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

EFFECT OF AGROFORESTRY ON PHENOLOGY AND COMPONENTS OF YIELD OF DIFFERENT VARIETIES OF DURUM WHEAT

Inurreta Aguirre HD *, Dufour L, Dupraz C, Lauri PÉ and Gosme M

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

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Introduction

Agroforestry, by its conception, imposes light reduction to the crop (i.e. shade). This modification of the environment produces an effect on the thermal time (Lott et al. 2009), and on the phenology of the understory crops (Sudmeyer and Speijers 2007). In addition to this, other modifications to the environment caused by the interactions between trees and crops (e.g., reduction of microclimate extremes (Lin 2007), changes of the evapotranspiration (Ong and Wilson 2014) or competition for resources (Jose et al. 2000a; Jose et al. 2000b), have an impact on the components of crop yield. Our hypothesis was that these changes in the environment affect wheat phenology and therefore the various traits of yield components. Furthermore, the genotype of the crop, among other factors, is crucial to determine the direction and magnitude of these impacts (Gill et al. 2009).

In the Mediterranean region, durum wheat suffers from heat stress in spring and drought stress in summer (Loss and Siddique 1994) and it is expected that this situation will intensify in the future due to climate change (Chourghal et al. 2015). Agroforestry could mitigate these effects (Campi et al. 2009; Lott et al. 2009). However, as the current varieties of durum wheat were selected for conventional agriculture (Wolfe et al. 2008), i.e. in full sun conditions, it is necessary to identify desirable traits of the crop for agroforestry systems. The aim of this work was to assess the performance of different varieties of durum wheat under an agroforestry system (AFS) in the Mediterranean region compared to cultivation in full sun (FS), through the effects on both phenology and yield components.

Material and methods

The experimental plot is located in the domain of Restinclières in the Hérault department (43°42'N, 3°51'E), the climate is Mediterranean and the soil is deep calcareous silty clay. Two systems were tested, AFS (15 year-old poplars, 30 m in height, with East-West tree rows, 13 meters between rows and 6 m between trees along the row), and FS (actually sorb trees, less than 2 m high providing negligible shade).

The crop alley in each system was split into 36 1.55x6m microplots (6 across the alley, 6 along the alley in front of the trees). Twelve durum wheat varieties (old varieties taken out of the genebank maintained by INRA + 1 control variety) were tested, each variety being repeated 3 times in each system. The control variety was LA1823, a variety recently created for organic farming. The old varieties were chosen by crop breeders based on a preliminary test in pots under shading cloth. Sowing density was 350 seeds/m2. Sowing was done on January 12th, 2015 (because of floods that prevented sowing in autumn). Harvest was done on June 30th, 2015. No fertilizers or pesticides were applied because the sowing was too late compared with other wheat plots of the farmer. The phenology was recorded every week from the beginning of stem elongation (April 16) to ripening (June 25), using Zadok's developmental scale (Zadoks et al. 1974). At harvest, yield was measured from harvesting one 1x1m quadrat from each microplot. Yield components (plants per m2, tillers per plant, spikes per tiller, grains per spike and the weight of 1000 grains) were also recorded. The effect of variety, system and their interaction was tested by first selecting the best model (including or not these effects) based on AIC. Then multiple comparisons of each pairs of modalities were performed with Tukey HSD using the best model to control the effect of the (possible) other factors. Threshold for significance was set at $\alpha=0.05$.

Results

Variety “L3534” did not emerge and, therefore, was not considered for further analysis. The phenology of the durum wheat in the two systems (AFS and FS) was almost the same until anthesis (Z65). After this stage, the phenological development in FS was faster until shortly before reaching physiological maturity (**Figure 1**). FS reached ripening around the 10th of June, while AFS did not reach this stage until the 21st of the same month. The AFS had higher variability in phenological stage between varieties until ripening. An ANOVA was performed on phenological stage for each date separately; it showed no difference between varieties and systems on April 24th, 30th, May 7th (the date that showed the biggest variation between the treatments) and May 13th. However, there was a significant effect of the system on April 16th, just before stem elongation for all varieties, plants being more developed in AFS than in FS, and from May 28th onwards, FS was significantly more advanced than AFS. The varieties did not show significant difference between them at any date.

