Impact of tree root pruning on yield of durum wheat and barley in a mediterranean alley-cropping system

Pierre-Eric Lauri, Hector Daniel Inurreta Aguirre, Christian Dupraz, Marie Gosme

IMPACT OF TREE ROOT PRUNING ON YIELD OF DURUM WHEAT AND BARLEY IN A MEDITERRANEAN ALLEY-CROPPING SYSTEM

Inurreta-Aguirre Hector Daniel[1]*, Lauri Pierre-Éric[1], Dupraz Christian[1], Gosme Marie[1]

* Correspondence author: hector-daniel.inurreta-aguirre@supagro.fr

(1) INRA, UMR 1230 SYSTEM F-34000

Short abstract

Tree root pruning in agroforestry could reduce water competition and increase the crop yield. The aim of this study was to evaluate the impact of tree root pruning on the yield of winter cereals in a mature Mediterranean alley cropping system considering crop phenology and the position in the alley. An experiment was conducted in a walnut alley cropping. Two modalities were established: root pruning (RP+) and no root pruning (RP-). In each one four genotypes of winter cereals were sown. Microclimate, soil matric potential (SMP), crop phenology and yield components were measured. The SMP presented higher values in RP+, especially in the central part of the alley. The impact on crop phenology of the root pruning and the position in the alley varies according to the genotype. The barley yield was statistically higher in RP+, whereas wheat yield did not show significant differences between modalities.

Keywords: winter cereals, crop phenology, soil matric potential, position in the alley.

Introduction

Agroforestry has been claimed as a way to increase total land productivity (Muschler 2015), however, it usually results in a decrease in crop yield compared to the pure crop because of the competition for resources between the crop and the tree (Jose et al. 2004). Belowground competition for water could reduce the productivity of the crop (Jose et al. 2000). On the other hand, agroforestry modifies the understory microclimate (Lin 2007) which could modify the evapotranspiration rate (Karki and Goodman 2013) and crop phenology (Inurreta-Aguirre et al. 2018). Due to the spatiotemporal complexity of the system (Talbot and Dupraz 2012), the net effect of agroforestry on crop productivity is uncertain (Ivezic and Van Der Werf 2016) and often depends on management practices (Gill et al. 2009).

Several authors have proven that tree root pruning in agroforestry could be a good management practice to increase crop yield (Wajja-Musukwe et al. 2008). The Mediterranean region presents particular climatic patterns, especially hot and dry summer, so it is important to know if root pruning can provide any advantage for the crop. The aim of this study was thus to evaluate the impact of tree root pruning on the yield of durum wheat and barley in a mature Mediterranean alley cropping system, considering the phenology of the crop.

Materials and methods

The experiment was carried out in 2017 in the “Restinclières Agroforestry Platform (RAP)” in Hérault department in the South of France (43° 42'N, 3° 51'E). The climate is sub-humid Mediterranean and the soil is deep calcareous silty clay. The experiment was conducted in an alley of 13m width, with an East-West orientation, planted with 23-year-old hybrid walnut trees (*Juglans nigra* X *regia* type NG23) at a density of 96 trees ha^{-1} with an irregular planting pattern, due to previous tree thinning in the plot (within-row distances between trees ranged from 4 to 12m). In order to minimize light competition and focus on the effect of the belowground competition, a branch pruning of 50% of the branches was applied to all the trees in the alley on November 8, 2016. Two modalities were established: root pruning (RP+) and no root pruning (RP-). The root pruning was done on October 21, 2016, using a tractor root pruner at a depth of one meter and at two meters from the centre of the tree line. Each modality was split into 24 plots (six across the alley and four along the alley) of 10.85 m² each (1.55 x 7m). In both modalities and each of the six positions relative to the tree row, an early (Claudio) and a late

(Karur) variety of wheat and an early (Orpaille) and a late (Cassia) variety of barley were sown in a randomized pattern. Sowing was made on December 13, 2016. Two applications of mineral fertilizer, 50 kg of total nitrogen per hectare in each one, were carried out on February 21, 2017, and April 8, 2017, respectively. No pesticides were applied. In each modality, the air temperature and the global solar radiation in the centre and in the two borders of the alley were monitored, using humidity and temperature probes (HMP155, Campbell Scientific, USA) and pyranometers (SP1110, Campbell Scientific, USA), respectively. The soil matric potential (SMP) was measured with tensiometers placed at a depth of 1m, in the centre and in the southern border of the alley, i.e. just north of the tree row.

