South African Avocado Growers' Association Yearbook 1993. 16:59-64

ORCHARD MICROCLIMATE AS MODIFIED BY WINDBREAKS: A PRELIMINARY INVESTIGATION

M. HOLMES[1] AND D. FARRELL[2]
Institute for Soil, Climate and Water, Private Bag X11208, Nelspruit, 1200, RSA[1] Hans Merensky Technological Services, Westfalia Estate, P.O. Box 14, Duiwelskloof, 0835, RSA[2]

ABSTRACT

The avocado is a subtropical fruit tree crop which is sensitive to wind damage. Windbreaks succeeded in reducing wind cull in an orchard of Hass by 26%. Daily maximum air temperatures and daily maximum and minimum humidity were all higher leeward of the windbreak while daily minimum temperatures were lower leeward of the windbreak. The change in microclimate alone does not warrant the planting of windbreaks unless windcull is limiting orchard productivity.

INTRODUCTION

The South African subtropical fruit industry is predominantly export orientated and European consumers demand fruit of a high cosmetic quality. However, wind cull to subtropical fruit grown in wind prone areas can, in certain seasons, be as high as 50% (Green, 1968). The avocado is one of the subtropical fruit tree crops which is sensitive to wind damage and the potential loss of revenue to the farmer due to wind cull necessitates effective wind management.

The negative effects of wind on avocado production can be summarised as follows:

a) mechanical wind damage eg. broken branches;

b) poor fruit set due to flowers that are blown off and poor insect pollination

c) wind induced stress which can hamper fruit development;

d) poor pest/disease control in the orchard;

e) poor external fruit quality due to wind scar.

A windbreak trial in an avocado crop was initiated at Everdon Estate, Natal (29°27' S, 30°32' E, 914 m above sea level). The aim of the trial was to critically evaluate the established windbreaks with a view to determining the wind reduction efficiency and to compare wind cull between a protected and unprotected orchard. Furthermore it was decided to monitor the microclimate both windward and leeward of a windbreak since large differences in microclimate could result in changes to a farmer's management strategy

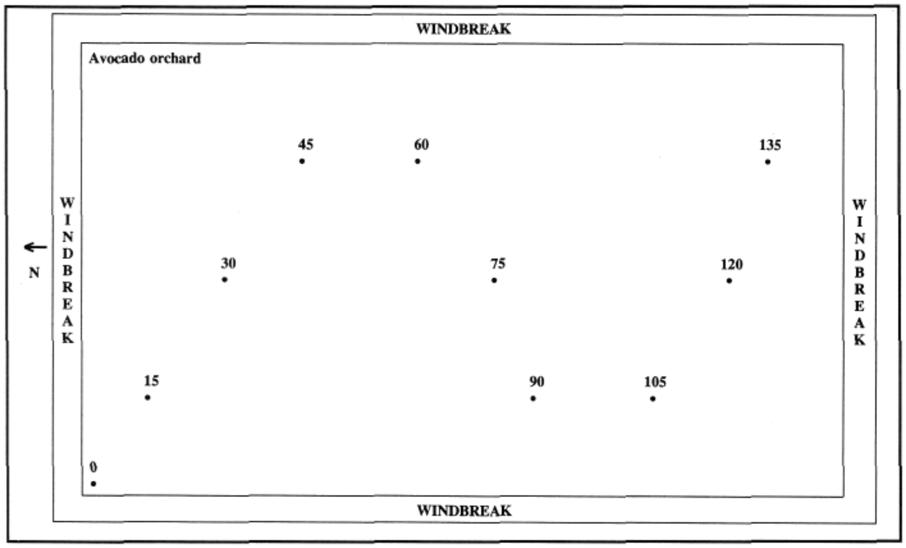

FIG. 1 Positioning of wind recorders in the avocado orchard. All positions are relative to the reference point 0.

