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Growth and weed suppression ability of common and new cover crops in Germany

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ABSTRACT

Cover crops have a wide-ranging influence on the agroecosystem and create multiple benefits for farmers. A major benefit of cover crops is the suppression of weeds during fall and winter, which can help to reduce soil tillage and herbicide use. However, only a small number of cover crop species are currently grown in Germany. To enlarge this number, four new cover crop species including tartary buckwheat, forage radish, red oat and grain amaranth were tested in comparison with common cover crop species such as white mustard, oilseed radish and phacelia. Emergence, soil coverage, dry matter production and weed suppression ability was assessed for all cover crop species. White mustard emerged faster than all other cover crops and produced the highest amount of shoot dry matter at both locations in southwest Germany twelve weeks after planting (WAP). Oilseed radish was the only cover crop that reduced the weed dry matter in all experiments eight WAP. Phacelia was able to reduce weed density by 77% at Meiereihof twelve WAP. Tartary buckwheat offered the highest soil coverage four WAP, produced the greatest shoot dry matter eight WAP and reduced weed dry matter by more than 96% at Meiereihof and Ihinger Hof twelve WAP. Forage radish produced the highest root dry matter and reduced spring weed density by more than 81% in all experiments. Red oat and grain amaranth emerged slowly, produced less biomass than other cover crops and did not suppress weed growth. The results show that tartary buckwheat and forage radish are well suited as new cover crops in Germany due to their fast growth and good weed suppression ability.

1. Introduction

Cover crops influence the agroecosystem in many positive ways. They protect the soil from wind and water erosion (Baets et al., 2011; Parlak and Parlak, 2010), capture, recycle and redistribute nutrients, especially nitrate (Hooker et al., 2008), increase the soil organic matter (Ding et al., 2006), reduce leaching of herbicides (Potter et al., 2007), provide a habitat for beneficial insects (Tillman et al., 2004), suppress weeds and volunteer crops and produce additional forage often resulting in higher yields of subsequent crops (Blanco-Canqui et al., 2012). Cover crops can suppress weeds and volunteer crops either by competition for light, water and nutrients or the release of allelopathic substances from living or decomposing plant tissue (Bezuidenhout et al., 2012; Creamer et al., 1996). For significant weed suppression, a rapid emergence, intensive soil coverage and dry matter production of cover crop are required (Brennan and Smith, 2005).

In the last decades, diversity of cover crop species in Germany has rather been low. White mustard (*Sinapis alba* L.) and oilseed radish (*Raphanus sativus* L. *var. oleiferus*) have been cultivated because of their high biomass production and capability of certain varieties to reduce the populations of phytopathological nematodes in crop rotations including sugar beets (*Beta vulgaris* L.) and potatoes (*Solanum tuberosum* L.) (Smith et al., 2004). They also decrease the risk of nitrate losses due to leaching (Wyland et al., 1996) and provide good weed control (Brennan and Smith, 2005). Phacelia (*Phacelia tanacetifolia* Benth.) is commonly grown as cover crop because it is not related to any main crop in Germany and hence not expected to be a host of important pests and crop diseases. Phacelia is mostly used in crop rotations including canola (*Brassica napus* L.). Phacelia also attracts bees and delivers nectar and is able to prevent nitrate leaching and suppress weed growth (Brant et al., 2009). Common cover crops require sufficient soil water, moderate temperatures and good seed-bed preparation for

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quick emergence and vigorous growth within the first few weeks after planting. However, growing conditions are often less favorable after harvest of annual grain crops. Therefore, new cover crop species are required that are more tolerant to unfavorable growing conditions such as drought and compacted soils but still guarantee vigorous growth in fall.

Among those potential new cover crops, tartary buckwheat (*Fagopyrum tataricum* L. Gaertn.) may be well suited for cultivation under short-term and unfavorable environmental conditions due to its fast emergence and strong growth within the first few weeks after planting. Tartary buckwheat is closely related to common buckwheat (*Fagopyrum esculentum* Moench) and shows similarities in its morphology and growth rate (Matsuura et al., 2005), however leaves of tartary buckwheat are arrow-shaped and shoots are more branched than of common buckwheat (Campbell, 1997). Buckwheat species are well known for their high competitive ability that enables them to suppress even perennial weeds (Bicksler and Masiunas, 2009). Another potential new cover crop species is forage radish (*R. sativus* L. var. *longipinnatus*), which has already been investigated as a summer annual cover crop in the Mid-Atlantic region of the USA (White and Weil, 2010). Forage radish is able to cover the soil surface completely within a few weeks after sowing and produces high shoot- and root dry matter that results in excellent weed suppression (Lawley et al., 2011). The third potential new cover crop for Germany is red oat (*Avena byzantina* K. Koch). Red oat is closely related to common oat (*Avena sativa* L.) and is cultivated especially in the south of Brazil for grain and forage production and as cover crop in no-tillage systems (Martinez et al., 2010). Until now, little is known about growth and weed suppressing ability of red oat as cover crop in Europe. Also cultivation of grain amaranth (*Amaranthus cruentus* L.) as cover crop has only been investigated in few studies before. Boer et al. (2008) and Mennan et al. (2009) found that grain amaranth produces equal dry matter to common cover crops in Turkey and Brazil.

