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Topic 1 - Ecological approaches to systems' health

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EXPLORING THE TOTAL SOIL VOLUME: ROOT LENGTH DENSITIES AND ROOTING DEPTH OF DIFFERENT COVER CROPS DETERMINED WITH THE PROFILE WALL METHOD

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Abstract: Roots of cover crops are important for nutrient uptake and prevention of nitrogen leaching. Root length density (RLD) and rooting depth of eight cover crop species were determined with the profile wall method before and after winter. High RLD was found for winter rye and crimson clover. A gain in RLD during winter was detected for winter rye and crimson clover, whereas bristle oat, oil radish, oil radish 'deeptill' and phacelia reduced RLD during winter. Great rooting depth before winter were found for oil radish and winter turnip rape. Mixtures of cover crops with a high RLD and a deep-rooting cover crops might be an approach to enlarge nitrogen uptake from the soil by cover crops' roots.

Introduction: Cultivation of cover crops is a multifunctional tool in organic arable farming. The main aims are soil cover, weed suppression and prevention of nitrogen loss due to catching mineral nitrogen via the roots (Thorup-Kristensen et al., 2003). As nitrogen uptake is to a large degree determined by root length density (RLD), detailed knowledge on this parameter for different cover crops is indispensable. The ideotype of crops in organic production systems has a large root system to explore the soil volume more completely (Lammerts van Bueren et al., 2002). Thus, cover crops with high RLD are particularly desirable. On the other hand, rooting depth of cover crops is important for catching nitrogen (Thorup-Kristensen, 2001).

As intercropping is effective if crop partners use niche differentiation to minimize interspecific competition (Vandermeer, 1989), intercropping of cover crops with contrasting root architecture might enlarge the total soil volume reached by cover crops' root systems. Therefore, RLD and rooting depth of different fibrous and tap-rooting cover crops were compared with the profile wall method before and after winter to find potential mixture partners.

Material and methods: The field experiment was carried out on the research station for Organic Farming 'Wiesengut' of the University of Bonn in Hennef, Germany. Located at 50°48', N 7°17' E and an altitude of 65 m a.s.l., the site is characterized by a silty loam soil, a mean annual temperature of 10.3 °C, and a mean annual precipitation of 840 mm. Compared to the long-term means, the period from May 2018 to November 2018 was warmer by 2.2 °C and dryer by 181 mm.

The field experiment was carried out as a randomized complete block design with four blocks and a plot size of 1.5 m × 12.5 m. However, only three blocks were analysed for root traits. The following cover crops were sown with a plot seeder on 12th August 2018: crimson clover (*Trifolium incarnatum* L., cv. Linkarus 30 kg/ha), winter rye (*Secale cereale* L., cv. Bonfire 120 kg/ha), bristle oat (*Avena strigosa* SCHREB., cv. Pratex 80 kg/ha), all with fibrous root systems, and tap-rooted blue lupin (*Lupinus angustifolius* L., cv. Boruta 120 kg/ha), oil radish (*Raphanus sativus* L., cv. Silentina 25 kg/ha), oil radish (*Raphanus sativus* L., cv. Deeptill 12 kg/ha), winter turnip rape (*Brassica rapa* L., cv. Jupiter 15 kg/ha) and phacelia (*Phacelia tanacetifolia* BENTH., cv. Beehappy 12 kg/ha). Previous crop was faba bean (*Vicia faba* L.). After inversion tillage, the field experiment was irrigated with 50 mm before and with 54 mm after sowing. Seedbed preparation was carried out with a rotary harrow. During crop establishment, hand weeding was carried out.

RLD was analysed using the profile wall method (Böhm, 1979), before winter at the end of October 2018 and after winter at the end of March 2019. A trench with a depth of 1.2 m was dug with an excavator transversely to the plot. After root counting, the trench was closed and re-opened in March 0.5 m further into the plot. A profile wall of 1 m × 1 m was smoothened with a spade and sharp blades for every plot. To expose the roots, a 5 mm thick soil layer was removed by using a toothed metal scraper and spraying water with a hand sprayer. A 1 m wide frame with a grid of 5 cm × 5 cm was fastened to the profile wall. Root length units equivalent to 5 mm root length were counted in each square of the grid. RLD, which is root length per soil volume, was calculated for each square by dividing the root length by 12.5 cm^3.

Data were analysed with the R package. For RLD a non-linear regression was fitted with the function NLS in the R package. A three-parameter logistic function was used:

$y=a/(1+be^{cx})$

where y is RLD, x is soil depth and a, b and c are parameters. For graphical representation the diagram was rotated by 90 degrees so that the axes are swapped. Maximal RLD at a virtual depth of 0 cm and the depth at half maximal RLD were calculated for each crop for a rapid comparison of root distribution. Rooting depth was analysed by analysis of variance and means were compared with a Tukey test at a significance level of $\alpha=0.05$.

