ARTIFICIAL WINDBREAKS AND THE REDUCTION OF WINDSCAR OF CITRUS

BRIAN FREEMAN
Gosford Horticultural Research Station,
P.O. Box 720, Gosford, New South Wales, Australia

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Abstract. Windscarring is a rind blemish problem of citrus in Australia. It occurs almost exclusively within 12 weeks of petal fall in late October, and this coincides with the period of the strongest and most frequent winds. Artificial windbreaks of polyethylene woven fabric of 44% permeability were constructed 5.2m (17 ft) high by 61m (200 ft) long and located in an exposed grove with a known history of badly scarred fruit. Mean packouts of top grade fruit for protected and exposed trees were 53% and 30% respectively. Protected trees outyielded exposed ones on a unit canopy area basis by 17% and 21% for fruit number and weight, respectively. Wind-speed reduction ranged from 25% to 70% between 2 parallel barriers 50m (160 ft) apart; and wind run was correlated with windscar severity. The basic issues of wind protection and the practicability of artificial windbreaks are discussed.

Windscarring (Fig. 1.) is a common cause of downgrading of citrus fruits in Australia (8), South Africa (13), Florida (14) and California (16). It is initiated almost exclusively within 12 weeks of petal fall (2, 5, 8) and can assume several different forms according to the time of injury within this period (9).

Fig. 1. Windscar on Valencia oranges. This injury occurred when the fruit were less than 12 weeks old.

Control of windscar requires wind protection. Wind speeds in excess of 25 km h⁻¹ (15 mph) are sufficient to cause scarring (13, 18). Adequate wind protection was shown to minimize blemish problems and improve the grade of the fruit, while at the same time increasing tree growth and yield (1, 3, 4, 15, 16, 18, 24, 26).

This study aimed to evaluate artificial windbreaks and their effects upon fruit yield and quality in an exposed citrus grove. Preliminary results were reported by Freeman (7) in 1973.

Materials and Methods

‘Valencia’ sweet orange trees, 28 years old and a rough lemon (Citrus jambhiri Lush.) rootstock in a commercial orchard, exposed to the west, were used.

The grove had a history of badly scarred fruit. The trees averaged 3.3m (11 ft) in height and were planted 5.8m (19 ft) apart in east-west rows. There were 10 rows of 14 trees each in the block.

An artificial windbreak system (Fig. 2) consisting of 2 polypropylene woven fabric barriers, 5.2m (17 ft) high, were constructed in July 1971. The fabric was later replaced by a more UV-stable polyethylene. The fabric were 44% permeable (i.e. 44% air space) and were considered ideal for wind protection (6). The barriers were each 61m (200 ft) long and intersected each other at their mid points; thus dividing the block into 4 quadrants. The east-west barrier was removed in October 1972, the north-south one left intact and a new barrier was erected parallel to this and 50m (160 ft) to the east. The block was then divided into 2 sections. Section A contained 80 trees and was between the barriers while section B contained 60 trees windward (west) of the barriers.

Continuous wind direction and velocity records were maintained with a Munro IM 184 chart recording anemometer having a cup height of 6.1m (20 ft). Six Munro IM 119A cup counter anemometers were positioned at varying locations within the block to determine wind reduction patterns by the windbreak. Cup height was 3.0m (10 ft). Readings were also taken in the same block prior to windbreak construction. The total yield per tree was determined at the first harvest in November 1972. A random subsample of 150 fruits per trees was selected and graded for size and packout. Fruits with no more than 15% of surface blemish were included in a standard grade. A blemish severity index was also derived (equation 1).

\[ B = \frac{a + 2b + 3c}{n} \]  

equation 1.

Fig. 2. One of the two parallel windbreaks used in the experiment. It is 61m (200 ft) long, 5.2m (17 ft) high and the poles are spaced at 6.1m (20 ft) intervals.
where \( a \) = the number of fruits with 0 — 5% surface area blemished, \( b = 6 - 15\% \), \( c = > 15\% \) and \( n = \) the total number of fruit.

The subsequent crop was harvested in February 1974. A blemish severity index was derived as before but was expanded to 5 classifications (equation 2),

\[
B = \frac{a + 2b + 3c + 4d + 5e}{n}
\]

where \( a \) = number of fruits with 0 — 5% surface area blemished, \( b = 6 - 10\% \), \( c = 11 - 15\% \), \( d = 16 - 25\% \) and \( e = > 25\% \). Similarly, the packout range was increased to choice (0 — 5% surface blemish) and standard (0 — 15%) grades.

The canopy area of each tree was determined each year according to the method of Serfontein and Catling (21).

**Results**

Wind reduction by the windbreak.

The data are summarized in Figure 3 and apply only to 1973-74. The maximum wind reduction was 24% in the center of the block prior to the erection of the windbreaks. Wind reduction on the southern side of section A, between the two parallel barriers ranged from 83% to 55% at distances of 2H and 7H leeward of barrier A respectively (H = Height of windbreak). On the more exposed northern side, wind reduction ranged from 42% to 10% also at distances of 2H and 7H from barrier A respectively. The average wind reduction, between the barriers, taken as the average of all rows when westerly winds were predominant, ranged from a maximum of 70% at 2H to 37% at 7H. All wind measurements were recorded when W-NW winds were blowing as the majority of all blemish-inducing winds in this area were shown to be W-NW in origin (7).

