. Irrigation, fertilizing and weed control are essential activities. Good soil preparation and weed control prior to planting will favour early and rapid establishment. Care should be exercised in the type of herbicides used as many native species are sensitive to damage. Establishing internal windbreaks requires an equivalent level of management. Consider and cost the use of plastic mulch or weed matting and trickle irrigation underneath the windbreak for initial establishment.

Management

Proper management is essential for getting the best efficiency out of the windbreak. Management includes: weed control, nutrition, irrigation, pruning and pest and disease control.

- **Weed control**

Remove weeds before planting as excessive weed growth will compete with the newly planted trees. Both synthetic and natural mulches can be used to reduce weed problems. Contact herbicides can be used however care is needed to avoid spraying the immature green bark of young trees. Hand held applicators with a shield should be used.

- **Nutrition**

Adequate nutrition needs to be provided, particularly for the exotic deciduous species. Willows are the most demanding and alders the least. Native species will respond to fertiliser application, but care must be taken to select a fertiliser formulated for native plants.

- **Irrigation**

Most horticultural windbreaks require supplementary irrigation during summer months. Permanent irrigation is recommended for young trees in drier areas. Native species may not develop a good deep root system if irrigated. In high rainfall areas some tree species will grow well with little irrigation, but requirements vary between species.

- **Deep ripping**

Deep ripping may be required annually and is best done when the ground is damp. Depending on circumstances deep rip to a depth of one metre. Try and vary the rip site from year to year to stop roots growing below the rip line and up into the root zone of the crop. Where you have citrus planted on both sides of a windbreak deep rip alternate sides.

- **Pruning**

Pruning and trimming are needed to maintain the correct shape and permeability of the windbreak. Encouraging a single leader is essential in young trees. Depending on vigour and species, older trees can be hedged every second or third year. The ideal timing for pruning varies with species. Casuarinas should be pruned in late October, just prior to the growth flush. This ensures good development of new lateral growth.

- **Pest and disease control**

The use of pesticides to control insects and diseases should be kept to a minimum and have minimal impact on the local environment. Scale, borers leaf eating and sap sucking insects are the most common and need to be monitored.

Artificial Windbreaks

A variety of polythene mesh products are available with known porosities which makes it easy to select the right permeability. The initial expense may be a little higher than a living windbreak but mesh will satisfy all the requirements of the ‘perfect’ windbreak. Advantages include: they are instant, are very low maintenance and are more easily installed into an existing planting. The life of the mesh can vary but most probably last for up to 10 years. However, as artificial windbreaks are normally not as high as living trees, they need to be closer together in order to achieve the same result.

There are examples of using poly mesh over the whole planting. A thorough economic analysis of this would be wise, perhaps targeting particular niche markets. The August 2003 edition of *Australian Citrus News* contained an article on a 5.5ha fully enclosed windbreak structure. The story reported that this 17% shade hail netting was producing a 98% packout of one of the summer navels.

Photo 12: An artificial windbreak

Pests and Biological Control

Integrated pest management (IPM) is becoming essential for sustainable pest management. This work would not be complete without comments from Dan Papacek, a pests expert with both national and international recognition.

"We have always considered windbreaks to be an advantage with regard to biological control. Windbreak trees can provide refuge for some beneficials such as predatory mites, ladybird beetles and lacewings. Additionally some windbreaks are also pollen producers. The pollen can provide supplementary food for predatory mites. Generally biological diversity is a good thing in an orchard and the presence of windbreak trees can contribute to this. I have heard of suggestions that windbreaks can harbour pest species but this has not been our experience. Generally if they do have pests present then the natural enemies will also coexist (unless some disruption has occurred).

In South Africa there have been reports that Casuarina species as windbreaks were likely to increase the presence of Scirtothrips in citrus orchards. In coastal orchards, where higher humidity and higher rainfall incidences occur, closely planted windbreaks may restrict airflow and sunlight and hence can cause an increase in the occurrence of diseases such as Alternaria alternata (Brown spot) and Guignardia citricarpa (Black spot.)"

Common mistakes with windbreaks:

- not planning correctly
- pruning off bottom branches
- rows too short
- not protecting access ways
- not immediately replacing trees that die
- not pruning regularly
- not irrigating
- only planting one when two rows are needed
- planting too close to the crop
- not deep ripping regularly or deep enough
- not varying the position of the rip line.

