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Influence of soil conservation practices on legume crops growth

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ABSTRACT

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In a three-year experiment, three types of soil conservation techniques were tested in the legumes cultivation systems. Our treatment types were no-till, standard tillage to the depth of 8 cm and deep tillage to 20 cm. The study evaluated winter pea (cv. Enduro), spring pea (cv. Eso), white lupine (cv. Amiga), narrow-leaved lupine (cv. Boregine) and soybean (cv. Merlin) in two autumn terms (winter pea only) and in spring term (all legume species). In no-till technology, the average yield of all legumes was 2.24 t/ha. For standard tillage (2.58 t/ha) and deep tillage (2.62 t/ha), yields were significantly higher than in no-till technology. From the monitored parameters, deep tillage appeared as the best soil treatment. Although the yield was similar to standard tillage, the soil was less stiffened, resulting in a higher content of nitrogen in the seed and a better use of the pre-crop value of the legumes. In the experiment, winter pea spring sowing term (2.93 t/ha) was better than both autumn sowings (2.68 t/ha and 2.65 t/ha).

Keywords: soil compaction; *Pisum sativum* L.; *Lupinus albus* L.; *Glycine max* (L.) Merr.; agroecological farming

Legumes are an important and irreplaceable group of crops from the point of view of agricultural and agro-ecological concepts. Although the importance of legumes for agriculture and landscaping is undeniable, the growing area of legumes is declining in Europe. This is due to relative yield uncertainty, need for increased agro-technical care, including plant protection, and large competition of non-European production of cheap soya for feeding and food processing (Houba 2009). Legumes are mostly used as an excellent forecrop for cereals (Preissel et al. 2015). Thanks to rhizobia, nitrogen fixation of legumes is a unique process that solves two major problems of modern agriculture: reduction of the fossil fuels use and greenhouse gas emissions by reducing nitrogen fertilizers. All this leads to a reduction of inputs and promotes sustainable agriculture (Rispail et al. 2010). Most legumes, unfortunately, have little autoregulation ability to produce productive branches. Consequently, the legumes do not thicken during vegetation compared to cereals. Legumes also do not respond significantly to additional agrotechnical measures such as fertilization (Lahola 1990).

One way to increase yields may be to use winter forms that can compete better with weeds. Also, they can use winter moisture and better tolerate the spring droughts from which the spring types suffer greatly (Urbatzka et al. 2005). It is also possible to use biologically active substances which are used for seed treatment before sowing (Procházka et al. 2015). A major problem with legumes is the flowers shedding during stressful periods. In particular, high temperatures combined with low rainfall lead to a significant reduction in yields (Atkins and Smith 2004). In Australia and America, this problem was responded by using minimization and soil protection technologies (Gladstones and Atkins 1998).

The use of land-based technologies is constantly expanding throughout the world. Farmers have many

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reasons to do so. These technologies reduce wind and water erosion, conserve soil moisture, have a positive influence on the soil structure, and – last but not least – save labour and improve the economy of cultivation (Dang et al. 2015). Another big problem is soil stiffness. Crops growing on congealed soil have a demonstrably lower root system, with a decline in biomass growth of up to 60% (Krebstein et al. 2014). Newly, deep loosening begins, where soil is better able to react and retain more precipitation (Su et al. 2015). Today, erosion is the biggest problem in Europe, but farmers also struggle with a long drought periods or intensive rainfall over a short period of time. All these problems need to be addressed by new technological processes that prevent soil degradation and can retain water (Panagos et al. 2016). In recent years, deep cultivators (so-called chisel ploughs) have been widely promoted. As part of primary soil treatment, these machines are often considered as an alternative to a classical ploughs; in particular in case of farmers who cultivate larger areas (Kroulík et al. 2016). Deep loosening contributes not only to better water infiltration, but also to better aeration of the soil. Plants are then able to use better the nutrients needed for their growth (Pulkrábek et al. 2015).

