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Proc. Fla. State Hort. Soc. 100:103-108. 1987.

FREEZE PROTECTION METHODOLOGY REVIEWED IN THE LIGHT OF DEPENDENCE ON WEATHER AND CLIMATE INFORMATION

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Additional index words. cold protection, frost protection, grove covers.

Abstract. **Five major freezes have occurred in Florida in the last 10 years. Methods of protecting mature orchards from cold damage fail in windy freezes such as those of Christmas 1983 and January 1985. Questions have been raised as to the potential of windbreaks under these conditions. So a 0.38 ha porous cover, 3.6 m in height and with 45 degree sloping sides, was erected using a column and cable design. A 50% shade of knitted polyethylene material formed the top and a 80% shade of woven polypropylene provided the side curtains. Three partial blowdowns led to modifications including increased anchor size, decreased irrigation prior to storms, and refined cable clamping. A computer-controlled system for microclimatic data acquisition was developed. The structure reduced wind speeds by 80%, which suggested that covers in combination with conventional cold protection methods, such as heating and/or irrigation, may be effective in windy freezes. There was little modification of the temperature. Thus, the windbreak cover alone cannot be expected to provide much protection. The construction of the cover, its maintenance, and the acquisition of data during cool, windy episodes were enhanced by weather information from the Federal-State Frost Warning Service, now in its 52nd year of operation in Florida. A brief review of the reliance of cold protection methodology on such a service seems appropriate in a year in which the Florida Society for Horticultural Science is celebrating its 100th anniversary.**

Last year a report (6) was made to this audience regarding the redirection of resources within the Fruit Crops Department of IFAS from weather satellite information networking to cold protection methodology. This redirection was in part a response to the deliberations of the Statewide Citrus Advisory Committee which from its inception contained a working group on weather and cold protection methodology. An interim report was made at the Indian River Citrus Seminar in Vero Beach on 18 March 1987 and a summary was published by the Citrus Industry Magazine (5). This is the third report to that committee and the growers that they represent and it exemplifies the grass roots philosophy of extension working through the Society. However, there is concern in regard to the future of the weather information network which has evolved within the Federal-State Frost Warning Service (2), on which cold protection methodology depends.

Use of windbreaks to enhance the effect of conventional frost protection methods may be appropriate for adult orchards. Sprinkling the top of a shade structure during freezing weather (1, 9) to close the pores with ice formation may have merit. Norcini (8) reviewed cold protection methods with special attention to windbreaks, shade structures and water in conjunction with them to provide protection. These articles signal activity in the ornamental horticultural industry that closely parallels interests of the citrus industry. This report describes progress made on the investigation of a grove cover as an example of a windbreak having resistance to vertical as well as horizontal transport of heat and moisture.

Materials and Methods

A column-cable-porous cloth structure was constructed (6) and maintained over a rootstock evaluation block just south of Hull Road and across that road from Fifield Hall on the main campus of the University of Florida (Fig. 1). The structure is 3.6 m (12 ft) in height, supported by steel columns (Allied Tube and Conduit, Chicago) and occupies 0.38 ha (0.93 acre) (6). The locations of the columns and cables in relation to the planting grid are shown in Fig. 2. The horizontal panels on top of the structure were provided by Weathashade (Apopka, FL) and are of a knitted polyethylene termed "50% Shade." The side panels, at 45 degrees, are of a woven polypropylene granted by Chicopee (Gainesville, GA) and designated "80% Shade."

A data acquisition system for observing the effect of the orchard cover on the microclimate has been described (5, 6) but some details can be added. Currently 20 channels of temperature and 5 channels of light-chopper anemometry are operational (Fig. 3). An intention to add humidity sensors, likely of the chilled mirror type, for direct measurement of dew point temperature, is indicated. Observations were accumulated on the systems-controlling minicomputer's disk. The removable disk was returned to the laboratory after a series of runs where a sister minicom-

Florida Agricultural Experiment Station Journal Series No. 8616. Appreciation is expressed for materials granted by DOE, U. S. Research & Development Corp., Allied Tube & Conduit, Weathashade, Chicopee, and James Rivers. Drs. L. K. Jackson, W. J. Wiltbank, R. A. Bucklin, and G. W. Isaacs, as well as H. E. Hannah, Dean Holmes, R. T. Fernandez, M. B. Baker, R. T. Fernandez, J. L. Jackson, J. G. Georg, Ferris Johnson, Jr., and Fred Crosby have made contributions to this effort that deserve acknowledgement.