METHOD AND MATERIALS

In April 1991 an orchard of four year old Hass, approximately 4.5 m tall, was chosen as the trial site (east facing slope). Initial orchard tree spacing was 5 m by 5 m (in a north-south row direction) but increased to 7.5 m by 7.5 m due to thinning which took place during October 1991. Measuring 151 m long and 62 m wide the orchard was protected around the perimeter by a *Casuarina cunninghamiana* (Beefwood) windbreak. The windbreak was approximately 9.5 m tall at the beginning of the experiment. Spacing between *Casuarina* trees was 1.5 m, giving rise to a permeability of approximately 55%, which is a desirable permeability (Green, 1975a; Blight, 1983; Lewis, 1985).

Nine Woelfe wind recorders, placed at 15 m intervals throughout the orchard, continuously monitored hourly windspeed and wind direction at a height of 3.5 m above ground level (Fig. 1). This height represented ¾ of the orchard tree height and below which 75% of the fruit set could be found.

Lewis (1985) and McAneney &Judd (1991) both report that maximum wind protection leeward of a windbreak occurs at a distance two to four times the effective height of a windbreak (effective height (H) = windbreak height orchard tree height). At a site within the orchard, situated 2H leeward of the windbreak, the following meteorological measurements were recorded:

a) maximum and minimum temperature;

b) maximum and minimum humidity;

c) Class A pan evaporation.

The above meteorological measurements were recorded at only one site within the orchard since it was realised that the windbreak would not provide adequate protection throughout the orchard. Thus measurements were recorded only where a changed microclimate was most likely to be found.

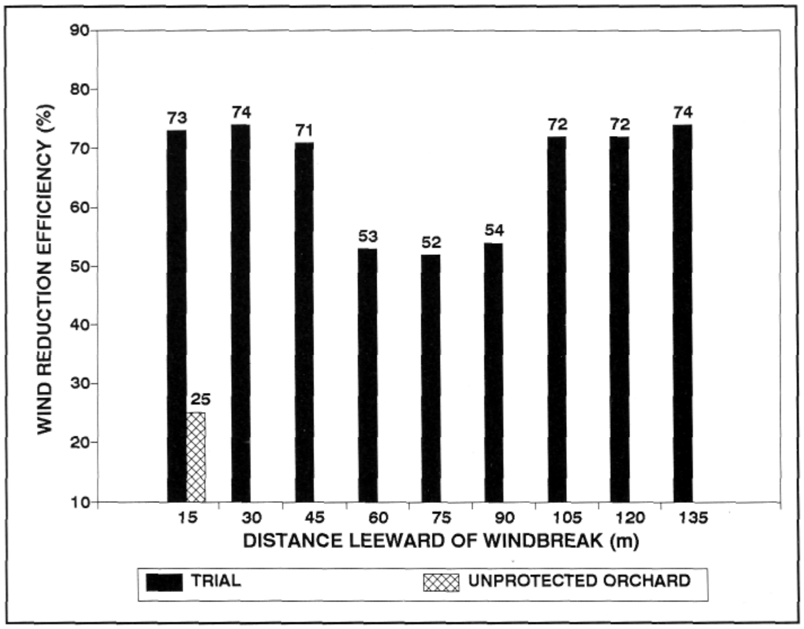

FIG. 2 Wind reduction efficiency leeward of the windbreak.

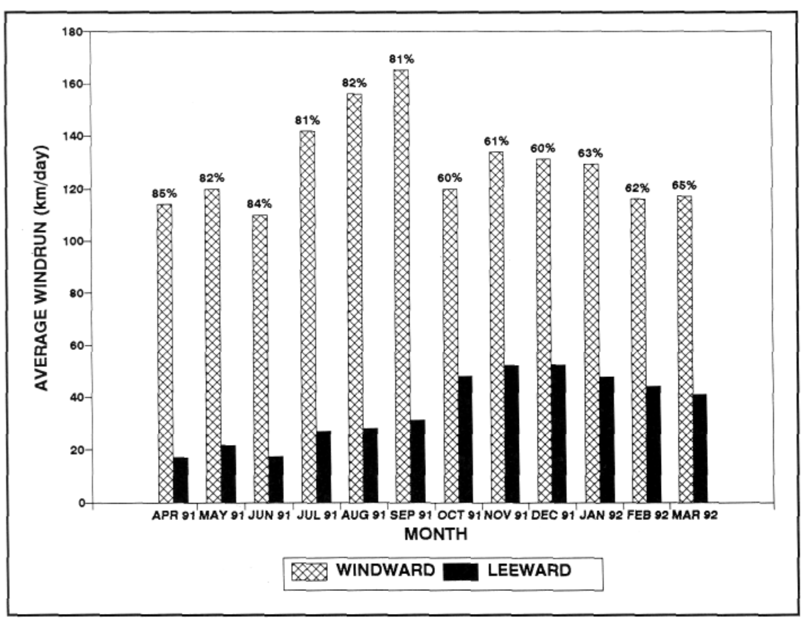

FIG. 3 Comparison of the average monthly windrun windward and leeward of the windbreak.

