INTERACTIVE EFFECT OF TREE CANOPY COVER AND DEFOLIATION ON GROWTH OF *FESTUCA PALLESCENS* IN MEDITERRANEAN SILVOPASTORAL SYSTEMS IN NW PATAGONIA, ARGENTINA

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Introduction

The "limiting resource model" (Wise and Abrahamson 2005) proposes that grass growth after defoliation under tree canopy cover is lower than under full sun situation and further decreases with increased tree canopy cover and frequency of defoliation. This response is directly related to amount of biomass loss that limits the radiation or focal resource uptake (Wise and Abrahamson 2007). Testing the "limiting resource model" in Mediterranean silvopastoral systems could allow to determine which resource –radiation or water- is the focal one under these conditions, and therefore, if defoliated plants under tree canopy cover could grow better than in open situations due to facilitation effects of trees on their water status.

The objective of this study was to evaluate the effect of different levels of tree canopy cover on the growth and dry matter production of *Festuca pallescens* in N.W. Patagonia, in interaction with different intensity and frequency of defoliation. The hypothesis was that the morphophysiological changes caused by defoliation increase the positive effects (facilitation) and decrease the negative effects (competition) caused by the tree layer on the herbaceous layer in Mediterranean silvopastoral systems such as the studied model.

Materials and methods

The study was conducted during three growing seasons (October to April) from 2004 to 2007, at Lemú Cuyén Ranch (40,29º S; 71,13º W), Neuquen province, Argentina. The average annual rainfall is about 800 mm, with 615 mm in autumn-winter, and 185mm in spring-summer, resulting in summer water deficit. The maximum and minimum average annual temperatures are 17,1ºC ± 0.5 and 2.1 ± 4 ° C, respectively. Precipitation fallen differed in the three studied seasons, leading to relatively wet and dry seasons.

In a stand of *Pinus ponderosa* (2 ha), 10 plots (1600 m^2 each) were established and two thinning treatments were applied, 500 trees ha^{-1} and 350 trees ha^{-1} (n = 5). In adjacent open areas, 5 plots were also placed. Within these plots, 2 m x 2 m subplots were established containing 3 to5 *Festuca pallescens* plants on which the defoliation treatment was applied. The evaluated situations, in addition to a control without defoliation, were: a) Intensity of defoliation: removal 50 or 70% of the aboveground biomass only once at the beginning of the season, b) Defoliation frequency: low frequency, applying a single defoliation of 50 % of aboveground biomass; high frequency, applying the same treatment every two months; and c) moment of defoliation: removal of 50% of the above ground biomass only once in October, December or February.

Continuously the air temperature (°C) and relative humidity (%) were measured. Periodically, volumetric soil water content (0-120 cm) was measured by TDR and gravimetric methods.

In plants without defoliation, 10 tillers were randomly selected from the periphery of each plant, which were surrounded by a wire ring. In defoliated plants, two tillers groups of the same characteristics were chosen per plant. Every month, between October to April, the number of tillers in each ring was counted and net tillering was estimated. Five identified tillers of each plant were also measured monthly to determine the amount and maximum lenght of green leaves. Measurements were expressed as a proportion of the value in the initial month (Oct) and thus three indices were calculated: "relative net tillering", "relative number of green leaves per tiller" and "relative increase of leaves". The product of the three indices conformed the "relative growth index" (RGI).

At the end of the season, the plants were harvested to estimate biomass production, cutting all the biomass above the same height as the defoliation treatments. The biomass of the different harvests was dried at 70°C to constant weight and weighed (gDM). The dry matter produced in each treatment was estimated from the sum of all harvests, being only one in the control plants (final harvest) and two, three or four harvests depending on the frequency of defoliation in the other treatments.

Results

The daily average temperature in the coldest months of the year (July-September) was 0.7°C and 0.3°C higher under 350 trees ha^{-1} and 500 trees ha^{-1} respectively, compared to the average temperature in the open grassland. During warm February and March, air temperature and atmospheric demand were lower under tree canopy cover with marked differences in temperature between the control and the highest canopy cover.

In the dry season, a negative effect of tree canopy cover was observed on soil water content in the 0-20 cm layer between October to January. However, in March, when extreme drought was achieved with less than 5 %Vol in this layer, there was no difference between the different cover treatments ($p < 0.05$, n = 9-12). In the wet season, until January, the soil water content throughout the soil profile (0-120 cm) of the 500 trees ha^{-1} plots was higher or not different from open grassland plots.

Regarding the RGI, defoliated plants, both at low and high intensity treatments, showed higher RGI than plants without defoliation when growing under both tree canopy cover levels (5.2 to 6.6 vs. 0.8-0.9, $p < 0.05$, n = 3). Low frequency defoliated plants also showed higher RGI than plants without defoliation in all treatments (4.9 to 9.1 vs. 0.8 to 1.3, $p < 0.05$, n =3- 5). In contrast, the RGI of high frequency defoliated plants under tree canopy cover decreased as the number of defoliation events increased. After the third defoliation, defoliated plants under tree canopy cover showed lower RGI than plants without defoliation.The moment of defoliation during the growing season did not alter the response ($p > 0.05$).

