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MICROCLIMATE MODIFICATION BY TREE WINDBREAKS IN FLORIDA FARMS

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Abstract: Florida citrus and vegetable crops generate billions in revenue every year. However, winds, freezes, hurricanes, and citrus canker (*Xanthomonas campestris*) impact production. Windbreaks located perpendicular to the prevailing wind can reduce soil erosion and increase irrigation efficiency and farm production mostly by simply modifying microclimate. Windbreaks can also control the spread of pathogens such as citrus canker. To study how tree windbreaks modify microclimate in southern Florida, weather stations were established in 2008 along transects behind a 1-row eastern redcedar (*Juniperus virginiana*) windbreak at the Southwest Florida Research and Education Center (SWFREC/University of Florida) at Immokalee, and a 1-row cadaghi (*Corymbia torelliana*) windbreak at C&B Farms, Clewiston, to assess spatial variation in wind speed, temperature, and relative humidity at 2m above the ground. The windbreaks significantly reduced wind speed; minimum wind speed was at two times the windbreak height (2H) behind dense (17% porosity) redcedar and at 6H behind relatively porous (20% porosity) cadaghi when the wind direction was nearly perpendicular to the windbreak. Wind speed at 2H behind eastern redcedar was approximately 5% of the open wind speed and at 6H behind cadaghi was approximately 3-30%. Wind speed at 14H behind cadaghi and redcedar windbreak was approximately 60% and 80% of the open wind speed, respectively. Temperature behind both windbreaks was relatively warmer than in the open. However, the extent of temperature and relative humidity modification was less compared to wind speed. Windbreaks are an effective use of forest trees to modify microclimate and appreciably enhance Florida farm production.

Key Words: Agroforestry, shelterbelt, porosity, wind reduction; microclimate modification

INTRODUCTION

Damages to crops by high winds and nutrient loss through soil erosion are widely recognized in agricultural systems. This has been a major problem in areas where top soil contains the nutrients. Studies have shown that wind transported soil contains more nutrient than the top soil from where it is derived from (Nuberg 1998, Sudmeyer and Scott 2002). Strong wind also reduces flowering, increases flower shedding, reduces pollination and increases endosperm abortion in some fruit trees such as cherry. Finally, high winds may reduce the number of pollinators such as bees (Peri and Bloomberg 2002).

Windbreaks are widely used to reduce the impact of high winds. They have proved to be promising for sustainable agriculture and provides both sustainable production and conservation attributes. Well designed windbreaks located in the direction of prevailing wind increase both crop and livestock productions, reduce wind erosion, provide shelter for structures and livestock, improve microclimate and improve irrigation efficiency. Windbreaks also control the spread of pathogen such as citrus canker (*Xanthomonas campestris*). In addition, they increase nitrogen uptake leading to better plant growth and yield (Shah and Kalra 1970).

Florida is the major citrus producer and one of the leading vegetable producers in the U.S. (FDACS 2007). Both productions are profitable and generates about $20 billion annually. Citrus alone contributed about $9.29 billion in 2003/04 season (Hodges et al. 2006). Agriculture in Florida is still profitable exporting products to other US states and 140 countries across the globe (FDACS 2007).

Increase in disease incidences in citrus (canker and greening), impact of high winds (including hurricanes) and freezing temperatures have threatened Florida agriculture recently. Limited information is available on citrus greening and growers are exploring new ways to control it. Citrus canker is caused by bacteria and spread through wind and rain splashes. The spores are carried to nearby trees/areas by rain splash and wind. Its spread intensifies during catastrophic events such as hurricane.

During 2004 hurricane season, more than 80,000 acres of commercial citrus were believed to be infected or exposed to citrus canker and infected trees were removed and destroyed (about 120,000 trees per week). Hurricane Wilma in October 2005 further spread the disease from about 32,000 infected acres that remained to be destroyed and experts believed that additional 168,000 to 220,000 acres had to be destroyed to eradicate the disease. Due to citrus canker and greening disease in 2004/2005, experts suggest that the state will never reach the level of citrus production prior to 2003.

