

The Effect Of Tree Rows On Yield Of Grain Crops: A Meta-Analysis On Agroforestry Systems In Temperate Climates

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Introduction

Silvoarable agroforestry consists of intercropping arable crops with largely spaced trees, where trees can be distributed following different designs, such as alley-cropping, scattered trees and line belts (Mosquera-Losada et al., 2009). Silvoarable systems are receiving increasing attention for improving resilience to climate change in temperate regions, by providing shade with their canopy and shelter through windbreak effect. However, preserving crop yield remains one of the most critical issues when implementing sustainable agroforestry systems, as significant yield losses are commonly documented in the interaction zone with trees (Pardon et al., 2018; Dufour et al., 2013). Here, a meta-analysis on agroforestry systems in temperate climates has been carried out in order to summarize the available knowledge on the impact of trees, arranged as rows, on yield of the neighboring arable grain crops. Although the related research questions are many, here the following are addressed:

- i. Does the effect of the distance from the tree row vary according to crop species? It is expected that the distance from the tree line is less relevant on grain yield in winter vs. summer crops.
- ii. Does the impact of trees on grain yield of the associated crops vary according to the distance from the tree row? It is expected that the most relevant yield reductions are observed in positions closer to the tree line.

Materials and Methods

A systematic literature search was conducted using Scopus and Web of Science, for peer-reviewed studies that investigated the grain yield of grain crops in silvoarable agroforestry systems (AF) as compared to adjacent controls under full sun without trees (C) (published from January 1980 up to December 2020). Only studies including trees arranged as rows were here considered, excluding scattered trees and hedgerows. Studies were retained in analysis when meeting the following criteria: (i) the study site is located in temperate regions, as defined by Köppen-Geiger climate classification (ii) empirical data of yield of field crops are available (reviews and modelling studies were excluded), (iii) trials considered natural open field conditions with real trees (pot, greenhouse and artificial shading experiments were excluded), (iv) true controls are present allowing yield comparison with and without tree rows. An overall amount of 18 original research articles were considered, allowing the calculation of standard deviation of the mean: 13 from Europe, 1 from North America, 1 from South America, 2 from Africa and 1 from Asia. Among crops, triticale and chickpea were excluded due to the poor number of observations, while analyses focused on wheat, barley, soybean and maize, with a total of 195 observations. According to their growing cycle and level of radiation required, winter and barley are also referred as winter crops, while soybean and maize as summer crops. The log response ratios (RR) was calculated as a measure of the effect size (Hedges et al., 1999), by calculating the logarithm of the ratio between the mean response of a crop in agroforestry (AF) at a certain distance from the tree row and the

mean response of such crop in adjacent open field controls without trees (C). A positive response ratio ($RR > 0$) means that the presence of trees has a positive effect on crop yield, whereas a negative response ratio ($RR < 0$) indicates a negative effect; little or no effect are indicated by $RR \approx 0$.

Results

Statistical analysis revealed lower crop yield in positions close to the tree rows and a gradual recovery as the distance-to-tree height ratio (D/H) increases (Figure 1). However, significant variations of the response ratio (RR) dynamics were revealed, depending on the crop species considered. Winter crops, such as wheat and barley, were confirmed to be less affected by tree competition than summer crops like maize and soybean. In particular, barley showed no effects of the tree line, as highlighted by poor regression coefficient ($b=0.0259$) and determination coefficient ($R^2=0.03$). In wheat, grain yield was slightly affected by the tree row, with small negative variation of the RR at $D/H < 1$ (i.e., $\ln(D/H)=0$, $R^2=0.18$). The strongest impact of the distance from the tree line was observed in summer crops, i.e. maize, and even more in soybean, with markedly lower yield when getting closer to the tree line.

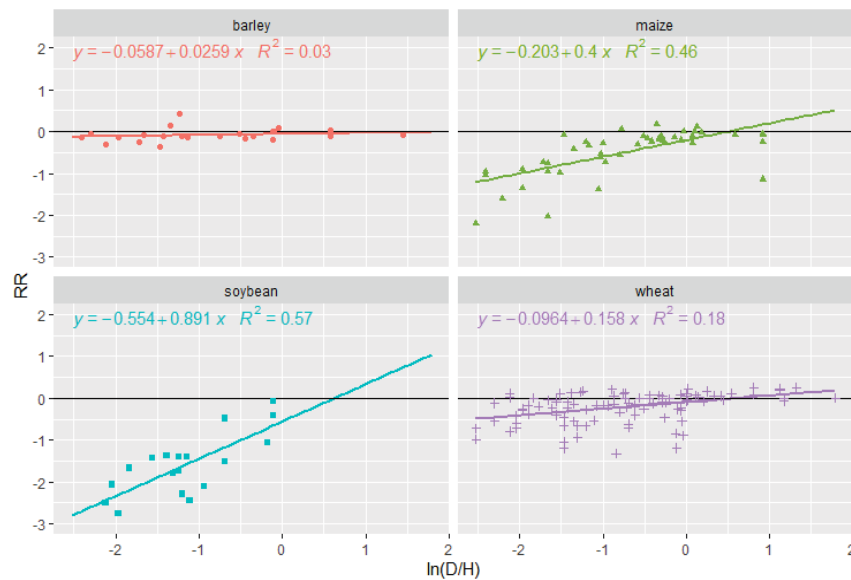


Figure 1. Effects of the distance from the tree rows on yield of grain crops as response ratio (RR). Negative values of $\ln(D/H)$ indicate distances from the tree row (D) lower than tree height (H), and viceversa. Each marker represents an individual observation.

Conclusions

In agroforestry systems with deciduous tree species, winter crops such as wheat and barley are less affected by tree competition compared with high light-demanding summer crops like maize and soybean. This depends on lower overlap of growing season with tree foliage duration, and likely to the C3 metabolism vs. C4 of maize, although the most sensitive crop was soybean. In order to maximize the productivity of silvoarable systems in temperate climates, it is suggested to include summer crops in rotation during the first years of the tree cycle, while further research is required to identify suitable crop varieties.

Literature

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