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# EFFECT OF AN ARTIFICIAL WINDBREAK ON RIND BLEMISH AND YIELD OF HAMLIN ORANGE

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*Abstract.* **The most severe factor lowering grade of fresh fruit in a well managed citrus grove is superficial rind blemishes. This normally results from abrasion of very small fruit rubbing on leaves and twigs. Winds of 10 mph and greater have been found to be responsible for this damage. This experiment was designed to test the effectiveness of an artificial windbreak on rind damage and yield, in a mature "Hamlin" orange (*Citrus sinensis* (L.) Osb.) grove, over a 2-year period. Of the factors studied, differences due to protection of trees from the windbreak, were either inconsistent with wind speed and direction, or so small as to be of little economic importance. The "end effects" of the windbreak were insignificant. Wind data indicates that the north-south direction of the windbreak is best, however, damaging winds came from all measured sectors frequently enough to cause damage.**

Wind injury to the surface of fruit is a very common cause of reduced packouts in many citrus growing areas of the world (1). In Florida it has been found to be the most severe factor in certain years (5). Windscar is most commonly produced by the edges of leaves rubbing on the young fruit. This occurs almost entirely during the first 12 weeks after blossom fall (2, 3). It has also been observed that during the first week or two the calyx actually protects the young fruit to some degree while its radius is larger than the fruit radius (4).

As early as 1858, Sir Francis Beaufort published a wind force scale stating that winds of 8-12 mph caused leaves and small twigs to be in constant motion. More recent observation with wind scarring of citrus places a threshold at around 10 mph.

This study was initiated to determine if an artificial windbreak could economically modify wind within a grove to the extent that fruit damage could be reduced.

## Materials and Methods

Hamlin orange trees on rough lemon (*C. jambhiri* Lush) rootstock, planted in 1942, were used. They were in a commercial grove located in the Groveland, Florida area on Astatula sand, 0-12% slope. Trees were spaced at 30 feet by 30 feet. They were hedged to establish an 8 foot middle and topped to 16 feet on a routine program. Trees received 250 pounds of nitrogen and potassium per year.

A windscreen was erected in a north-south direction, 10 rows into the grove on the west side. The screen was 30 feet tall and 900 feet long. The windscreen was constructed by attaching five, 6 foot wide strips of 47% polypropelene shade cloth, to wires running horizontally between poles. The 5 strips were then wired together to produce a solid screen. The poles were classified as number 7, creosoted. The poles were 35 feet long. The 5 feet placed in the ground was anchored by two 10 foot long deadmen, cut from other poles, and wired to the upright pole just below the ground surface. A cable was run along the top of each pole, from which the screen could be attached, to reduce sag. Diagonal cables were also run, one on each side of the screen, forming an X between each pole. These were wired to the horizontal wires they crossed. This grove middle was hedged to 18 feet to provide passage along each side of the screen.

Continuous wind speed and direction were recorded over the study period. This was done at a 30 foot elevation, 150 feet south of the south end of the windscreen and at a 60 foot elevation, 1300 feet northeast of the screen. The average wind speed and direction was estimated from the recording charts for each 10 minute period during the duration of the study. The average velocity was transformed to the appropriate Beaufort Wind Scale Force (Table 1). This enabled tabulation of the total number of minutes the wind blew from each of the 16 compass points at each wind force.

Fruit samples were taken for yield, fruit weight, and windscar determinations. All trees were harvested individually for tree yield. This was determined by harvesting each tree separately and measuring to the nearest one-half inch the depth of the fruit in a standard 26 or 26-1/2 inch deep pallet box. Inches were then converted to standard field boxes.

