BREEDING FOR AGROFORESTRY: IS IT ONLY BREEDING FOR SHADE?

Panozzo A[1], Desclaux D[1*]

(1) DiaScope- Inra – Domaine de Melgueil- 34130 Mauguio, France

*Corresponding author: dominique.desclaux@inra.fr

Abstract

As most of the crop varieties used by farmers were selected in full sun conditions, crop breeding programs looking at agroforestry-adapted cultivars are often reduced as programs for shade-tolerant cultivars. Implementing a breeding program for the understorey crops requires a large surface of agroforestry (AF) design. We evaluated the relevance of a pre-breeding test in a greenhouse (limited area, artificial shade) which may allow to screen a great number of varieties for their adaptation to shade. The artificial shelter test helped to select some interesting genotypes adapted to AF systems but it also may conduct to select uninteresting ones or to reject some others that could be AF adapted. The presence of the trees in the field is not adequately simulated by articificial shade effect in the greenhouse. Numerous others effects occuring in the field like belowground interaction between plants and between plants and trees may have a greater effect on some genotypes than the shade.Thus selecting shade-tolerant varieties is not equal as selecting agroforestry-adapted varieties.

Keywords: greenhouse; field; crop; durum wheat; PAR

Introduction

Several authors assessing light competition in temperate agroforestry systems concluded that the success of agroforestry depends on the selection of shade-tolerant varieties (Artru et al. 2017; Ehret et al. 2015; Friday et al. 2002; Barro et al. 2012). Implementing a breeding program for the understorey crops requires a large surface of agroforestry system to evaluate a wide range of varieties. The main idea of this study is to evaluate the possibility of a pre-breeding test in a greenhouse (limited area) which may allow to screen a great number of varieties for their adaptation to shade. As light is likely to be the principal limiting resource for understorey crops, previous studies tested the effect of artificial shade on crop growth and yield by using different shading materials and for variable periods. Artru et al. (2017) monitored winter wheat growth and productivity under artificial shade provided by camouflage shade-netting, to reproduce a rapidly fluctuating sun/shade pattern. Varella et al. (2011) investigated whether wooden slatted structures reproduced well the daily periodic light fluctuation and the spectral composition observed under trees, in comparison with conventional plastic shade-cloth. In order to mimic the increasing leaf area of walnut trees, Dufour et al. (2013) added overlapping shade cloth during [illegible] o Varella et al. [illegible] t environment and the plant responses to it. The aim of the present work was to assess the appropriateness of a permanent shading cloth over durum wheat plants grown in pots (1 plant/pot) inside a greenhouse to be used as pre-breeding test for selecting shade-tolerant genotypes. The main questions were:

- Is the greenhouse environment able to represent the field environment?
- Does the permanent shading cloth in the greenhouse mimic the shade effects determined by olive trees rows in an agroforestry system?
- Is shade the only limiting factor for crop yield in AF system?

Materials and methods

The experiments were conducted at INRA station DiaScope in Mauguio, France (43º35'N, 3º45'E) in 2016 and 2017. 25 genotypes of durum wheat were tested each year in two experimental trials: (i) Field: two treatments: open field without trees (Control) or agroforestry system with natural shade provided by olive trees in an alley cropping design (AF); (ii) Greenhouse : two treatments: without (Control) or with artificial shade (Shade).

Experimental design. **In the field**, 11 populations of durum wheat (*Triticum turgidum durum*) and 14 pure lines were sown (sowing density = 350 seeds/m^2) each year around mid-November (just after olive harvesting) in two experimental conditions: in open field without trees (Control, Figure 1-left) and between trees in an olive orchard (AF: Figure 1-right). AF was a 6x6m design olive orchard and trees have been yearly pruned from 2012. In each treatment, a randomized block design was implemented with two plots (reps) per genotype. Each plot was 1.55 m wide and 10 m long. Each treatment then hosted 50 plots of durum wheat in an annual rotation with legumes crops.

Figure 1: Pictures of the Control treatment (left) and the olive trees/d. wheat AF intercropping treatment (right).

