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# IMPACT OF POLLARDING ON GROWTH AND DEVELOPMENT OF ADULT AGROFORESTRY WALNUT TREES

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## Abstract

In temperate alley cropping agroforestry systems, light competition often limits the crop yield. The trees pruning and particularly pollarding reduces this competition. This practice results in three productions on the same field: crop, fuel or others purposes wood and timber wood. To be profitable, pollarding must not affect too much the trunks growth in diameter and the trees provide enough branches biomass when they are cut. In our experiment on adult walnut trees, during the 4 years after pollarding, the diameter growth of the pollards was  $2.8 \pm 0.9$  cm for the pollards vs  $3.2 \pm 0.9$  cm for the control and they produced, in average, 81 kg of branches biomass per tree. The question is now to know how if repeated cuttings will not be affected trees growth and survival.

**Keywords:** alley cropping; light competition; pollards; trees growth; wood production

## Introduction

Pollarding is a traditional practice consisting in topping the trunk of a tree and pruning steadily all branches (Chesney 2012). It results in a distinctive thick bushy appearance of the tree. The tree size and leaf area are dramatically reduced during the first years after pollarding. This management was frequently practiced for fodder or firewood collection (Sjolund and Jump 2013). In an alley cropping system, pollarding the trees may reduce the light and water competition of the trees, and consequently may enhance crop yield (Dufour et al. 2016). If the trunk diameter growth of the timber tree were not too severely impacted, pollarding would be a smart way to yield three products simultaneously in an agroforestry field: annual crops, branch and leaves biomass for energy, fodder or wooden chips (Valipour et al. 2014), and timber wood (Mansion 2010). Even though pollarding is an age-old practice that converged over the world from farmers and foresters' good sense (Thomas 2000), the growth and physiological responses of pollards have rarely been studied, even less in an agroforestry context. Our objective was to assess the impact of pollarding on the growth, both in trunk diameter and branch biomass, and development (phenology) of hybrid walnut trees, which are not traditionally pollarded, in an alley-cropping agroforestry system.

## Materials and methods

The study was conducted on adult hybrid walnut trees in a cereal-based agroforestry system under a Mediterranean climate. Fifty trees placed on two adjacent tree lines were pollarded in December 2013 in an agroforestry plot planted in 1995 with East-West tree lines separated by 13 m. The trees were topped at 4 m height, using a mobile platform lift. The cropped alley was 12 m wide and the intercrops were winter field crops (durum wheat, barley and pea). Control trees, always pruned up to 4 m height, were selected in the 8 remaining tree lines of the plot, so that each pollard was paired with a control tree with the same height and trunk girth in 2013. Pollarding was repeated in October 2017.

The height and diameter at breast height (DBH) of each tree (pollard and control: a total of 100 trees) were measured yearly. The DBH growth of each tree was monitored once every two weeks, with microdendrometers, starting from the 6<sup>th</sup> of May 2014. The phenology of the 100 trees was recorded at the same time, documenting 4 stages: budburst, end of short shoots expansion, end of long shoots expansion and leaf fall. The number and the basal diameter of each cut branch were measured at the second pollarding. At the same time, the dry biomass of a sample of branches covering the full range of diameters was measured. This allowed us to establish an allometric equation relating branch basal diameter and dry biomass, and thus to estimate the branch biomass of each tree. The sky mask resulting from the trees canopies was estimated as 100 minus the gap fraction obtained by the software Winscanopy (Regent Instruments) from hemispherical photographs taken on 14/06/2014, 19/06/2015 and 21/06/2016 at 2.5 m from the trunks on the Northern side.

Data were analysed using R statistical software. The paired data of height, DBH and their yearly increment were analysed using paired t tests for each year separately. For the analysis of the intra-annual DBH growth, each year was divided into 3 periods (summer: May15<sup>th</sup>->July15<sup>th</sup>, autumn: July16<sup>th</sup>->November 15<sup>th</sup>, and winter: November 15<sup>th</sup>->May15<sup>th</sup>), and the daily increment in DBH was analysed for each year-period separately using a mixed model with type of tree (pollard vs control) as a fixed effect and tree identifier as a random effect, to take into account repeated measurements.