Windscar was determined from a 25 fruit sample taken from each tree prior to harvest. Six fruits were taken from the top to the bottom of each tree on each of 4 sides. One additional fruit from the inside of the canopy completed the sample. Fruit were divided into seven catagories of damage as follows:

a—no windscar
b—1-5% of surface scarred
c—6-10% of surface scarred
d—11-15% of surface scarred
e—16-20% of surface scarred
f—20-25% of surface scarred
g—greater than 25% of surface scarred

A rating for each sample was derived from the formula:

$$\frac{Oa + 1b + 2c + 3d + 4e + 5f + 6g}{a + b + c + d + e + f + g}$$

Table 1. Beaufort scale.

| Force | Wind Speed (MPH) |
|---|---|
| 1 | 0-5 |
| 2 | 5-7 |
| 3 | 8-12 |
| 4 | 13-18 |
| 5 | 19-24 |
| 6 | 25-30 |
| 7 | 31 + 38 |

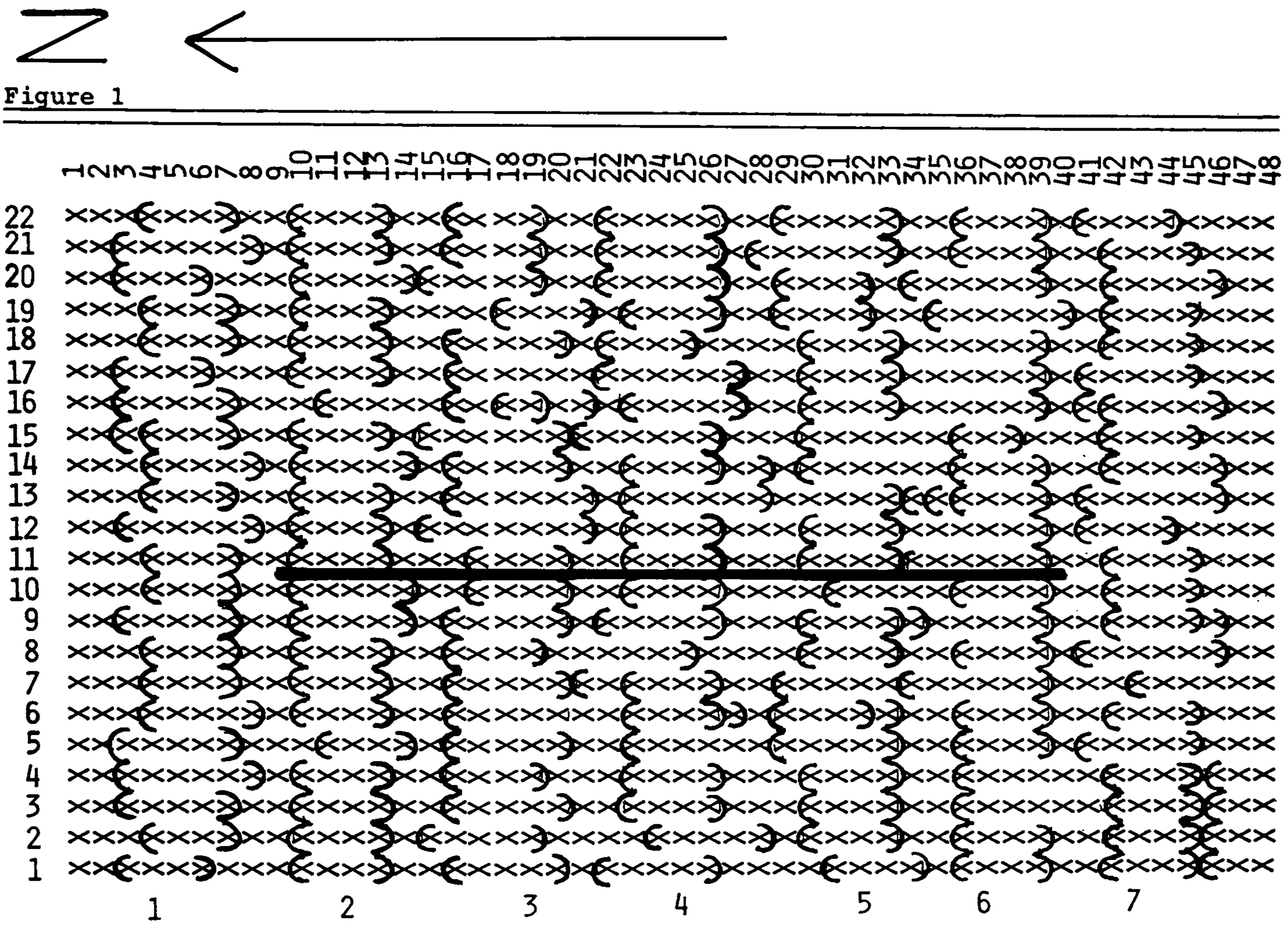

Figure 1

where *a* through *g* equaled the number of fruit in each grade catagory.

Fruit weight was determined by weighing the 25 fruit sample taken for the windscar rating of each tree.

Two statistical designs were used. To determine the effect of distance from the screen, 28 trees were chosen in each of 10 rows to the west of the screen and 12 rows to the east. These 28 trees were divided into 7 groups of 4 trees each. Groups 1 and 7 were just to the north and south of the screen. The other 5 groups were behind the screen, see Figure 1. This provided 32 treatments with 28 replications. Rows 11 and 12 on the east side were considered check treatments.

To study the possible end effects of the windscreen, the 7 groups in each row were made treatments with 4 replications. Six hundred sixteen trees were studied over a 2 year period.

