

S34-007

Photosynthetic characterization of different leaf layers of field - grown grapevines cv Thompson Seedless.

C. Pacheco, V. Garcia de Cortazar, C. Cordova, U. Morales, M. Pinto

Faculty of Agronomic Sciences, University of Chile, Casilla 1004, Santiago, Chile.

Email: manpinto@uchile.cl

Keywords: LAI, PFD, fluorescence, Vitis vinifera

Introduction

In Chile, table grape (*Vitis vinifera* L) varieties are commonly grown on a particular trellis structure, named “*parronal*”. Due to the horizontal distribution of the leaf layers, this system leads to big attenuation of the photon flux density (PFD) throughout the canopy, particularly when plants reach a leaf area index around 4. This commonly occurs after veraison when demand for photosynthates starts to be an active process. At that time, almost all of the direct PFD is intercepted by leaves growing on top of the canopy, raising concern about the real contribution of lower leaf layers to the total CO₂ assimilation of the plants. In fact, leaves situated on the lower layers would be close to the PFD compensation point for most of the day. This has made to suppose that in grapevine most of the photosynthates transported to the clusters come from leaves directly exposed to the sun (Smart 1974). However, in *parronal* system this seems to be not totally clear. Depending on the sun position and intensity of wind, leaves from the lower layers can also be reached by direct PFD in the form of sunflecks. As a consequence, parts of the lower canopy can have high photosynthesis rates for different periods. Contribution of this to the total plant photosynthesis is not well known and has not been evaluated in the *parronal* system.

On the other hand, leaves from the upper part of the canopy, are most of the day exposed to very high PFDS. In consequence, is possible that their photosynthetic capabilities cannot be fully expressed due to photoinhibition or other stresses during the day. Daily losses on the CO₂ assimilation capacity has been observed in grapevine (Chaves et al 1987; Patakas 1993) that in some cases have been associated with decreases in stomatal conductance (Chaumont et al 1994). However, high light can also cause daily photosynthesis decreases by non-stomatal factors like losses in the photochemical capacity (Chaves et al 1987; Correia et al 1990).

The objective of this work was to characterize the daily photosynthesis of leaves from the upper and the lower part of the grapevine canopy grown under *parronal* system and to determine the relative contribution of each leaf layer to the total CO₂ assimilation of plants.

Materials and Methods

During 2000-2001 growing season, measurements of leaf area index (LAI), PDF profiles inside the canopy, fluorescence, and net CO₂ assimilation rate were done 3 times in the season in an orchard of table grapes cv Thomson Seedless located in the Central valley of Chile, 33° Lat. S and 71° Long.W. Plants used were ten years old, drip irrigated, planted at 4x4 m of distance and conducted under *parronal* system. In this system, four main branches normally oriented to North – South - East and West directions are left at 1.8 m. height. From the main branches, every season secondary shoots are allowed to grow in all directions forming a dense and flat canopy that is sustained by wires. This system allows the development of horizontal leaf layers over the wires, and the clusters to hang freely below them facilitating its manipulation.

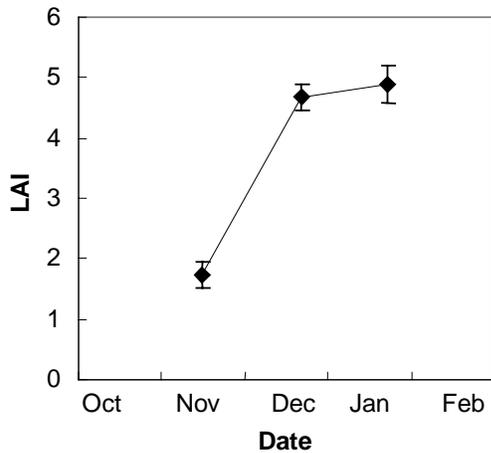


Figure 1. Time course of leaf area index (LAI). Each value is the average of 4 plants. Vertical bars indicate ± 1 s.e.

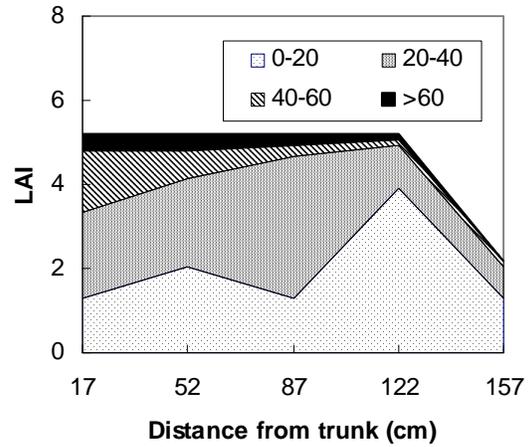


Figure 2. Vertical distribution of LAI as a function of distance from the trunk, along the main branches. The canopy was divided vertically in layers 20 cm thick, with the zero value at the height of the trellis.