Windbreaks are widely used in South America and Australia for canker control and are effective in controlling both spatial and temporal spread (Leite and Mohan 1990, Smith and Papacek 1991, Gottwald and Timmer 1995). Citrus growers in Florida are following the same practices and are introducing windbreaks in their groves. Due to urgency, growers are using non-native fast-growing species such as cadaghi (*Corymbia torelliana*) and other eucalypts. Growers seem to prefer cadaghi because of its fast growth, dense canopy and lower branch retention. In Florida, the species has been successfully planted in windbreaks.

This study evaluated the effectiveness of established eastern redcedar (*Juniperus virginiana*) and cadaghi windbreaks and studied the extent of microclimate modification in the protected area.

MATERIALS AND METHODS

Study Area

The study was conducted at SWFREC and C&B Farms, Clewiston. SWFREC has a 20-year-old eastern redcedar windbreak which marks the northern boundary of the property. At C&B Farms, several cadaghi windbreaks divide the farm into blocks. Windbreaks are planted approximately every 305m (1000ft) and are of various ages. Sugarcane windbreaks planted within the blocks further divide the farm into sub-blocks. Windbreak 1 which marks the northern boundary is the oldest windbreak (20-years-old). Windbreak 2 is south of windbreak 1 by about 305m. The characteristics of the windbreaks are given in Table 1.

Table 1: Characteristics of the windbreaks in the study area

Windbreak	No. of rows	Age (Yrs)	Height (m)	DBH (cm)	Porosity (%)	Crown length (m)	Spacing (m)
Eastern redcedar	Single	20	7.3	14.6	17	6.9	1.2
Cadaghi WB 1	Single	20	17.5	40.5	20	13.9	2.3
Cadaghi WB 2	Single	8	10.3	24.6	39	9.4	4.9

Methods

Automated weather stations were installed at 2H (distance equivalent to twice the windbreak height H), 6H, 10H and 14H along two separate transects on the leeside of the windbreak at SWFREC between January and June of 2008. At C&B Farms, established sugarcane windbreaks provided open space only for a transect. Measurement stations were established between Windbreak 1 and Windbreak 2 along a transect perpendicular to both the windbreaks. Automated weather stations were installed at 2H, 6H and 10H from windbreak 1. Another series of stations were installed at 2H, 6H and 8H from windbreak 2 along the same transect. Stations at 10H, 6H and 2H from windbreak 1 were approximately at 15H, 23H and 31H from windbreak 2. Similarly, stations at 8H, 6H and 2H from windbreak 2 are approximately at 13H, 14H and 16H from windbreak 1.

At each monitoring station wind speed, temperature and relative humidity were measured at a height of 2m above the ground. Wind speed was measured using HOBO wind speed smart sensors (Part: S-WSA-M003) and temperature/relative humidity was measured using HOBO temperature/relative humidity sensor (Part: S-THA-M002). Automatic measurements were taken every 30 seconds and recorded in HOBO micro station data logger (Part: H21-002) and hourly averages were computed. A reference station at each site also measured wind speed and temperature/relative humidity at 2m above the ground. Wind direction was also measured at 2m at reference stations using wind speed and direction smart sensor (Part: S-WCA-M003).

Collected data were filtered by wind direction and used in the analysis only when the wind direction was between 0 and 180 degrees to the windbreak. Measured wind speed, temperature and relative humidity on the leeside of the windbreak were divided by the field wind speed, temperature and relative humidity during that interval, respectively, to calculate relative wind speed, temperature and relative humidity. Relative values were used to study patterns in the protected area behind the windbreak.

RESULTS AND DISCUSSION

Wind Speed Reduction

Wind speed behind the windbreaks never reached the open wind speed when the wind was from the north. Minimum wind speed was generally recorded at 2H behind redcedar windbreak. Wind speed at 2H was less than 5% of the open when the wind direction was nearly perpendicular to the windbreak (90±15 degrees). When the direction was 90±45 degrees to the windbreak, relative wind speed at 14H behind redcedar windbreak was mostly less than 80% of the open wind speed (Fig. 1). Relative wind speed at 2H was always lower than 17%. Wind was not detected at 2H when the open wind speed was below 2.5m/s.

