SUGAR BEET YIELDS AND SOIL MOISTURE MEASUREMENTS IN AN ALLEY CROPPING SYSTEM

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Introduction

Agroforestry for arable farmers is not a common practice in Germany. However, alley cropping for woody biomass production is of interest because of its high potential to concurrently provide a biomass feedstock and an arable crop. One of the systems that exists, although at an experimental level, is the integration of rows of fast growing trees, such as poplar or willow, with arable crops.
The experimental plots were initially established as part of the German joint research project "AgroForstEnergie - Economic and Ecological Evaluation of Agroforestry Systems in Farming Practice", funded by the German Federal Ministry of Food and Agriculture (AgroForstEnergie 2015). The goal of this project was to study alley cropping systems, which concurrently produce a woody biomass feedstock and conventional agricultural crops. Currently the work is continued through the AGFORWARD Project.
The State of Brandenburg is known for its light sandy soils that are prone to wind erosion. The introduction of tree hedgerows within the agricultural landscape can reduce wind erosion (Böhm et al. 2014). In addition, microclimatic conditions such as soil moisture, wind speed reduction, relative humidity and air temperature have been more favourable for plant growth in crop alleys compared to reference crop areas (Böhm et al. 2014; Quinkenstein et al. 2009).
Sugar beets are a common crop for conventional agricultural systems in Western Europe. As part of agroforestry systems, sugar beets have rarely been studied. Even though sugar beets can root up to a depth of 2 meter, their yields can be significantly reduced due to a lack of water (Hoffmann 2010; Bloch et al. 2006). Agroforestry systems that consist of tree hedgerows and crop alleys, also known as Alley Cropping Systems, have the potential to increase plant moisture in comparison to conventional agricultural systems (Quinkenstein et al. 2009).
This study aims to assess tree hedgerow effects on sugar beets. The objectives of this study were to; 1) assess how tree hedgerows planted at three distances affected sugar beet yields; 2) to correlate soil moisture values of the top 15 cm with sugar beet yields at the same distance of the tree row; 3) to assess the effects of drought stress on sugar beet yield.

Material and Methods

Site description

The study site is located on land owned by the Agricultural Cooperative Forst in close proximity to the city of Forst (Lausitz), Germany. The system studied is considered an Alley Cropping System (ACS) of which the tree hedgerows consist of short rotation coppice fast growing woody crops. The sugar beet yield study took place in the Northwestern part of the ACS. In this part of the alley cropping system the tree hedgerow consists of poplar (*Populus nigra L.*× *P. maximowiczii* (variety Max 1)) and black locust (*Robinia pseudoacacia*). This part of the experimental site was planted in 2010. The poplars did not establish well during the first year and were replanted in 2011. The spacing within the hedgerows was 4 double rows with 75 cm within the double row, 1.8 m between the double rows and 90 cm within the row. The tree hedgerows are 12 meter wide, which includes a buffer strip of 1.8 m on both sides. The crop alleys are 96m, 48m and 24m wide.

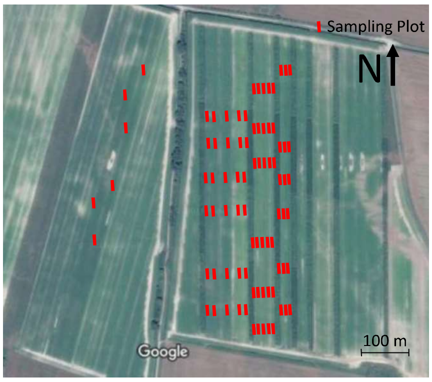

Figure 1. Map of the Agricultural Cooperative Forst field site. Coloured squares indicate sampling plots for the manual sugar beet harvest. Plot size varies between 5 - 6 m².