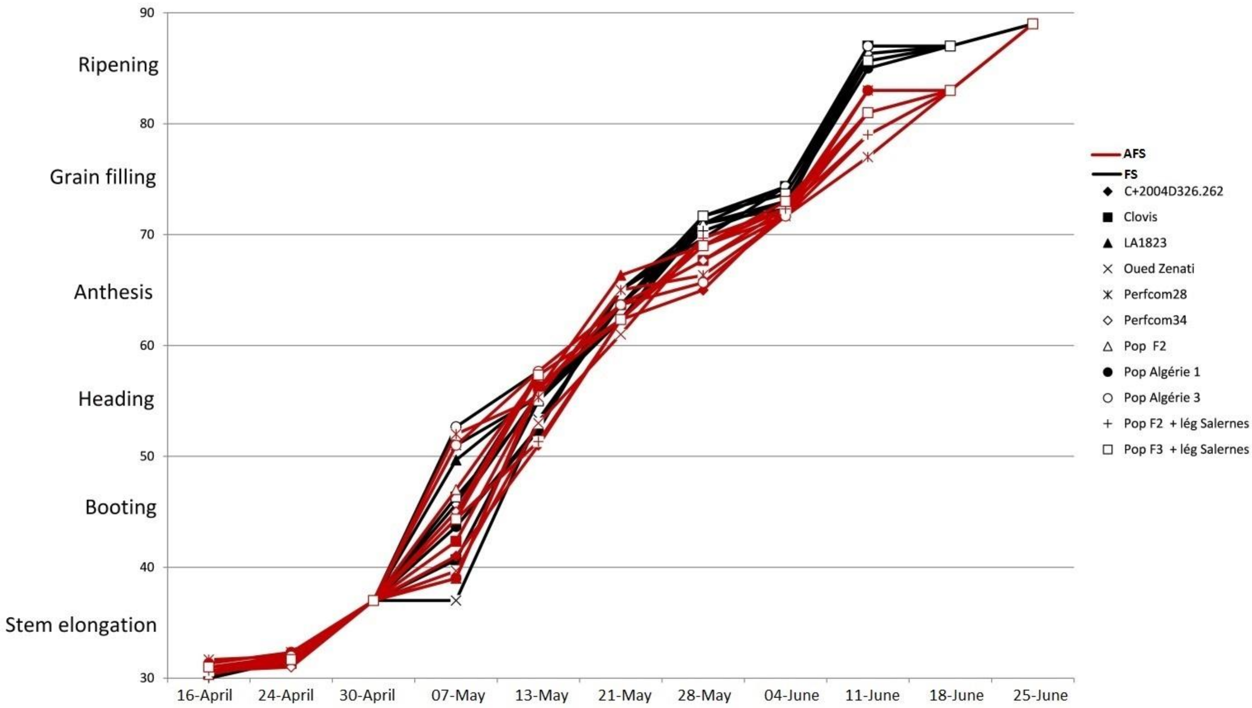

Figure 1: Phenological development of 11 varieties of durum wheat in AFS and FS.

As shown in **Table 1**, the number of plants per m^2 showed significant differences between varieties and systems. The number of spikes per m^2 and the number of grains per spike were significantly different only between systems. The number of spikes per tiller and the weight of 1000 kernels did not show significant difference between systems, only between varieties. Five varieties were different from the others at least in one component; (a) "2004D326.262" for the number of plants per m2, (b) "Oued Zenati" for the number of plants per m^2 and weight of 1000 grains, (c) "Perfcom34" in spikes per tiller, (d) "PopF2" for the plants per m^2 and (e) "PopAlgérie1" for the spikes per tiller and also the weight of 1000 grains. Other components of the yield (tillers per m^2, tillers per plant, and grains per m^2) did not show significant differences between varieties or between systems. None of the yield components showed a significant interaction between variety and system.

