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Peach leaf physiology and irrigation water and light availability

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Abstract. We studied the effect of available water and light into the canopy on leaf characteristics and physiology of two clingstone peach cvs. Irrigation water was reduced by 90% (deficit) since late June (3 weeks before harvest) and, the same day, 1.2 m wide Extenday reflective mulch strip was applied on the row. Incident and reflected ultraviolet (UV) and photosynthetically active radiation (PAR) were measured inside the canopy. Specific leaf weight (SLW) and chlorophyll content were measured every month from late May to late August on light exposed and shade leaves. Photosynthesis (Ps), transpiration (E) and other physiological parameters were measured or calculated in light exposed leaves periodically. The reflective mulch significantly increased reflected UV and PAR radiation in the canopy compared to control, while no similar trend was found for incident radiation. SLW and chlorophylls (a, b and total) were not affected by treatment in both cvs, while significant changes with time and leaf position were always observed. Deficit irrigation increased leaf temperature and decreased stomatal conductance, Ps and water use efficiency (WUE) compared to control. Combination of reflective mulch and water deficit was even more detrimental to leaf physiological functions as this combination treatment increased leaf temperature and decreased E, stomatal conductance, Ps, WUE and quantum yield compared to control and often to other treatments.

Keywords. Prunus persica – Photosynthetically active radiation – Photosynthesis – Transpiration – Chlorophyll – Specific leaf weight.

Physiologie de la feuille de pêcher et disponibilité en eau d'irrigation et en lumière

Résumé. *L'effet de la disponibilité en eau et en lumière dans le couvert sur les caractéristiques et la physiologie des feuilles de deux cultivars de pêchers pavies a été étudié. Trois semaines avant la récolte (fin juin), l'irrigation a été réduite de 90% (déficit) et un mulch Extenday réfléchissant de 1,2 m a été installé sur le rang le même jour. Les rayonnements UV et PAR incidents et réfléchis ont été mesurés à l'intérieur du couvert. Le poids foliaire spécifique (SLW) et la teneur en chlorophylle ont été mesurés tous les mois de fin mai à fin août sur des feuilles exposées à la lumière et à l'ombre. La photosynthèse (Ps), la transpiration (E) et d'autres paramètres physiologiques ont aussi été mesurés ou calculés périodiquement sur des feuilles exposées à la lumière. Le mulch réfléchissant a augmenté significativement les rayonnements UV et PAR réfléchis dans le couvert. Le SLW et la teneur en chlorophylle n'ont pas été modifiés par le traitement en déficit. La réduction de l'irrigation a entrainé une augmentation de la température des feuilles et une réduction de la conductance stomatique, de Ps et de l'efficience de l'eau (water use efficiency, WUE), par rapport au témoin. La combinaison de la réduction de l'irrigation et du mulch réfléchissant a eu des effets encore plus négatifs sur les fonctions physiologiques des feuilles.*

Mots-clés. *Prunus persica – Rayonnement photosynthétique actif – Photosynthèse – Transpiration – chlorophylle – Poids foliaire spécifique.*

I – Introduction

Irrigation consumes most of the available water quantities in the Mediterranean basin. Any possible improvement in water efficiency is necessary for the agricultural sustainability in the area (Laraus, 2004).

Peach tree has strong shoot growth thus requiring substantial amounts of irrigation water during the summer to sustain leaf productivity and yield. In peach trees, irrigation water is required mainly during the 3rd fruit growth phase when fruit cells expand dramatically. Less water is required after fruit harvest, when, in the case of mid season ripening cultivars, water needs can be almost half of that of the summer period. On the contrary, most peach growers do not differentiate their irrigation strategies and continue to apply more than required water throughout the summer period. In addition, excees water during fruit growth can increase fruit size and yield, but it may significantly reduce peach quality. Thus, studies on water consumption by peach trees during the summer period and ways to monitor tree reaction to deficit irrigation are needed for the Mediterranean region.

Light availability inside the tree canopy is a major factor influencing leaf and fruit productivity and fruit quality. Pruning and training are practiced regularly in commercial orchards to optimise light availability and productivity. Fruit quality is even more influenced by light availability and fruit grown in the shaded parts of trees have poor taste and colour and require repeated harvests increasing crop costs and reducing the economic return in general (Lewallen and Marini, 2003).

