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Qualitative effects of pea and spring cereals intercrop in the organic farming systems

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Abstract. The experiment aimed to ascertain the influence of pea and spring cereal intercrops on the yield and quality of spring crops was carried out in 2007 and 2008 at the Lithuanian Institute of Agriculture in different experimental sites, soil and cultivation conditions. Pea (*Pisum sativum* L.) and spring wheat (*Triticum aestivum* L.), spring barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.), triticale (x *Triticosecale* Wittm.) were sown as intercrops 50:50 or as sole crop. The results obtained during the two experimental years showed that the productivity and quality of spring cereal sole crops or intercrops depended on the species of cereals and varied between different experimental sites. The cultivation conditions were different in 2007 and 2008, therefore the results varied in the same experimental sites in the first and second experimental years. The experimental evidence is still inconclusive to firmly suggest which of the intercrops could be more stable, however it indicates the benefits of legumes for spring crops grown together.

Key words: grain pea, spring cereal, yield, protein

INTRODUCTION

Legumes are of great importance in organic plant production as crops in general, because of their biological nitrogen fixation and because they provide protein-rich forage. Legumes may also provide cost savings by reducing the requirement for nitrogen application (Anil et al., 1998). Intercropping of cereals and grain legumes is a neglected theme in agricultural science and practice in both conventional and organic farming systems (Dahlmann & Fragstein 2006). The purpose of intercropping is to generate beneficial biological interactions between the crops: increasing grain yields and stability, more efficiently using available resources, reducing weed pressure and sustaining plant health (Hauggaard-Nielsen et al., 2003; Jensen et al., 2006). Mixing species in cropping systems may lead to a range of benefits that are expressed on various space and time scales, from a short-term increase in crop yield and quality, to longer-term agroecosystem sustainability, up to societal and ecological benefits (Malezieux et al., 2009). The design of crops to exploit diversity should ideally factor-in all traits and aspects of the production system and reach the best compromise to achieve enhanced crop function (Newton et al., 2009).

Among grain legumes, peas are the most common legume in crop rotations and are quite productive in temperate conditions including Lithuania (Auskalnis, 2001).

Peas are productive as a main crop, but their vines also could be useful as nitrogen sources (Tripolskaja et al., 2008). However, in organic farming sole pea crops are poorly competitive against weeds as compared with cereal crops. Therefore, growing pea in intercrops could mitigate the impact of weeds and improve the quality of cereal grains. The experiment was aimed to ascertain the influence of pea and spring cereal intercrops on the yield of spring crops in various crop combinations and on yield quality.

MATERIALS AND METHODS

The field experiment was carried out in 2007 and 2008 at the Lithuanian Institute of Agriculture in Dotnuva on a loamy *Endocalcari-Epihypogleyic Cambisol*. The soil pH varied between 7.5, humus content was 2.3 per cent, available P 74-79 mg kg^{-1} and K 135-140 mg kg^{-1}, in Joniskelis on clay loam *Endocalcari-Epihypogleyic Cambisol*. Soil pH 6.4, humus content 2.2 per cent, available P 52 mg kg^{-1} and K 200-220 mg kg^{-1} and in Perloja on light – textured *Hapli – Albic Luvisol*. Soil pH 4.7, available P 67 mg kg^{-1} and K 115 mg kg^{-1}.

Wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.) and triticale (x *Triticosecale* Wittm.) were grown as sole crops and intercrops with field pea (*Pisum sativum* L.). The experimental plots were laid out in a complete one–factor randomised block design in three replicates. The intercrop design was based on the proportional replacement principle, with mixed pea grain and spring cereals grain at the same depth in the same rows at relative frequencies of 50 : 50. Wheat seeds rate were 5.5, barley 4.7, oat 6.0, triticale 4.5 and pea 1.0 mln seeds ha^{-1} for sole crop. The crops were cultivated according to organic management practices.

The crops were harvested at complete maturity stage. After threshing the grain dry matter yield was determined. Chemical composition parameters of cereals were determined by the following method: nitrogen-after Kjeldahl, crude protein according to the amount of nitrogen, multiplying it by 6.25 for pea and 5.7 for spring cereals. The experimental data were statistically processed using analysis of variance.

RESULTS AND DISCUSSION

The results obtained during the two experimental years showed that the productivity of spring cereal sole crops or cereal and pea intercrops depended on the species of cereals and varied between different experimental sites, soil and cultivation conditions (Table 1).

The results estimated in the first experimental year showed that in Dotnuva on loam the productivity of spring barley and wheat intercrops was significantly higher compared with that of the other intercrops and cereal sole crops, except for spring wheat (Table 1). Several researchers (Jensen, 1996; Lauk &Lauk, 2005) noticed that intercropping of legumes and cereals has produced higher yields than sole cereal crops without nitrogen fertilization. The cultivation conditions were different in 2007 and 2008, therefore the results varied in the same experimental sites in the first and second experimental years. In the second experimental year yields of cereal sole crops were lower than in the first year, because the climatic conditions were droughty in the summer of 2008.

