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“Cropping the roots” of agroforestry systems: applying moderate water stress and water competition at plantation to increase tree root biomass

Oswaldo Forey ^{*±1}, Jacques Wery ² & Aurélie Metay ²

¹ INRA, UMR System, Bât. 27, 2 place Viala, 34090 Montpellier Cedex

² Montpellier Supagro, UMR System, Bât. 27, 2 place Viala, 34090 Montpellier Cedex

* Speaker

± Corresponding author: (oswaldforey@gmail.com)

1 Introduction

Agroforestry systems performances and stability rely on reduced competition for soil resources between trees and the intercrop. A management strategy at plantation could hence be designed to shape root systems, so that crop roots forage the top soil horizon and tree roots forage deeper horizons. We hypothesize that root growth can be favored by applying a moderate water stress that limits tree shoot growth while maintaining net carbon assimilation (Li *et al.*, 1989; Pellegrino *et al.*, 2006) in order to allocate more carbon to the roots. We therefore hypothesized that such type of soil water deficit should increase root biomass and if combined with a shallow-rooted intercrop stimulate this additional tree root growth in deeper horizons. Therefore, our study aims to investigate the effects of a moderate water stress and intercrop competition on net photosynthesis and carbon allocation to root and shoot compartments, of peach trees intercropped with a grass cover (continuous under the trees) during the first growing season after plantation.

2 Materials and Methods

A 2000m² drip-irrigated peach tree orchard with 475 one-year old trees was planted in January 2014 on a clay-loam soil in Southern France with three water treatment replicated three times in a Latin square design: (i) a well irrigated with a canvas soil-cover control treatment (T1), a moderately stressed with a canvas soil-cover treatment (T2) and (ii) a moderately stressed treatment intercropped with a grass cover crop (T3). Soil water potential within the tree root zone was monitored every two days with tensiometers (3 replicates per treatment) and readings at 40cm depth were used to keep soil water status in T1 between 0 and -200hPa, and between -400 and -600hPa in T2 and T3, which is for T2 and T3 sufficient to limit shoot growth without impacting net photosynthesis (Pellegrino *et al.*, 2005). Net photosynthesis was monitored three times with a portable Licor 6200, and pre-dawn leaf water potential twice during the growing season with a pressure chamber. Total root and shoot biomass were weighed at the end of the root growth season on three trees per treatment. Effect of water treatment on these variables was tested with one way Anova.

3 Results – Discussion

Soil water potential (SWP) from the beginning of the fast-growing shoot phase (2014/06/01) to the stopping of irrigation (2014/09/05) indicates that in T1, water status was on average kept at -241 ± 263 hPa, in T2 at -405 ± 342 and in T3 at -372 ± 288 hPa (mean values \pm standard deviation). This corresponds to our target range only for T2 due to soil heterogeneity (in T3 two tensiometers mean values out of three fall within the range, in T1 one out of three) and some unavoidable variability of SWP in such type of irrigation management in field conditions, as can be seen in Fig. 1, A.

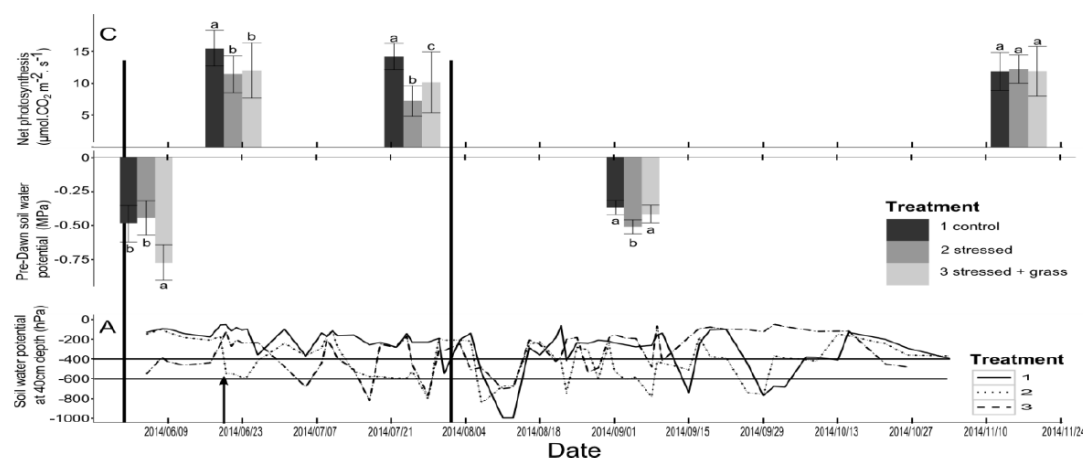


Figure 1: A: soil water potential at 40cm depth (hPa) mean values (n=3), B: pre-dawn water potential (Pa) mean values (n=12) \pm standard deviation and C: Net photosynthesis ($\mu\text{mol CO}_2 \cdot \text{m}^{-2} \cdot \text{s}^{-1}$) mean values (n=6) \pm standard deviation per treatment. Figures followed by different letters are significantly different at $P < 0.05$ according to Tukey test. Verticals bars delineate the fast-growing shoot phase and black arrow is the date of T2 soil-cover removal.