At a control site (in an open pasture) situated 300 m windward (and to the north) of the trial orchard, hourly windspeed, air temperature, humidity and evaporation data were recorded by a Campbell datalogger. Furthermore, hourly windspeed and direction was recorded in an "unprotected" orchard (windbreaks too small to provide significant wind protection).The trial began inApril 1991 and with the exception of windspeed measurements (still being monitored), all other meteorological measurements continued until May 1992.

RESULTS AND DISCUSSION

a. Wind reduction effects

Fig. 2 shows the wind reduction efficiency at various distances leeward of the windbreak. An average wind reduction of 72% was recorded within the first 45 m leeward of both the northern and southern sections of the windbreak. Wind reduction was greatest in these sections since the dominant wind directions were SSE, SSW and NW respectively (although the most damaging winds, greater than 20 km/hr, blew from the N and SSW). The sudden decrease in wind reduction toward the middle of the orchard is further evidence that the windbreak does not provide adequate protection throughout the orchard. This was not unexpected since the effective height of the windbreak was only 5 m and many authors report that adequate wind protection occurs up to only 10 times the effective height of the windbreak (Green, Bozalek & Schoeman, 1975; Freeman, 1976; Rollin, 1983; Pienaar, 1987). Furthermore, the results indicate that approximately 25% of the total wind reduction can be ascribed to the wind reducing effect of the avocado trees alone.

Analysis of windspeed data reveals that within the unprotected orchard, windspeeds greater than 20 km/hr were recorded 8% of the time with a maximum windspeed of 31 km/hr. This in comparison to a maximum windspeed of 16 km/hr recorded within the protected orchard. This large decrease in windspeed resulted in a reduction in windcull from approximately 36% in the unprotected orchard to 10% in the protected orchard.

Of interest in Fig. 3 is the sudden decrease in wind reduction from an average of 82% during the initial 6 months of the experiment to 60% as from October 1991. This was a result of the thinning program which took place during October. Note how the wind reduction efficiency gradually increased as the remaining trees began to occupy the open space.

b. Temperature

i. Maximum temperature

The average maximum air temperature leeward of the windbreak was significantly higher ($p < 0.05$) than that windward of the windbreak with an average increase of 0.9°C for any given day in a year (Fig. 4). This data agree closely with McAneney, Salinger, Porteous & Barber (1990) who report that daily maximum air temperature leeward of a windbreak increases linearly with windbreak height. They obtained a regression of 0.1°C per metre of orchard shelter. An average increase in maximum air temperature of 0.9°C implies additional 180 degree days over a 6 month (spring/ summer) period and could possibly be reflected in accelerated plant and fruit growth rates.

Despite the avocado thinning program which took place during October 1991, maximum air temperatures leeward of the windbreak remained significantly higher than windward of the windbreak. This suggests that the windbreak per se is the major contributing factor towards the difference in temperature recorded between windward and leeward sides of the windbreak.

ii. Minimum temperature

There was no significant or consistent relationship with respect to the influence of windbreaks on average minimum air temperature despite a tendency during the winter months toward lower minimum air temperatures leeward of the windbreak (Fig. 5). This erratic scenario was not altogether unexpected since the lower branches (¾ m) of the windbreak were removed in order to allow cold air drainage to occur unimpeded.

iii. Diurnal temperature

Fig. 6 and 7 show diurnal air temperature regimes for a typical summer and winter's day respectively. The sharp drop in air temperature leeward of the windbreak from approximately 15h00 on a winter's day (Fig. 7) was due to localised aspect and shading by the windbreak. During winter afternoons when the sun lies lower in the horizon, the windbreak shades the trial site which was east facing, resulting in the rapid fall of air temperature.

