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PHOTO-OXIDATION IN AVOCADO LEAVES

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SUMMARY

Leaf yellowing in winter is suspected of being a symptom of photo-oxidation in avocado leaves. Photosynthetic performance is thought to be reduced in leaves with photo-oxidation damage and damaged leaves are likely to drop earlier. Photo-oxidation is caused by excess light energy, which is unable to be dissipated due to cool temperatures. The experimental program aims to answer three questions: What is the photosynthetic performance of avocado leaves during summer and winter months in the Bay of Plenty? What is the relationship between leaf yellowing and photosynthetic performance? And, is there an effective treatment to return photosynthetic performance to normal? Photosynthesis was investigated by examining net CO2 assimilation and chlorophyll fluorescence techniques were used to determine the quantum efficiency of leaves, an indication of light stress. Xylem tension was measured to determine water stress. Initial measurements, completed on the 26th to the 31st of March 2005 showed little sign of light or water stress. Measurements will be made regularly in the coming summer, autumn and winter months (December 2005 to August 2006). An evaluation of the use of low biuret urea and magnesium sulphate as a restorative treatment will be carried out in the winter of 2006.

Key words: photo-inhibition, temperature, chilling, gas exchange, chlorophyll florescence, xylem tension

INTRODUCTION

After periods of low temperature, avocados trees show signs of leaf yellowing which is suspected to accompany a loss of leaf function such as reduced photosynthetic performance. Low temperature, high light conditions, like those on clear cold winter mornings in the Bay of Plenty during the winter months, leads to the creation of free radical oxygen which damages photosynthetic components in the leaf. Leaf yellowing may be an indicator of only the more severe chilling events, with a possible loss of photosynthetic performance occurring before the onset of leaf yellowing.

The experimental program aims to answer three questions: What is the photosynthetic performance of avocado leaves during summer and winter months in the Bay of Plenty? What is the relationship between leaf yellowing and photosynthetic performance? And, is there an effective treatment to return photosynthetic performance to normal? To achieve these aims, it is necessary to determine the normal performance of avocado leaves in summer when there is no cold stress. Daily photosynthetic performance patterns will be obtained for the summer and winter months and defined leaf yellowing events will be captured as they occur, or created artificially with chilling chambers.

Existing plant physiology techniques will be used to quantify photosynthetic performance and a range of other plant stress and environmental factors. Diurnal net photosynthesis and stomatal conductance will be measured using modern porometric systems (CIRAS and Walz CMS400). Portable chlorophyll fluorescence instruments (Walz Mini PAM) will be used to quantify maximal quantum efficiency during summer and winter as this technique is established as a method for detecting damage to leaf photosystem II. These measurements will be made on trees with and without a foliar nitrogen treatment. A climate station within the study orchard will capture important climate information, including air temperature, humidity and incident light intensity. Leaf chlorophyll content will be monitored during yellowing and subsequent recovery.

An evaluation of the use of low biuret urea and magnesium sulphate as a restorative treatment for photo-oxidation yellowing will be completed in the winter 2006. Treatments will be applied during a naturally occurring leaf yellowing event or yellowing events created artificially using chilling chambers on branches within the orchard.

The study will be completed as a requirement for a Masters in Science degree at the University of Waikato, for completion in November 2006.

MATERIAL AND METHODS

Current

An orchard was selected near Katikati, Bay of Plenty, New Zealand, that has a history of winter leaf yellowing events. Gas exchange was determined with a Walz Compact Minicuvette System (Heinz Walz GmbH. Eichenring, Germany) on two sun exposed leaves from 26th to the 31st March 2005. The leaves at this time were fully expanded and dark green. A small leaf chamber (12.5cm^2) was placed over the sun exposed leaf, with the upper leaf surface exposed to the atmosphere and the under side provided with ambient CO_2 concentrations and humidity. Cuvette temperature was automatically controlled to follow ambient temperature. Net CO_2 assimilation was monitored automatically in differential mode.

Xylem tension was determined using a digital pressure bomb. Three fully expanded, sun exposed leaves from each of two trees, were excised and placed into a plastic bags. Measurements were made every two hours from 7am to 5pm on 27th and 28th of March 2005. Chlorophyll fluorescence measurements were obtained using a pulse amplitude modulated fluorometer, Walz Mini PAM (Heinz Walz GmbH. Eichenring, Germany). Diurnal quantum efficiency was obtained on leaves dark adapted for 15 to 30 minutes. Measurements were taken on 10 marked leaves on the north side of two trees and 10 marked leaves from the south side of the trees, on 27th and 28th of March 2005.

A standalone climate station based on a Campbell Scientific CR10X (Campbell scientific inc. Utah, USA) datalogger recorded air temperature, soil temperature, relative humidity and photosynthetically active radiation during the experimental period (data not shown).