Comparing plants under tree canopy cover vs those in open grassland, low frequency defoliated plants under moderate levels of tree canopy cover (40-50%, 350 trees ha^{-1}) showed RGI similar or higher than defoliated plants in open grassland. However, increases in tree canopy cover (500 trees ha^{-1}) cause a reduction in RGI of defoliated plants compared to defoliated plants in the open grassland.

Tree canopy cover negatively affected the dry matter production of individual grasses compared to those in the open grassland ($p < 0.01$, n = 12-14), regardless of the level of defoliation. The defoliation effect over the dry matter production depended on the level of tree canopy cover. Low frequency defoliated plants in 350 trees ha^{-1} treatment showed no significant differences in dry matter production compared to plants without defoliation in the same treatment, although mean values were lower (5.5-7.7 vs 9.9-14.7 g $plant^{-1}$, $p > 0.05$, n = 12-14). In contrast, in 500 trees ha^{-1} treatment, dry matter production of low frequency defoliated plants was significantly lower than in plants without defoliation. In open grasslands treatment, the dry matter production of defoliated plants was also lower than non-defoliated plants (10.3 vs. 22.4 g $plant^{-1}$, p <0, 05, n = 12).

Discussion

The tree canopy cover, by interfering with the air mass flow and altering the emission and absorption of radiation produces a buffer effect on daily and seasonal temperature (Aussenac 2000). According to this, we found better temperature conditions for grass growth under tree cover, both in late winter and during the summer months, when tree cover reduced the maximum atmospheric demand and promoted better water conditions for understorey grasses. This microclimatic effect increased with tree canopy cover higher than 50% (our 500 trees ha^{-1} treatment). In similar conditions of tree canopy cover of *Quercus pubescens* and under European Mediterranean climate, Garnier and Roy (1988) found similar results to the present study.

In dry seasons or periods, the soil water content near the soil surface (0-20 cm) under tree canopy cover was lower compared to the open grassland area, while in wet seasons or periods the opposite trend was observed. Eighty percent of the water used by *F. pallescens* during the growing season comes from the 0-20 cm soil layer (Fernandez et al. 2008). Therefore it is expected that only in wet seasons and under tree canopy covers above 50%, a facilitation effect of trees on grasses mediated by soil water availability could be observed.

Despite the beneficial microclimatic effects observed under trees, at least in some periods during the growing season, the growth response of plants without defoliation suggests that radiation is the main limiting factor in these systems since plants growing under tree cover showed lower RGI and less dry matter production than undefoliated plants in open grassland.

Considering the interaction with defoliation, the redistribution of carbon between below and aboveground biomass of the grasses is an immediate and proper post-defoliation response in herbivory adapted species (Caldwell et al., 1981; Richards and Caldwell 1985). However, this process may not work properly under tree cover due to low radiation availability, which induces also a reallocation of carbon to aboveground biomass (Pierson et al. 1990, Fernandez et al. 2004) but affects carbohidrate reserves. Alternatively, as hypothetized here, a better re-growth response could be expected if water is a limiting resource and it is facilitated by trees. Our results suggest that, at least in the short term, a low frequency defoliation allows regeneration and redistribution of carbohydrates needed for *F. pallescens* regrowth under moderate levels of tree canopy cover (40-50%, 350 trees ha^{-1}), where RGI and biomass production were similar or higher than in defoliated grasses in the open. However, higher canopy cover (close to 80%, as in 500 trees ha^{-1}) limited re-growth response of *F. pallescens*, even with facilitative effects on water status of the plants. In addition, a high frequency defoliation limits re-growth response under trees, regardless of the canopy level.

Conclusion

Our results indicate that radiation is more or less limiting than water, in relative terms, depending on defoliation interaction. In this regard, under tree canopy cover the net result of competition and facilitation interactions for plants without defoliation was neutral or negative, while, based on RGI, low frequency defoliated plants showed a net result of interactions neutral or positive compared to plants in the open grassland. Since the RGI of defoliated plants under tree canopy cover was higher than plants without defoliation, we found evidence in favor of the hypothesis stating that defoliation is able to increase the positive effects and reduce the negative effects produced by the tree layer on the herbaceous layer in Mediterranean silvopastoral systems.In ecosystems with this type of climate, the buffer effect of tree canopy cover was shown to be important against the prevailing abiotic stress. The positive effect of *P. Ponderosa* canopy cover on the water availability, air temperature and atmospheric demand, allowed a post-defoliation recovery of *F. pallescens,* but this positive effect was only up to a tree cover threshold and at low frequency defoliation treatment. These results must be considered when planning forage management under trees.

References:

Fernández, M.E., Gyenge, J.E., Licata, J., Schlichter, T., Bond, B.J. 2008. Belowground interactions for water between trees and grasses in a temperate semiarid agroforestry system. Agroforestry Systems, 72(2): 185-197

Garnier, E. y Roy, J. 1988. Modular and demographic analisys of plant leaf area in sward and woodland populations of Dactilys glomerata and Bromus erectus. Journal of Ecology, 76: 729-743.

Wise, M.J. y Abrahamson, W.G. 2005. Beyond the compensatory continuum: environmental resource levels and plant tolerance of herbivory. Oikos, 109: 417-428.

Wise, M.J. y Abrahamson, W.G. 2007. Effects of resource availability on tolerance of herbivory: A review and assessment of three opposing models. The American Naturalist, 169: 443-454.