Root growth response of spring wheat (*Triticum aestivum* L.) and mallow (Malva sylvestris L.) to biopore generating precrops

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Abstract

Little is known about root growth in biopores. The aim of this study was to quantify differences of root-length density (RLD) in biopores between a tap root system (mallow) and a fibrous root system (wheat).
A field experiment was undertaken near Bonn, Germany on a Haplic Luvisol developed from loess. Lucerne (Medicago sativa L.) and chicory (Cichorium intybus L.) were grown as precrops in a field trial followed by spring wheat (Triticum aestivum L.) and mallow (Malva sylvestris L.). Biopore density was measured on horizontal areas of 50 x 50 cm. RLD was estimated using the profile wall method to 160 cm soil depth. Roots growing in biopores with a diameter > 2 mm were recorded separately from the roots in the bulk soil.
Biopore density was higher after chicory compared to lucerne cultivation. RLD of wheat in the topsoil was higher and in the subsoil lower than RLD of mallow. RLD in biopores of mallow was higher than of wheat. Both crops showed higher RLD in biopores after chicory.
The results indicate that the response of root growth to the presence of biopores is more pronounced for tap root systems than for fibrous root systems.

Introduction

Biopores are created by roots or earthworms and/or other soil organisms and can possibly facilitate the access of roots to water stored in the subsoil (McKenzie et al. 2009; Gaiser et al. 2012). This might be of major importance in the future as it is predicted that climate change will lead to more frequent dry spells in middle Europe (Gornall et al. 2010). To date, few attempts have been made to quantify root growth in biopores (Kautz & Köpke 2010). For example it is unclear whether plants with different root systems (tap vs. fibrous roots) use biopores to a different extent.
In this study we quantify biopore density generated of two different taprooted precrops and compare the root-length density (RLD) of following crops (spring wheat and mallow) to determine the relevance of biopores for different root systems.

Material and methods

The field experiment was conducted on a Haplic Luvisol (WRB) derived from loess (loamy silt) on the research station of the university of Bonn Campus Klein-Altendorf, Germany (50°37'9''N 6°59'29''E) with a mean annual temperature of 9.6 °C and 625 mm annual rainfall.
The taprooted lucerne (*Medicago sativa* L.) and chicory (*Cichorium intybus* L.) were grown as precrops continuously for one or two years in order to increase the number of biopores. After these precrops two species with a contrasting root system were grown: mallow (*Malva sylvestris* L.) with tap roots and spring wheat (*Triticum aestivum* L.) with fibrous roots.
Only after the decay of blocking roots all the biopores established by these roots are visible (Jones et al. 2004). Therefore the areas designated for biopore quantification were excavated to 45 cm soil depth in 2010 after the precrops were plowed and a GeoTex-sheet was placed on the horizontal surface in order to prevent the creation of new pores through roots. After two years in spring 2012 when most of the roots of lucerne and chicory have decayed the biopore density of medium (2 – 5 mm diameter) and large (> 5 mm diameter) sized biopores was measured. The horizontal soil surface was cleaned from soil particles with a vacuum cleaner and the biopores were marked accordingly to their diameter on plastic sheets.
Root-length density (RLD) of spring wheat (July 27th to July 30th 2010) and mallow (August 18th to August 20th 2010) was estimated with the profile wall method (Böhm 1979). Observations were made in four treatments (spring wheat and mallow grown after lucerne or chicory) in two field replications. An excavator was used to install a trench (depth: 1.8 m). A 100 cm wide soil profile wall was smoothed transversely to the plant rows with a spade to the maximum depth of investigation in 1.60 m. Roots exposed from the wall were removed by scissors. With a fine spray of water at 3 bar pressure and using a small toothed scraper, a 0.5 cm thick soil layer was washed away along the vertical wall of the soil pit to expose the roots. A frame

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(inner dimensions 100 cm x 60 cm with a grid of 5 x 5 cm) was attached to the profile wall. Root-length units (RLU) equivalent to 0.5 cm root-length were recorded in each square. RLD (cm root cm^{-3} soil) was calculated based on RLUs for each cube with a volume of 5 x 5 x 0.5 cm.

Results

Density of medium (2 – 5 mm in diameter) and large (> 5 mm in diameter) sized biopores was higher after chicory cultivation compared to lucerne cultivation (Fig. 1). After chicory cultivation 126 large sized pores per m^{-2}, after lucerne cultivation 96 large sized pores per m^{-2} were measured, the difference was not significant. The density of medium sized biopores was 248 pores per m^{-2} after chicory (significant) and 169 pores per m^{-2} after lucerne cultivation.

