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Rates of photosynthesis and transpiration of wheat and barley as influenced by fodder precrops and their cropping period

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Abstract

*Long term cultivation of fodder crops can enhance water accessibility in the subsoil by creating biopores which can make rooting easier. In a factorial field trial we cultivated lucerne (*Medicago sativa *L.), chicory (*Cichorium intybus *L.), and tall fescue (*Festuca arundinacea *SCHREB.) each with duration of one, two, and three years (2007 – 2009). Spring wheat (*Triticum aestivum *L.) in 2010 and winter barley (*Hordeum vulgare *L.) in 2011 were first and second subsequent crop, respectively. Rates of photosynthesis and transpiration of both cereals were investigated using a porometer. Series of measurement covered for spring wheat as well as for winter barley a dry period in early summer. Spring wheat showed higher rates of gas exchange after perennial precropping compared with annual precropping. In contrast to this winter barley was not influenced by the precrop's cropping period. Results suggest that spring cereals grown under dry condition can profit by perennial fodder precrop more than winter cereals.*

Introduction

Perennial fodder cropping as compared to rotations including annual ploughing can increase the number of medium and large sized biopores in the subsoil (Kautz *et al.* 2010). This can result in potentially facilitated root growth followed by increased accessibility of water in the subsoil. Additional plant-available water can enable stands to cope with dry periods in early summer, which will take place more often in future due to climate change. In this context we investigated whether crop species or cropping period of forage cropping influenced rates of photosynthesis and transpiration as indicators for water availability of spring wheat (*Triticum aestivum* L.) and winter barley (*Hordeum vulgare* L.).

Material and methods

On a Haplic Luvisol (WRB) derived from loess (loamy silt) in Klein-Altendorf near Bonn, Germany (9.6 °C mean annual temperature, 625 mm annual rainfall), from 2007 to 2009 lucerne ('*luc*'; *Medicago sativa* L.), chicory ('*chi*'; *Cichorium intybus* L.), and tall fescue ('*fes*'; *Festuca arundinacea* SCHREB.) were cultivated each for one, two, and three years. The fodder crops were mulched four times a year. The field trial was arranged in a three-factorial strip-design with four field replicates. The plots had an area of 60 m². In 2010, spring wheat was cultivated as first subsequent crop following each precrop treatment. In the next year, winter barley was grown as second subsequent crop following the first subsequent crop spring wheat. In spring of both years, plant available mineral soil-N of the treatments was measured and equalized by adjusted fertilization.

Using a porometer (CIRAS 2, PP Systems), rates of photosynthesis (RP) and rates of transpiration (RT) were measured as follows: in case of spring wheat in seven precrop treatments (*luc* 1, 2 & 3 years, *chi* 1, 2 & 3 years, *fes* 1 year) six measurements (BBCH 59 to 84) were conducted by testing five flag leafs per plot. In case of winter barley, in six precrop treatments (*luc* 1 & 2years, *chi* 1 & 2 years, *fes* 1 & 2 years) in five measurements ten leafs per plot were chosen.

Series of measurement both of spring wheat and winter barley included periods of dry conditions. In June and early July 2010 42 mm rainfall was determined, *i. e.* 20 mm below the long term average. In April and May 2011 a dry period occurred (60 mm rainfall, *i. e.* 47 mm less than on long term average).

Flagleaves were placed in the cuvette, strictly separated from environmental air and light conditions. An adjusted air-similar gas mixture with a CO_2-concentration of 400 ppm and a flow rate of 200 mL min^{-1} was applied. LEDs illuminated the tested leaf area with a photon flow rate of 1500 µmol m^{-2} s^{-1}. The rates of photosynthesis and transpiration increased under these conditions and reached their maximum after 1 – 3 minutes. Determined data were stored, averaged per plot and statistically analysed.

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Results

RP and RT of spring wheat following *luc* and *chi* differed when comparing annual *vs*. perennial cultivation of fodder crops. RT of spring wheat following one year fodder cropping was lowest in all measurements, compared with spring wheat following perennial fodder cropping. Both RP and RT of spring wheat following annual *vs*. perennial fodder cropping were significantly lower in the last three measurements (fig. 1).

