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Effect of cover crops in smothering weeds and volunteer plants in alternative farming systems

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ABSTRACT

Alternative farming systems such as sustainable and organic farming are used to produce premium price food products and retain the viability and fertility of soil. Field experiments were conducted at Joniskelis Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry in 2006–2012. The research objective was to investigate the competitive ability of plants cultivated as cover crops: narrow-leafed lupine (*Lupinus angustifolius* L.) in mixture with an oil radish (*Raphanus sativus* var. *Oleiferus* Metzg.) (LUPRA); white mustard (*Sinapis alba* L.) (WM); white mustard in mixture with a common buckwheat (*Fagopyrum exculentum* Moench.) (WMBU) to smother weeds in organic and sustainable farming systems in soil with low (1.90–2.01%) (LH) and moderate (2.10–2.40%) (MH) humus content. Cover crops cultivated for green manure were investigated during the post-harvest period of winter wheat. This experiment showed that cover crops have a strong competitive ability to smother weeds and emerged volunteer plants. It also demonstrated that narrow-leafed lupine in combination with oil radish, cultivated in the organic farming system, was less effective at smothering weeds compared with white mustard cultivated as a sole crop or in combination with buckwheat. In a rotation without cover crop in soil with low and moderate humus content, the number and biomass of weeds was higher compared with the farming systems with cover crops. A correlation-regression analysis showed that the cover crops had a higher impact on the biomass of weeds and volunteer plants in soil with low humus content to compare with moderate humus content. The most effective inhibition of volunteer plant and weed biomass in soils with both humus contents was observed, when white mustard and a mixture of white mustard and buckwheat were used as cover crops. The practical implication of this research is suggestion, that cover crops could be successfully used as integrated weed control tool in farm fields.

1. Introduction

Organic and sustainable farming systems are based on natural soil fertility that is capable of supplying a plant with the optimum amount of nutrients during all its growth stages and the produce obtained must have a similar quality to that grown in intensive farming systems. Intensive farms are often characterized by low biodiversity with a prevalence of winter and spring grain crops, and face many problems: the spread of diseases and pests, increased crop weediness and the maintenance of consistent crop productivity (Arlauskiene et al., 2011; Pilipavicius et al., 2010). Therefore, plant protection solutions and the issues of nutrition and soil fertility maintenance are of the utmost importance. One of the necessary biological means for crop and soil sustainability in both organic and conventional farming systems is crop rotation. Natural agrotechnical methods have become particularly important recently; with increased attention paid to organic farming, the reduction of environmental pollution, and safe food production (Keating et al., 2010).

Crop weediness is one of the main agronomy problems in alternative farming systems, especially in organic systems, as the

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non-chemical weed control means employed are less effective than the use of herbicides in intensive farming systems (Pilipavicius et al., 2011; Romaneckas et al., 2012). In organic and sustainable farming systems, weeds mainly determine the yield and quality of agricultural produce (Lithourgidis et al., 2011; Seufert et al., 2012). Weed control in these systems is based on the ability to manipulate the competitive interaction between agricultural plants and weeds (Rueda-Ayala et al., 2011; Swanton et al., 2015; Velicka et al., 2016). Because of this, the competitiveness of agricultural plants is the main mechanism of indirect weed control that allows the reduction of conventional methods (Mhlanga et al., 2016). The direct damage caused by weeds depends on the environmental conditions, the biological properties of agricultural plants and the intensity of soil surface coverage (Boguzas et al., 2010; Swanton et al., 2015). Previous experiments have proved that the spread of perennial weeds in organic farming systems is much higher compared with conventional farming systems (Boguzas et al., 2004; Raslavicius and Povilaitis, 2013) and their control is more complicated than that of annual weeds (Pilipavicius et al., 2011; Romaneckas et al., 2012; Ulber et al., 2009). The main methods used to reduce the spread of weeds in farming systems are increasing plant biodiversity via crop rotations and the application of soil cultivation technologies that induce germination of weed seeds prior to main tillage operations (Arlauskiene et al., 2011; Lithourgidis et al., 2011; Seufert et al., 2012). Compared with agricultural plants, weeds are better adapted to existing climatic conditions and weed seeds germinate earlier, allowing them more strongly compete with agricultural plants. To avoid the weeds, which are still able to mature and spread their seeds and remain in the stubble after crop harvesting; cover crops of short vegetation plants or mixtures of such plants can be cultivated to smother weeds. The cultivation of short vegetation plants can reduce the development of diseases, pests and weeds, protect soil against direct environmental impacts for a longer post-harvest period, and incorporate the nutrients remaining in soil into a biological metabolism cycle (Kassam and Brammer, 2013).