Alternative ways to increase light availability inside the tree canopy include reflective mulch on the orchard floor, which could increase light availability inside the lower (i.e. the most shaded) parts of the canopy (Green *et al.*, 1995). The mulching could also influence weed growth, irrigation water evaporation from the soil surface and leaf and tree overall physiology. The effect of reflective mulch in combination with normal or deficit irrigation on peach leaf physiology has not been studied.

This study was an attempt to understand how reflective mulch on the tree row can influence light availability inside the canopy, fruit quality and leaf physiology under normal or deficit irrigation regimes.

II – Materials and methods

The peach (*Prunus persica* L.) orchard under study consisted of two clingstone cvs Loadel and Fortuna. During 2007, the trees were 8 years old, cup shaped and irrigation was performed by two dripper lines on each row with a 4 L/hr dripper every 50 cm. At least six trees - replicates were used per treatment.

Irrigation was performed twice a week for a total of 8 hrs/week until harvest and 6 hrs/week during the rest of summer until September (control treatment). Deficit irrigation trees received around 10% of the water applied above during the last 3 weeks before harvest (late June) and thereafter until September. In total, during the last three weeks until harvest control trees received weekly 500 L/tree and deficit trees 60 L/tree and during July, August and early September 400 L/tree and 50 L/tree, respectively.

Extenday® reflective mulch 1.2 m wide was applied on the tree row under the canopy in six control and six deficit trees three weeks before harvest and left in place until early September. Thus we studied 4 treatments: control, reflective mulch, deficit irrigation and combination of reflective mulch plus deficit irrigation.

Soil water content was monitored periodically with 60 cm soil profile capacity probes and tree response to irrigation and light manipulation treatments with thermal dissipation probes. These data are not presented in this article.

Light availability inside the canopy was measured with an ultraviolet sensor (included 250-400 nm, model UVM, Spectrum Techn., Plainfield, IL.) and a photosynthetically active radiation (PAR) 3-sensor compensating instrument (model LQS-QM, Spectrum Techn.). Incident light was measured 50 cm away from the trunk and 30-50 cm above the ground inside the canopy with the sensor facing up. Reflected light was measured at the same points but with the sensor facing down. Light was measured midday on the four horizons and their mean values are presented.

Leaf dry matter, specific leaf weight and chlorophyll content were measured or calculated periodically from the beginning of treatments and during the rest of summer in sun-exposed and in shade leaves. Leaf disks were removed with 9 mm diameter corer, their fresh weight and surface were measured, dried at 80°C and reweighed. The % leaf dry matter content and specific leaf weight were then calculated. Similar leaf disks were extracted in 95% ethanol and chlorophyll was measured spectrophotometrically based on the method of Wintermans and Mots (Wintermans and Mots, 1965).

Leaf physiological parameters were measured in two-day sets, immediately after an irrigation event and 1 day later, over the summer before and after harvest. Chlorophyll fluorescence was measured in sun-exposed and shade leaves (12 dark-adapted leaves per treatment) at noon time with a chlorophyll fluorometer (model OS-30p, Optisciences Inc., Tyngsboro, MA). A photosynthesis unit (model LCpro, ADC Bioscientific Ltd., Herts, England) was used to measure or calculate leaf temperature, PAR, leaf conductance, net photosynthetic and transpiration rates, water use efficiency and quantum yield (8 leaves per treatment) during the morning hours from 09:00 to 12:00, before high midday temperatures would significantly reduce leaf functioning.

Statistical analysis involved analysis of variance over treatment and time (and incident or reflected light in light measurements inside the canopy) for all parameters tested with SPSS programme (SPSS 14.0, Chicago, IL.). LSD or Duncan's mean separation is shown.

III – Results and discussion

Ultraviolet (UV) and photosynthetically active radiation (PAR) inside the peach tree canopy increased significantly above the reflective mulch (Table 1). Incident UV and PAR did not change significantly inside the canopy and were kept very low and close to compensation point for net photosynthesis. Reflected UV and PAR in the canopy above the reflective mulch were more than 10-fold and 4-fold, respectively, higher than above bare soil exceeding the 50% of incident light inside the canopy. Thus, UV radiation inside the canopy above the reflective mulch reached levels able to positively affect fruit quality in the lower most shaded part of the peach tree. Reflective mulches have previously been found to increase light availability inside the canopy (Green *et al.,* 1995).