Indeed, pre-dawn water potential (Fig. 1, B) show that only T3 was stressed at the beginning of the fast-growing shoot phase (2014/06/05), due to the weed control canvas sheet used on T2 which prevented soil evaporation. Soil was then uncovered in T2 leading SWP to decrease and reach the target level of stress after 12 days (vertical arrow on figure 1, C). On the other hand at the end of the summer (early September), T3 was above the target SWP due to an excessive supply of water. The target levels of soil water deficit was therefore hard to maintain for each treatment during all the crop cycle but were achieved for most of the period and/or in most parts of the orchard.

By the end of June, net photosynthesis in T2 and T3 decreased in comparison with the control (T1), showing that water stress was sub-optimal in T2 and T3 (Fig. 1, C). At the end of July, i.e. at the maximum of the fast-growing shoot phase, net photosynthesis was lower in T2 than in T3. One explanation could be that trees in T2 having been stressed later than trees in T3, they had time to develop a higher leaf area (data not shown) and therefore a higher transpiration making it more difficult to maintain SWP in the target range. By the end of the growing season and after the stopping of irrigation, net photosynthesis was identical for all treatments.

Final tree biomass (Root+Shoot biomass) was significantly lower in T3 compared to T1 and T2 (Fig. 2) which is consistent with an earlier soil water deficit reducing plant photosynthesis. T3 also had a significantly higher Root/Shoot ratio than T1 and T2, whereas T2 was not significantly different from T1. Our first hypothesis was that water stress would increase Root biomass without decreasing net photosynthesis and hence total biomass. We therefore expected both T2 and T3 to have a higher Root/Shoot ratio than T1 but with an equal total biomass. This is the case for T3, but not T2, certainly due to an inappropriate timing and level of water stress. T2 was stressed later than T3, which allowed trees to produce more biomass before net photosynthesis decreased, but certainly too hard at a time where its water demand was high due to its high leaf area. Our second hypothesis was that water stress and competition with a herbaceous plant would force tree roots to growth at depth. We expected T3 roots to be found at depth, which is not the case (figure 3). The reason is that T3 was stressed too early and too hard, which hindered leaf development and hence carbon fixation, leading to dwarf trees with not enough carbon resource to allow sufficient root and shoot growth.

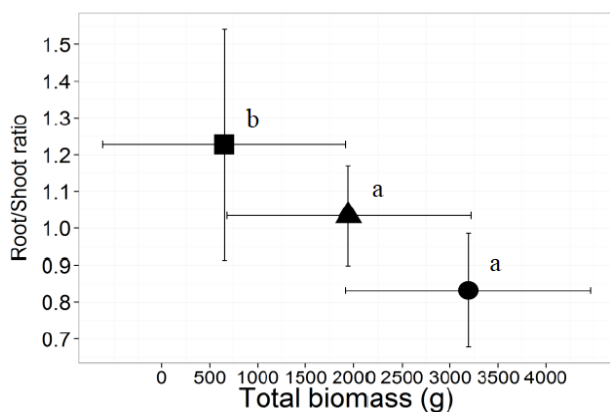


Figure 2: Root/Shoot ratio vs total biomass mean value (n=3) \pm standard deviation per treatment at the end of the root growing season.

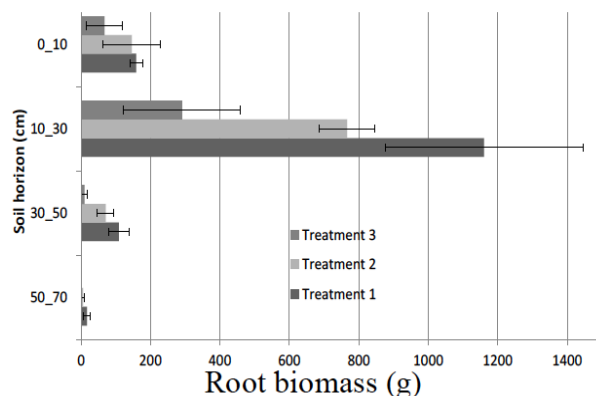


Figure 3: Root biomass mean value (n=3) \pm standard deviation per soil horizon and per treatment at the end of the root growing season.

4 Conclusions

Our results show that photosynthesis, a physiological process thought to be the last to be impacted by water stress (Pellegrino *et al.*, 2006), is actually impacted by a moderate stress within the range of tensiometers readings. This means that tensiometers are appropriate tools to apply such a moderate stress, even though it is still difficult to steer water stress with them in field conditions. It also means that in order to test our hypothesis that root growth can be favored by applying a moderate water stress, we need to lower our water stress target range, in order not to decrease net photosynthesis. We also need to apply this water stress later during the growing season so that trees can develop a sufficient leaf area to assimilate enough carbon to support differential root growth.

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