Table 1. Grain yield data of pea and spring cereals in the experimental years, t ha^{-1}.

Treatment	Experimental site					
	Dotnuva		Joniskelis		Perloja	
	2007	2008	2007	2008	2007	2008
Pea	4.23	2.34	3.84	2.39	0.75	1.83
Pea+Spring wheat	4.49	2.14	4.48	2.39	1.35	1.86
Pea+Spring barley	3.95	1.85	3.77	2.68	1.02	1.67
Pea+Oat	3.01	2.38	4.37	4.47	1.43	2.45
Pea+Triticale	3.57	2.01	3.76	2.92	1.42	1.67
Spring wheat	4.65	2.21	3.77	3.62	1.37	1.68
Spring barley	3.30	2.11	4.23	3.08	0.72	1.32
Oat	3.20	2.85	4.69	3.90	1.62	1.57
Triticale	3.77	2.34	4.51	2.98	1.27	1.61
$P > 0.05$	0.374	0.566	0.845	0.951	0.711	0.255

Oat sole crop produced the highest grain yield. Oat and pea intercrop grain yield was highest compared with the other intercrops. Pea sole crops in Dotnuva in both years 2007 and 2008 were one of the most productive, however, the scale of productivity difference varied between years. In 2007, the pea crop was significantly out-yielded by the sole wheat and wheat intercrop, however, the difference between them was insignificant. The productivity of barley intercrop was insignificantly lower, and that of all the other crops was significantly lower than that of pea sole crop. In 2008, no significant differences were established between pea sole crop and the other crops. On clay loam, in Joniskelis, in the first experimental year the highest yield was in oat sole crop and it was significantly higher compared with pea and spring wheat sole crops and pea and spring barley or triticale intercrops. Spring wheat and oat intercrops out-yielded other intercrops and pea and spring wheat sole crops, whereas in the second experimental year intercrops were less productive than sole cereal crops, except for the pea oat intercrop. Productivity of pea sole crop was similar to or lower than intercrops. Although yields of intercrops were lower or very similar to sole crop yields, intercrop, as was noticed by researchers from other countries, is shown to have a much better utilization of plant growth resources than sole crops (Hauggaard-Nielsen et al., 2003). In Perloja on sandy loam the productivity of the tested crops was lower than that in Dotnuva on medium-textured loam Cambisol and in Joniskelis on clay loam. The highest grain yield was estimated in oat sole crop and in pea and oat, pea and triticale intercrops in the first experimental year. In 2008, assessment of pea sole crop and mixtures with cereals revealed yield trends similar to those in Dotnuva. Mixed crops were more productive or similar to sole cereal crops. Some researchers noted that the yield of the intercrops was more stable than that of sole crops (Corre-Hellon et al., 2006).

The concentration of crude protein is one of the most important criteria for grain quality evaluation. Analysis of grain quality showed that crude protein concentration of the intercropped cereals increased compared to sole cereal crops in all experimental sites, but was estimated lower than in sole pea (Table 2). The content of crude protein yield in the first experimental year did not differ significantly between wheat and barley or triticale intercrops, however, pea increased the concentration of crude protein in intercrops' yield compared with sole cereals in the Dotnuva site.

Table 2. Crude protein content and yield in intercrops and in sole pea or spring cereals.

Treatment	Experi-mental year	Experimental site					
		Dotnuva		Joniskelis		Perloja	
		CP% DM	CP kg ha^{-1}	CP% DM	CP kg ha^{-1}	CP% DM	CP kg ha^{-1}
Pea	2007	22.7	961.0	22.9	799.9	20.3	152.3
	2008	23.3	549.0	19.9	402.9	23.0	420.9
Pea+Spring wheat	2007	15.3	689.4	14.7	561.6	15.8	476.6
	2008	14.3	307.7	13.3	263.9	15.2	281.9
Pea+Spring barley	2007	15.5	611.2	12.9	417.8	16.4	349.1
	2008	14.0	263.0	10.7	242.3	15.6	260.6
Pea+Oat	2007	14.0	422.5	10.9	414.6	11.3	451.3
	2008	14.1	334.4	11.5	438.4	11.3	276.1
Pea+Triticale	2007	15.3	545.0	15.7	524.3	13.6	431.4
	2008	13.7	284.4	15.2	377.4	13.7	228.0
Spring wheat	2007	11.3	525.0	11.7	370.5	12.4	169.3
	2008	10.1	246.7	10.6	327.4	10.7	180.0
Spring barley	2007	12.8	423.0	10.8	390.7	11.9	85.7
	2008	9.5	181.4	9.6	251.4	9.7	127.9
Oat	2007	11.1	360.0	9.7	381.2	10.6	171.7
	2008	10.6	268.4	10.0	331.2	8.1	127.1
Triticale	2007	11.6	439.0	14.1	538.8	12.1	153.3
	2008	9.8	257.0	12.1	306.1	10.6	169.8
$P > 0.05$	2007	0.995	61.5	1.70	156.36	0.90	10.28
	2008	0.684	124.9	1.17	79.40	1.15	20.13