Specific leaf weight (SLW) increased during the summer time from late May to early September in all treatments and both cvs studied. SLW data for cv Loadel are shown in Figure 1. SLW for cv Fortuna reached a plateau during August. Deficit irrigation applied since late June had no significant effect on SLW in both cvs. The presence of reflective mulch during July and August did not affect SLW. Only leaf position had a significant effect on SLW with sun leaves having overall about 20% higher SLW than shade leaves from early in the season until late summer (Marini and Sowers, 1990). As expected, sun leaves had higher SLW due to much higher net photosynthesis compared to shade leaves, which are marginally self sustained due to low PAR availability.

Leaf chlorophylls a and b followed the same trends as described herein for total chlorophyll. Leaf total chlorophyll (TCHL) decreased mainly in late summer in both cvs studied. TCHL data for cv Loadel are shown in Figure 2. Deficit irrigation and reflective mulch treatments did not significantly affect TCHL content in any of the two cvs studied. Shade leaves had higher TCHL than sun leaves, as an attempt to collect sufficient light for photosynthesis. The ratio chlorophyll a over chlorophyll b decreased with time over the summer, was not affected by deficit or reflective mulch treatments and was higher in sun leaves compared to shade leaves.

Various leaf physiological parameters were measured or calculated in two day sets before harvest and after harvest in July and later in August. The two day sets following each irrigation event were different for each cv as the time required for measurement of all parameters in certain number of leaves during the proper hours was the limiting factor. Nevertheless, leaf chlorophyll fluorescence measurements in sun exposed and shade leaves showed that deficit irrigation and reflective mulch treatments did not clearly affect chlorophyll fluorescence (data not shown). The

Fo and Fv/Fm leaf chlorophyll parameters showed clear changes between measurement days related to air temperatures prevailing. Also sun leaves always had higher Fo and lower Fv/Fm than shade leaves (data not shown). Chlorophyll fluorescence measurements showed that this factor is important to enlighten daily stress due to high temperatures, but could not depict (if any) stress due to deficit irrigation or reflective mulch and clearly distinguished sun exposed and shaded leaves.

Leaf functioning was also measured periodically in sun leaves. Sun exposed leaves from deficit irrigated trees had lower PAR compared to leaves from mulched trees (Tables 2 and 3). Leaf temperature of sun leaves increased in deficit irrigated trees and even more in mulched trees compared to control ones (Tables 2 and 3). The combination of lower PAR availability and higher leaf temperature in deficit irrigated trees suggests lower stomatal functioning compared to well irrigated (control) trees.

Actually, leaves from deficit irrigated peach trees had lower stomatal conductance than leaves from well irrigated ones in both cvs studied (Tables 2 and 3). Similarly, due to high PAR incidence and leaf temperature, leaves from reflective mulched trees had lower stomatal conductance than leaves from well irrigated ones. The combination of deficit irrigation and reflective mulch had the largest negative impact on stomatal conductance. This reduction in stomatal conductance resulted in a reduction in leaf transpiration rate due to both treatments, deficit irrigation or reflective mulch, and their combination compared to leaves from well irrigated trees in both cvs studied (Tables 2 and 3).

The reduction in stomatal conductance had further negative consequences on leaf net photosynthetic rate. Leaves from deficit irrigated peach trees had lower photosynthetic rate than leaves from well irrigated trees (Tables 2 and 3). This reduction in net photosynthetic rate was more pronounced when deficit irrigated trees were mulched as well, as leaf stomatal conductance was even lower. Well irrigated and mulched trees had lower (cv Fortuna) or similar (cv Loadel) leaf net photosynthetic rate compared to well irrigated (control) trees. Drought stress has previously been found to reduce stomatal functioning and net photosynthetic rate (Cornic and Massacci, 1996).

The reduction in net photosynthetic rate in leaves from deficit irrigated or mulched trees was larger than the reduction in transpiration rate. This resulted in significant reductions in leaf water use efficiency in deficit irrigated or reflective mulched trees compared to well irrigated ones (Tables 2 and 3).

Due to increased PAR availability and lowered net photosynthetic rate in reflective mulched trees, quantum yield was lowered compared to control especially when trees had the lowest net photosynthetic rate in the combination treatment with reflective mulch in deficit irrigated trees (Tables 2 and 3). Leaves from deficit irrigated trees had similar (cv Fortuna) or lower (cv Loadel) quantum yield compared to leaves from well irrigated trees as both available PAR and net photosynthetic rate decreased compared to well irrigated trees.