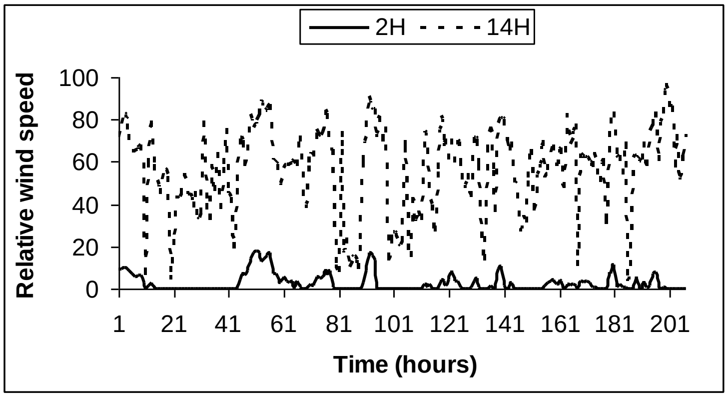

Fig. 1. Relative wind speed at 2H and 14H behind eastern redcedar windbreak when the wind direction was 90±45 degrees.

When the wind direction was within 45 degrees to the windbreak, relative wind speed at 14H remained more or less the same (Fig. 1 and 2). However, there was a significant increase in wind speed at 2H compared to when wind direction was 90±45 degrees.

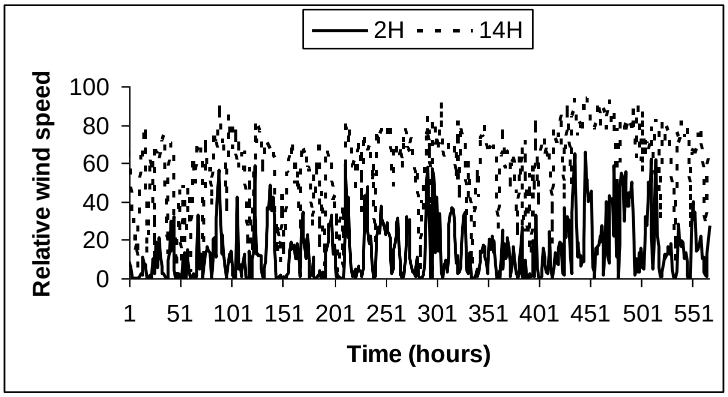

Fig. 2. Relative wind speed at 2H and 14H behind eastern redcedar windbreak when the wind direction was within 45 degrees to the windbreak.

At C&B farms, the maximum wind speed recorded behind windbreak 1 was about 95% of the open wind speed. In contrast to SWFREC, the minimum wind speed was generally recorded at 6H when the wind direction was nearly perpendicular (90±15 degrees) (Fig. 3). Wind speed gradually increased up to 14H, but wind speed at 14H was still 30% less than the open. As the wind approached windbreak 2, it slightly decreased again at 16H.

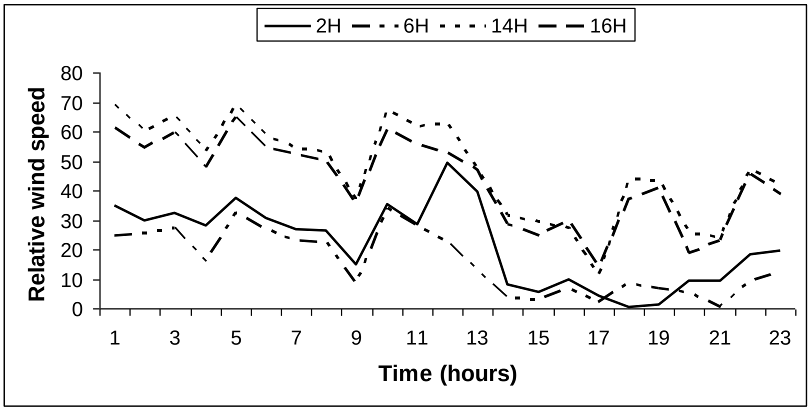

Fig. 3. Relative wind speed at different distances from the windbreak at C&B Farms when the wind direction was nearly perpendicular (90±15 degrees) to the windbreak and when open wind speed was greater than 2m/s.

Wind reduction in the current study was higher than observed in Denmark where the wind speed was 86% at 7H (Foereid et al. 2002). Other studies have recorded wind speeds between 40-100% in the protected zone (Brenner et al. 1995, Zhang et al. 1995), but the wind speed measured in the protected area during the study was always lower than in those studies. It is likely that the dense windbreaks in the study area were more effective in reducing wind speed. Taller windbreak also provided protection up to a longer distance. Others have found extremely variable wind reduction in the protected zone (Zhang et al. 1995).