The yield was decomposed into measurable yield components. The yield components considered in the analysis were the number of plants per m², the number of tillers per plant, the percentage of fertile tillers, the number of grains per spike and the weight of grains. Due to time constraints, only 12 plots per modality (36 in total) were kept free of weeds with two manually weeding conducted on 25 March and May 9, respectively. These 36 weed-free plots were considered in the analysis of the yield components of the four genotypes in three different positions in the alley (southern border, centre, and northern border). Each yield component was analysed using a mixed effect model ('lmer' package of R statistical software), considering the root pruning as a fixed effect and the species (both varieties of a same species pooled) as a random effect. These components develop sequentially throughout the growing season and determine the final yield of the crop (Moragues et al. 2006). Therefore, studying yield components allows identifying the phenological stage when adverse conditions reduced yield (Gate 1995). To consider this in the study, the phenology was assessed twice a week using the Zadoks scale (Zadoks et al. 1974).

Results

The SMP was always almost the same in both modalities and in both positions until the tree leaf sprouting. From then on, RP+ presented higher values, especially when comparing the central areas of the alley. Comparing the distance from the tree line within a same modality, one can notice that in RP+, the SMP was lower in the border part, while in RP- the tendency was not so clear, the lowest value alternating between the two positions (**Figure 1**).

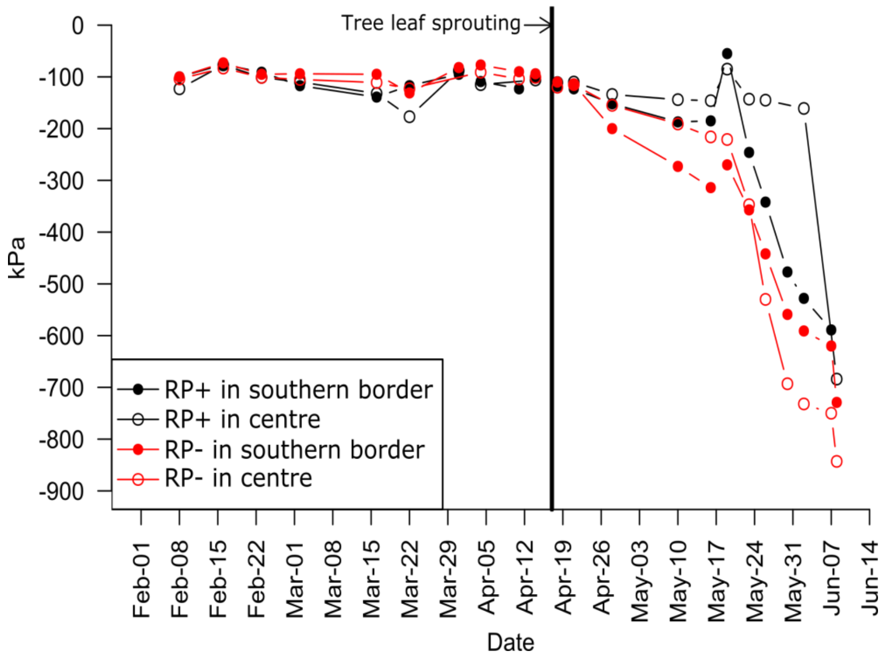

Figure 1: Soil matric potential (SMP) at 1m depth throughout the crop cycle in two different positions in the alley (southern border and centre) in the two modalities: root pruning (RP+) and no root pruning (RP-).

There was no difference in the global radiation between the modalities along the crop cycle (data not shown). The average air temperature presented small differences between systems (lesser than 0.4 °C). The RP+ modality was slightly warmer at the beginning of the cycle and slightly cooler at the end, the change in the trend occurred also around the tree leaf sprouting (data not shown).

The phenology of Claudio was the same regardless the modality or the position. For Karur, in both modalities, the border part of the alley showed a slight advance in the phenology in the spikes formation period. The phenology of Cassia was slightly faster in RP- from around tree leaf sprouting for the border part and after anthesis for the central part. RP+ also delayed the phenology of Orpaille, but in this case, the central part of the alley in RP+ was the one that was slower from around leaf sprouting and the border part of the alley was delayed from the end of anthesis (Zadoks stage 60) (**Figure 2**).