Table 1: Means of yield components per variety and system. Means with the same letter inside a column and a tested effect (variety or system) are not significantly different

Variety or system	Plants/m^2	Spikes/tiller	Spikes/m^2	1000 kernels weight in g	Grains/spike
2004D326.262	119.14 (c)	0.52 (ab)	92.09	34.10 (ab)	12.74
Clovis	150.54 (ac)	0.55 (ab)		33.36 (ab)	
LA1823	157.85 (ac)	0.65 (ab)		39.23 (ab)	
Oued Zenati	193.98 (a)	0.53 (ab)		43.07 (a)	
Perfcom28	135.05 (bc)	0.68 (ab)		34.28 (ab)	
Perfcom34	157.85 (ac)	0.69 (a)		32.69 (ab)	
PopF2	195.70 (a)	0.55 (ab)		33.89 (ab)	
PopAlgérie1	154.84 (ac)	0.43 (b)		34.69 (b)	
PopAlgérie3	152.69 (ac)	0.61 (ab)		36.80 (ab)	
PopF2+Lég Salernes	168.60 (ac)	0.49 (ab)		31.80 (ab)	
PopF3+Lég Salernes	178.49 (ab)	0.46 (ab)		33.35 (ab)	
AFS	168.37 (a)	0.59 (a)	114.94 (a)	36.93 (a)	11.22 (b)
FS	152.49 (b)	0.53 (a)	69.24 (b)	33.48 (a)	14.27 (a)

Discussion

Although some yield components were impacted by agroforestry and/or variety, there was no significant interaction between these two factors, which reduces the opportunity for selection of wheat cultivars specifically adapted to agroforestry. However, yield was higher in AFS than in FS, showing that light was not the limiting factor in our conditions. The only yield component that was negatively impacted by agroforestry was the number of grains per spike, and this yield component should be watched closely in future breeding programs for agroforestry. However, this study did not establish detailed relationships between the incident radiation and changes in the phenology or morphology and how these changes could impact the components of yield.

The information generated in this work did not allow us to correlate the differences in the components of yield with the differences in the phenological development. The number of plants per m2 is a component of yield formed during the early phenological development, from emergence until the end of tillering (Gate, 1995). However, despite the fact that in this study a significant difference among some components of yield was detected between the systems and between some varieties, it was not possible to relate this with differences in the phenology because the recording of phenological development began after the stem elongation phase. For the number of spikes per tiller and for the spikes per m2, something similar happens, because the development of these component of yield starts also at emerging but ends latter than the number of plants per m2 (shortly after meiosis) (Gate 1995).The number of spikes per tiller was significantly different between "Perfcom34" (highest number of spikes per tillers) and "PopAlgérie1" (lowest number of spikes per tiller), although these varieties showed a similar phenological development, being just slightly slower for "PopAlgérie1" in the latter part of the formation period of this component. Furthermore, the number of spikes per m2 was significantly different between systems, although the phenological development did not show differences between systems in the period of formation of this component of yield. The average weight of grain, whose formation occurs after meiosis to ripening (Gate 1995), was different for two varieties that did not show significant differences in their phenological development for that period of time. Something similar occurs with the number of grains per spike, which only showed significant differences between systems, but the difference was not visible in the phenological development.

These negative results might be due to the fact that the measurements of the phenological stages started too late, missing the information of the development in the early stages, which are crucial for the development of several components of yield. In addition, there was a high density of weeds with different predominant species according to the system, which may have increased the differences in the components of yield between systems, independently of the phenology.

However, correlating yield components, not only with the phenological development, but also with the presence of abiotic stress at different stages could provide valuable information about the impact of agroforestry on the yield of wheat in the Mediterranean region.

This information could be used for improve crop simulation models, enhancing their capacity to predict the effect on components of yield of different management practices or climate conditions (e.g. climate change). For all these reasons, we propose to conduct a similar work in which the phenology will be recorded since emergence, with a better control of weeds and an accurate monitoring of the microclimate especially with regards to the factors that can cause abiotic stress.

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