The "pre-breeding test" was implemented inside **a greenhouse** (rigid PVC walls (ONDEX Bio 2 Cristal) and a ground surface of 83 m²). Inside the greenhouse, the same 25 durum wheat varieties were cultivated in pots (one plant/pot) and subjected to two treatments: Control and Shade. Shade effect was created by placing pots under a shelter from sowing to harvesting, three repetitions/treatment (Figure 2). Neither fertilizer neither protection products were used, as in the field trial. The maximal temperature threshold of the greenhouse was set at 25 °C during day hours and at 22 °C during night hours. An irrigation system (capacity of 2 litres/hour) run 10 minutes per two days/week from sowing to harvesting.

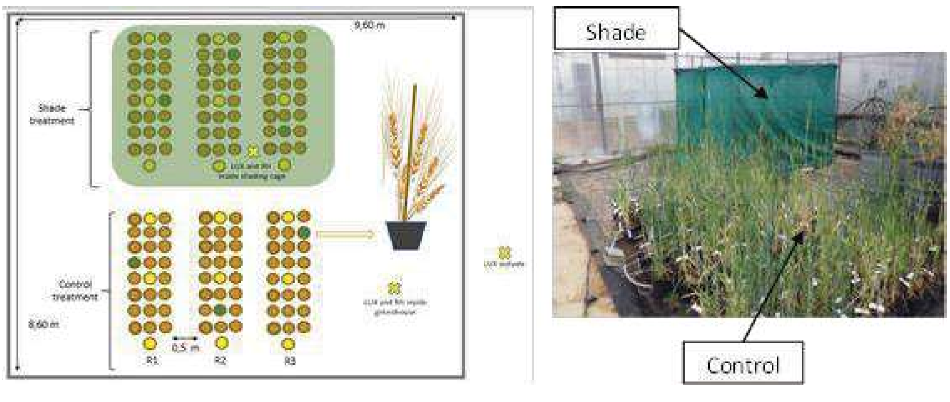

Figure 2: Design of the greenhouse treatment (left), a photo of the control treatment and the shade treatment in the greenhouse (right).

Data collecting. Photosynthetic Active Radiations (PAR) were recorded in the greenhouse via a Luxmeter (Voltcraft-DT 8820) and in the field by pyranometers SP-LITE in the two treatments. The average PAR levels in the greenhouse (Shade) and in the field (AF) treatments were respectively 320 and 250 µmol/m^2/s. Compared to the Controls, these data represent a reduction of PAR equal to 57% in the greenhouse and 50% in the field. Concerning the temperature, no significant differences were found between the two control treatments (greenhouse and field) in the one hand, and the two shade treatments in the other. At maturity the yield and its components were measured for each genotype and repetition.

Results and discussion

Representativity of the greenhouse experience. To assess the representativity of the greenhouse experimentation, the mean yield and yield components of each genotype observed in the greenhouse Control treament were compared to those measured in the field Control (Figure 3). Considering the yield (grains dry matter/plant), the production in the greenhouse was higher than in the field (different scale axis) because of the absence of competition between plants. However, there is a general good correlation between the yield obtained in the greenhouse control treatment and those obtained in the field control treatment (Figure 1, left). The two highest yielding genotypes in the greenhouse reached also the highest results in the field. As the same time, the genotypes with the lowest grains dry matter/plant were also the same in the greenhouse and in the field. However, for some genotypes (outside the ellipse) the greenhouse results do not fit well with the performances reached in the field. Two reasons to explain it: for some of them, the yield was reduced by weeds present in the field in 2016, for others that are populations, the within-cultivars heterogeneity can not be well represented by the choice of 1 plant per pot in the greenhouse!