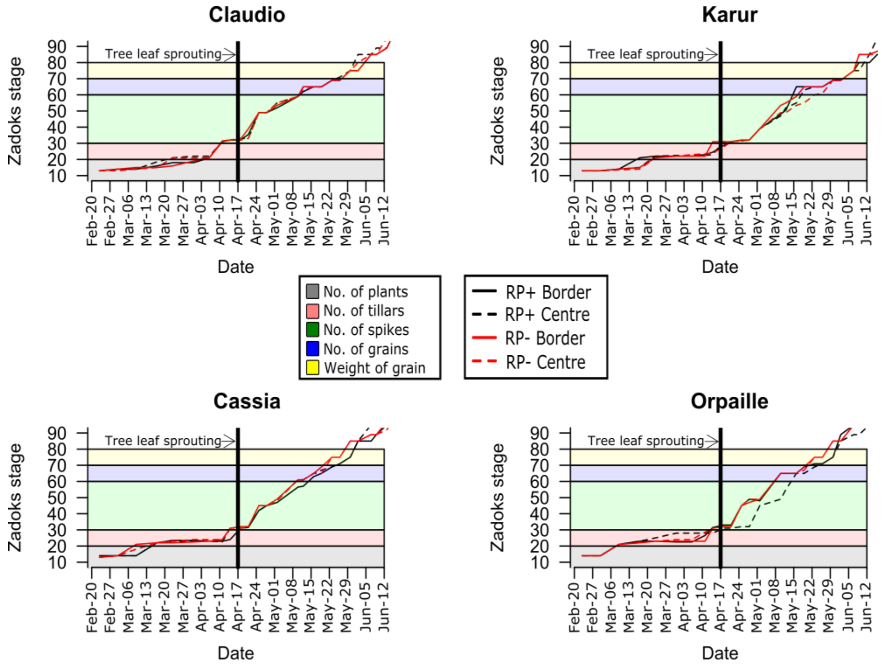

Figure 2: Phenology of the crops as a function of date. Background colours indicate the development period of the different yield components.

The grain yield of the wheat (combining both varieties) did not show significant differences between modalities. Nevertheless, two yield components were statistically higher in RP+, the number of plants per m² and the number of grains per spike. The grain yield of barley (combining both varieties) was statistically higher in RP+. All the yield components were higher in RP+, however, the only one statistically different from RP- was the weight of the grains (**Table 1**).

Table 1: Yield components (mean ±SD) and yield of the crop species [mean of both late and early varieties and the three positions (southern border, centre, and northern border)] in root pruning (RP+) and no root pruning (RP-)

	Modality	Pm^{-2}	TP^{-1}	%FT	GS^{-1}	TKW	GY
Wheat	RP+	142.25 (±33.53)*	3.38 (±0.48)	53 (±17)	16.45 (±1.45)*	44.08 (±3.13)	176.65 (±60.6)
	RP-	112 (±19.22)	3.88 (±1.18)	80 (±26)	14.87 (±1.94)	46.66 (±4.73)	246.87 (±140.7)
Barley	RP+	237.75 (±113.46)	5.38 (±2.43)	48 (±32)	13.57 (±2.74)	52.72 (±2.47)*	302.76 (±99.1)*
	RP-	202.50 (±59.75)	4.88 (±1.18)	36 (±13)	12.35 (±1.5)	48.43 (±2.87)	199.63 (±64.92)

Comparisons were made between modalities with the same crop. **Pm^{-2}:** number of plants per square meter, **TP^{-1}:** number of tillers per plant, **%FT**: percentage of fertile tillers, **GS^{-1}:** number of grains per spike, **TKW:** thousand kernel weight, **HI:** harvest index, **GY**: grain yield in g.m^{-2}. *: The means are significantly higher according to Tukey's HSD, ($p<0.05$).

Discussion

The SMP was lower in the RP+ modality after leaf sprouting, probably due to the transpiration of the unpruned trees, which produced a depletion of water. These results agree with what was obtained by Hou et al. (2003) in soybean with a windbreak (*Fraxinus pennsylvanica* L., *Pinus nigra* Arnold, and *Juniperus virginiana* L) in Mead, Nebraska. After the tree leaf flush, both varieties of barley had a slower phenology in RP+. This difference could be attributed to the lower temperature observed in the RP+ modality after leaf flush. This is surprising because the difference in temperature was very small. However, this acceleration in phenology could be due to water stress of the plants in the RP- modality. In accordance with this, Angus and Moncur (1977) reported an acceleration in the development of wheat plants sown in pots which had encountered a mild stress immediately and 20 days after of after floral initiation. Similarly, González et al. (2007) found that 12 different varieties of barley plants under stress in the terminal part of the growth cycle (Zadoks stage 41) reached maturity later than well-watered plants.