The modified air temperature regime leeward of a windbreak could prove critical if farming in a climatically marginal area with higher maximum and lower minimum air temperatures resulting in growing conditions which exceed the optimal norms. Analysis of the area under the curves reveals that during the summer, greater daily heat unit accumulation occurs leeward of the windbreaks. However, during the winter, less heat unit accumulation occurs leeward of the windbreak.

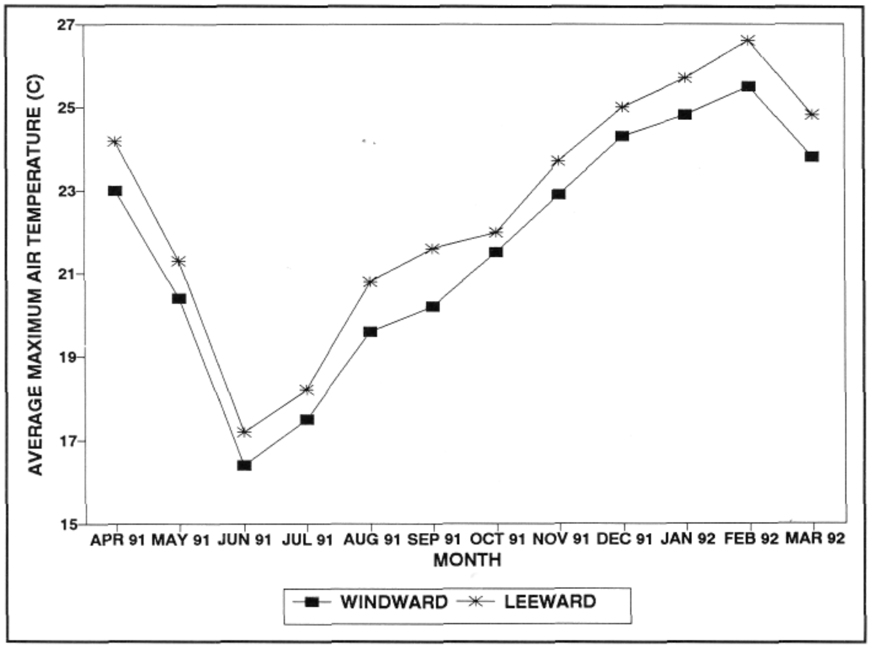

FIG. 4 Comparison of the average monthly maximum air temperature windward and leeward of the windbreak.

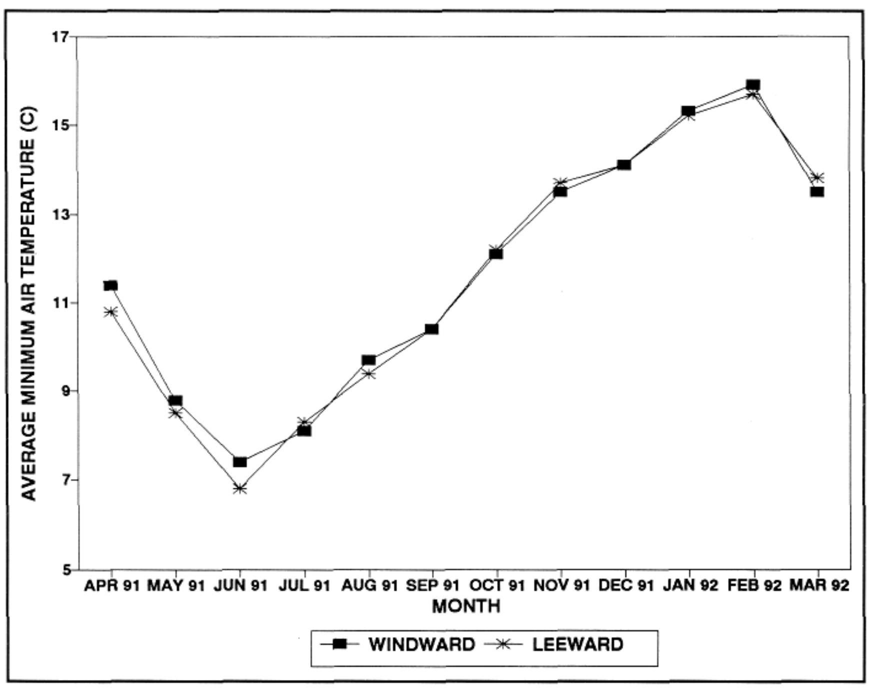

FIG. 5 Comparison of the average monthly minimum air temperature windward and leeward of the windbreak.