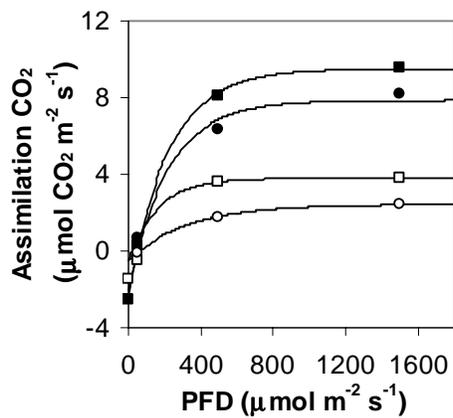


Figure 3. CO₂ uptake curves as a function of PFD for two times: bloom (circles) and 10 days after veraison (squares) and two leaf growth conditions: sun-acclimated (filled) and shade acclimated (empty)

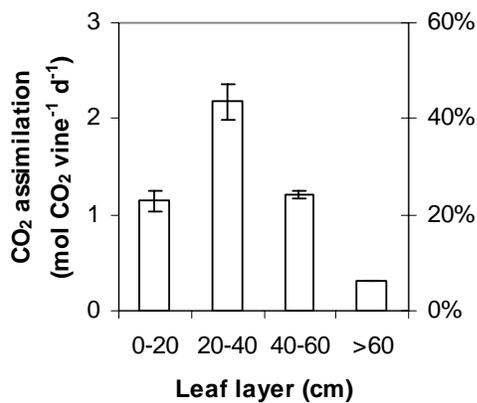


Figure 4. Simulation of daily net CO₂ assimilation at veraison for the layers of fig. 2. The right axis is the fractional contribution of each layer to whole plant photosynthesis. Bars indicate ± 1 s.e.

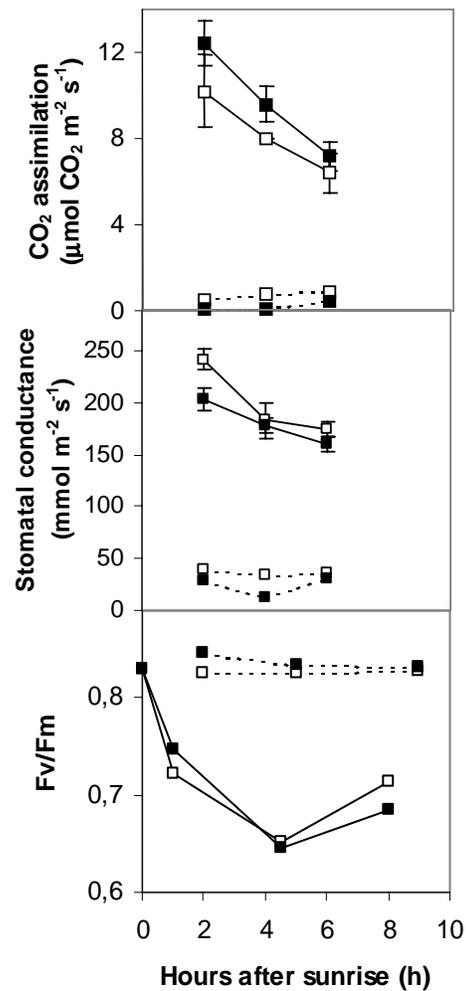


Figure 5. CO₂ assimilation(a), stomatal conductance(b) and Fv/Fm ratio(c) as a function of time after sunrise. For two dates: bloom (empty squares), 10 days after veraison (filled squares) and two growth conditions: sun-acclimated (continuous lines) and shade acclimated (dotted lines)

Measurements were performed at early bloom (Nov 15, 2000), one month later (Dec 21, 2000) and ten days after veraison (Jan 22, 2001). Values of LAI were obtained with the gap fraction method (Norman and Campbell, 1989) using line quantum probes (Delta-T Devices Inc, UK). Vertical profiles of direct PFD were obtained by inserting the probe vertically along the 4 main branches of 4 plants at distances of 35 cm near solar noon. Vertical profile of leaf area was estimated by the gap fraction method from the profile of PFD and the extinction coefficient of the canopy.

CO₂ assimilation curves and stomatal conductances were obtained at different times of the day from sun- and shaded-acclimated leaves using a portable IRGA (PPsystems, UK). Fluorescence measurements were performed at similar times in dark-adapted leaves using a PEA non-modulated fluorometer (Hansatech, UK).

Canopy photosynthesis was simulated with the model described by Forseth and Norman, (1993) and using measured values of LAI, extinction coefficients and CO₂ assimilation curves as data inputs. The canopy was divided in 4 horizontal layers, 20 cm thick using the trellis line as the base as more than 90% of PFD interception occurred within this zone. Each layer was divided in sunlit and shaded leaves, and layer photosynthesis was the weighted sum of the contribution of each type of leaves.