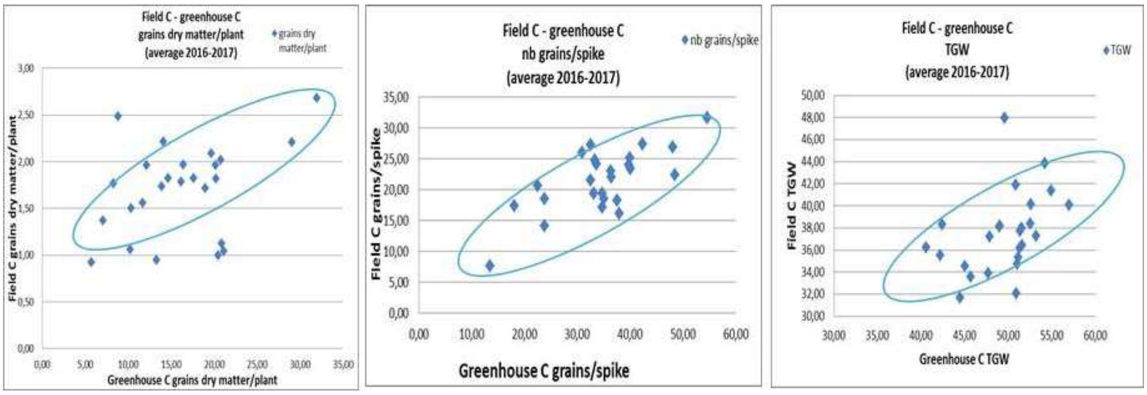

Figure 3: Correlation between Greenhouse Control and Field Control for yield, number of grains per spike and thousand grain weight (TGW)). A point represents the mean of the two years and two reps data for one genotype (without years effect)

Considering the number of grains/spike and the thousand grain weight (TGW), the correlations are higher (same scale axis). The genotypes showing the highest number of grains/spike were the same in the greenhouse and in the field as were the genotypes with the lowest rate. Concerning TGW, the two points outside the ellipse are two durum wheat populations. We can therefore conclude that the Control greenhouse experiment is able to represent the results of field Control, mainly for the pure lines genotypes.

Rank of the genotypes in the shade treatments. The mean yield and yield components of each genotype observed in the greenhouse Shade treament were compared to those measured in the olive tree orchard (AF treatment; Figure 4).

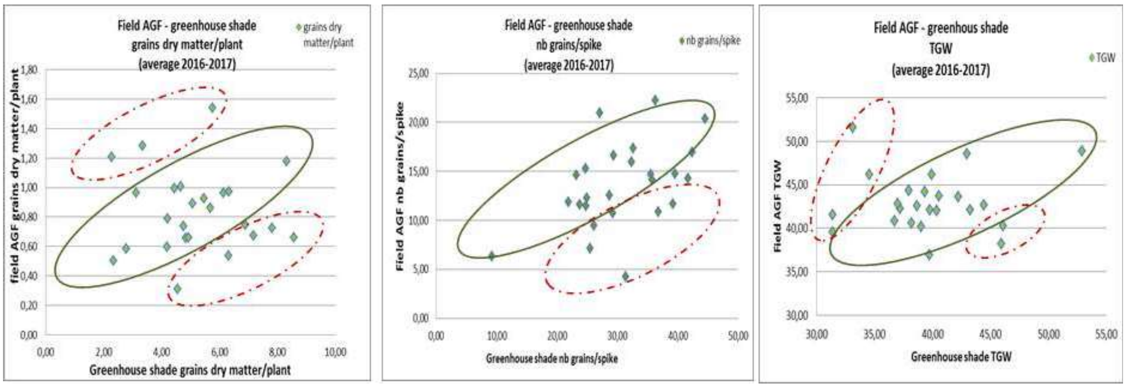

Figure 4: Correlation between Greenhouse shade and Field AF treatments for the yield (grain dry matter/plant), the nb of grains/spike and the thousand grains weight

The correlations between the greenhouse (shade) and field (AF) treatments are lower compared to those obtained for the two control treatments: the three highest yielding genotypes in the field were not the highest in the grenhouse (red ellipse above the green), and some others reaching the best yields in the greenhouse were under the mean in the field (dashed ellipse over the full line one). However, for some genotypes, the results obtained in the greenhouse shade treatment fit well the results obtained in the field AF treament (full line ellipse). Almost the same remarks can be made for the considered yield components (grains/spike or TGW). The points out of the full line ellipse are not all coming from populations. For these genotypes we might suppose that light was not the major or not the only limiting factor determining yield results.