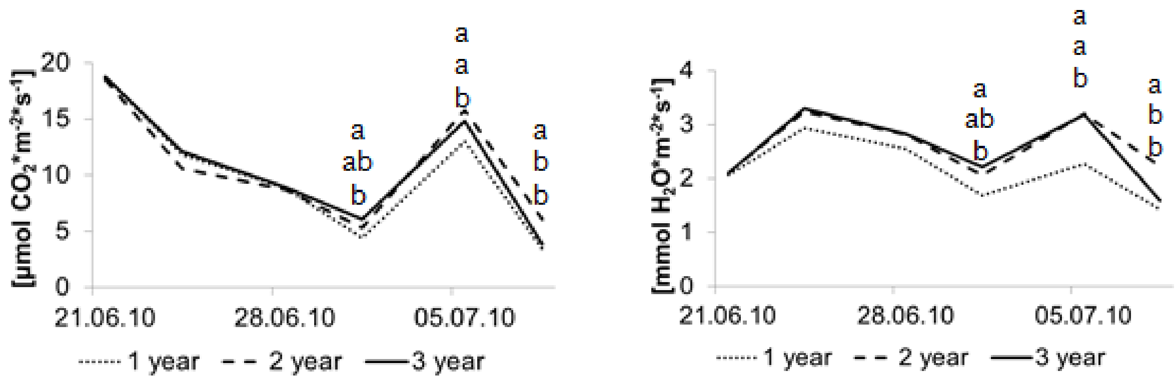

Figure 1: RP (left) and RT (right) of spring wheat following one, two, and three year fodder cropping (*luc* and *chi* averaged). Data with different letters are significantly different (Tukey α=5%).

After one year fodder cropping no influence of the fodder crop species on RP or RT of spring wheat was found (fig. 2).

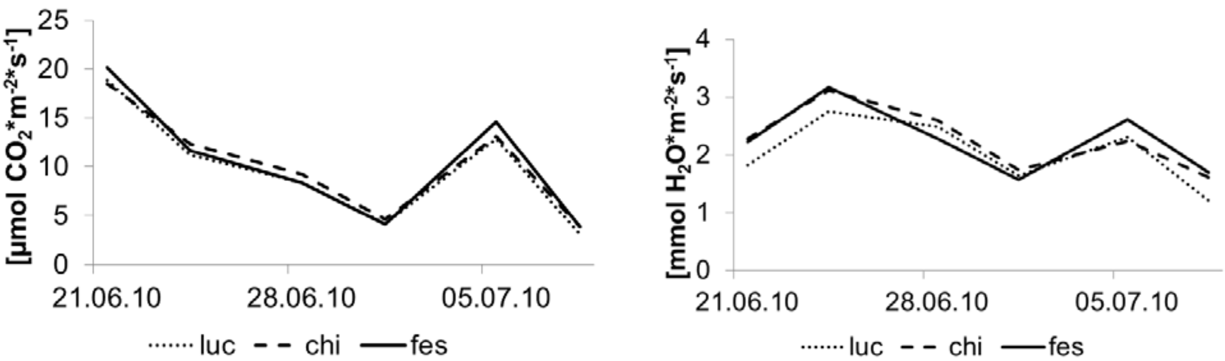

Figure 2: RP (left) and RT (right) of spring wheat following *luc*, *chi*, and *fes* (only one year cropping). Data with different letters are significantly different (Tukey α=5%).

Neither precrop species nor duration of their cultivation influenced RP or RT of winter barley except the fifth measurement, when a higher RP of winter barley following *luc* was determined (fig.3 and 4).