Future work

In the coming summer, autumn and winter months (December 2005 to August 2006), measurements will continue for gas exchange, xylem tension, chlorophyll florescence and chlorophyll content. Leaves will be marked shortly after the spring flush to monitor leaf age. Photosynthetic performance will also be monitored on 100 leaves under saturating light intensities (10 leaves on the north side and 10 leaves on the south side of 5 trees) using a Ciras-1 portable photosynthesis system (PP Systems, Massachusetts, USA). Measurements will be taken every 3 weeks, with measurements at 10am and 12pm.

An evaluation of the use of low biuret urea and magnesium sulphate as a restorative treatment for photo-oxidation yellowing will be completed in the winter 2006. Treatments will be applied during a naturally occurring leaf yellowing event or created artificially using chilling chambers on branches within the orchard.

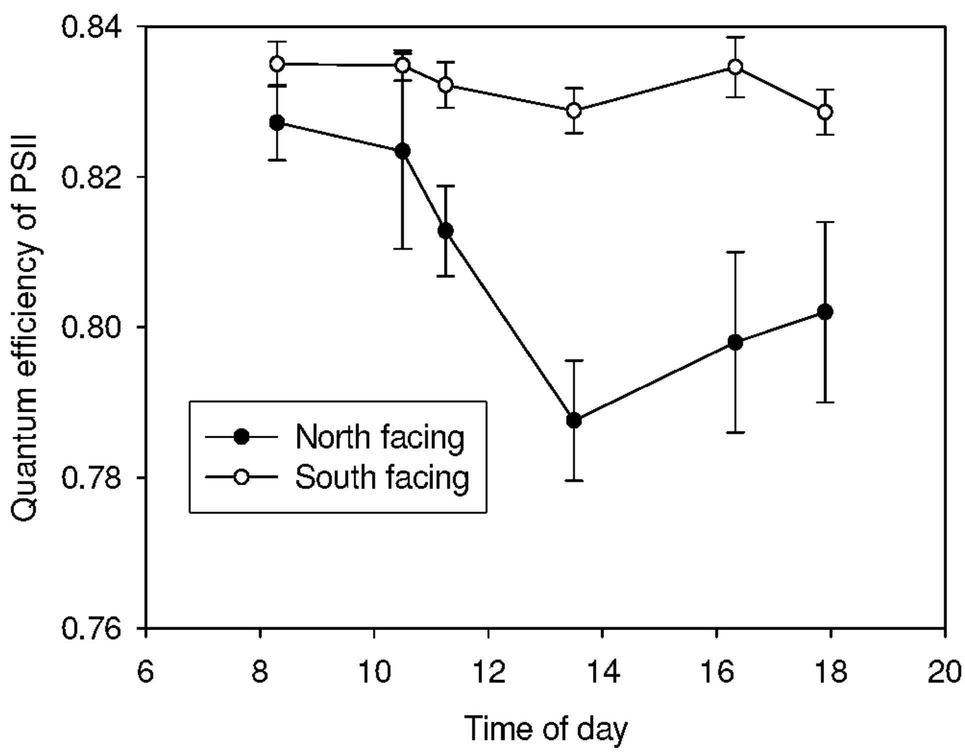

Figure 1. Mean quantum efficiency of north and south facing leaves, n = 10. Vertical bars are std. error of the mean.

RESULTS AND DISCUSSION

For shade adapted leaves on the south side of the trees, the mean quantum efficiency of photosystem II remained relatively unchanged during the course of the day, remaining about the theoretical maximum of 0.84, indicating that the photosystem was under no light stress during the day (Figure 1). Leaves on the north side of the tree had reduced mean quantum efficiency relative to the south side shortly after sunrise, at 8am. Mean quantum efficiency continued to decrease to 0.785 at 1pm, returning to 0.80 by 6pm, indicating that the sun exposed leaves on the north side were slightly light stressed during the middle of the day. This technique has the greatest potential for monitoring light stress during a leaf yellowing event and subsequent recovery.