In conclusion, the application of reflective mulch did not affect specific leaf weight and leaf chlorophyll content although it increased the available light inside the canopy and partially in the outer parts of the canopy. This resulted in increased leaf temperature, which was detrimental to leaf functioning as stomatal conductance, transpiration and net photosynthetic rates, water use efficiency and quantum yield were reduced even more when mulching was applied in deficit irrigated trees to reduce water evaporation and weed growth.

Similarly, reduction of irrigation volume to 10% of well irrigated trees did not affect specific leaf weight and leaf chlorophyll content but it reduced stomatal conductance, increased leaf temperature and, as a result, reduced most leaf functions.

Table 1. Mean values of incident and reflected ultraviolet and photosynthetically active radiation measured inside the canopy of Fortuna and Loadel peach trees above bare soil (control) or reflective mulch on the tree row.

	cv. Fortuna		cv. Loadel	
	Control ($\mu mol/m^2/s$)	Reflective mulch ($\mu mol/m^2/s$)	Control ($\mu mol/m^2/s$)	Reflective mulch ($\mu mol/m^2/s$)
Incident UV	6.9 a	7.1 a	4.9 a	6.3 a
Reflected UV	0.4 b	3.7 a	0.4 b	4.2 a
Incident PAR	91 a	109 a	59 a	85 a
Reflected PAR	21 b	71 a	18 b	94 a

Mean values per cultivar and parameter measured are significantly different when followed by different letters based on Duncan's mean separation.

Table 2. Mean values of Fortuna peach leaf physiological parameters when trees were deficit irrigated, mulched with reflective cloth on the tree row or mulched and deficit irrigated.

Physiological parameter	Control	Deficit Irrig.	Deficit + Refl	Reflective
PAR ($\mu mol\ mol^{-2}\ s^{-1}$)	1243 ab	1207 b	1266 ab	1306 a
Leaf Temp (°C)	33.0 b	33.6 a	33.8 a	33.8 a
Transpiration ($mmol\ mol^{-2}\ s^{-1}$)	4.62 a	4.57 a	4.23 b	4.57 a
Stomatal Conductance ($mmol\ mol^{-2}\ s^{-1}$)	0.301 a	0.265 b	0.222 c	0.255 b
Photosynthesis ($mmol\ mol^{-2}\ s^{-1}$)	15.7 a	14.4 b	13.4 c	14.6 b
WUE ($mmol\ mol^{-1}$)	3.49 a	3.24 b	3.24 b	3.20 b
QY (mol/100mol)	1.33 a	1.27 a	1.08 b	1.13 b

Mean values per parameter measured or calculated are significantly different when followed by different letters based on Duncan's mean separation.

Table 3. Mean values of Loadel peach leaf physiological parameters when trees were deficit irrigated, mulched with reflective cloth on the tree row or mulched and deficit irrigated.

Physiological parameter	Control	Deficit Irrig.	Deficit + Refl	Reflective
PAR ($\mu mol\ m^{-2}\ s^{-1}$)	1314 ab	1281 b	1372 a	1372 a
Leaf Temp (°C)	33.2 c	33.8 b	34.2 a	34.0 ab
Transpiration ($mmol\ m^{-2}\ s^{-1}$)	4.84 a	4.57 b	4.32 c	4.95 a
Stomatal Conductance ($mmol\ m^{-2}\ s^{-1}$)	0.294 a	0.232 b	0.199 c	0.256 b
Photosynthesis ($mmol\ m^{-2}\ s^{-1}$)	15.4 a	13.4 b	12.3 c	14.6 a
WUE ($mmol\ mol^{-1}$)	3.27 a	3.00 b	2.92 b	2.97 b
QY (mol/100mol)	1.19 a	1.07 b	0.93 c	1.08 b

Mean values per parameter measured or calculated are significantly different when followed by different letters based on Duncan's mean separation.