To reduce nutrient losses and protect soil from the direct impact of the precipitation and wind erosion as long as possible, cover crops are cultivated in the ecosystems of different countries (Arlauskiene and Maiksteniene, 2012; Basche et al., 2016; Doltra and Olesen, 2013; Kunz et al., 2016; Masilionyte et al., 2014; Ruhlemann and Schmidtke, 2015; Schipanski et al., 2014; Tripolskaja et al., 2013). Cultivation of cover crops is more important in the ecosystems of organic farming because the biomass accumulated by the plants is one of the main sources of organic fertilizer (Aguilera et al., 2013; Masilionyte and Maiksteniene, 2016). Including high-biomass cover crops in intensive farming systems can be complementary to conventional methods for weed management, especially, for the management of herbicide resistant weed species (Webster et al., 2013). The use of cover crops for controlling summer weeds can contribute to reducing the number of herbicide treatments (Alcantara et al., 2011).

In conventional farming systems, crop rotation and complementation of it with cover crops serves as a preventive and prophylactic mechanism of weed control, and in organic farming is vital. Crop rotation with cover crops also provides an opportunity to reduce yield losses in organic farming (Nygaard Sorensen and Thorup-Kristensen, 2011). Cover crops supress weeds because of intensive competition for light, water, space and nutrients (Bezuidenhout et al., 2012). Furthermore, different allelopathic substances released by cover crops and their residues influence weed germination and growth (Farooq et al., 2011). Kunz et al. (2016) states, that biochemical effects play a major role in weed suppression of cover crops. Cover crop species and/or cultivar is one of the important cover crop's features. The combination of main crop and cover crop species may be one of the important factors causing the stability of weed suppression in various environmental conditions. Uchino et al. (2012) reported that winter rye (*Secale cereale* L.) was the most suitable candidate for inteseeding as a cover crop with main crops in Japan, because its high weed suppression and relatively low plant height. Among leguminous species, hairy wetch (*Vicia villosa* Roth) was found to be an effective cover crop for weed suppression.

The main objective of this research was to evaluate the competitive ability of plants with different biological features cultivated as cover crops in organic and sustainable farming systems with low and moderate soil humus content.

2. Materials and methods

2.1. Experimental site

Research was conducted at Joniskelis Experimental Station (56°12′ N, 24°20′ E) of the Lithuanian Research Centre for Agriculture and Forestry (LRCAF) between 2006 and 2012. The soil of the experimental site was Endocalcari-Endohypogleyic Cambisol (Drainic), according to texture – clay loam on silt clay with deeper lying sandy loam. In arable soil layer, the content of sand was 22.73%, silt – 50.24%, clay – 27.03%; humus – 1.90–2.01% in low humus content soil, and 2.10–2.40%– in moderate humus content soil.

The soil agrochemical properties at a depth of 0–20 cm ranged as follows: pH_{KCl} 6.0–6.1, the amount of mobile phosphorus (P_2O_5) in soil 115–145 mg kg^{-1}, mobile potassium (K_2O) 220–230 mg kg^{-1}. The soil density in the plough layer was 1.42–1.48 Mg m^{-3} and the total porosity 43.1–45.1 Mg m^{-3}.

2.2. Crop rotation

The research was performed during the crop rotation: a red clover (*Trifolium pratense* L.) variety 'Vyliai' → a winter wheat (*Triticum aestivum* L.) variety 'Ada' + cover crops → a pea (*Pisum sativum* L.) variety 'Pinochio'→ a spring barley (*Hordeum vulgare* L.) variety 'Luokė' with red clover as an undersown crop were cultivated. The analyses of cover crop plants, weeds and volunteer plants were carried out during the post-harvest period of winter wheat only.

2.3. Experimental design

The experiment complied with randomized complete block design and were conducted in soils that had two humus content levels: 1) low humus content (1.90–2.01%) (LH); 2) moderate humus content (2.10–2.40%) (MH). Four farming systems were included in the experiments that during the post-harvest period of winter wheat, chopped straw was spread on the surface of soil and, stubble was tilled with disc harrows. Common for Lithuanian meteorological conditions and farming systems cover crops of different biological properties were sown for green manure in organic and sustainable farming systems (Table 1). In organic farming system 1 – a narrow-leafed lupine (*Lupinus angustifolius* L.) variety 'Boruta' in mixture with an oil radish (*Raphanus sativus* var. *Oleiferus* Metzg.) variety 'Rufus' (LUPRA) was grown; in organic farming system 2 – a white mustard (*Sinapis alba* L.) variety 'Sinus' (WM). In sustainable farming system 1 – white mustard in mixture with a common buckwheat (*Fagopyrum exculentum* Moench.) variety 'Smuglianka' (WMBU). Sustainable farming system 2 was without cover crops (NC). Therefore, the experiment included eight experimental treatments in with three replicates with a plot size of 32.2 m^2 (14 m × 2.3 m). In the sustainable farming systems, N_{30} was