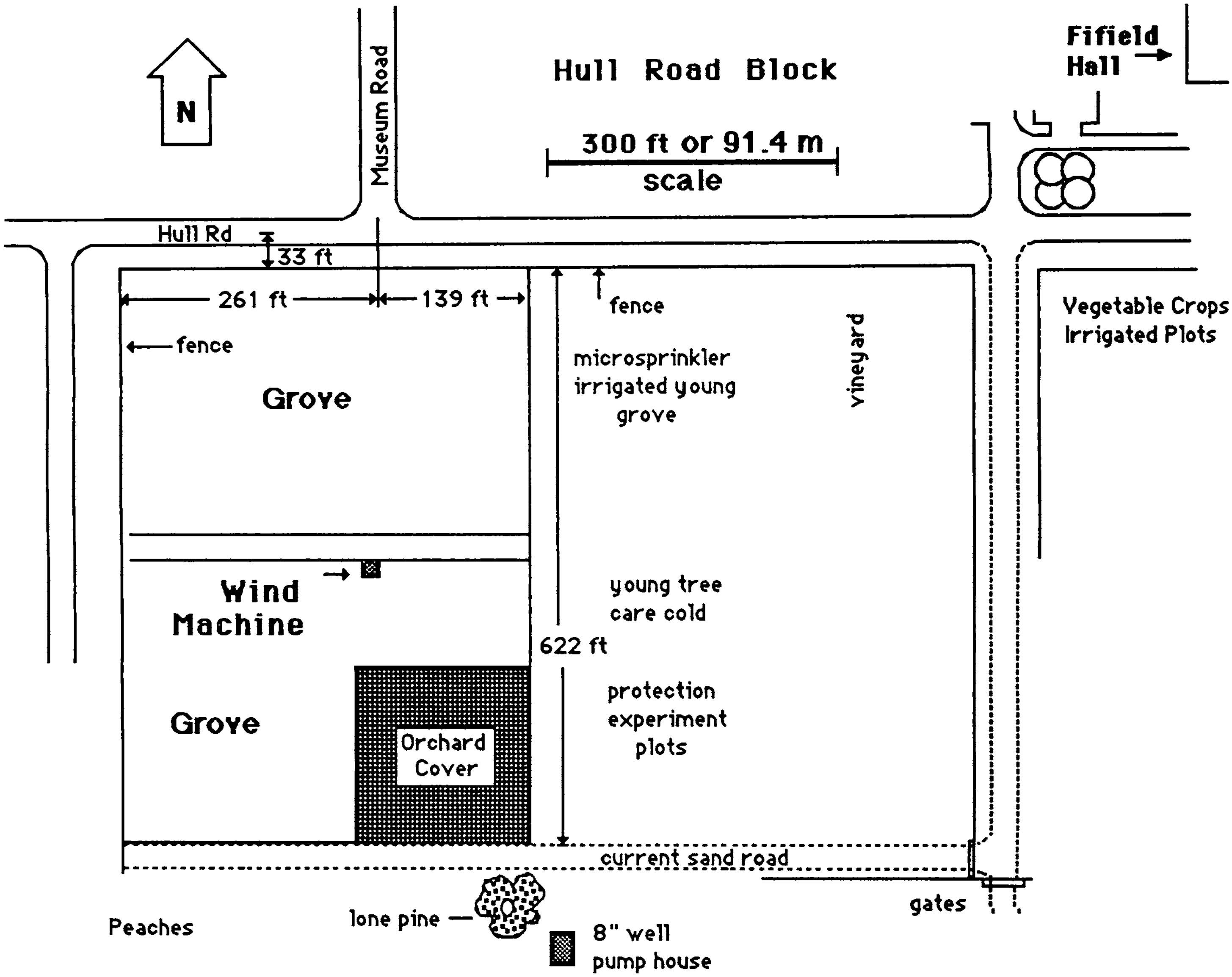

Fig. 1. The location of the orchard cover in the research block on the old agronomy farm at the University of Florida, Gainesville, is indicated.

puter divided the disk record into files read, in turn, by a Macintosh microcomputer (Apple Computer, Inc., Cupertino, CA) and analyzed within a spreadsheet application [EXCEL, Microsoft, Redmond, WA] which has an integrated charting capability. The charts were transferred to a graphics package [MacDraw, Apple Computer Inc., Cupertino, CA] where the the labeling and shading were modified but not the relative location of the graphed data points. The resulting graphs were printed by a dot-matrix printer immediately but the presentation of data in publishable form required the use of a laser printer with capability to handle MacDraw files stored on 3.5 inch disks. They were processed by appointment in Weil Hall [CIRCA Lab, see Figure 3].