Results: Before winter, highest RLD was determined for winter rye and crimson clover in the topsoil (Fig. 1). Tap-rooted species had low RLD in the topsoil, RLD of bristle oat was intermediate. In the subsoil, high RLD was detected for phacelia. Maximal RLD at 0 cm depth was high for winter rye and crimson clover and low for blue lupin, oil radish 'deeptill' and phacelia (Table 1). Depth at half maximal RLD was high for bristle oat, oil radish 'deeptill' and phacelia, and shallow for crimson clover and oil radish. Greatest rooting depth before winter was recorded for oil radish and winter turnip rape, lowest for crimson clover (Table 1). Rooting depth of oil radish and crimson clover differed significantly.

Fig. 1: Root length density (RLD) of different cover crops depending on soil depth before winter (October 2018)

Fig. 2: Root length density (RLD) of different cover crops depending on soil depth after winter (March 2019)

Over winter, RLD of winter rye and crimson clover increased further, so that both cover crops had highest RLD not only in the topsoil, but also in the subsoil down to 50 cm. RLD of bristle oat, oil radish, oil radish 'deeptill' and phacelia decreased during winter (Fig. 1 and 2). Minimal change in RLD during winter was determined for blue lupin and winter turnip rape. All

crop species except for phacelia had reached the maximum rooting depth of about 60-80 cm. Maximal RLD at 0 cm soil depth and soil depth at half maximal RLD showed the same relations as before winter.

Table 1: Rooting depth, maximal RLD at 0 cm depth and depth at half maximal RLD for different cover crops before winter (October 2018) and after winter (March 2019). Different letters indicate significant differences between rooting depth within one date (α=0.05).

date	cover crop	rooting depth [cm]	maximal RLD [cm/cm³] at 0 cm soil depth	soil depth [cm] at half maximal RLD
October	winter rye	57 ab	0,99	23
	crimson clover	42 b	0,83	21
	bristle oat	65 ab	0,53	28
	blue lupin	62 ab	0,30	25
	oil radish	77 a	0,40	22
	oil radish 'deeptill'	60 ab	0,38	27
	winter turnip rape	75 ab	0,42	26
	phacelia	53 ab	0,35	28
March	winter rye	82 a	1,29	21
	crimson clover	68 a	1,47	15
	bristle oat	73 a	0,39	28
	blue lupin	62 a	0,15	23
	oil radish	70 a	0,31	14
	oil radish 'deeptill'	67 a	0,15	33
	winter turnip rape	78 a	0,24	21
	phacelia	55 a	0,19	25

Discussion: With high overall RLD that increased further over winter, fibrous rooted winter rye and crimson clover explored the soil volume most down to a depth of 50 cm. Tap-rooting cover crops had lower RLD, but especially the cruciferous cover crops oil radish and winter turnip rape reached the maximum rooting depth faster than the other species. Root distribution of phacelia and bristle oat was in between tap- and fibrous rooted species, with greatest depth at half maximal RLD. Higher RLD values but similar relations between RLD of different cover crops were found by Wendling et al. (2016). They reported RLD between 5 and 6 cm/cm³ for oil radish and phacelia and 7.4 cm/cm³ for bristle oat. These differences in RLD depend on the method determining RLD. In the above-mentioned studies soil cores were taken and roots were washed. The lower RLD determined by the profile wall method compared to RLD determined by methods washing roots from soil samples is described by Böhm (1979). Deep rooting of cruciferous cover crops was previously found by Thorup-Kristensen (2001). Consequently, it might be interesting to combine crimson clover or winter rye with a high RLD and a deep-rooting cover crop like oil radish to design a mixture with complementary root architecture for more complete nitrogen extraction from the soil.