One of the reasons for planting windbreaks around citrus groves is to reduce wind speed below 8m/s. Winds above 8m/s forced canker bacteria into leaf stomates and damaged plant parts and fruit (Graham et al. 2004). When the open wind speed was 8.1m/s, eastern redcedar reduced it to 2.2m/s at 2H and 6.3m/s at 14H when the wind direction was 25 degrees to the windbreak. If the direction is perpendicular to the windbreak, windbreaks can potentially reduce winds above 8m/s to lower levels. Since wind speed reduction is generally equivalent to windbreak density (Cleugh et al. 2002), wind speed reduction in the current study is within the expected range.

Temperature and Relative Humidity Modification

Changes in temperature and relative humidity were less compared to wind speed. Under normal weather conditions, daytime temperature near the windbreak was a few degrees warmer than in the open (Fig. 4a). Temperature at 14H was more or less similar to open temperature. Temperatures at 2H and 6H were similar and generally warmer than at 10H and 14H (Fig. 4).

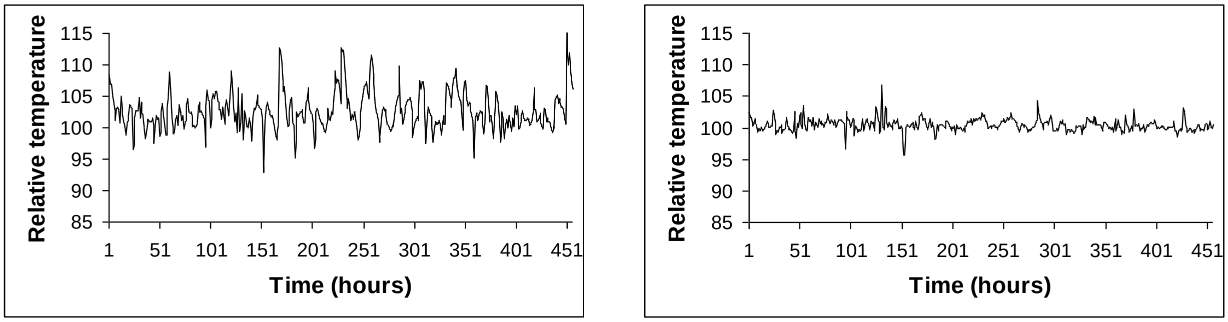

Fig. 4. Diurnal (6AM-5PM) temperature behind redcedar windbreak (a) at 2H (left) and (b) at 14H (right)

The opposite pattern was observed at night. Temperatures at 10H and 14H were generally warmer than at 2H and 6H (Fig. 5). Temperatures at 2H and 6H were generally lower than in the open. Similarly, temperature at 14H was generally warmer than the open when the open wind speed was less than 3m/s. When the open wind speed was greater than 3m/s temperature at 14H was either equal to or lower than the open.

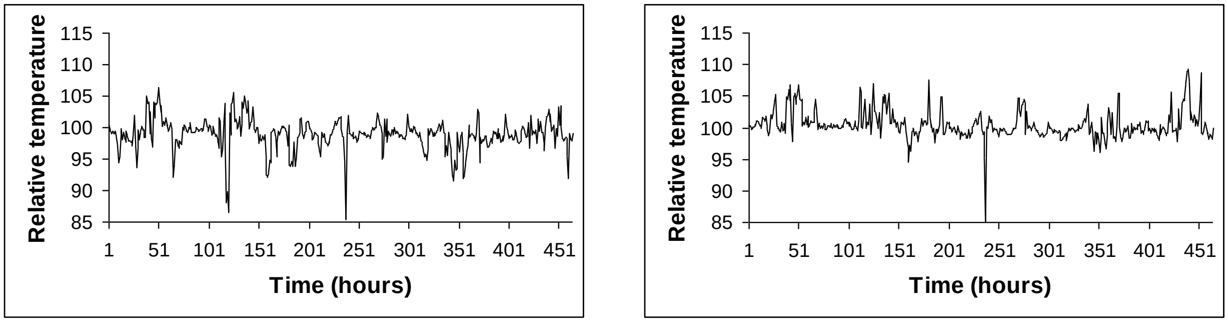

Fig. 5. Night time (6PM-5AM) temperature behind redcedar windbreak (a) at 2H (left) and (b) at 14H (right).