The objective of this study was to evaluate the growth and weed suppression ability of common and new summer annual cover crops after harvest of cereal grains such as wheat (*Triticum aestivum* L.) or barley (*Hordeum vulgare* L.) to find new suitable cover crops for cultivation in Germany.

2. Material and methods

2.1. Experimental sites

Field experiments were conducted at the experimental stations Ihinger Hof (48°74′N, 8°92′E, 478 m altitude) in 2010 and 2011, Meiereihof (48°71′N, 9°21′E, 435 m altitude) in 2011 and Trossin (51°61′N, 12°81′E, 120 m altitude) in 2011. At Ihinger Hof and Meiereihof in the southwest of Germany, soil type was a Haplic Luvisol. Soil texture at Ihinger Hof was “Clay Loam” with a soil mineral nitrogen (N_{min}) content in topsoil before cover crop seeding of 18.1 kg ha^{-1} in 2010 and 17.5 kg ha^{-1} in 2011. At Meiereihof soil texture was a “Sandy Clay Loam” with an N_{min} content of 36.4 kg ha^{-1} in 2011. At Trossin in the east of Germany, soil type was a Cambisol with “Sandy Loam” as soil texture and an N_{min} content of 20.9 kg ha^{-1}. Annual average temperatures at Ihinger Hof and Trossin were 9.2 °C and 9.1 °C, respectively, while Meiereihof was slightly cooler and reached 8.8 °C. Annual average precipitation is 794 mm at Ihinger Hof, 700 mm at Meiereihof and 500 mm at Trossin.

2.2. Experimental design and treatments

Experimental design in all experiments was a randomized complete block with four replications and a plot size of 2 m by 10 m. In 2010, white mustard, oilseed radish, forage radish, and a no cover crop control to identify the weed suppression ability of cover crops were tested. In 2011, additionally phacelia, tartary buckwheat, red oat and grain amaranth were analyzed at Ihinger Hof and Meiereihof. At Trossin, red oat and grain amaranth could not be tested due to governmental restrictions. Cover crop varieties and seeding rates were equal at all location and years (Table 1). The experiments at Ihinger Hof and Meiereihof were carried out following winter wheat, while at Trossin, winter barley was the previous main crop. After harvest, straw was removed and tillage was conducted with a disc harrow at a depth of 5 cm the following day. Cover crop plots were seeded in 2010 at Ihinger Hof on August 21st, and in 2011, at Trossin on July 16th, at Ihinger Hof on August 4th, and at Meiereihof on August 10th. Cover crops were seeded using a plot seeder with double disk openers and a row spacing of 11 cm. Sowing depth was 2 cm for all cover crops. No fertilizers were applied in the experiments.

2.3. Data collection

Seedling emergence of cover crops was counted daily for a period of eight days after planting and subsequently at three-day intervals until no further seedlings emerged. Seedlings were counted using a 0.1 m^2 frame at four randomly selected places in the plots. Soil coverage was measured eight weeks after planting (WAP) at Ihinger Hof in 2010, four, six and eight WAP at Ihinger Hof and Meiereihof in 2011 and eight WAP at Trossin in 2011. To determinate soil coverage, RGB-pictures were taken with a digital camera from an area of 12 m^2 in each plot. If weeds or volunteer grain were visible on pictures, they were manually separated using “Adobe Photoshop CS6”. Pictures were analyzed with “ImageJ” Version 1.47a. After converting the pictures into HSB-color space, green color of cover crops was separated from bare soil using the “Color Threshold” procedure. To estimate separated areas, the “Analyze Particles” procedure was conducted. Shoot- and root dry matter of cover crops and weeds were measured, excavating plants to a depth of 30 cm from an area of 0.25 m^2 at Meiereihof and 0.5 m^2 at Ihinger Hof four, eight and twelve WAP. At Trossin, plant samples were taken from an area of 0.25 m^2 eight and sixteen WAP, however, sixteen WAP, only the shoot dry matter of weeds was measured due to dry soil conditions that prevented an excavation of roots. Plants were washed, divided into shoots and roots and dried at 80 °C for three days. At every harvest date in fall and mid-March of the following spring, plant density of weeds and volunteer grain was measured in an area of 0.1 m^2 at four randomly selected positions in the plots.

2.4. Statistical analysis

Statistical analysis was conducted with the statistical language R version 2.15 (R Core Team, 2012). Daily numbers of emerged cover crops were transformed in percentage values by setting the overall

Table 1
Variety, seed weight and seeding rate of the evaluated cover crop treatments.

Cover crop treatment	Variety	1000-seed weight (g)	Seeding rate (kg ha^{-1})
White mustard	Accent	6.4	12.7
Oilseed radish	Da Capo	11.4	29.3
Phacelia	Angelia	1.9	10.3
Tartary buckwheat	Lifago	20.7	82.6
Forage radish	Tillage radish	17.7	9.0
Red oat	Sao Carlos	24.6	98.4
Grain amaranth	Bärnkraft	1.2	4.7