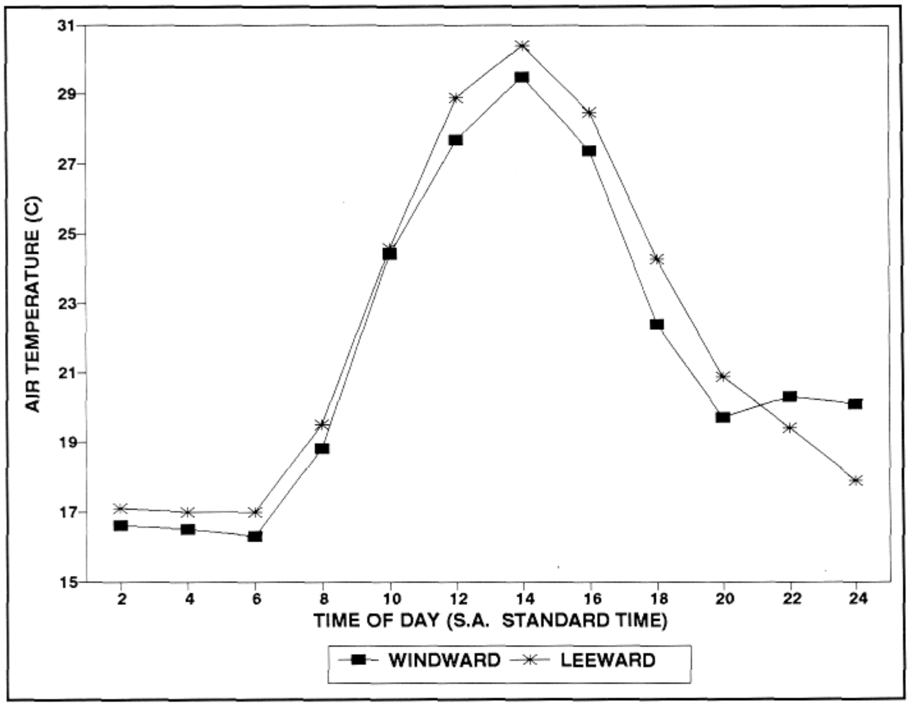

FIG. 6 Comparison of the diurnal air temperature regime for a typical summers day windward and leeward of the windbreak.