Five Thornthwaite precision cup anemometers (wind speed indicators) were modified to interface with the data acquisition system by upgrading the electronics within the original transmitters. To reduce the drag on the shaft on which the three light metal reinforced plastic cups rotate, a window on the shaft passes a light source and the pulse of light transmitted is sensed by a phototransister. The term "light-chopper" describes this mechanism and denotes an anemometer sensitive to light winds. These instruments were placed on a horizontal bar within a few feet of one another at 1.8 m (6 ft) from the ground and exposed for several periods of time to determine if they all responded equally to the same wind flow. The cup assemblies and the transmitters have numbers impressed into their housings at the factory and these are recorded in the log with location of the instrument in the log so that any bias that shows in subsequent calibration runs may be considered in interpreting the results. The five anemometers used in this test were assumed to have no significant difference in their response to wind speed. The algorithm used to convert transmitted pulses per minute to wind speed in centimeters per second [44.7 cm per sec equals 1 mph] was one taken from previous work (7, 10).

The thermocouples used to measure air temperature were made of 0.5 mm in diameter [24 AWG] copper-constantan fused into beads of approximately 1 mm with the leads forming a loop of about 5 mm in diameter. The bead and the loop were coated with epoxy resin. These thermocouple loops were simply exposed with the loop vertical without aspiration and without radiation shielding. The

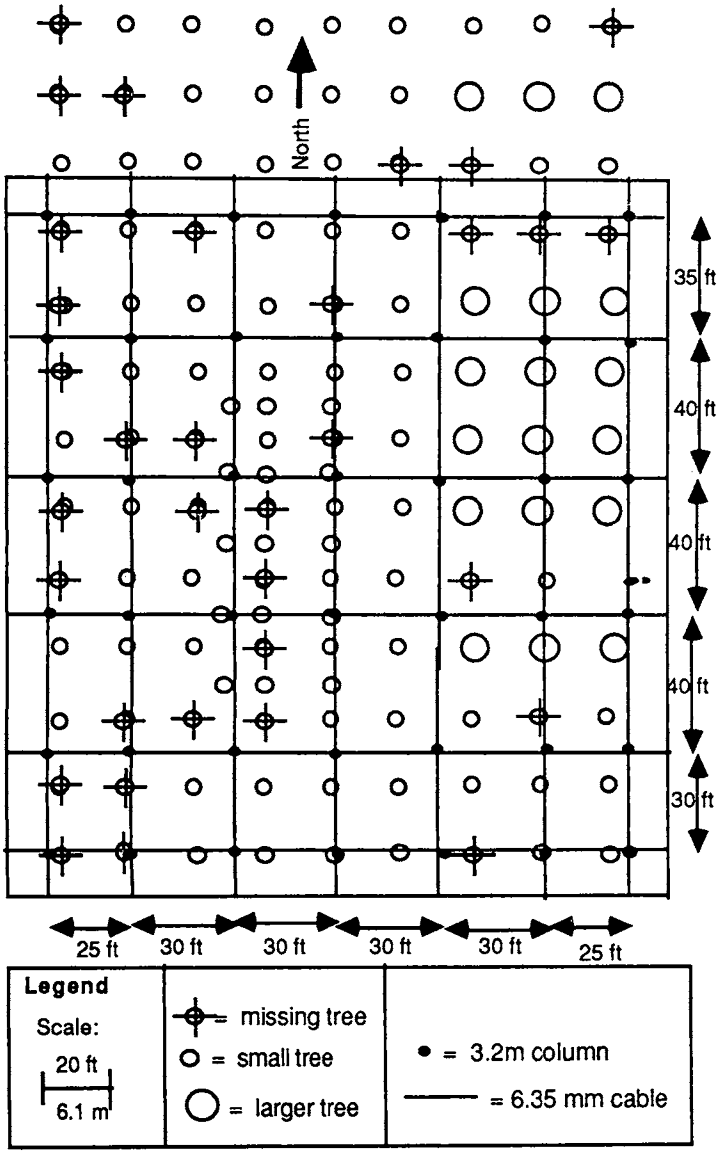

Fig. 2. A diagram of the spatial distribution of young trees in the rootstock experiment and the location of elements of the orchard cover, i.e. the cables and columns. The trees are on a 20 ft square grid with some interplants as indicated.

assumption was that in wind speeds of interest the natural aspiration of the wind increases the convective exchange sufficiently to overwhelm the radiational cooling. The electronic reference junction and conversion of output to temperature [a function of one of the cards in the data acquisition system] was assumed to be operating properly when the thermocouples were found to indicate 0 degrees C in an ice bath.