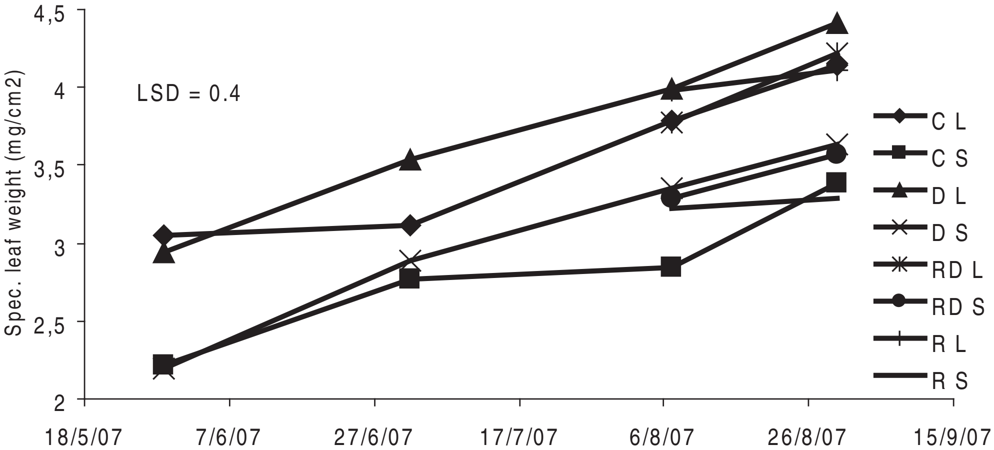

Figure 1. Specific leaf weight changes in sun exposed (L) or shaded (S) leaves during the summer 2007 in control (C), deficit irrigated (D) or reflective mulched (R) Loadel peach trees.

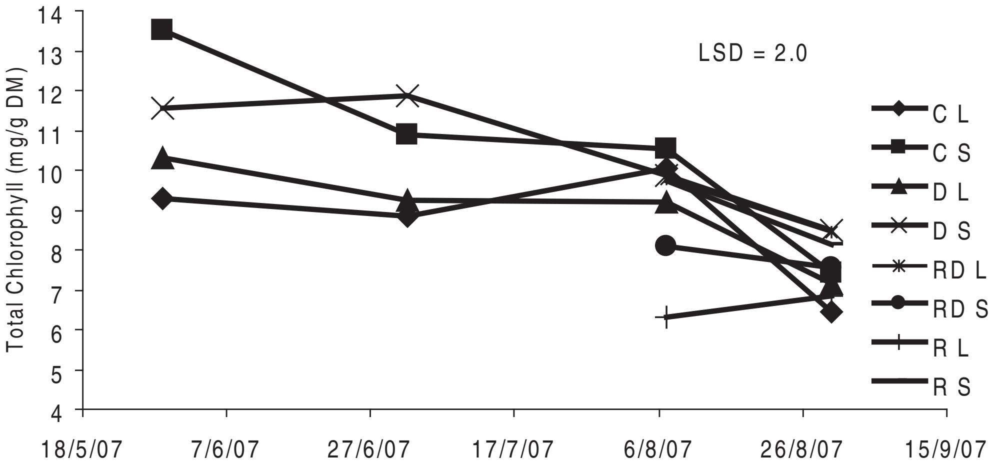

Figure 2. Total leaf chlorophyll content changes in sun exposed (L) or shaded (S) leaves during the summer 2007 in control (C), deficit irrigated (D) or reflective mulched (R) Loadel peach trees.

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References

Cornic, G., Massacci, A., 1996. Leaf photosynthesis under drought stress. In: N.R. Baker (ed). *Photosynthesis and the environment.* The Netherlands: Kluwer Academic. pp. 347-366.

Green, S.R., McNaughton, K.G., Greer, D.H., McLeod, D.J., 1995. Measurement of the increased PAR and net all-wave radiation absorption by an apple tree caused by applying a reflective ground covering. *Agr Forest Meteorol*, 76, 3/4. pp. 163-183.

Laraus, J., 2004. The problem of sustainable water use in the Mediterranean and research requirements for agriculture. *Ann App. Biol,* 144. pp. 259-272.

Lewallen, K.S., Marini, R.P., 2003. Relationship between flesh firmness and ground color in peach as influenced by light and canopy position. *J Am Soc Hortic Sci,* 128, 2. pp. 163-170.

Marini, R.P., Sowers, D.L., 1990. Net photosynthesis, specific leaf weight, and flowering of peach as influenced by shade. *HortScience,* 25, 3. pp. 331-334.

Wintermans, I.F., Mots, A., 1965. Spectrophotometric characteristics of chlorophylls a and b and their pheophytins in ethanol. *Biochim Biophys Acta,* 109. pp. 448-453.