During the cold fronts, temperature at 2H was relatively cooler than the stations further away from the windbreak when the open wind speed was lower than 2m/s. When the wind speed was greater than that, temperature at 2H was almost similar to other stations (Fig. 6).

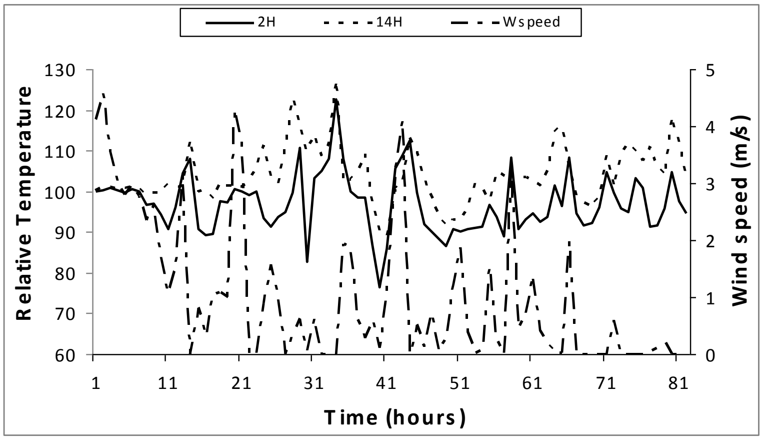

Fig. 6. Relative temperature at 2H and 14H behind eastern redcedar windbreak during cold fronts

All stations showed similar patterns in relative humidity during the study period (Fig. 7). Relative humidities at 2H and 6H were slightly lower and at 10H and 14H were slightly higher then the open till the end of February at both sites. But beginning March, relative humidities at all stations were generally higher than in the open.

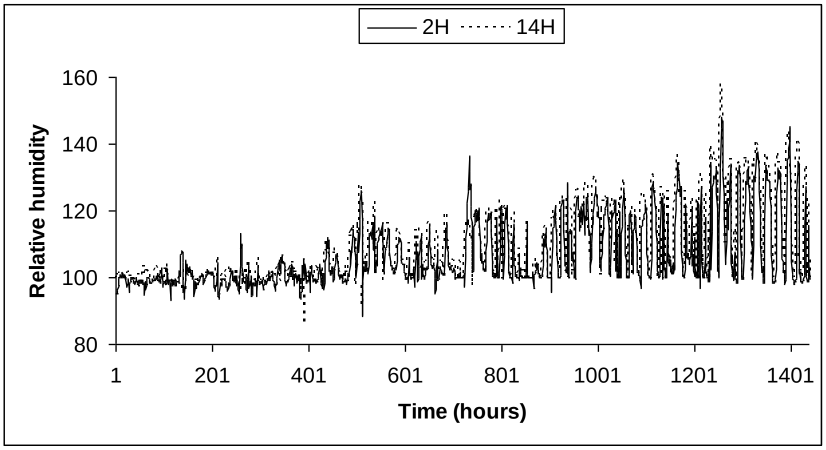

Fig. 7. Relative humidity at different distances from the windbreak during the study

Wind speed reduction in the protected area changed temperature and relative humidity. The temperaure and humidity patterns observed in the current study are consistent with other studies. Foereid et al. (2002) also observed higher temperature near willow windbreak in Denmark. Temperature increased during the day but decreased at night near the windbreak. Relative humidity also increased in the sheltered area during the day (Sudmeyer et al. 2002). However, compared to wind speed reduction, temperature and humidity modifications are limited to shorter distance. Wind speed reduction can be expected up to 25-30H, but temperature and humidity modification extends up to 10-12H behind the windbreak (Cleugh et al. 2002).

CONCLUSIONS

Windbreaks have the potential to modify microclimate behind the windbreak. Modified microclimate enhances crop growth and final yields. At the same time windbreaks can also control the spread of pathogens such as citrus canker. They maintain the productivity of the agricultural systems by conserving soil and nutrients and at the same time can provide many ecological services.

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