Wheat yield was lower (but not significantly) with root pruning, although two yield components (number of plants per m^2 and number of grains per spike) were significantly higher with root pruning. The number of grains per spike is known to be sensitive to water stress in wheat (Moghaddam et al. 2012), which could explain why it was higher with root pruning. For barley, there was a general trend of higher yield components in the RP+ system, but only grain weight was significantly higher with root pruning. This led to a significantly higher grain yield with root pruning. This reduction in grain weight of barley in RP- conditions could be due to the acceleration in the development caused by a mild water stress, which led to a shorter grain filling duration and therefore to a lower accumulation of dry matter in the growing grains (Samarah et al. 2009).

In conclusion, we found that root pruning could increase the productivity of barley in alley cropping systems in Mediterranean conditions, however, this effect was not observed in durum wheat. Before translating these results into recommendations for farmers, it would be necessary to study the impact of root pruning on tree growth, in order to check if the yield gain on the crop outweighs the potential growth decrease of the tree due to root pruning.

References:

Angus JF, Moncur MW (1977) Water stress and phenology in wheat. Aust J Agric Res 28:177–181. doi: 10.1071/AR9770177

Gate P (1995) Ecophysiologie du blé, 1st edn. Lavoisier Tec & Doc, Paris

Gill RIS, Singh B, Kaur N (2009) Productivity and nutrient uptake of newly released wheat varieties at different sowing times under poplar plantation in north-western India. Agrofor Syst 76:579–590. doi: 10.1007/s10457-009-9223-0

González A, Martín I, Ayerbe L (2007) Response of barley genotypes to terminal soil moisture stress: Phenology, growth, and yield. Aust J Agric Res 58:29–37. doi: 10.1071/AR06026

Hou Q, Brandle JR, Hubbard K, et al (2003) Alteration of soil water content consequent to root- pruning at a windbreak/crop interface in Nebraska, USA. Agroforest Syst 57:137–147.

Inurreta-Aguirre HD, Lauri P-E, Dupraz C, Gosme M Yield components and phenology of durum wheat in a Mediterranean alley-cropping system.

Ivezic V, Van Der Werf W (2016) Relative crop yields of European silvoarable agroforestry systems. In: Amaral Paulo J, Borek R, Burgess P, et al. (eds) 3rd European Agroforestry Conference. European Agroforestry Federation, Montpellier, France, pp 291–293

Jose S, Gillespie AR, Pallardy SG (2004) Interspecific interactions in temperate agroforestry. Agrofor Syst 61:237–255.

Jose S, Gillespie AR, Seifert JR, Biehle DJ (2000) Defining competition vectors in a temperate alley cropping system in the midwestern USA: 2. Competition for water. Agrofor Syst 48:41–59.

Karki U, Goodman MS (2013) Microclimatic differences between young longleaf-pine silvopasture and open-pasture. Agrofor Syst 87:303–310. doi: 10.1007/s10457-012-9551-3

Lin BB (2007) Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. Agric For Meteorol 144:85–94. doi: 10.1016/j.agrformet.2006.12.009

Moghaddam HA, Galavi M, Soluki M, et al (2012) Effects of Deficit Irrigation on Yield, Yield Components and Some Morphological Traits of. 2:825–833.

Moragues M, García Del Moral LF, Moralejo M, Royo C (2006) Yield formation strategies of durum wheat landraces with distinct pattern of dispersal within the Mediterranean basin I: Yield components. F Crop Res 95:194–205. doi: 10.1016/j.fcr.2005.02.009

Muschler RG (2015) Agroforestry : essential for sustainable and climate-smart land use? In: Pancel L, Kohl M (eds) Tropical Forestry Handbook, 2nd edn. Springer-Verlag Berlin Heidelberg, Berlin, Germany, pp 2013–2116

Samarah NH, Alqudah AM, Amayreh JA, McAndrews GM (2009) The effect of late-terminal drought stress on yield components of four barley cultivars. J Agron Crop Sci 195:427–441. doi: 10.1111/j.1439-037X.2009.00387.x

Talbot G, Dupraz C (2012) Simple models for light competition within agroforestry discontinuous tree stands: are leaf clumpiness and light interception by woody parts relevant factors? Agrofor Syst 84:101–116. doi: 10.1007/s10457-011-9418-z

Wajja-Musukwe T-N, Wilson J, Sprent JI, et al (2008) Tree growth and management in Ugandan agroforestry systems: effects of root pruning on tree growth and crop yield. Tree Physiol 28:233–242. doi: 10.1093/treephys/28.2.233

Zadoks JC, Chang TT, Konzak CF (1974) A decimal code for the growth stages of cereals. Weed Res 14:415–421. doi: 10.1111/j.1365-3180.1974.tb01084.x