## Results and Discussion

*1976 Row Effects.* Yield Average yield per row did differ, however, none yielded more fruit than rows 21 and 22 which were considered to be check treatments (Table 2). On the east side of the screen there was a highly significant correlation showing yields increased as distance from the wind screen increased (Table 3). This was not significant on the west side however. Yield appeared lower next

Table 2. Windscreen data in 1976.

| Row | Distance (ft) from Windscreen | Yield (Boxes/tree) | Fruit weight (oz.) | Windscar Index |
|---|---|---|---|---|
| 1 | 285 | 14.079 BC[z] | 6.504 AB | 2.533 A |
| 2 | 255 | 13.679 BCD | 6.532 AB | 2.683 AB |
| 3 | 225 | 14.843 AB | 6.471 AB | 2.511 AB |
| 4 | 195 | 13.725 BCD | 6.743 AB | 2.582 A |
| 5 | 165 | 15.021 AB | 6.536 AB | 2.425 ABC |
| 6 | 135 | 14.054 BC | 6.675 AB | 2.425 ABC |
| 7 | 105 | 13.596 BCD | 6.589 AB | 2.356 ABC |
| 8 | 75 | 14.111 BC | 6.582 AB | 2.354 ABC |
| 9 | 45 | 14.325 AB | 6.775 AB | 2.173 BC |
| 10 | 15 | 11.954 D | 6.889 A | 2.321 ABC |
| Windscreen | | | | |
| 11 | 15 | 12.396 CD | 6.611 AB | 2.397 ABC |
| 12 | 45 | 13.650 BCD | 6.654 AB | 2.548 A |
| 13 | 75 | 14.646 AB | 6.579 AB | 2.399 ABC |
| 14 | 105 | 14.532 AB | 6.500 AB | 2.530 AB |
| 15 | 135 | 16.021 A | 6.529 AB | 2.589 A |
| 16 | 165 | 15.007 AB | 6.371 B | 2.608 A |
| 17 | 195 | 15.150 AB | 6.354 B | 2.437 ABC |
| 18 | 225 | 15.225 AB | 6.568 AB | 2.471 AB |
| 19 | 255 | 15.429 AB | 6.511 AB | 2.323 ABC |
| 20 | 285 | 15.211 AB | 6.875 A | 2.395 ABC |
| 21 | 315 | 15.243 AB | 6.564 AB | 2.311 ABC |
| 22 | 345 | 16.054 A | 6.621 AB | 2.102 C |

[z]Means within columns followed by different letters are significantly different according to Duncan's multiuple range test.

