How does a winter wheat composite cross population perform in temperate agroforestry? A Swiss case study

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Introduction

In agroforestry systems, where environmental conditions are highly variable at small spatial scales, the use of uniform genetic material of a single cultivar commonly grown in monoculture cropping might not be optimal. Breeding for maximum and/or stable yield in competitive, heterogeneous and low-input environments should ideally be undertaken under exactly such conditions. The dynamic gene pool of a composite cross population (CCP) provides the potential of adaption to locally heterogeneous environmental conditions as they are found in agroforestry (Smith, Pearce, and Wolfe 2012, Vollenweider et al. 2020). A CCP is obtained by the reciprocal inter-crossing of genotypes and mixing of the progeny and is a particularly plastic and adaptable culture (Knapp et al. 2020).

Objectives and research questions

In a one-year field experimentation at two temperate agroforestry sites in Switzerland, the potential of CCPs for improved yield (stability) and quality of wheat under agroforestry conditions in different spacing to tree rows was assessed. It was hypothesised that a wheat CCP will outperform a commercial cultivar in terms of yield and quality in particular in proximity to the tree row. Furthermore, it was assumed that quality traits (such as protein and mineral content) of CCP would be improved, especially near the tree.

Methodology

A common winter wheat variety ('Wiwa') and a winter wheat CCP ('CC-2k') were grown from autumn 2021 to summer 2022 at two organically managed agroforestry systems with standard fruit trees in Switzerland. CC-2k is a composite cross obtained as a cross of 20 wheat varieties and breeding lines from Switzerland and from Europe, its development started in 2000 at the Agroscope site in Changins (Nyon, Switzerland).

The experimental fields lay on the North side of plum and apple tree rows in Feusisberg (705 m a.s.l.) and Wollerau (620 m a.s.l), respectively, to include the effect of shade cast by the 4 to 6 m high trees. Wiwa and CC-2k were planted in two 1.8 x 9 m strips in a "split-plot" design with three replicates per site. Within each long plot, four observation and sampling plots of 1 m^2 were defined at 1.0, 2.4, 3.8 and 7.0 m distance from the tree-row border (Fig. 1).

Measurements included leaf chlorophyll content, stomatal conductance, plant height, total grain weight, grain mass, number of grains, thousand grain weight (TGW), protein and mineral contents.

Results

CC-2k outperformed Wiwa in terms of yield at one of the two sites, Wiwa outperformed CC-2k in terms of quality. Variety and the interactions of site and distance and site and population/variety significantly affected wheat yield ($p < 0.05$). Yield of CC-2k (1.9 ± 0.8 Mg ha^{-1}) was significantly higher than yield of Wiwa (1.4 ± 0.9 Mg ha^{-1}) across both sites and all distances. Mean CC-2k yield was identical for Feusisberg and Wollerau while mean Wiwa yield in Wollerau was only 35% of mean Wiwa yield in Feusisberg. The coefficient of variation was 40% for CC-2k and 64% for Wiwa across the two sites.

Yield was highest and lowest at 3.8 m in Feusisberg and Wollerau, respectively, and similar at 1.0, 2.4 and 7.0 m distance to the tree row. The interaction of population/variety and distance varied with CC-2k having higher yields in proximity to the tree row in Feusisberg but lower ones in Wollerau compared to the reference yield at 7.0 m distance.

TGW was significantly affected by distance ($p < 0.05$), differences between Wiwa and CC-2k were not significant. Distance influenced plant height significantly ($p < 0.001$), with plants being higher close to the tree. Protein content was significantly affected by population/variety ($p < 0.01$) and marginally significantly by site ($p = 0.06$). Protein content was significantly higher in Wiwa (12.7 ± 1.0%) than in CC-2k (11.1 ± 0.6%) and in Wollerau (12.2 ± 1.3%) than Feusisberg (11.5 ± 0.9%). Potassium, phosphorus, calcium, magnesium, iron and zinc content significantly depended on population/variety. Some nutrients showed effects by site, distance and interactions of site and population/variety, site and distance and distance and population/variety.

Chlorophyll content was significantly affected by month, site and distance. Volumetric soil moisture was significantly affected by month and the interaction of distance and population/variety.

Conclusion

CC-2k was more apt to grow well under the heterogeneous and low-input conditions at both agroforestry sites and outperformed the commercial organic variety Wiwa in terms of yield but not in terms of grain quality at one agroforestry site in this year. As variety-/population-specific yield was independent from the distance to the tree row, it may be concluded that shade-induced reductions in yield-related characteristics must not have been decisive or might have been outweighed by positive interactions or a beneficial microclimate in the agroforestry systems of this experiment.