The sugar beet crop was seeded within the crop alleys and on an adjacent conventional agricultural field during the middle of April 2016. A manual harvest of sugar beets at the study site took place between the 30th of September and October 6th. Measurements took place at the three western crop alleys of the alley cropping system (Figure 1). Within the alley cropping system both crops in close proximity to the tree rows and crops in the middle of the alleys where harvested in order to take the interaction at the crop/tree interface into account (Roa and Coe 1991). For the 96 m and 48 m wide crop alleys crop plots were measured at 3 m, 12 m east and west of the tree row and in the centre of the alley and for the 24 m wide alley at 3 m east and west of the tree row and in the centre. Six replications were carried out for each treatment. Sampling plots were approximately 3 – 5 m² in size and consisted of 3 sugar beet rows. Prior to sugar beet extraction all beets in those sampling plots were counted and the exact plot size was measured. These values were required for subsequent yield calculations. For sugar beet harvest in each of the plots the following protocol was used: 1) above- and below ground biomass of 12 sugar beets were harvested and weighted separately (in kg); 2) two sugar beets were collected for dry matter determination. The two beets for dry matter determination were stored in ziploc bags, transported to the laboratory and dried until a constant weight at 105°C.
Soil moisture was measure with a Time Domain Reflectometry (TDR) (IMKO GmbH, Ettlingen, Germany) mobile probe to a depth of 15 cm on a bi-weekly basis between mid-May and the end of August.

Statistical Analysis
Statistical analysis was carried out using SigmaPlot 12.5 (Systat Software GmbH, Erkrath, Germany). Differences in sugar beet yields between the ACS and the conventional crop reference site were assessed with two-way ANOVAs Dunnetts method for each of the alley widths separately. Differences in soil moisture between the ACS and the reference crop site were assessed with ANOVA Dunnetts method. Differences between eastern and western (leeward and windward) side of the tree hedgerow for the 96m and 48m alleys were assessed with a one-way ANOVA on Ranks (Kruskal-Wallis method), because the normality test failed. For all statistical test we used a significance level of $\alpha = 0.05$ unless mentioned otherwise.

Results
The overall trend for sugar beet yields showed a reduction in close proximity to the tree hedgerow and an increase at 12 m and in the middle of the alleys in comparison with the adjacent reference crop field (Figure 2). The yield differences main effects were significant for the 96m (p=0.026) and 48m (p=0.004). A comparison between each of the distances and the reference field showed significant differences for the 48-W12 (p=0.006).
The amount of leaves of the sugar beet crop was less for all distances except for the 12 m west side of the 48m alley within the alley cropping system compared with the reference site. Significant differences were measured among the different distances and the control site for the 48 m alley (p=0.02). No significant differences were present between the separate distances and the control site.
Soil moisture values decreased over the course of the growing season with values between 40% and 45% during the beginning of June and as low as 20% during the end of July (Figure 3). Significant differences in soil moisture were measured between the reference site and the 48m alley for July 27 when taking all distances into account ($p<0.001$). For the 96m alley soil moisture values were higher in comparison with the references site when only taking measurement point of 21m or less into account (for better comparison with the 48m alley) for July 27 as well, but these differences were not significant (p=0.283). Differences between the leeward and the windward site were tested for the 96m (p=0.0451) and the 48m (p=0.133) alleys as well, but were not significantly different.

Discussion
The lower sugar beet yields in close proximity to the tree hedgerows can be explained by competition for light and water (Grünewald et al. 2009). Increased weed competition and a lack of soil tillage close to the hedgerow could have resulted in lower yields at a distance of 3 m from the hedgerow as well. In addition, competition for soil nutrients and interactions related to weeds may have affected sugar beet yields (Rao et al. 1998). The greater yields at a distance of 12 on the other hand can be explained by a reduction in temperature extremes, evapotranspiration, erosion due to wind and water (especially on the leeward side) (Grünewald et al. 2009; Böhm et al. 2014). Lower wind speeds and a reduction in temperature extremes were measured for the ACS compared

with the reference site during the 2015 growing season (data not shown). The reduced evapotranspiration and lower temperature extremes on the leeward side also corresponded with higher soil moisture values on the leeward side of the hedgerow on the 27th of July. The greater soil moisture values were most prominent for the leeward 48m alley, which corresponded with the significantly greater sugar beet yields at 12m distance.

Sugar beet yields that varied between 15 and 25 Mg ha^{-1} $year^{-1}$ were on the high side of estimated sugar beet yields for Europe ranging from 6 to 25 Mg ha^{-1} $year^{-1}$ (Van Lanen et al. 1992). For water limited yield this value ranged from 3 to 20 Mg ha^{-1} $year^{-1}$.