## Results

Pollarding changed tree phenology: budburst was delayed during the first, third and fourth year after pollarding, leaf fall was noticeably delayed for pollards compared to control trees the second year after pollarding. As a result, the time when the trees had leaves was extended by 26 days in 2015 (Table 1).

Table 1: Comparison of non-pollarded and pollarded trees phenology.

Year	Budburst		Leaf fall		Growing season duration	
	Control	Pollard	Control	Pollard	Control	Pollard
2014	30 April	6 May	13 November	27 November	197	205
2015	13 May	13 May	12 November	26 November	183	197
2016	9 May	16 May	16 November	23 November	191	191
2017	3 May	10May	2 November	NA	183	

Pollards had a significantly higher height growth than control trees ( $p < 0.0001$  in 2014 and 2015, and  $p = 0.0002$  in 2016) and their diameter growth was not much slower than the control trees, except during the first year (Table 2, Figure 1). The diameter increment was significantly reduced for pollards only during the first year ( $p = 0.01$  in 2004,  $p = 0.43$  and  $0.44$  in 2015 and 2016). DBH growth of pollards was significantly reduced in both summer and autumn in 2014 ( $p < 0.0001$ ). In 2015 and 2016, DBH growth of pollards was smaller than control in summer but higher in autumn, and in 2017, it was not significantly different neither in summer nor in autumn ( $p = 0.6$  and  $0.2$  respectively). Pollarding reduced the sky mask of the trees canopies by 60% in 2014, 13% in 2015 not in 2016 (increase of 3% of the mask).

Table 2: Trees height and DBH and their annual increase, *in italics*. The intervals are the standard errors. Stars indicate that the difference between control and pollarded trees was significant.

Year	Total height (cm)				DBH (cm)			
	Control		Pollard		Control		Pollard	
2012	959±35		948±33		19.8±0.8		20.0±0.8	
2013	1011±36	53±6	400*		21.1±0.8	1.3±0.1	21.2±0.9	
2014	1040±37	29±9	664±14*	264±14*	22.0±0.9	0.9±0.2	21.6±0.8*	0.4±0.1*
2015	1040±37	0±8	794±14*	130±10*	22.2±0.9	0.3±0.2	22.1±0.9*	0.5±0.1
2016	1112±40	72±12	929±22*	135±12*	23.0±0.9	0.7±0.1	22.8±0.9*	0.7±0.1

The number of branches cut at the second pollarding was  $29.6 \pm 0.4$  (mean, standard error) per tree, with a mean branch diameter of  $4.5 \pm 0.07$  cm. The allometric equation between the branches circumference and their dry biomass allowed us to estimate the biomass of branches produced between the two pollardings to  $80.9 \pm 7.6$  kg per tree.