Case Studies

John Cox, Waikerie, South Australia

Fruit quality audits for navel oranges have been kept for four years on 31 different sites at properties owned by John Cox at Waikerie, South Australia. Between 100 and 150 fruit are examined at each site for various types of rind damage. Table 1 shows the average and maximum percentage of fruit with major and minor wind blemish across all sites. Other blemishes were also recorded including insect damage and albedo breakdown. However, in 2005 wind damage accounted for 75% of all major blemishes and 87% of all minor blemishes.

Blemish definitions are taken from the Riversun manual. A 'major wind blemish' is defined as light coloured marks greater than or equal to 20mm surface area, deep (>1mm) or darkened marks greater than or equal to 12mm surface area. There is a zero tolerance for this type of blemish in grade 1 fruit. A 'minor wind blemish' is defined as light coloured marks covering an area less than 20mm, deep (>1mm) or darkened marks, but covering an area less than 12mm. There is a 10% tolerance for this blemish in grade 1 fruit.

On one of John Cox's properties there are two Washington Navel blocks separated by a road where a wind break was established five years ago on the southern side of the property. Most of the prevailing winds come from the south east although there are also some strong north winds at various times after petal fall. This wind break is comprised of *Casuarina cunninghamiana* at a 1.5m spacing. They have been hedged and were 10m to

Photo 13: A windbreak of Casuarina trees on John Cox's property at Waikerie.

Year	Average % Wind Blemish		Maxium % Wind Blemish	
	Major	Minor	Major	Minor
2002	17	5	40	19
2003	20	11	32	19
2004	14	5	26	8
2005	24	8	41	17
Average all years	***19***	***7***	***35***	***16***

Table 1: Blemish results from fruit quality survey, John Cox, Waikerie, South Australia.

Year	% Wind blemish in block without Wind Break		% Wind blemish in block with Wind Break		Percent Reduction	
	Major	Minor	Major	Minor	Major	Minor
2003	26	8	18	2	30.8	75.0
2004	16	5	10	4	37.5	20.0
2005	21	14	12	9	42.9	35.7
Average	**21.0**	**9.0**	**13.3**	**5.0**	**36.5**	**44.4**

Table 2: Results of fruit quality audit between blocks with and without windbreaks.

12m in height in early 2006. Their height was less during the time of the navel fruit quality audits in 2002- 2004.

Table 2 shows that there has been a 30% to 40% reduction in wind damage in the block with protection from the windbreak, which has reduced the amount of blemished fruit (both major and minor) from 30% to 18%. Whilst this is only a small study it is an actual situation. The average of three years indicates a reduction of 12% in the amount of wind blemish sustained behind the windbreak. For every tonne of fruit over the three years 2003-2005, there were an additional six boxes of fruit available for the grade 1 market. This equates to an extra 240 boxes of better quality fruit based on production of about 40 tonnes per hectare. In terms of dollar value, using average returns for United States (US) grade 1 export fruit, of $800/tonne in 2001 and $250/t in 2002 a 12% reduction in down grading due to wind damage represents increased returns of between 0.12 X $250 X 40 t/ha = $1,200/ha and 0.12 X $800 X 40 t/ha = $3840/ha. This example illustrates the dollar value in reducing wind damage to trees.

Rod Hand, Colignan, Victoria

Rod has established sorghum as a temporary windbreak for protecting young trees. Currently

Photo 14: Sorghum windbreaks planted to protect newly established citrus trees under sprinkler irrigation. Trees established Spring 2003.

he plants a row of sorghum every third row of trees. The sorghum is irrigated with a drip line and receives the same water and nutrients as the young citrus trees. When the citrus trees grow bigger the drip line in the sorghum will be moved into the row of citrus trees. Trees directly beside the sorghum windbreak show better growth than rows further from the break. For future plantings, Mr Hand will plant a sorghum windbreak every second row of citrus trees. Tree spacings are 7m x 3m for the sprinkler irrigated block and 6m x 2m for the drip block. Mr Hand will plant the sorghum seed at less than the recommended sowing rate so as to achieve good windbreak height sooner and allow more porosity.

Photo 15: Improved tree growth in rows directly beside the sorghum wind break, using drip irrigation. Trees planted December 2004.

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