Results and Discussion

High winds damaged the cover three times during the first year. During the installation of non-porous polyethylene side curtains, a strong wind ripped the material from the cables and it billowed into a sail that in turn displaced several cables and bent a few columns. A more substantial and porous material, the Chicopee 80% Shade, was then used in its place. The other two partial blowdowns resulted from thunderstorms that coincided with periods when the soil surrounding the cable anchors was wet, either from rain or from a recently completed irrigation. Larger anchors were installed on the corners since each of the blowdowns involved a corner. The worst of these partial blowdowns occurred on 23 July 1987 resulting in 90 degree bends in the NE corner post and the one directly west of it. The "S" shaped connector between the anchor and the cable snapped and one cable clamp slipped.

The data acquisition scheme [Fig. 3] resulted in part from work at the Pennsylvania State University with a similar system (7) and the granting of some of that equipment by the Horticulture Department there to this study. A sample of the wind speed data (time-averages over the period of a minute) collected and smoothed by space-averaging data from the two outside sensors and plotting that average versus the space-average of data from the three inside sensors is shown in Fig. 4. Notice that the wind is gusty, i.e. speed varies extensively in time. This characteristic suggests that turbulent transfer theory will be required for estimates of heat and moisture transfer (7). The location of the anemometers and the mean wind speeds from each of the sensors is shown in Fig. 5. The average wind direction during this one-hour period was 30 degrees east of north. The wind speed 5h from the cover showed no difference from that at 10h [where h = 3.6m (12 ft), the cover height]. There seemed to be a lull near the middle of the cover, i.e. at 5h inside. This showed up periodically in the data but apparently did not persist for it was not apparent in the averages for the whole night (Fig. 6). There was an indication that the outside anemometer closest to the cover was influenced by the presence of the cover. The tendency for slightly more wind near the side curtains than within the cover was also apparent. To develop a feel for how the wind speed varies with height, 4 anemometers were set at different heights near the center of the cover (see Fig. 6). Air movement within the cover was unusually uniform with height although the wind speed is higher near the overhead cover and at the h/2 level (6 ft). Since there is more resistance to flow nearer the ground, i.e. at h/4 (3 ft), it is not surprising that the minimum wind speeds would be at this level.

The flow just above and just below the horizontal cover is indicated in Fig. 7 as intermediate between the undisturbed flow and that well within the covered volume. Knowledge of the flow near the cover is expected to be useful in the development of a model of the transport of heat and water vapor through the porous cover.

A windbreak of this type reduces wind speed sufficiently to anticipate an increase in the effectiveness of irrigation or heating for cold protection used in conjunction with the cover. One of the goals of this project is to document such effects and in the process refine the ability of models of the heated and/or irrigated orchard to predict such effects. This process of measurement and modeling is expected to elucidate windbreak design for maximizing their effectiveness during windy low temperature events.

The construction and maintenance of the cover in conjunction with the use of heaters and irrigation raises concern about the heavy dependence on weather information in this program. As a residual of the Satellite Frost Forecast System [SFFS], the research lab remains linked to the facilities of the Federal-State Frost Warning Service (2), a cooperative effort between the University of Florida, IFAS and NOAA's National Weather Service, located in Ruskin,