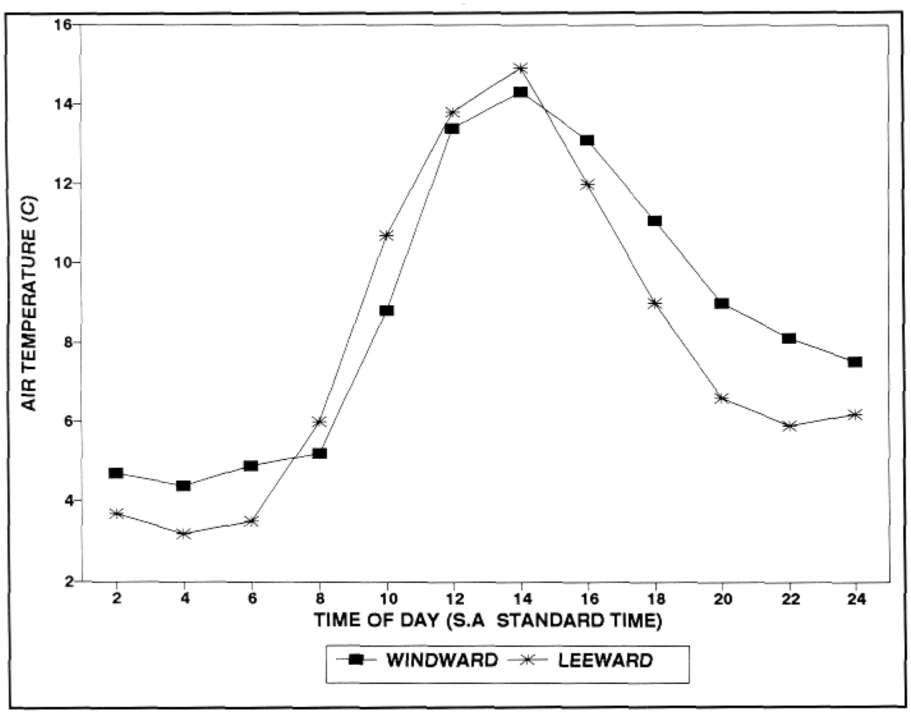

FIG. 7 Comparison of the diurnal air temperature regime for a typical winters day windward and leeward of the windbreak.

c. Humidity

Although not significantly different, the maximum humidity leeward of the windbreak was consistently higher than that windward of the windbreak (Fig. 8). The difference in maximum humidity was most pronounced during August when strong Berg wind conditions prevail and least evident during spring and summer when cold fronts and thunderstorm conditions prevail.

The minimum humidity leeward of the windbreak was significantly higher ($p < 0.05$) than that windward of the windbreak with an average increase of 6% for any given day in a year (Fig. 9). Again, the difference in minimum humidity was most pronounced during dry and windy conditions (August and September).

Some implications of a changed humidity regime include:

i. The elevated humidity regime leeward of the windbreak should reflect in a reduced atmospheric demand and thus evaporation rate.

ii. As a result of the elevated humidity regime leeward of the windbreak, effective disease management becomes imperative especially from September onward when the fruitlets are developing and *Cercospora* is rife.

d. Evaporation

Evaporation leeward of the windbreak was marginally less than windward of the windbreak with the difference in total monthly evaporation varying between 3 and 9% (Fig. 10). This effect is not unexpected since reduced wind movement decreases turbulent mixing leaving the humid orchard air layer intact.

The irregular variation in evaporation between the two sites can be ascribed to the poor choice of instrumentation used. The Class-A-Pan is insensitive to monitoring the response of evaporation to changing wind regimes. Furthermore in high (summer) rainfall areas it is common to receive rainfall events greater than 25-30 mm, often resulting in the A-pan overflowing and thus the loss of evaporation data for that day.

In view of the above it is suggested that the Piché atmometer be used as a more suitable method by which to monitor the influence of windbreaks on evaporation. The Piché has been successfully used to monitor the aerodynamic component of the Penman Monteith equation (Van Zyl *et al.,* 1989) and would thus appear sensitive enough to monitor differences in evaporation due to changing wind regimes.

It should be noted that a reduced evaporation rate leeward of a windbreak does not necessarily constitute a saving in irrigation water, since a protected orchard will not experience water stress as early on as an unprotected orchard. Thus stomata may stay open for longer, enabling transpiration to continue for longer (Rosenberg, 1966; Brown & Rosenberg, 1971; Skidmore *et al*, 1972; Miller *et al.,* 1973).

CONCLUSION

The results of this investigation show that windbreaks are effective in reducing wind cull;

in this case wind cull was reduced by 26%. However, any such advantage from reduced wind cull must be balanced against a reduction in yield due to competition effects and the loss of otherwise productive land occupied by windbreaks.

Although the primary aim of windbreaks lies in wind reduction per se, there is little doubt that they modify the microclimate. In this trial, daily maximum air temperature and daily minimum humidity were significantly higher leeward of the windbreak. Evidence on the effect of windbreaks on evaporation was inconclusive due to the poor measurement technique used.

The modified microclimate brought about by the establishment of windbreaks for crops grown in climatically marginal areas could be beneficial or detrimental to crop production, depending on the climatic requirements of the crop in question. It should also be borne in mind that the influence of a network of windbreaks on the microclimate is likely to be more pronounced than the data presented here.

ACKNOWLEDGEMENTS

Our sincere thanks to Mssrs.T. Mans and F. Scheepers for their meticulous recording of meteorological data.