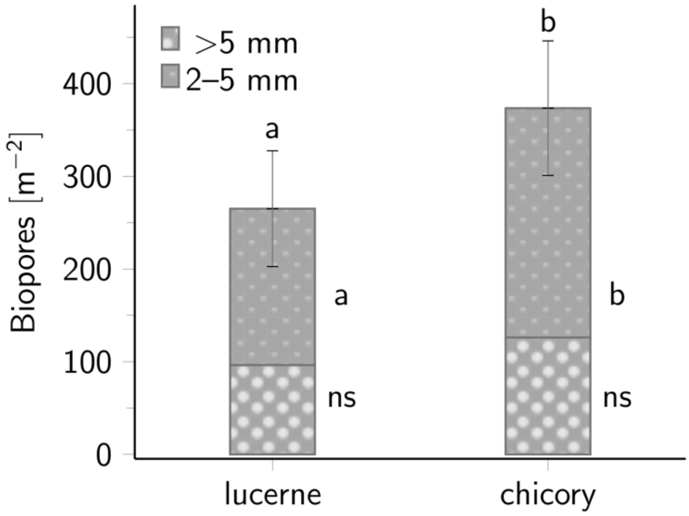

Fig. 1: Density of biopores (> 5 mm and 2-5 mm diameter classes) as a function of precrop (lucerne or chicory). Different letters indicate significant differences (t-test, α=0.05), ns: not significant, error bars show the standard deviation.

In the topsoil (above 45 cm soil depth) wheat had higher total RLD than mallow which changed for the subsoil (45-160 cm) as the decline of RLD with depth was steeper for wheat (Fig. 2). The relative amount of roots in subsoil biopores was for both crops highest after chicory and reached up to 18 % of the total RLD. Generally, the share of roots in biopores was higher for mallow than for wheat after both precrops.

Total RLD and RLD in biopores of mallow were tendencially, but not significantly higher after chicory precrop. In contrast wheat only showed higher RLD in biopores after chicory, whereas the total RLD was similar for both precrops.

Discussion

The results indicate that response of root growth to the presence of biopores is more pronounced for taproot systems than for fibrous root systems. This is also supported by visual impressions of barley and oilseed rape gained by endoscopy (Athmann et al. 2013). For mallow and wheat the amount of RLD in biopores was tendencially higher after chicory than after lucerne. This might be due to higher biopore densities (>2 mm) after chicory (374 m^{-2}) in comparison to lucerne (265 m^{-2}) (Fig. 1). It can be assumed that the differences of biopore density showed in 45 cm soil depth remain in deeper soil layers as it has been shown in the same field trial (Perkons et al. 2013).

The steep decline of root-length density in biopores below 105 cm might indicate that in the C-horizon biopores are less relevant than in the comparatively dense Bt-horizon.

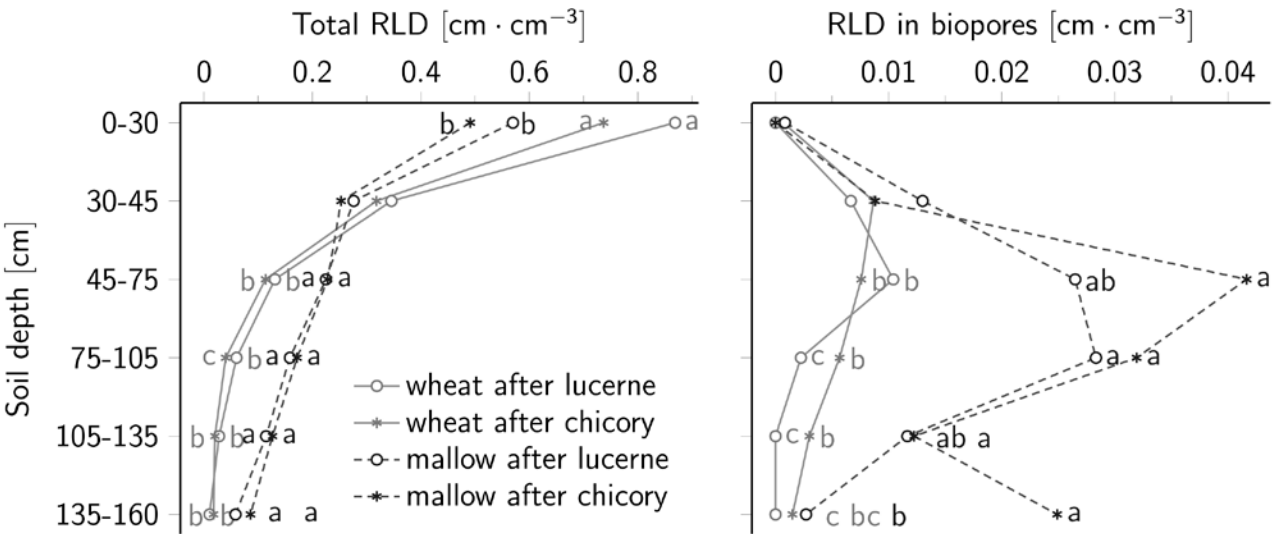

Fig. 2: Total root-length density and root-length density in biopores (diameter class >2 mm) of spring wheat and mallow grown in 2010 as a function of precrop (lucerne or chicory) and soil depth. Profile wall method. Different letters indicate significant differences (Kruskal-Wallis-test followed by stepwise multiple comparison procedures (Campbell & Skillings 1985), α=0.05).

Conclusions

It is concluded that the relevance of biopores in the subsoil for facilitating root growth depends on the specific characteristics of the root system. Spring wheat had a high RLD in the topsoil and less RLD in the subsoil whereas mallow had a significantly lower RLD in the topsoil but a significantly higher RLD in soil depths below 45 cm. Even though the RLD in biopores differed strongly between the root systems, spring wheat as well as mallow showed an increase in RLD in biopores with increasing biopore density.

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