Table 1. Cultivation technology of experiments in individual years

Year/term	2013/operation	Year/term	2014/operation	Year/term	2015/operation
15.9. 2012	disc plough (8 cm) chisel plough (20 cm)	13.9. 2013	disc plough (8 cm) chisel plough (20 cm)	15.9. 2014	disc plough (8 cm) chisel plough (20 cm)
12.10. 2012	sowing (Enduro I.)	10.10. 2013	sowing (Enduro I.)	12.10. 2014	sowing (Enduro I.)
26.10. 2012	sowing (Enduro II.)	24.10. 2013	sowing (Enduro II.)	26.10. 2014	sowing (Enduro II.)
10.11. 2012	treatment by PRE Glyfos (3 L/ha) (Enduro I., II.)	5.11. 2013	treatment by PRE Glyfos (3 L/ha) (Enduro I., II.)	7.11. 2014	treatment by PRE Glyfos (3 L/ha) (Enduro I., II.)
27.4. 2013	sowing (other legumes)	1.4. 2014	sowing (other legumes)	4.4. 2015	sowing (other legumes)
29.4. 2013	treatment by POST Escort New 3 L/ha (Enduro I., II.)	3.4. 2014	treatment by POST Escort New 3 L/ha (Enduro I., II.)	6.4. 2015	treatment by POST Escort New 3 L/ha (Enduro I., II.)
29.4. 2013	treatment by PRE Escort New 3 L/ha + Glyfos 1.5 L/ha (other legumes)	3.4. 2014	treatment by PRE Escort New 3 L/ha + Glyfos 1.5 L/ha (other legumes)	6.4. 2015	treatment by PRE Escort New 3 L/ha + Glyfos 1.5 L/ha (other legumes)
25.6. 2013	treatment by fungicide Amistar Xtra 1 L/ha (all legumes)	15.6. 2014	treatment by fungicide Amistar Xtra 1 L/ha (all legumes)	18.6. 2015	treatment by fungicide Amistar Xtra 1 L/ha (all legumes)
10.7. 2013	desiccated by Reglone 3 L/ha + Spodnam 1 L/ha (all peas)	10.7. 2014	desiccated by Reglone 3 L/ha + Spodnam 1 L/ha (all peas)	14.7. 2015	desiccated by Reglone 3 L/ha + Spodnam 1 L/ha (all peas)
15.7. 2013	harvest (all peas)	13.7. 2013	harvest (all peas)	18.7. 2015	harvest (all peas)
5.9. 2013	desiccated by Reglone 3 L/ha + Spodnam 1 L/ha (lupine and soya)	4.9. 2013	desiccated by Reglone 3 L/ha + Spodnam 1 L/ha (lupine and soya)	8.9. 2015	desiccated by Reglone 3 L/ha + Spodnam 1 L/ha (lupine and soya)
10.9. 2013	harvest (lupine and soya)	9.9. 2014	harvest (lupine and soya)	14.9. 2015	harvest (lupine and soya)

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Table 2. Scheme of experiment

	Deep tillage			Tillage			No-till		
Autumn term of sowing	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro
	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro
Spring term of sowing	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro	Enduro
	Eso	Eso	Eso	Eso	Eso	Eso	Eso	Eso	Eso
	Boregine	Boregine	Boregine	Boregine	Boregine	Boregine	Boregine	Boregine	Boregine
	Amiga	Amiga	Amiga	Amiga	Amiga	Amiga	Amiga	Amiga	Amiga
	Merlin	Merlin	Merlin	Merlin	Merlin	Merlin	Merlin	Merlin	Merlin

MATERIAL AND METHODS

The experiment was based on the land of ZD Nečín near Dobříš in the years 2013–2015. The soil was processed by three soil protection technologies. The first was a deep tillage (20 cm) by Terraland (chisel plough). As the second technique of soil cultivation, the standard tillage was used to a depth of 8 cm and the third part of experiment was without soil treatment (no-till) (Table 1). In the experiment, two pea cultivars – spring form cv. Eso and winter type cv. Enduro – were tested. They were sown in two autumn terms and in one spring term, respectively, when sowing other legumes. Other species were white lupine (cv. Amiga), narrow-leaved lupine (cv. Boregine) and soybean (cv. Merlin) (Table 2). The area of one tested parcel was 1200 m^2, each treatment had 3 repeats. All legumes had the same number of seeds (90 thousand seeds/ha). The seed treatment was done by Maxim XL (25 g/L fludioxonil and 10 g/L metalaxyl-M) and was inoculated with Nitrazon+. No fertilization was used in the experiment. The row spacing was 12.5 cm with the depth of sowing of 6 cm.

The soil was processed 14 days before the first autumn term of winter pea sowing. The second sowing took place in 10 days. Sowing was done using the Great Plains sowing machine, which can be used for direct sowing without soil treatment. Two weeks after sowing, a total herbicide (glyphosate 360 g/L) at a dose of 3 L per hectare was applied to plots. The spring sowing took place according to the weather during the month of April. In autumn terms, post-emergence herbicide treatment with Escort New at 3 L per hectare (16.7 g/L imazamox and 250 g/L pendimethalin) took place. The pre-emergence Escort New treatment at the same day was 3 L per hectare + total herbicide at 1.5 L per hectare). The yield and nitrogen content in seeds were evaluated. The individual species and cultivars of all legumes were tested among themselves. The soil compaction was monitored for the soil cultivation treatments. Monthly rainfall is shown in Figure 1.