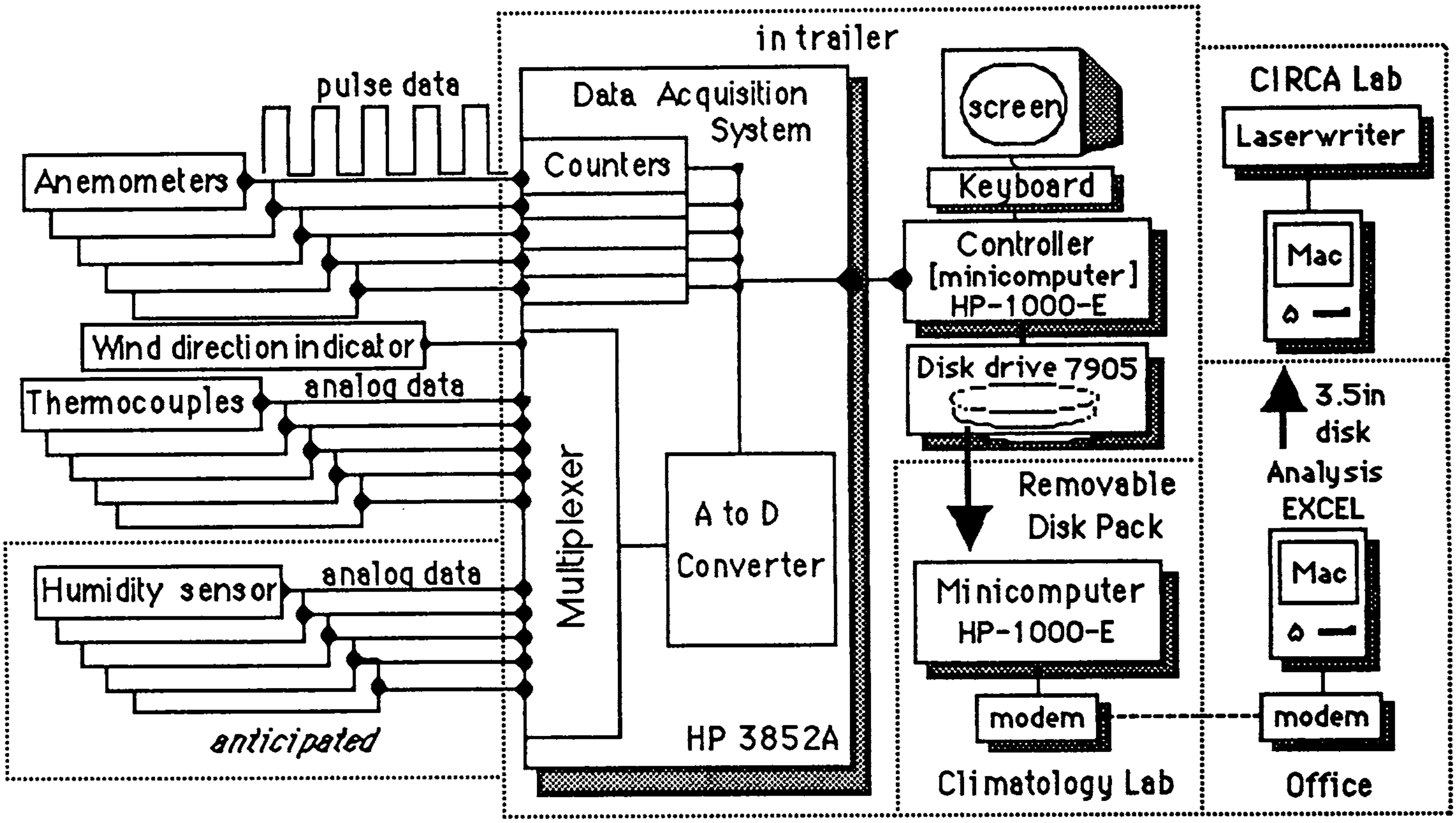

Fig. 3. A block diagram of the data acquisition system and the links from the environmental sensors to microcomputers in which the data is processed and composed into figures (see Figures 4-7).