Table 3. Correlation coefficients for 1976.

| Variables (Y) | Variables (X) | # of obs. (n) | Correlation Coefficient (r) |
|---|---|---|---|
| Yield | Distance | 10 | +0.4278NS[z] |
| Fruit Weight | Distance | 10 | −0.7283* |
| Windscar | Distance | 10 | +0.8695** |
| Yield | Distance | 12 | +0.7562** |
| Fruit Weight | Distance | 12 | +0.1428NS |
| Windscar | Distance | 12 | −0.6226* |
| Yield | Fruit Weight | 10 | −0.6884* |
| Yield | Windscar | 10 | +0.1017NS |
| Windscar | Fruit Weight | 10 | −0.5132NS |
| Yield | Fruit Weight | 12 | −0.1249NS |
| Yield | Windscar | 12 | −0.2349NS |
| Windscar | Fruit Weight | 12 | −0.3015NS |
| Fruit Weight | Yield | 10 | −0.6884 |
| Windscar | Yield | 10 | +0.1017 |
| Fruit Weight | Yield | 12 | −0.1249 |
| Windscar | Yield | 12 | −0.2349 |

[z]N.S. indicates that correlation is not significant, *, ** correlation is significant at 0.05 and 0.01 level, respectively.

to the screen, probably due to the hedging, but shading may have also been a factor reducing yield.

Although there was a significant difference between fruit weights for different rows, there did not appear to be a clear cut relationship between fruit weight and distance (Table 2). Fruit was heavier on the trees along the wind screen, especially on the west side where yield was considerably reduced. Fruit weight and yield were negatively correlated on the west side, but not at all on the east side (Table 3). Correlations for fruit weight and distance were the same as fruit weight and yield.

The smallest amount of windscar was in the check row, row 22, on the east side of the screen. This was followed by row 9, one row away from the screen on the west side (Table 2). On the west side the effect was clear, however, differences were not large. There was a very high correlation between increasing windscar and increasing distance from the screen on the west side (Table 3).

On the east side, the correlation was not as strong, but it was negative showing scarring decreased with increased distance. There was a trend for scarring to decrease from the west side of the experiment to the east side. This, however, was not significant. Neither yield nor fruit weight were correlated with windscar on either side of the wind screen (Table 3).

The apparent protection on the west side of the screen cannot be fully explained by the wind data (Table 4). Approximately 11% more of the damaging winds came from westerly directions rather than easterly. There were about 86% more of the total wind from easterly than westerly directions.

*Group (End) Effects.* Tree yield was greater to the north of the center of the screen than it was south of the center (Table 5). This difference averaged approximately 2 boxes per tree. There was approximately 43% more damaging winds from the southeast through south to the southwest than there was from northeast through north to the northwest, which would possibly explain this yield increase (Table 4). No such effect was observed from winds blowing into the screen at more direct angles as seen in the row effects (Tanle 2). There did not appear to be any pattern in effect of the screen on fruit weight although differences are present (Table 5).

Windscar was generally less in groups along the screen, however group 1 off the north end differed only from group 7 which had more scarring (Table 5). Group 2 just behind the screen on the north end had the least scarring.

There were no significant correlations between any of the group effect factors studied.

*1977 Row Effect.* There was no difference in yield between rows (Table 6). Again, as in 1976, yield from the row on each side of the screen appeared to be reduced.

Table 5. Group effects on the windscreen in 1976.

| | Group 1[z] | 2 | 3 | 4 | 5 | 6 | 7[y] |
|---|---|---|---|---|---|---|---|
| Yield (boxes) | 15.6A | 15.4A | 15.6A | 14.0B | 14.1B | 13.1B | 13.4B |
| Fruit wt. (oz) | 6.6B | 6.9A | 6.4B | 6.5B | 6.5B | 6.6B | 6.7AB |
| Windscar[x] | 2.5C | 2.1D | 2.3CD | 2.3CD | 2.3C | 2.6B | 2.9A |

[x]Windscar rating.
[z]North end of screen.
[y]South end of screen.