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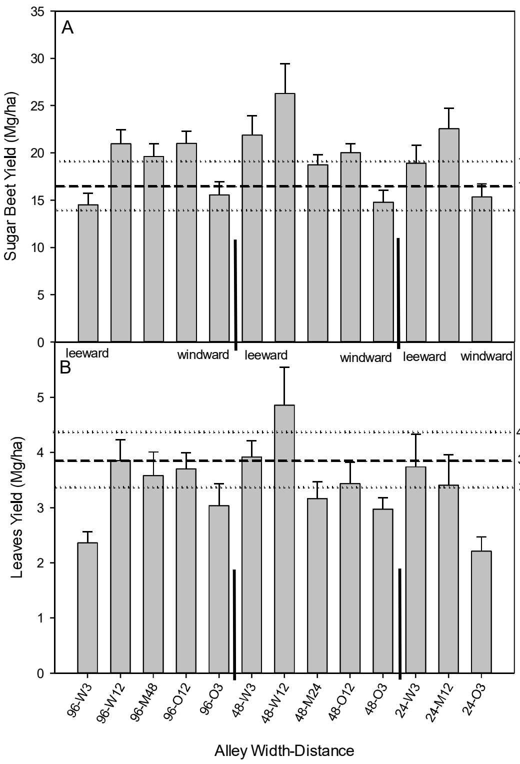

Figure 2. Sugar beet yield ± SE (A) and leaf yield ± SE (B) for three alley cropping widths (96m, 48m and 24m) and yields at the adjacent reference site (dashed line ± SE). Yields were measured at different distances away from the tree hedgerow; at a distance of 3m (W3), 12m (W12) in the middle (M48, M24) of the alley for the 96m and 48m alleys and at a distance of 3m and in the middle (M12) for the 24m alley.

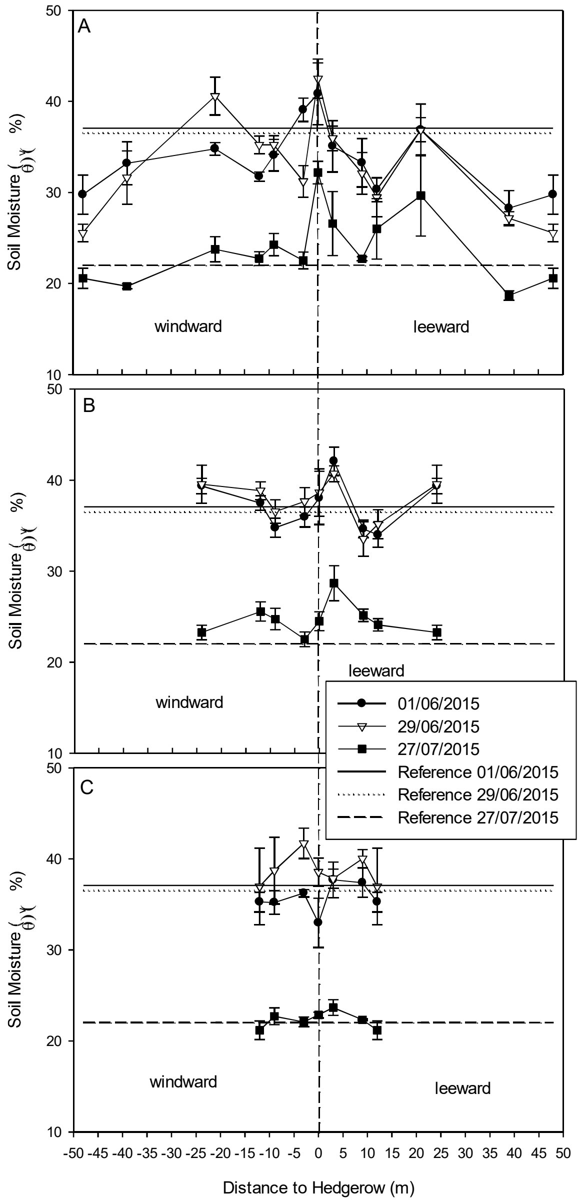

Figure 3. Mean soil moisture percentages in the upper 15 cm for three alley widths (A) 96m, (B) 48m, (C) 24m during three sampling dates in 2015.