Statistical analysis. The obtained results were statistically evaluated by the analysis of variance (ANOVA) method. The differences between mean values were evaluated by the Tukey's *HSD* (honestly significant difference) test in the SAS computer program (SAS Institute, Carry, USA), version 9.4., at the level of significance P = 0.05.

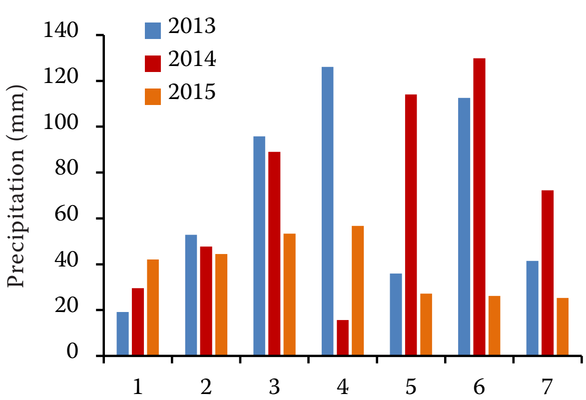

Figure 1. Monthly precipitations in vegetation (Central Institute for Supervising and Testing in Agriculture, Vysoká u Příbramě). 1 – April; 2 – May; 3 – Juni; 4 – July; 5 – August; 6 – September; 7 – October

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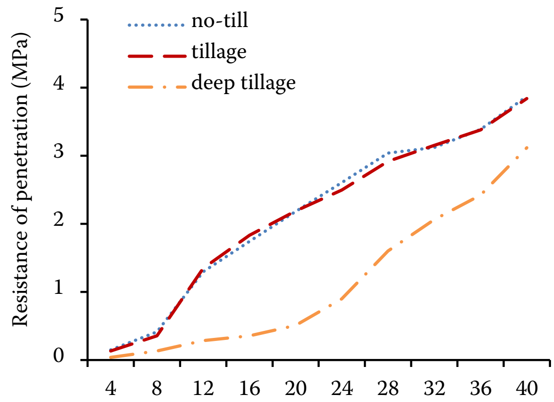

Figure 2. Average values of penetration resistance (MPa) of soil in years 2013–2015

RESULTS AND DISCUSSION

Figure 2 shows that there was demonstrably less soil compaction in deep tillage than in other soil treatments. In deep tillage treatment, soil compaction of 1 MPa was found in the depth of 25 cm, in other treatments, it was in the depth of 14 cm. The difference was still seen in the depth of 40 cm.

Batey (2009) states that legumes are very sensitive to soil compaction. For the proper development of nitrification bacteria tubers and nitrogen fixation they need aerated soil. That is why deep tillage can be considered as the most suitable soil treatment compared to other tested treatments; due to lower soil compaction it increases the pre-crop value. A positive effect of deeper soil cultivation was also observed in the subsequently grown crops.

Figure 3 shows the average yields over the three monitored years of all tested soil treatments. The most yielded legume was the spring pea cv. Eso (2.95 t/ha) and winter pea cv. Enduro (2.93 t/ha) sown in the spring. Autumn sowings of winter pea cv. Enduro reached 2.68 t/ha and 2.65 t/ha and were statistically significantly worse than spring sowings; however, Chen et al. (2006) noted that higher yields for winter peas were reached only on half of the tested sites. On the second half of the habitats, spring forms of pea were more profitable. White lupine yielded more (2.5 t/ha) compared to the narrow-leaved lupine (2.04 t/ha). This was confirmed by Borowska et al. (2015) and Koukolíček and Štranc (2013) in their experiments. The lowest yield was achieved by soybean (1.64 t/ha). It should be noted that the altitude of the site about 400 m a.s.l. is limiting for soybean growing in the Czech Republic conditions.