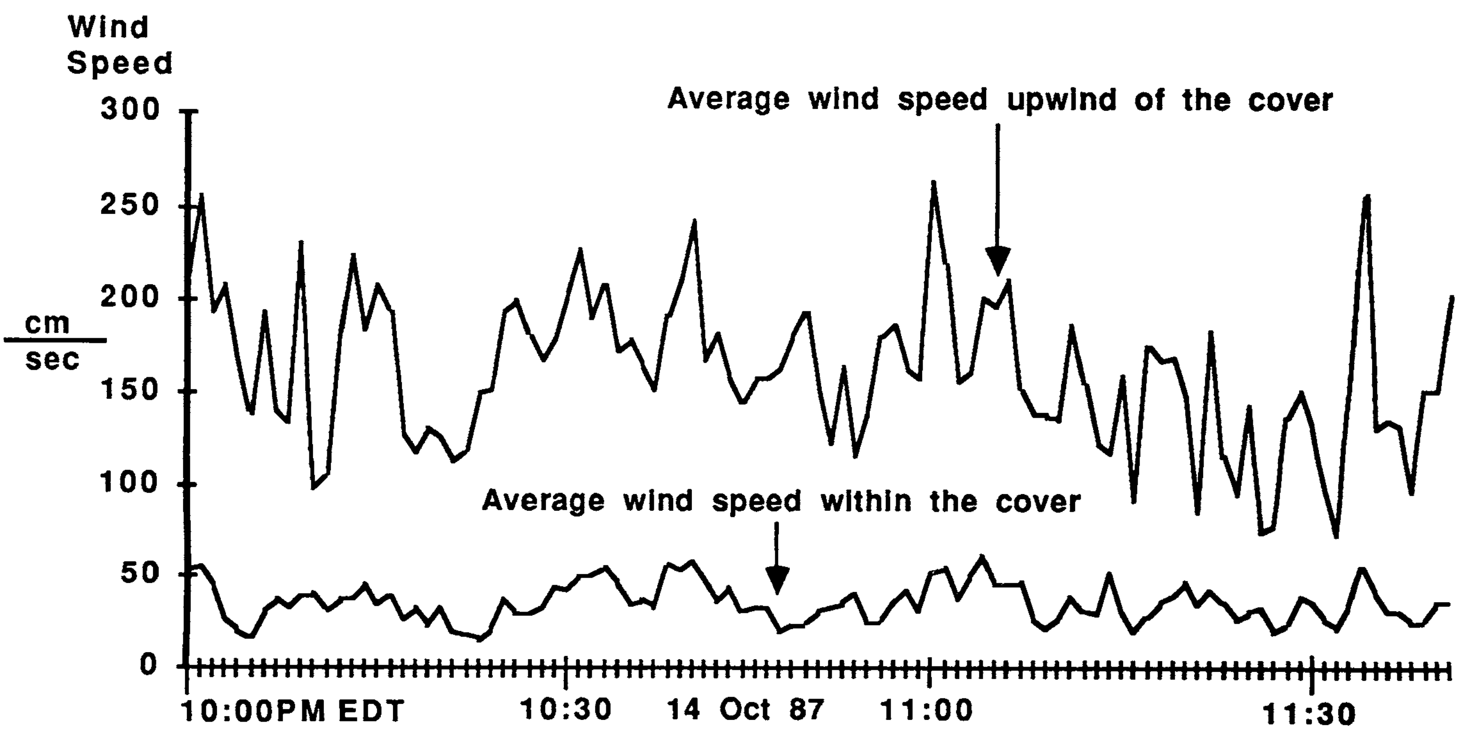

Fig. 4. A comparison of time series of data averaged in both space and time for upwind and inside cases for the same period. Notice that the stronger wind pulses [44.7 cm per sec = 1 mph] appear to be diminished more by the cover than the lower wind speeds. Wind gusts seem to be directed over rather than through the mound shaped orchard cover.