Table 4. Total wind force (hr. min.) from 19 April to 20 June 1976.

| | Period 1 | 2 | 3 | 4 | 5 & 6 | Total | % | Total Damage | % |
|---|---|---|---|---|---|---|---|---|---|
| N | 116.30 | 131.50 | 29.50 | | | 278.10 | 18.5 | 29.50 | 10.1 |
| NNE | 24.10 | 37.05 | 14.55 | .20 | | 76.30 | 5.1 | 15.15 | 5.2 |
| NE | 20.00 | 46.25 | 17.50 | | | 83.55 | 5.6 | 17.30 | 5.9 |
| ENE | 19.30 | 38.00 | 15.50 | | | 73.20 | 4.9 | 15.50 | 5.4 |
| E | 33.40 | 58.10 | 15.55 | .40 | .10 | 108.35 | 7.2 | 16.45 | 5.7 |
| ESE | 36.20 | 45.35 | 14.35 | .10 | .10 | 96.50 | 6.5 | 14.55 | 5.1 |
| SE | 31.45 | 78.20 | 10.35 | .50 | | 121.30 | 8.1 | 11.25 | 3.9 |
| SSE | 28.30 | 86.50 | 23.40 | .20 | .10 | 139.30 | 9.3 | 24.10 | 8.2 |
| S | 28.15 | 76.50 | 18.25 | 1.00 | | 124.30 | 8.3 | 19.25 | 6.6 |
| SSW | 16.40 | 42.50 | 16.40 | 2.20 | .50 | 79.20 | 5.3 | 19.50 | 6.7 |
| SW | 15.05 | 33.35 | 16.30 | 1.25 | .10 | 66.45 | 4.4 | 18.05 | 6.1 |
| WSW | 12.30 | 23.10 | 13.55 | 5.15 | .10 | 55.00 | 3.7 | 19.20 | 6.6 |
| W | 16.10 | 26.55 | 31.50 | 9.00 | | 83.55 | 5.6 | 40.50 | 13.8 |
| WNW | 12.45 | 20.15 | 15.50 | 3.00 | | 51.50 | 3.5 | 18.50 | 6.4 |
| NW | 12.55 | 18.05 | 8.00 | .10 | | 39.10 | 2.6 | 8.10 | 2.8 |
| NNW | 7.25 | 9.50 | 3.55 | .50 | | 22.00 | 1.5 | 4.45 | 1.6 |
| TOTALS | 432.10 | 773.45 | 267.55 | 25.20 | 1.40 | 1500.5 | | 294.55 | |

Table 6. Windscreen data in 1977.

| Row | Distance (ft) from Windscreen | Yield (Boxes/tree) | Fruit weight (oz.) | Windscar Index |
|---|---|---|---|---|
| 1 | 285 | 14.629NS | | |
| 2 | 255 | 14.729 | 4.700 C | 2.079 AB |
| 3 | 225 | 14.671 | | |
| 4 | 195 | 13.629 | 4.814 BC | 1.963 AB |
| 5 | 165 | 13.029 | | |
| 6 | 135 | 13.914 | 5.082 B | 1.999 AB |
| 7 | 105 | 12.900 | | |
| 8 | 75 | 13.857 | 5.061 B | 1.904 AB |
| 9 | 45 | 13.671 | | |
| 10 | 15 | 11.429 | 5.057 B | 1.801 B |
| Windscreen | | | | |
| 11 | 15 | 11.286 | 5.446 A | 1.988 AB |
| 12 | 45 | 13.400 | | |
| 13 | 75 | 13.071 | 5.446 A | 2.113 A |
| 14 | 105 | 13.800 | | |
| 15 | 135 | 13.514 | 5.100 B | 2.078 AB |
| 16 | 165 | 14.900 | | |
| 17 | 195 | 13.286 | 5.014 B | 2.078 AB |
| 18 | 225 | 13.900 | | |
| 19 | 255 | 14.457 | 4.932 BC | 2.132 A |
| 20 | 285 | 16.300 | | |
| 21 | 315 | 13.743 | 5.079 B | 2.195 A |
| 22 | 345 | 14.129 | | |

[z]Means within columns followed by different letters are significantly different according to Duncan's multiple range test.