Keywords

crop variety, Genetic resources, alley cropping, Organic Farming, understorey growth, adaptation, silvoarable agroforestry, Temperate

Aditional Attachment II.

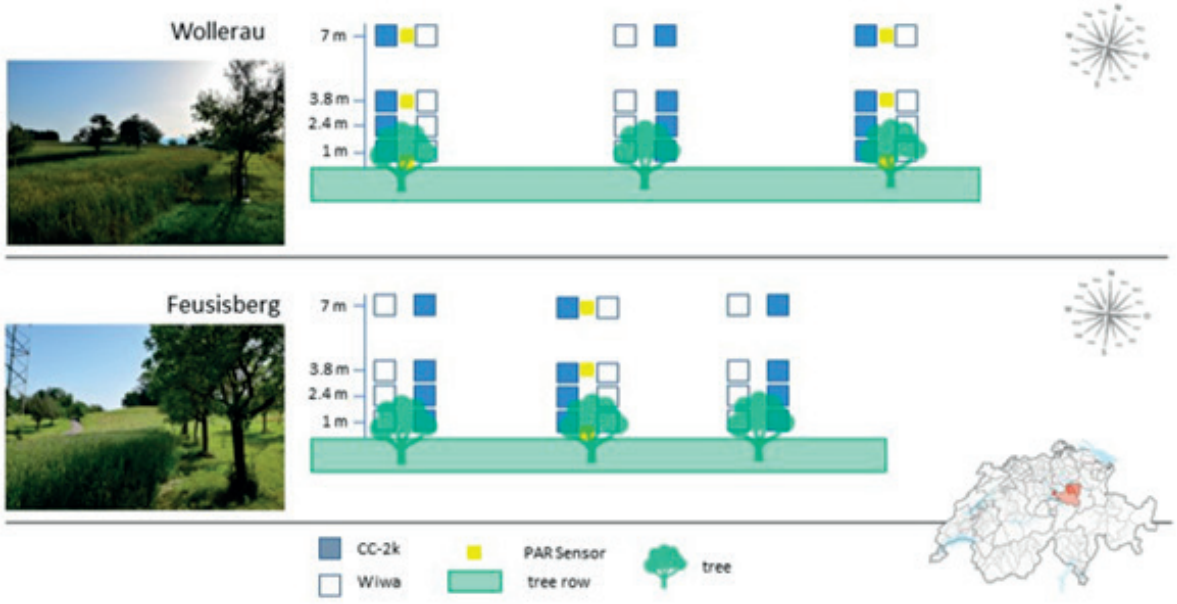

Fig. 1: Experimental design at two Swiss agroforestry systems in Feusisberg and Wollerau, respectively. Each replicate consisted of a strip ("long plot") with the composite cross population "CC-2k" and commercial variety "Wiwa". Physiological and yield parameters were collected from 1 m² plots at four distances (1.0, 2.4, 3.8 and 7.0 m) from the tree row.

Bibliography

Knapp, Samuel, Thomas F. Döring, Hannah E. Jones, John Snape, Luzie U. Wingen, Martin S. Wolfe, Michelle Leverington-Waite, and Simon Griffiths. 2020. 'Natural Selection Towards Wild-Type in Composite Cross Populations of Winter Wheat'. Frontiers in Plant Science 10 (February): 1757. https://doi.org/10.3389/fpls.2019.01757.

Smith, Jo, Bruce D. Pearce, and Martin S. Wolfe. 2012. 'A European Perspective for Developing Modern Multifunctional Agroforestry Systems for Sustainable Intensification'. Renewable Agriculture and Food Systems 27 (4): 323–32. https://doi.org/10.1017/S1742170511000597.

Vollenweider, Carl, Annette Haak, Kathrin Buhmann, Michael Locher, Verena Weyermann, Gabi Schwittek, Fabio Mascher, Maria Finckh, and Odette Weedon. 2020. 'Stability of Yield and Baking Quality Parameters of Heterogeneous Wheat Populations'. In 71st Conference. Breeding for Resilience against Biotic and Abiotic Stresses, edited by Vereinigung der Pflanzenzüchter und Saatgutkaufleute Österreichs. Online Conference, Raumberg-Gumpenstein, Österreich.