Results and Discussion

Leaf Area Index

On the first date of measurement the LAI was less than 2.0 (Fig. 1) with a ground cover of 54%. One month later LAI stabilized over 4.5 with a ground cover of approximately 90%. The spatial distribution of leaf area was not uniform. The “local” LAI near the trunk was higher than at the extremes of the main branches, reaching values over 6 two weeks after veraison. Vertically, the leaf area was concentrated at the lower part of the canopy (Fig. 2), where the first 20 cm over the trellis concentrated 53 % of the total plant leaf area, while the top 20 cm have less than 3%. On the whole canopy, only 38% of the leaves were exposed to direct PDF at solar noon. Hence, most of the berry growth occurred under conditions where less than 40% of the canopy was exposed to direct PFD.

Net CO₂ Assimilation

CO₂ assimilation vs. PFD curves of sun- and shade-acclimated leaves at bloom and two weeks after veraison are presented in Fig. 3. These are the average of measurements done at 10:30, 12:30 and 14:30 h. Two weeks after veraison, maximal CO₂ assimilation (A_{max}) of sun-acclimated leaves was almost 20% higher than at bloom. This could be due to the high photosynthate demand occurring in this period where berries are actively growing. CO₂ assimilation vs. PFD curves for shade-acclimated leaves were similar at both stages of growth, but their A_{max} were almost 2.5 times lower than those observed on sun-acclimated leaves. Using values of CO₂ assimilation, LAI and PFD distribution through the canopy, the CO₂ assimilation per layer was calculated (Fig. 4). Two weeks after veraison, even though leaves from the top layer can keep photosynthesis rates 4 times higher than those of leaves from the lower layers (Fig.5a), their contribution to whole plant assimilation is only 6% as they only represent 3% of the canopy LAI. Under these conditions, almost 70 % of the whole photosynthate production would come from leaves of the 2 lower layers, which in turn represent almost 80% of the canopy LAI.

In both growth stages almost 50 % of the leaves from the top layer were exposed during the day to PFD intensities over 1000 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ and hence under risk of photoinhibition. In fact, after 6 hours of exposure to PFD intensities averaging 1500 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, leaves from the top layer experienced reductions of 37% and 42% in net CO₂ assimilation rate at bloom and ten days after veraison respectively. This decline was paralleled by a decline in stomatal

conductance indicating a possible implication of the stomatal function on this depression (Fig. 5b). However non-stomatal factors could also be implicated. Fv/Fm values also decreased significantly after long exposure to high PFD (Fig. 5c). By the end of the photoperiod, Fv/Fm started to recover indicating that this decline was probably more due to action of photo protective mechanisms than to direct photodamage. Considering the low proportion of sunlit leaves with respect to the total LAI and that measured time of exposure to direct radiation in this system was not longer than 4 h per day (data non shown) this depression in CO₂ assimilation in sunlit leaves would not affect significantly the total carbon budget of the system.

Acknowledgements

FONDECYT Grant # 1000839 supported this work

Bibliography

- Chaumont M., Morot-Gaudry J.F. and Foyer Ch. 1994. Seasonal and diurnal changes in photosynthesis and carbon partitioning in *Vitis vinifera* leaves in vines with and without fruit. *J. Exp. Bot.* **45**,(278): 1235 - 1243
- Chaves M.M., Harley P.C. Tenhunen J.D. and Lange O.L. 1987. Gas exchange studies in two Portuguese grapevine cultivars. *Physiologia Plantarum* **70**, 639 – 647
- Correia M.J., Chaves M.M., and Pereira J.S. 1990. Afternoon depression in photosynthesis in grapevines leaves : evidence for a high light stress effect. *J.Exp. Bot.* **41**, 417 - 426
- Forseth, I.N. and Norman J.M., 1993. Modelling of solar irradiance, leaf energy budget and canopy photosynthesis. In Hall, D.O., Scurlock, J.M.O, Bohlär-Nordenkampf, H.R., Leegood, R.C., and Long, S.P. (eds.). *Photosynthesis and production in a changing environment: a field and laboratory manual*. Chapman & Hall, London. p 207-231.
- Flexas, J., Escalona, J.M. and Medrano H. 1998. Down-regulation of photosynthesis by drought under field conditions in grapevine leaves. *Aust. J. Plant Physiol.* **25**, 893 -900
- Norman, J.M. and Campbell, G.S., 1989. Canopy structure. In Pearcy, R.W., Ehleringer, J. R., Mooney, H.A., Rundel, P.W. (eds.). *Plant physiological ecology. Field methods and instrumentation*. Chapman and Hall. 457p.
- Patakas A. 1993. Diurnal changes in gas exchange and water relations in field-grown grapevines. *Acta Horticulturae – Irrigation of Horticultural Crops* **335**, 251 - 256
- Smart, R.E. 1974. Photosynthesis by grapevine canopies. *J. Appl. Ecol.* **11**, 997 - 1006