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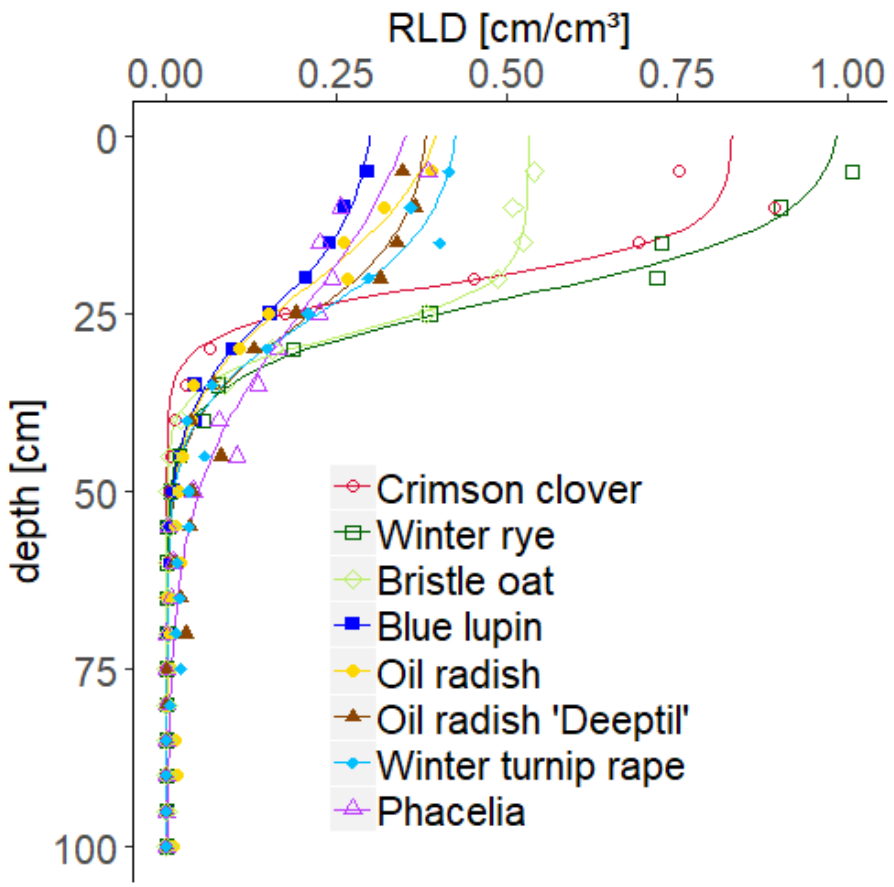
Image:



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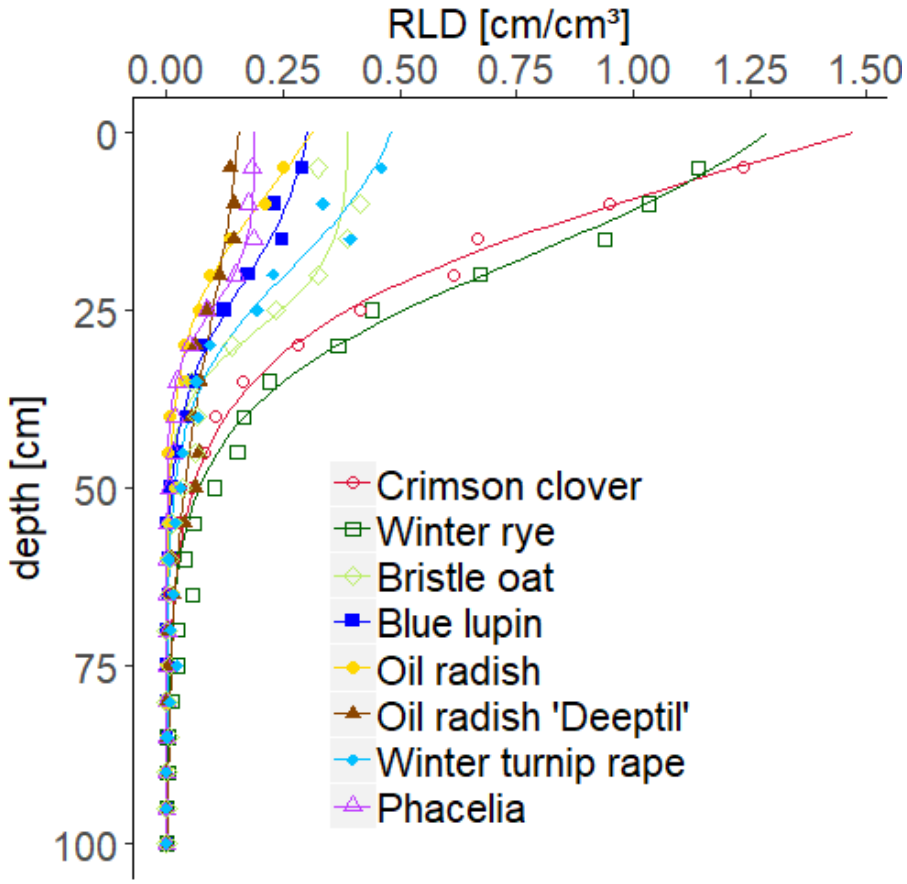

Disclosure of Interest: None Declared

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