In the greenhouse, the choice of growing each plant in a single pot avoided not only the belowground interaction with olive trees, but also any effect due to competition with neighboring durum wheat plants. In this way, the factor “light” was isolated from all possible belowground interactions. We may suppose that when field performances are well simulated by the greenhouse shade test, for these genotypes light is really the major limiting factor reducing yield. Considering the yield, genotypes situated in the bottom right part of the graphic (Figure 4; high level in the greenhouse, low level in the field), seem to be more sensitive than others to limiting factors other than light encountered in AF field conditions, such as belowground interaction/competition for water and nutrients. On the other hand, the three best yielding genotypes in the field, showing a low yield in the greenhouse (top left part of Figure 4) seem to have been more affected than other genotypes by the permanent shade effect of the shelter in the greenhouse. The PAR reduction in the shade greenhouse treatment was higher than in AF treatment and it seems that some genotypes cannot afford such level of light reduction.

Conclusion

As most of the crop varieties used by farmers were selected in full light conditions, crop breeding programs looking for shade tolerant traits are necessary to select cultivars adapted to agroforestry (Retkute et al. 2015). As the test implemented in greenhouse conditions without shade gives the same genotypes ranking than the full sun field test, we may conclude that the greenhouse is representative of the outdoor conditions and may be of interest to select the high-yielding varieties and eliminate the low-yielding ones. Moreover it requires less surface and therefore allows an economic gain. However, considering the selection for Agroforestry adaptation, permanent shelter in a grenhouse may help to identify some genotypes; but for some others, we conclude that the presence of trees in the field cannot be simulated by only shade effect in the greenhouse. Numerous others effects occuring in the field like belowground interaction between plants and between plants and trees may have a greater effect on some genotypes than shade. Therefore, by using the greenhouse shelter test, a breeder may reject some interesting varieties or select others varieties that might not be the best in the field. Thus selecting for shade-tolerant varieties is not equal as selecting for agroforestry-adapted varieties.

References

Artru S, Garré S, Dupraz C, Hiel MP, Blitz-Frayret C, Lassois L (2017) Impact of spatio-temporal shade dynamics on wheat growth and yield, perspectives for temperate agroforestry. Eur J Agron 82: 60-70.
Barro RS, Costa Varella A, Lemaire G, Borges de Medeiros R, Carlos de Saibro J, Nabinger C, Villamil Bangel F, Justin Carassai I (2012) Forage yield and nitrogen nutrition dynamics of warm-season native forage genotypes under two shading levels and in full sunlight. Revista Brasileira de Zootecnia 41: 1589-1597.
Dufour, Metay A, Talbot G, Dupraz C (2013) Assessing light competition for cereal production in temperate agroforestry systems using experimentation and crop modelling. J Agron Crop Sci 199: 217-227.
Ehret M, Graß R, Wachendorf M (2015) The effect of shade and shade material on white clover/perennial ryegrass mixtures for temperate agroforestry systems. Agrofor Syst 89: 557-570.
Friday JB, Fownes JH (2002) Competition for light between hedgerows and maize in an alley cropping system in Hawaii, USA. Agrofor Syst 55: 125-137.
Retkute R, Smith-Unna SE, Smith RW, Burgess AJ, Jensen OE, Johnson GN, Preston SP, Murchie EH (2015) Exploiting heterogeneous environments: does photosynthetic acclimation optimize carbon gain in fluctuating light? J Exp Bot 66: 2437-2447.
Varella AC, Moot DJ, Pollock KM, Peri PL, Lucas RJ (2011) Do light and alfalfa responses to cloth and slatted shade represent those measured under an agroforestry system? Agrofor Syst 81: 157-173.