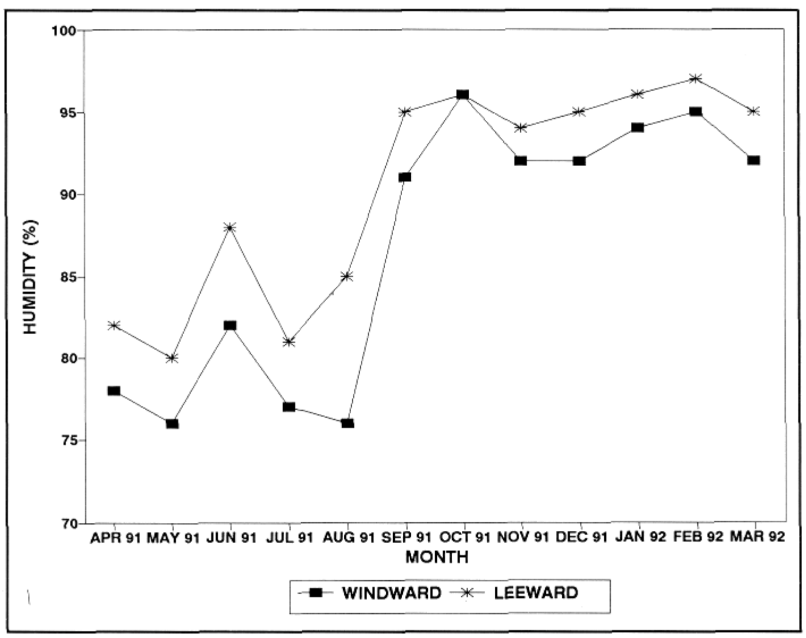

FIG. 8 Comparison of the average monthly maximum humidity windward and leeward of the windbreak.

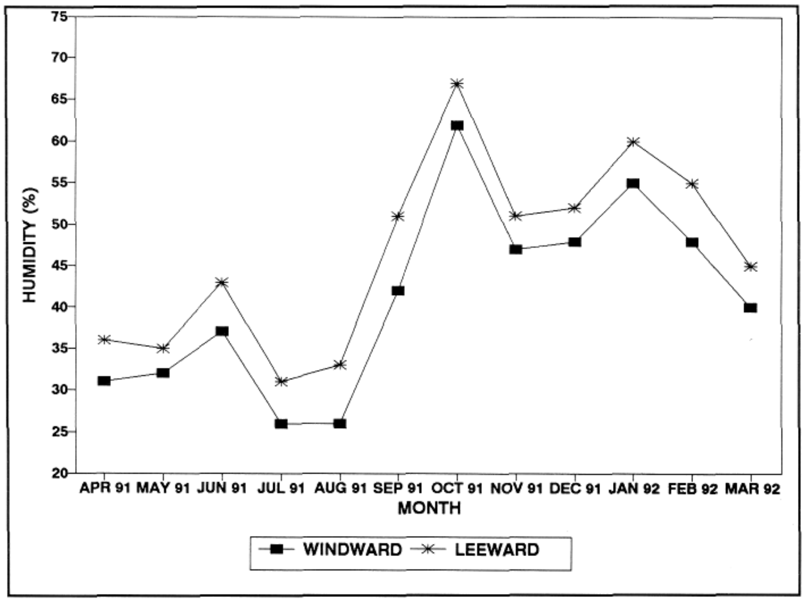

FIG. 9 Comparison of the average monthly minimum air humidity windward and leeward of the windbreak.