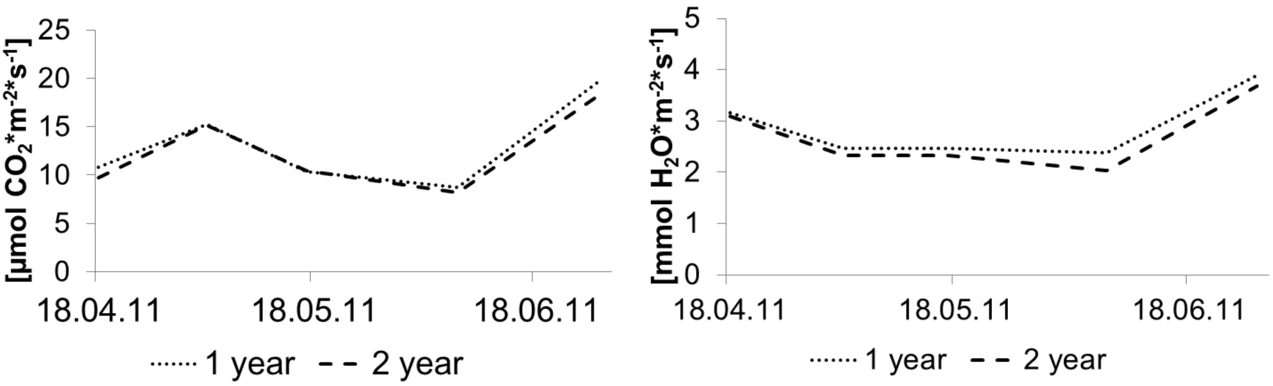

Figure 3: RP (left) and RT (right) of winter barley following one, two, and three year fodder cropping (*luc*, *chi* and *fes* averaged; 2007 – 2009) and spring wheat (2010). Data with different letters are significantly different (Tukey α=5%).

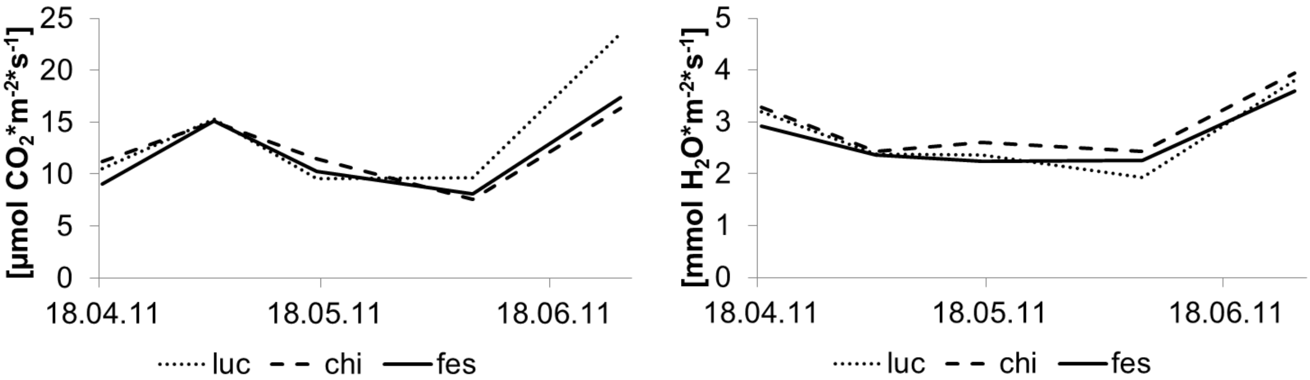

Figure 4: RP (left) and RT (right) of winter barley following *luc*, *chi*, and *fes* (one, two, and three years cropping averaged; 2007 – 2009) and spring wheat (2010). Data with different letters are significantly different (Tukey α=5%).

When comparing first subsequent crop spring wheat and second subsequent crop winter barley, greater amplitude of RP and RT and stronger response to fodder precrop-treatment were measured in spring wheat.

Despite comparing first *vs*. second subsequent crop grown in different years, dissimilar rooting depths of the subsequent crops may explain the results. The maximum rooting depth (defined as 95 % of all root length units above) of the cereals was analysed using the profile wall method (Böhm 1979). At end of June 2010, spring wheat following perennial cultivated *luc* or *chi* reached a greater maximum rooting depth (two years: 52 cm, three years: 55 cm) than spring wheat following one year cultivated fodder crops (48 cm).

In early June 2011, winter barley following two years cropped *chi* reached only slightly deeper soil layers compared with winter barley following one year cropped *fes* (148 cm *vs*. 142 cm).

Discussion

Maintenance of soil fertility by inserting forage cropping entailing perennial soil rest and increased bioporing, is an essential tool of organic farming. We investigated whether first subsequent crop spring wheat *vs*. second subsequent crop winter barley was able to profit more by perennial fodder cropping concerning water accessibility in the subsoil.

The results of the present investigation indicate that spring wheat grown under dry conditions can reach higher RP and RT after perennial cultivation of a precrop with tap root system like *luc* or *chi* when compared with annual forage production only. Studies of Gaiser *et al*. (2012) carried out in the same field trial showed that spring wheat following two year *luc* took up more water from 75 – 105 cm soil depth compared with spring wheat following one year *luc*. In this context the shown outcomes can be explained by a higher accessibility of spring wheat roots to deep soil water after perennial fodder cropping.

In contrast to that, a winter cereal like barley is considered as less affected by a dry period in early summer. We assume winter barley's maximum rooting depth enables water uptake from deep soil layer. Thus, the precrop effect may have a low impact on water accessibility when compared with spring sown cereals.

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