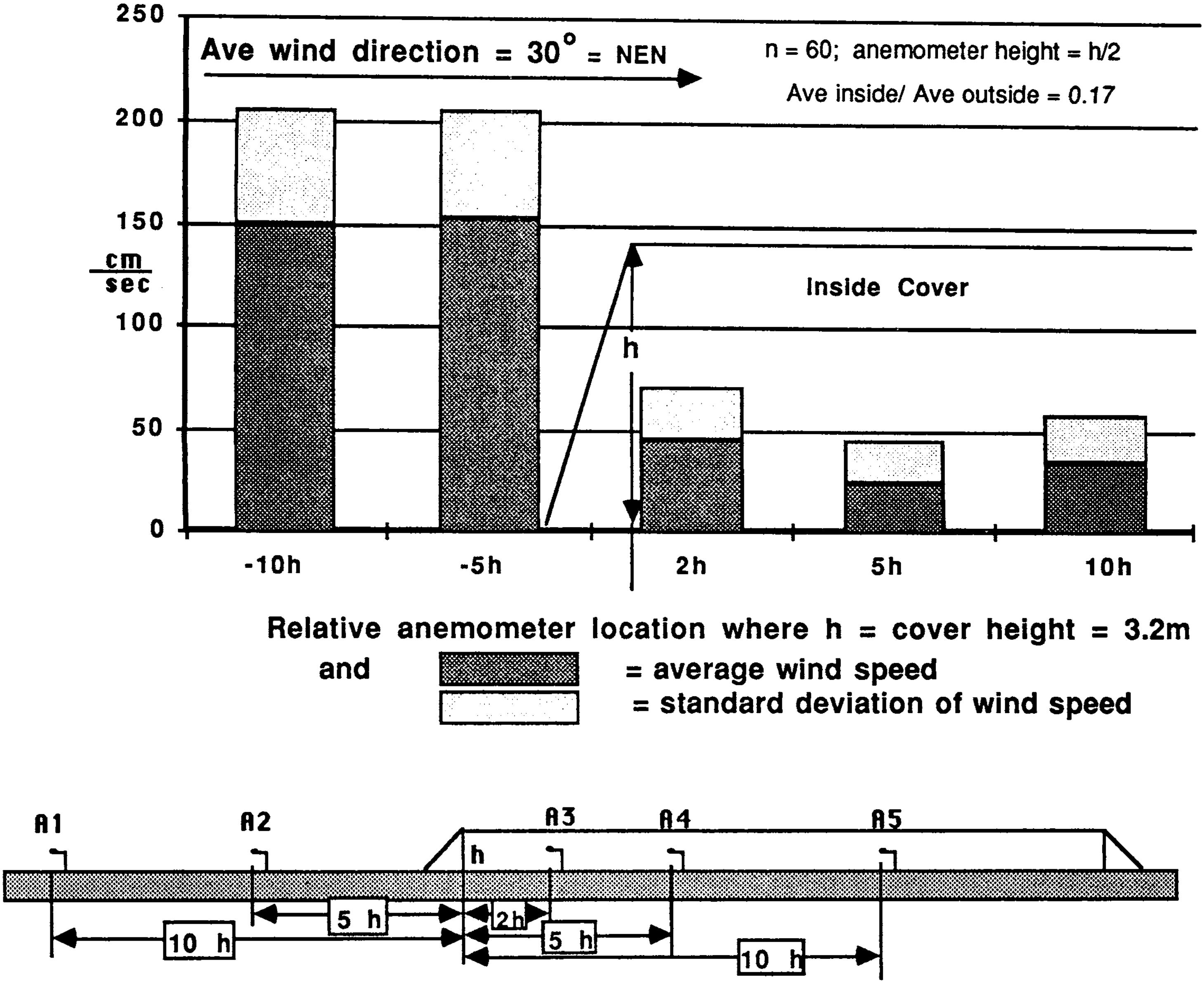

Fig. 5. These data describe the average conditions during the hour of 9 to 10 PM on 14 Oct. 1987, a night that is analyzed as a whole in Figure 6 and where h = 3.2 m (12 ft), a common distance and height scale factor used in the Figures 5-7.

FL. As our Society celebrates its 100th Anniversary, it seems appropriate to recall that the Federal-State Frost Warning Service is in its 52nd year and that the Florida State Horticultural Society played a role in the creation of that service, as Dr. Herman Reitz documents in his history of the Society published in this volume. The Society may have another opportunity to greatly influence the future in this area by assessing the value of the Federal-State Frost Warning Service in Florida and making such needs known to those who determine funding priorities.

The two participants in the Federal-State Frost Warning Service, have been considering changes in the service as resources are decreasing while the cost of technology to modernize the service is increasing. A not-for-profit corporation designed to provide computer ports for perishable information in return for fees has demonstrated that most horticulturists are not yet convinced that they should pay for such services. Perhaps there is an opportunity to influence the nature of future service at this crucial time.

Summary

Progress has been made in the evaluation of an orchard cover as a possible solution for protecting adult orchards against advective freezes. The maintenance of a covered block revealed that winds from thunderstorms following heavy rain or irrigation dislodge cable anchors, especially on the corners of the structure. A system of measuring wind speed reductions has recorded data indicating that a cover of 50% Shade material on top and 80% on the 45 degree inclined sides reduces wind speeds in the range of 100 to 300 cm per sec [2 to 6 mph] by 80%. A reduction of wind speed to about 1/5 of its undisturbed value is likely to have sufficient effect on the efficiency of heating and/or sprinkling beneath the cover to render such methods effective even in advective freezes. Opportunities to acquire data during freezes in Gainesville are expected to provide answers to grower questions about the combination of windbreaks and cold protection methods.