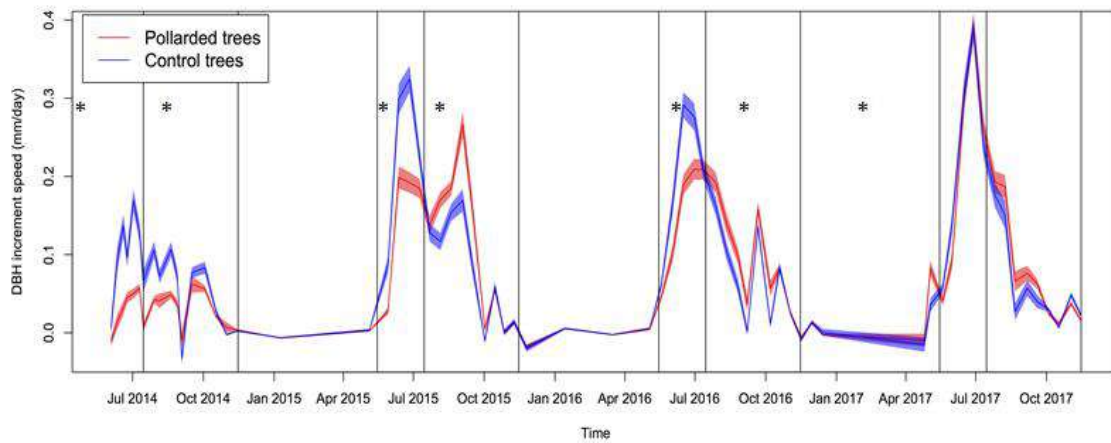


Figure 1: Speed of DBH growth measured with the microdendrometers on pollarded (red) and control (blue) trees as a function of time. The shaded areas indicate  $\pm$  standard error. The vertical lines indicate the periods (summer: May 15<sup>th</sup>->July 15<sup>th</sup>, autumn: July 16<sup>th</sup>->November 15<sup>th</sup>, winter: November 15<sup>th</sup>->May 15<sup>th</sup>). Stars indicate when the effect of pollarding on DBH increment was significant.

## Discussion

The first pollarding of adult walnut trees reduced their diameter growth while the height growth was boosted. The tree canopy was quickly replenished and the benefit for the crop yield only transient. The ability of the tree to grow back quickly after a total removal of its branches is due to very high reiteration capacity and was the result of numerous epicormic buds differentiation. High nutrients reserves in the trunk, stump and coarse roots probably helped the fast recovery. We may question if this compensation can operate several times, allowing the tree to keep growing in diameter (producing timber wood) while also producing branch biomass. Ghahramany et al. (2017) showed that Lebanon oaks (*Quercus libani* Oliv.) pollarded every 3 or 4 years had the same diameter growth until 55 years old. On the opposite, Lang et al. (2015) found that poplar pollarding resulted in a significant reduction in diameter growth and significantly increased the occurrence of stem rot. Future measurements will be made after the second pollarding to see if our walnut trees can produce both timber and branch wood through repeated pollarding.

Pollards kept their leaves for a longer period as compared to control trees during the four years, and this is often related to the lack of water stress (Delpierre et al. 2017). The leaves are also deep green, suggesting a high content in nitrogen. Both aspects may explain the high efficiency of pollards in recovering. Pollards may avoid stresses that full grown trees could face in summer thanks to their reduced leaf area and water needs, while they benefit from an extended rooting system.

Branch biomass production estimated in our study (20.2 kg of dry matter per tree and per year) is comparable to some estimates found in the literature for other fast growing species (AGROOF 2011): 29 kg/tree/year, with ash (*Fraxinus intermedia*) and oak trees (*Quercus robur*), 21 kg/tree/year with white mulberry (*Morus alba*).

Pollarding trees could be an option to produce additional biomass from branches, increasing the agroforestry field productivity. But pollarding may deplete soil nutrients due to the export of nutrient pools in the removed branches. This may increase the competition for nutrients with the crop. Furthermore, the rapid regrowth of the branches and their very dense shade increase light competition with the crop as soon as the third year after pollarding. More studies are needed to optimize the trade-offs between trunk (timber wood), branches (fuelwood or fodder) and crop

(agricultural production) productivities as a function of the frequency of pollarding and the density of pollards on the field. The frequency of pollarding should also be adapted to the intended use of the branch biomass. The branches can be ground to make ramial chipped wood used as mulching and improving soil fertility should be obtained from branches smaller than 7 cm in diameter. In our experiment, 4 years after pollarding 83% of the branches representing only 31% of the total biomass were fit for this use.

In conclusion, pollarding can be a way to improve the productivity of agroforestry systems, but a long term study must be conducted to ensure the sustainability of the timber production.

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