In Joniskelis, during the first experimental year, the crude protein content was higher in the triticale intercrop compared with the other intercrops. In Perloja, the concentration of crude protein obtained was significantly higher in spring wheat or barley and pea intercrops compared to the cereal sole crops and oat or triticale and pea intercrops. Differences of crude protein concentration between intercrops in the second experimental year were found to be insignificant in the Dotnuva site. In Joniskelis, during the second experimental year, as in the first, the content of crude protein was higher in the triticale intercrop compared with the other intercrops. The best concentration of crude protein was obtained in barley intercrop compared with other intercrops in Perloja site. In general, crude protein concentration in 2008 was lower than that in 2007 in all experimental sites; however, it was higher in intercrops than in sole cereals.

The intercrops' yield of crude protein varied between experimental years. Whereas the protein yields depended greatly on grain yield of crops, the yield of crude protein was determined lower in crops in 2007 than in 2008. However, the amount of crude protein in pea sole crop grain yield was significantly higher than in pea and cereal intercrops' grain yield. Our results suggest that the greatest grain crude protein yield was produced by pea sole crop in Dotnuva and Joniskelis where pea was cultivated on loam and clay loam. In Perloja, on sandy loam pea produced low grain yield compared with that in the other experimental sites; that is common for agricultural plants in those soil conditions.

Table 3. The concentration of crude protein in intercrops and in sole pea or spring cereals grain, % in DM.

Treatment	Plant species	Experimental site					
		Dotnuva		Joniskelis		Perloja	
		2007	2008	2007	2008	2007	2008
Pea	pea	22.7	23.3	22.9	19.9	20.3	23.0
Pea+Spring	pea	22.9	23.1	22.2	21.1	20.9	23.1
wheat	wheat	13.9	11.6	12.5	11.8	14.4	11.2
Pea+Spring	pea	23.1	22.4	18.9	18.6	21.0	22.4
barley	barley	14.0	10.8	12.6	9.4	13.2	10.6
Pea+Oat	pea	23.4	23.6	22.5	19.0	21.1	22.7
	oat	11.5	11.4	10.5	10.8	10.4	8.6
Pea+Triticale	pea	23.0	22.9	22.6	19.3	21.1	22.7
	triticale	12.9	10.9	14.2	13.2	12.6	10.6
Spring wheat	wheat	11.3	10.1	11.7	10.6	12.4	10.7
Spring barley	barley	12.8	9.5	10.8	9.6	11.9	9.7
Oat	oat	11.1	10.6	9.7	10.0	10.6	8.1
Triticale	triticale	11.6	9.8	14.1	12.1	12.1	10.5

However, the yield of crude protein was increased in pea and cereal intercrops compared with cereal sole crops in all experimental sites. Jensen et al. (2006) indicated that intercropping proved especially valuable for the production of protein on land with weed problems and for enhancing the grain protein concentration in cereals to levels which were only likely to be obtained with high levels of animal manure.

It is well known that the bread-making quality of wheat is much related to the protein content in grain, but in organic farming production of high quality is more difficult to achieve. Analysis of grain quality in our experiments showed that crude protein concentration of the intercropped cereals was increased compared to cereal sole crops, but was lower than that for sole pea in all experimental sites (Table 3). Higher concentration of crude protein in cereals grown in intercrops with pea showed that intercrops induced improvement in cereals baking quality parameters (Hauggaard-Nielsen et al., 2006).

CONCLUSIONS

1. The productivity of spring cereal sole crops or pea and cereal intercrops depended on the species of cereals and varied between different experimental sites, soil and cultivation conditions.
2. In Dotnuva, on a loamy *Endocalcari-Epihypogleyic Cambisol* the highest productivity was obtained by spring wheat intercrop in 2007 and in 2008 by oat intercrop. In Joniškėlis, on a clay loam *Endocalcari-Epihypogleyic Cambisol* and Perloja on a light–textured *Hapli–Albic Luvisol* the yield of oat intercrop was estimated to be higher in both experimental years compared with the other intercrops and cereal sole crops; in some cases the yield was very similar.
3. The concentration of crude protein was higher in pea and cereal intercrops' grain yield. However, the concentration of nitrogen in all cases was lower in 2008 than in 2007. The crude protein concentration in grain of cereals grown in intercrops was increased compared to sole cereal grains.

4. The experimental evidence is still inconclusive to firmly suggest which of the intercrops could be more stable on a long–term scale, therefore the experiments need to be continued.

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