Figure 4 shows the average content of nitrogen in seeds of different types of legumes during years 2013–2015. The highest content of nitrogen in seeds was found in soybean (38.29%). The highest content of nitrogen in seeds of peas was observed in cv. Enduro I. sown in the first autumn term (22.11%). Figure 5 shows average yields of legumes depending on the type of soil conservation techniques. The significantly worst treatment was no-till; it was negatively influenced by necrosis of the roots, especially in peas sown in autumn 2013. The reason for that was heavy rainfall in May and June, as shown in Figure 1. This period is very important for flowering and pods production. In the years 2014 and 2015, rainfall in these months was lower (Figure 1) and it positively influenced the yields of legumes. Especially for pea, there were yields between 3–4 t/ha. The difference was observed also among the tested soil conservation technologies.

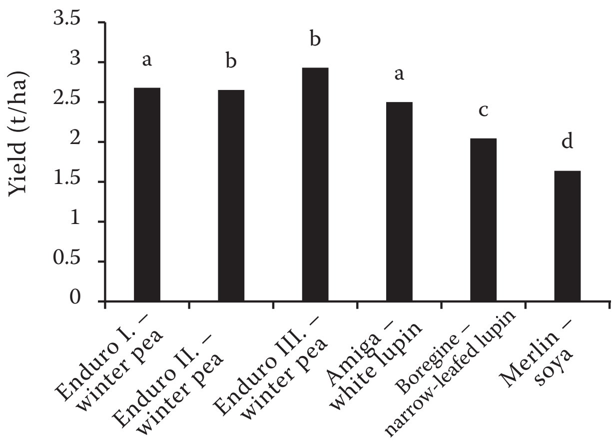

Figure 3. Average yield of different legumes in years 2013–2015; *HSD* = 0.1017; α = 0.05

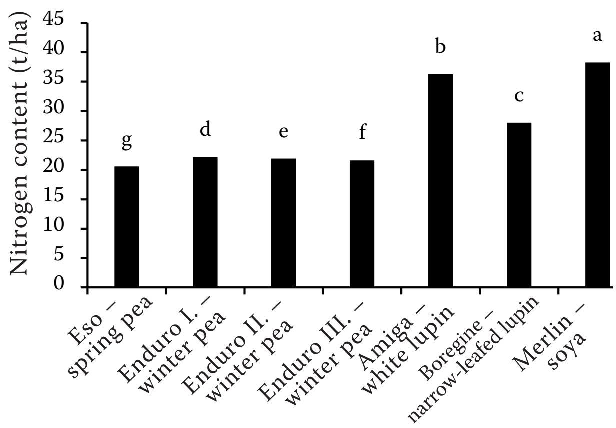

Figure 4. Average nitrogen content in seeds of different legumes in years 2013–2015; *HSD* = 0.127; α = 0.05

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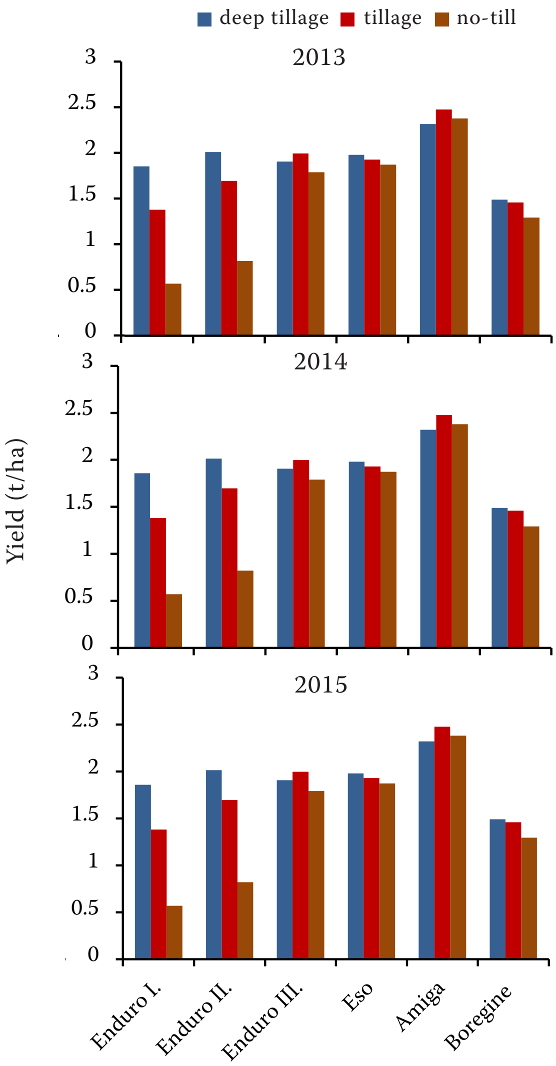

Figure 5. Average yield of different legumes under soil conservation techniques in year 2013, 2014 and 2015

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