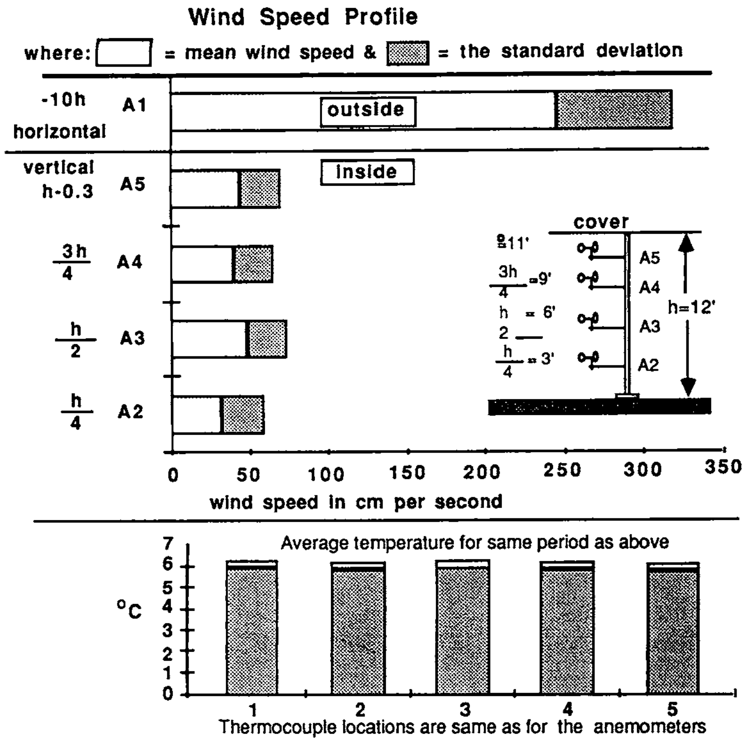

Fig. 6. Three hours of one-minute averages of wind speed observed from 2 AM EST through 4 AM on 28 October 1987 from 5 anemometers; one outside at 10h and the other 4 displayed as indicated. The average temperature at each location for the same period is also indicated revealing little, if any, effect of the cover on temperature in such winds.

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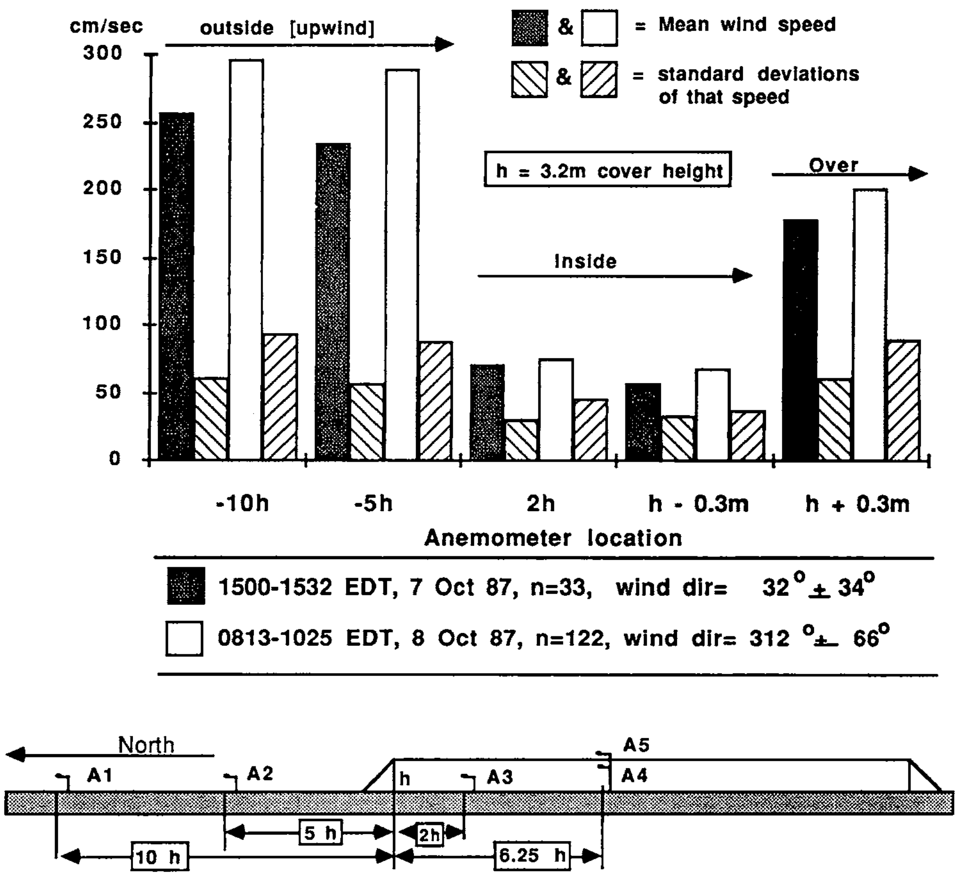

Fig. 7. The plotting of data from two different time periods [as indicated] where the wind direction is indicated in degrees clockwise when viewed from above from the North. Notice that the wind above the cover is much higher than within the cover.