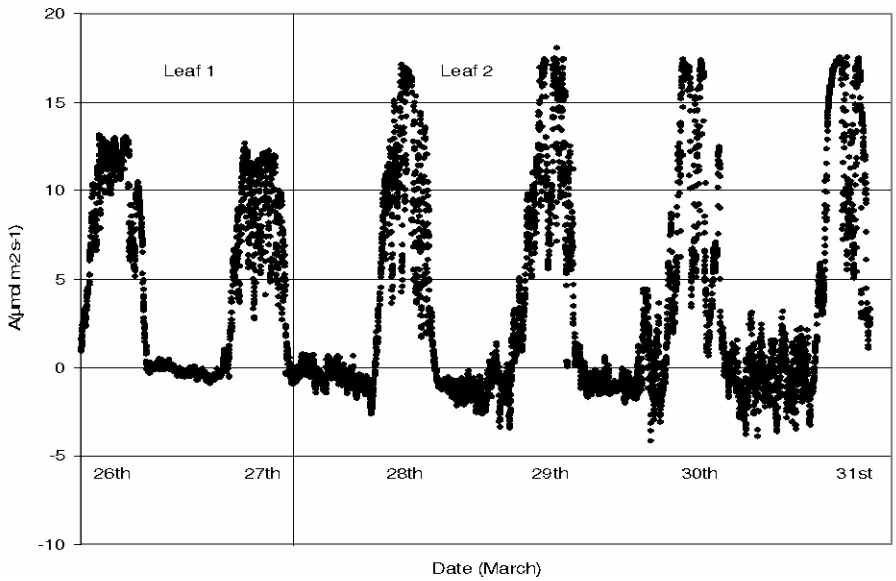

Figure 2. Net CO_2 assimilation, two leaves, 26th to 31st March 2005.

Photosynthetic performance was monitored with a Walz Compact Minicuvette System on two sun exposed leaves (Figure 2). Leaf one had a peak net CO2 assimilation rate of 13.1 µmol m^{-2} s^{-1} and leaf two 17.5 µmol m^{-2} s^{-1} recorded under full sunlight. Partly cloudy conditions existed on all of the study days, with a daily maximum temperature of 18.9 to 20.7°C. Photosynthetic performance will be monitored, on single leaves under ambient conditions and on 100 leaves under saturating light intensities (10 leaves on the north side and 10 leaves on the south side of 5 trees).

Xylem tension is a measure of water stress and needs to be considered as a contributing factor in stress experienced by avocado trees. Initial readings (Figure 3) at dawn and the quick recovery in both trees on both days suggests there was little water stress. Mean values of xylem tension did not exceed -0.8 MPa on either day, suggesting that there was little water stress during the middle of the day. Both days were partly cloudy and were preceded by several days of rain.

CONCLUSIONS

Photo-oxidation of avocado leaves occurs when excess light energy can not be dissipated due to cool temperatures, creating free radical oxygen and leading to leaf yellowing. Loss of photosynthetic performance and early leaf drop are suspected to be symptoms of photo-oxidation. Mean quantum efficiency indicated no light stress for leaves on the south side of trees and slight stress on leaves from the north side during the middle of the day. No indication of water stress was found. Over 6 days in March

2005 a maximum CO2 assimilation rate of 17.5 µmol m^{-2} s^{-1} was recorded.

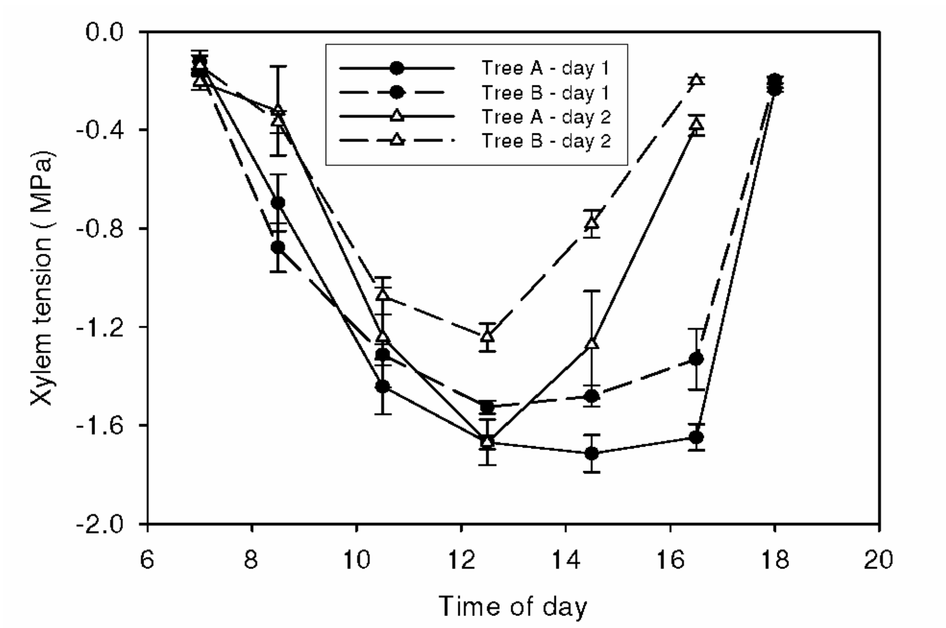

Figure 3. Xylem tension in avocado leaves. Sun exposed leaves on two trees, 26th and 27th March 2005. n = 3, vertical bars are std. error of the mean..

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