Yield.

The mean yield, with respect to fruit density in the canopy, of all trees in the two eastern quadrants (NE and SE) in 1972-73 was 13.2% greater than that for the exposed western (NW and SW) quadrants. The greatest yield difference was 15.9% in favor of the highly protected SE quadrant compared with the exposed NW quadrant. The SE quadrant out yielded the NW quadrant by 30.4% in terms of fruit volume. This reflects the increase in fruit size and number (Table 1) as a result of wind protection.

Table 1. Mean values of crop variables recorded in 1972-73 and 1973-74.

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>1972-73</th>
<th>1973-74</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>NE</td>
<td>NW</td>
</tr>
<tr>
<td>Yield</td>
<td>0.180</td>
<td>0.170</td>
</tr>
<tr>
<td>—kg/m²</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>—oranges/m²</td>
<td>28.4</td>
<td>28.4</td>
</tr>
<tr>
<td>Size—mean count/bu.</td>
<td></td>
<td>161</td>
</tr>
<tr>
<td>Blemish index</td>
<td>1.74</td>
<td>1.79</td>
</tr>
<tr>
<td>Packout—% Choice grade</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>—% Std. grade</td>
<td>83.1</td>
<td>80.4</td>
</tr>
<tr>
<td>Canopy area—% increase</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

*1 field case = 1.6 bushels.

**Packout.**

Wind protection resulted in a reduction of windscar rather than its removal. This is reflected in the smaller blemish indices and increased packout in the leeward zone (Table 1) in both seasons. The adjusted means of fruits in Choice grade were 53% and 37% for protected and exposed trees respectively in 1973-74. Similar results were experienced the previous year but the single packout classification masked much of the real effect. Trees with the highest yields were also those with the lowest blemish indices and were located in the regions of least wind. A highly significant positive correlation, \( r = 0.62 \), existed between mean blemish index and angular percent of normal wind (8).

**Tree growth.**

Tree canopy area increased by 12% and 8% in the leeward and windward zones, respectively during the 12 month
period 1973-74. The exposed trees were characterized by hardened leaves which were often rolled with signs of obvious mechanical injury. Trees behind the windbreak had larger and more flattened leaves and the trees appeared to be more healthy and vigorous.

Discussion

Wind reduction by the windbreak in this experiment was similar to that found for other systems (6, 20). The wind profile on the northern side of the block indicated that this was the zone of least protection between the barriers. This was due to "end effects" in which winds curl around the ends of the windbreaks thus minimizing their influence. End effects were not apparent on the southern side where maximum wind reduction occurred due to a Cypress pine (Tamarix spp.) windbreak 6.0m high in an east-west orientation adjacent to the block of trees in question. The ratio of windbreak length to height was 11:1 in this experiment. van Eimern et al. (6) considered that the ratio should be at least 11.5:1, while Gloyne (12) suggested 20:1. The greater the ratio, then the smaller the proportion of the leeward zone lost to end effects. Adjusting the data for end effects by neglecting the 3 outer rows on the northern side markedly improved the means in section A but had little or no effect in section B.

This experiment showed that wind protection in exposed groves could produce significant increases in fruit quantity and yield. Similar benefits resulting from windbreaks have been reported for a range of other crops (6, 10, 11, 17, 19, 22, 23, 25). The improvement in yield as a result of wind protection was a consequence of increased fruit size and fruit set. The fruit growing region in which this experiment was done experienced strong desiccating W-NW winds during the fruit-set period and it appears that their debilitating effects upon fruit set were favorably modified by the windbreaks.

The cost of protection is from $A.60 to $A.80 per acre per year under Australian conditions with parallel artificial windbreaks spaced at 10H intervals. The cost depends upon the type of fabric used in construction. This means an economic return within 2 to 4 years and annual net profits up to $450/acre depending upon current market fruit prices. The advantages of artificial shelter are the relatively small amount of space utilized and the absence of competition from water, light and nutrients, major drawbacks of natural windbreaks. The extent of protection leeward of windbreaks is generally 4 to 6H maximum and is acceptable to 10 to 15H (6, 20). A wind reduction of 30% or more was considered necessary to minimize wind scarring in this experiment and this was achieved successfully with two barriers spaced 9H apart.

A full knowledge of prevailing wind data is essential prior to the construction of artificial windbreaks. Consideration should also be given to the local topography and the influence of leeward or windward slopes upon wind velocity, direction and turbulence. On a windward slope parallel barriers should be spaced closer than on level ground, while on a leeward slope they may be spaced further apart. The effectiveness of a windbreak is maximal when the wind is 90° to the barrier, eg. maximum protection against a westerly wind is achieved with a north-south barrier. If the wind is blowing at 45° to the barrier then the zone of protection is reduced by approximately half.

These considerations of windbreak effectiveness generally hold true for crops that are up to but not greater in height than 75% of the windbreak height.

Literature Cited