Table 7. Correlation coefficients for 1977.

| Variables (Y) | Variables (X) | # of obs. (n) | Correlation Coefficient (r) |
|---|---|---|---|
| Yield | Distance | 10 | .7563* |
| Fruit Weight | Distance | 5 | −.8703NS |
| Windscar | Distance | 5 | .9322* |
| Yield | Distance | 12 | .6377* |
| Fruit Weight | Distance | 6 | −.8337* |
| Windscar | Distance | 6 | .8480* |
| Yield | Distance | 22 | .6835** |
| Fruit Weight | Distance | 11 | −.6295* |
| Windscar | Distance | 11 | .7203* |
| Yield | Fruit Wt. | 5 | −.5231NS |
| Yield | Windscar | 5 | .9163* |
| Windscar | Fruit Wt. | 5 | −.6675NS |
| Yield | Fruit Wt. | 6 | −.8026NS |
| Yield | Windscar | 6 | .8089NS |
| Windscar | Fruit Wt. | 6 | −.5054NS |
| Yield | Fruit Wt. | 11 | −.6381* |
| Yield | Windscar | 11 | .5294NS |
| Windscar | Fruit Wt. | 11 | .0171NS |

In variables (Y) is dependent, (X) is independent.
[z]N.S. indicates that correlation is not significant, *, ** correlation is significant at 0.05 and 0.01 level, respectively.

The middle had not been re-hedged so the hedging did not contribute to the reduction. There was a significant correlation between increased distance from the screen and increased yield (Table 7). This is true on both sides. However, if the first row on each side of the screen is omitted, the correlation is not significant. There is a negative correlation between yield and fruit weight overall showing that as yield on a tree increased, the fruit became smaller (Table 7). Increased yield was due to the presence of more fruit, not larger ones. There was also a correlation between yield and windscar, but only on the west side of the wind screen (Table 7). This is due to reduced yields and windscar next to the screen Tables 6 and 7).

Fruit weight decreased as distance from the screen increased (Table 6). This corresponded with the relationships found between yield and distance and yield and weight (Tables 6 and 7).

The severity of windscar increased as the distance from the screen increased (Tables 6), indicating some protection from scarring was afforded by the windscreen. This effect should be greater on the west side of the screen since the largest percent of damaging winds came from between north and east (Table 8). The difference was greater on the west as can be seen in Table 6 and from the correlation coefficients in Table 7 for windscar vs distance. Differences, however, are not of economic significance.

*Group (End) Effects.* There is a slight trend towards decreasing yields as you go south in the experiment, but group 7, off the southern end of the screen, is as large as the largest yielding group, group 3 (Table 9). There is no

Table 8. Total wind force (hr., min.) from 14 March to 5 June 1977.

