Artificial shading to mimic the effects of trees on old wheat varieties for future implementation in agroforestry systems

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Abstract
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Abstract

Introduction Agroforestry systems (AFS) are receiving renewed attention in temperate regions, as agricultural systems able to enhance crop resilience towards climate scenarios of increasing mean temperatures and shifting rainfall patterns. The shortening of crop growing cycle and the reduction of grain ripening duration are the main effects of climate change which leads to yield and quality impairments in cereal production (Ren et al., 2019). In silvoarable AFS, among the main factors affecting the development and yield of the cultivated intercrops there are the design and management of the system, which strongly influence the availability of resources such as light, nutrients and water, and the adaptability of the crop to the specific growing conditions (Pardon et al., 2018). Considering that actual quantitative data in temperate AFS is limited, especially with a mature tree component, artificial shading is an interesting experimental tool to mimic the effect of tree rows on the intercrop in order to investigate different shading intensity and dynamics on a limited space, and to isolate the light factor from other potential interactions between the two components of the AF system (Artru et al., 2017). In this study we investigated the effect of artificial shading with two levels of light reduction on the growth and yield of three varieties of common wheat: two old varieties originated in the NE of Italy, compared with a reference modern variety, in order to evaluate their future implementation in alley cropping AFS.

Materials and methods The experiment was conducted at the experimental farm of the University of Padova (Legnaro – NE Italy) during the 2018-2019 growing season on three wheat varieties (*Triticum aestivum* L.): the modern var. Bologna (SIS, Bologna, Italy) and two old wheat varieties preserved at the "N. Strampelli" Institute of Genetic and Agricultural Research in Lonigo (Vicenza, NE Italy), Terminillo and Piave. Sowing took place on 25 October 2018, with a density of 350 (Bologna) and 220 (Terminillo and Piave) seeds m^{-2}, and 12.5 cm row apart; harvest occurred on 26 June 2019. Artificial shading was implemented by covering wheat plants with white nets from the 19th of April to mimic the beginning of foliage development of poplar trees in NE of Italy, and kept constantly until harvest. Each variety underwent two shading levels, -30% and -50% of photosynthetic active radiation (PAR) availability, obtained with different mesh size of the nets, compared with a control under full sun conditions (C). Nets were supported by a metallic squared structure 2 m high placed over a 4-m^2 area. An equal surface without shading was considered as control area. In this area, 3 plots/replicates of 1 m^2 were defined for each variety × treatment, to perform statistical analysis. The phenological development and leaf vegetational indexes such as SPAD and NDVI were monitored periodically during the rest of the crop cycle. At harvest, yield, the thousand grain weight (TGW), grain protein content (Kjeldahl method) and the concentration of Ca, P an Mg in the grains (by ICP-OES) were determined. A factorial discriminant analysis and principal component analysis were carried out with MS Excel XLSTAT to describe the changes of growth and yield parameters according to variety choice and the treatment.

Results During the growing cycle rainfall was 608 mm, half of which occurring during April and May, and temperatures were similar to the historical 10-year average (except during May: -2°C). All varieties showed a significant delay of phenological development under artificial shading, completing heading and flowering (BBCH= 59 and 69, respectively) about one week later compared to full sun. Similarly, the longer maintenance of canopy greenness and the delay of leaf senescence were supported by higher values of NDVI and SPAD under shading. Grain yield was significantly reduced by shading in old varieties (-60% and -20% for Piave and Terminillo, respectively), while slightly increased in var. Bologna under the less severe shading (-30% PAR: +8% of yield vs C, not significant). The grain protein content was generally improved with both shading levels in all varieties, on average by 10%, and significantly for var. Bologna with -50% PAR: 15.7% s.s. vs. 14% of C. An increase of the mineral concentration (Ca, Mg and P) in grains was also observed in the old varieties, but not in the var. Bologna. Both shading levels, however, improved grain quality of var. Bologna, with a significant higher percentage of gluten and the Zeleny index (NIRS analysis). All the parameters investigated were informative to explain the variability between varieties and treatments (Fig. 1).

Conclusions Moderate shading level (-30% PAR) can positively delay leaf senescence and improve grain quality with no yield impairments in a reference modern wheat variety such as Bologna. Implementation in real AF systems will be fundamental to evaluate this result, since significant wheat yield reductions were reported in temperate AF systems with a similar PAR reduction (Dufour et al., 2013). The old tall varieties, that were damaged by abundant rainfall in spring and lodging, seem less suitable to shaded conditions, however the multiple potential interaction with trees in alley cropping AFS might reduce the impact of adverse climate on growth and yield. Further investigations with drier climate and variable shading levels should be studied for designing appropriately the AF systems.

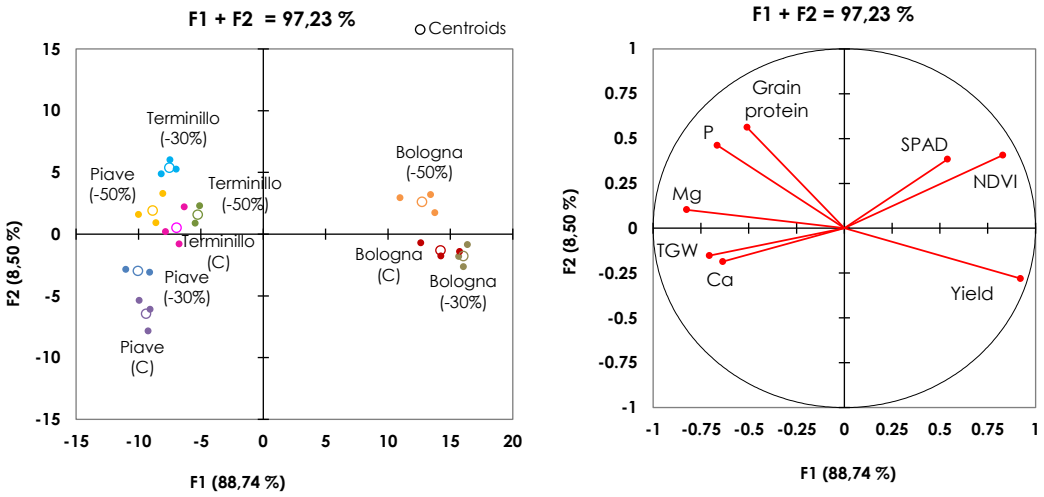

Figure 1. Principal component analysis (PCA, right) with variable loadings and discriminant analysis (DA; left) for the three wheat varieties and shading levels.

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