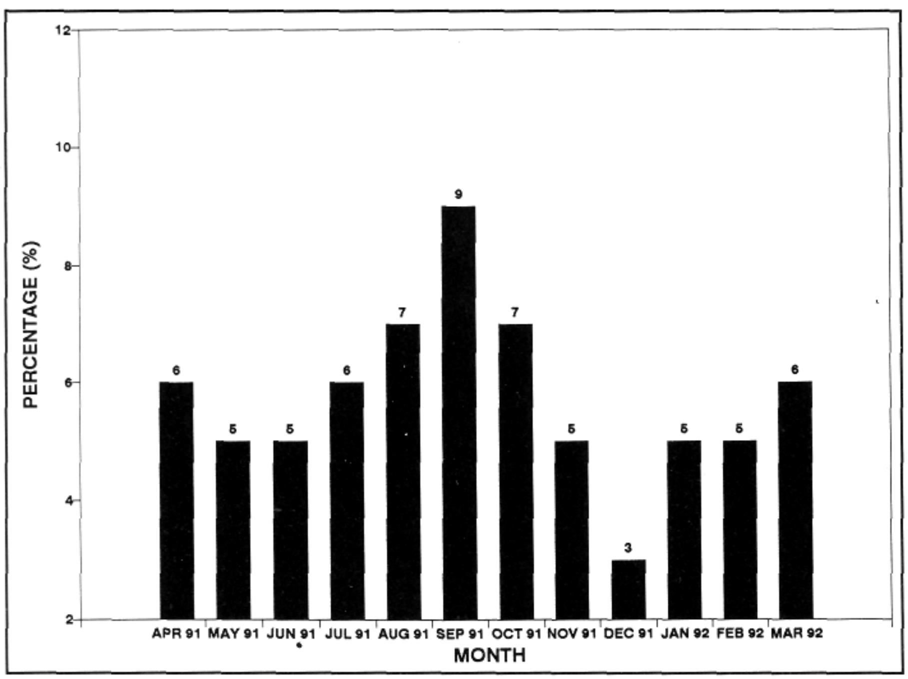

FIG. 10 Percentage reduction in the total monthly evaporation leeward of the windbreak.

REFERENCES

BLIGHT, H.C. 1983. Wind protection for Kiwifruit is fundamental. *The Citrus and Subtropical Fruit Journal* 597: 12 - 14.

BROWN, K.W. & ROSENBERG, N.J. 1971. Turbulent transport and energy transport as affected by a windbreak in an irrigated sugar beet field. *Agronomy Journal* 63, 3: 351 - 355.

FREEMAN, B. 1976. Artificial windbreaks and the reduction in wind scar of citrus. *Proceedings of Florida State Horticultural Society* 89: 52 - 54.

GREEN, G.C. 1968. Windbreaks for citrus orchards. *Farming in South Africa* 44, 6: 9 - 15.

GREEN, G.C. 1975a. Windbreaks for citrus and subtropical orchards. *Farming in South Africa* B1: 4 pages.

GREEN, G.G., BOZALEK, S.J. & SCHOEMAN, A.S. 1975. Windbreaks for citrus orchards. *Farming in South Africa,* B2: 7 pages.

LEWIS, J.R. 1985. Wind protection In Macadamia's in the near north coast. *Queensland Agricultural Journal* 111, 2: 101 - 104.

McANENEY, K.J., SALINGER, M.J., PORTEOUS, A.S. & BARBER, R.F. 1990. Modification of an orchard climate with increasing shelter-belt height. *Agricultural and Forestry Meteorology.* 49: 177 - 189.

McANENEY, K.J. &JUDD, M.J. 1991. Multiple windbreaks : An aeolean ensemble. *Boundary Layer Meteorology,* 54 :129 - 146.

MILLER, D.R., ROSENBERG, N.J. & BAGLEY, W.T. 1973. Soybean water use in the shelter of a slat fence windbreak. *Agricultural Meteorology* 11, 3: 405 - 418.

PIENAAR, P.J. 1987. Wind protection in orchards: effect on growth, production and fruit quality. *Deciduous Fruit Grower* 37, 8: 291 - 295.

ROLLIN, E.M. 1983. Influence of windspeed and wind direction on the reduction of windspeed leeward of a medium porosity hedge. *Agricultural Meteorology* 30*,* 1: 25 - 34.

ROSENBERG, N.J. 1966. Microclimate, air mixing, and physiological regulation of transpiration as influenced by wind shelter in an irrigated bean field. *Agricultural Meteorology* 3: 197 - 224.

SKIDMORE, E.L, JACOBS, H.S. & HAGAN, L.J. 1972. Microclimate modification by slat-fence windbreaks. *Agronomy Journal* 64: 160 - 162.

VAN ZYL, W.H., DE JAGER, J.M. & MAREE, C.J. 1989. Correction factors for evaporimeter coefficients used for scheduling irrigation of wheat. *Water Research Commission Report No.* 151/1/89: 154.