| | Period 1 | 2 | 3 | 4 | 5 & 6 | Total | % | Total Damage | % |
|---|---|---|---|---|---|---|---|---|---|
| N | 152.5 | 170.3 | 65.1 | 8.1 | 1.4 | 389.2 | 21 | 75.0 | 15 |
| NNE | 27.0 | 46.5 | 25.5 | 1.4 | — | 101.2 | 5 | 27.3 | 6 |
| NE | 35.1 | 53.1 | 71.1 | 10.4 | 1.1 | 171.2 | 9 | 83.0 | 17 |
| ENE | 39.2 | 60.0 | 63.0 | 10.5 | 1.0 | 174.1 | 9 | 74.5 | 15 |
| E | 60.1 | 83.4 | 50.1 | 3.3 | — | 197.3 | 10 | 53.4 | 11 |
| ESE | 42.0 | 57.4 | 13.1 | 1.3 | — | 114.2 | 6 | 14.4 | 3 |
| SE | 35.5 | 55.1 | 27.0 | .4 | — | 118.4 | 6 | 27.4 | 6 |
| SSE | 32.4 | 41.5 | 19.0 | .5 | — | 94.2 | 5 | 19.5 | 4 |
| S | 42.3 | 49.5 | 14.3 | 2.4 | — | 109.3 | 6 | 17.1 | 3 |
| SSW | 19.3 | 38.1 | 13.3 | 5.3 | .2 | 77.0 | 4 | 19.2 | 4 |
| SW | 16.3 | 35.5 | 13.3 | 5.0 | — | 70.5 | 4 | 18.3 | 4 |
| WSW | 7.2 | 31.1 | 11.0 | 5.1 | — | 54.4 | 3 | 16.1 | 3 |
| W | 18.2 | 36.1 | 20.3 | 3.0 | — | 78.0 | 4 | 23.3 | 5 |
| WNW | 12.2 | 23.4 | 11.3 | 2.0 | .2 | 49.5 | 3 | 13.5 | 3 |
| NW | 15.4 | 18.1 | 5.1 | .4 | — | 39.4 | 2 | 5.5 | 1 |
| NNW | 19.1 | 20.0 | 2.5 | — | — | 42.0 | 2 | 2.5 | 1 |
| TOTALS | 576.2 | 821.5 | 427.0 | 61.5 | 4.3 | 1891.3 | | 493.2 | |

Table 9. Group effects on the windscreen in 1977.

| | Group | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1[z] | 2 | 3 | 4 | 5 | 6 | 7[y] |
| Yield (boxes) | 13.8AB | 13.5AB | 15.0A | 13.9AB | 13.8AB | 11.9B | 14.2A |
| Fruit wt. (oz) | 4.86B | 4.97AB | 4.96AB | 5.20A | 5.17AB | 5.24A | 4.10AB |
| Windscar[x] | 2.14NS | 1.94 | 1.97 | 2.04 | 1.92 | 2.11 | 2.09 |

[x]Windscar rating.
[z]North end of screen.
[y]South end of screen.

clear cut evidence that the wind screen played an effect on the differences seen.

Fruit weight increases as you move southward (Table 9). There is no correlation between fruit weight and yield or windscar and yield (Table 7).

There was no significant difference in windscar between the groups (Table 9). Levels of windscar in each group in 1976 correlate at 5% level with those found in 1977, even though damaging winds came predominately from different directions. There were no correlations between yield or fruit weight within groups in the two years studied.

## Conclusions

Of the factors studied, differences due to protection of trees from the windscreen effects were either inconsistent with wind speed and direction, or so small as to be of little economic importance. The end effects of the windscreen were insignificant. Wind data indicate that the north-south direction of the break was best. However, damaging winds came from all measured sectors frequently enough, and for long enough durations, to cause damage.

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# WATER MANAGEMENT FOR CITRUS PRODUCTION IN THE FLORIDA FLATWOODS


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*Abstract.* **The effect of water table depth and irrigation frequency on citrus water relations with a drained flatwoods soil was studied. 'Pineapple' sweet orange (*Citrus sinensis* (L.) Osb.) trees on two rootstocks, Carrizo citrange (*Poncirus trifoliata* (L.) Raf. x *C. sinensis*) and Cleopatra mandarin (*C. reshni* Hort. ex Tanaka) were irrigated normally in 1985, and either frequently, normally, or not at all in 1986. Prolonged flooding or saturation of the root zone during 1985 caused low leaf water potentials, but brief flooding in 1986 had no effect. Stomatal resistance was low during the flooding events. The lower the water table in 1986, the lower the leaf water potentials. In the spring of 1986, with dry soil and a deep water table, citrus leaf water potential, but not stomatal resistance, responded to the irrigation treatments. The less frequent the irrigation, the lower the leaf water potential. Fruit yield was about 10% greater in 1985 than 1986. In 1986 the yield was increased with high-frequency irrigations and decreased with no irrigation relative to the normal-frequency irrigation treatment. Results suggest that drainage is needed in the summer, but should be controlled in the winter and spring to help provide an optimum water table depth for citrus.**

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