Effect of Pea and Spring Cereals Intercropping on Grain Yield and Crude Protein Content

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received / primljeno: 31.05.2010. accepted / prihvaćeno: 08.10.2010.
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Summary: The advantage of intercropping is beneficial biological interactions between crops and their different use of growth resources. Our experiment aimed at investigating the effects of pea intercropping with cereals on the improvement of cereal supply with nitrogen and protein content in grain on a loamy soil in organic farming conditions. It was carried out during 2007-2009 at the Lithuanian Institute of Agriculture in Dotnuva. Pea (*Pisum sativum* L.) and spring wheat (*Triticum aestivum* L.), spring barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), and triticale (x *Triticosecale* Wittm.) were sown as intercrops 50:50 or as a sole crop. The results obtained during the 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 year's cultivation conditions. Grain productivity in some cases was estimated to be higher in the intercrops, however it was not stable in three experimental years. The protein content and yield in the grain of cereals grown in intercrops was positively affected by pea intercrops.

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

Introduction

The inclusion of legumes in crop rotations and intercrops can provide increased protein-rich yields and a more sustainable source of nitrogen, while on the other hand it saves cost by reducing the requirement for mineral nitrogen application (Anil et al. 1998, Crews & Peoples 2004). In many countries, legume plants have recently been receiving increasing attention from researchers and growers (Hauggaard-Nielsen et al. 2009, Mariotti et al. 2009, Stoddard et al. 2009, Mikić et al. 2010). Pea (*Pisum sativum* L.) is the most common legume in crop rotations and quite productive in temperate conditions, as well as in Lithuania (Auskalnis 2001).

Being one of the most popular plants in the organic cropping system, pea provides high quality forage, rich in crude protein and mineral elements (Corre-Hellou & Crozat 2005, Lauk & Lauk 2008). However, it is not less important for its ability to accumulate atmospheric nitrogen, on which depends the state of the whole crop rotation and agroecosystem, and

possible farming benefit. Pea is productive as main crops, but its vines could also be useful as a nitrogen source (Tripolskaja et al. 2008). Various soils are suitable for pea cultivation, but the crop yields best on moderately heavy loam (Dovydaitis 1992). However, due to its biological characteristics, pea cultivation is not so simple. Although of more recent cultivars, pea-grown as a sole crop has some disadvantages – it is prone to severe lodging, which aggravates its harvesting and weed control. As a result, pea productivity is more dependent on proper soil and crop management (Auskalnis & Dovydaitis 1998, Auskalnis & Dovydaitis 1999, Maikštėnienė & Satkus 2000, Auskalnis 2001). When grown in a mixture, e.g. with spring barley (*Hordeum vulgare* L.), the crop does not lodge and in the conventional cropping system produces a grain yield of nearly 5 t ha⁻¹ (Auskalnis & Dovydaitis 2000). Intercropping of cereals and legumes is widely used in low-input agriculture because the mixture of nitrogen N-fixing and non-N-fixing crop species provides complementarities in the utilization of resources, reduces weed pressure and sustains 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 long-term agroecosystem

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sustainability, up to societal and ecological benefits (Malezieux et al. 2009).

Our experiment aimed at investigating the effects of pea intercropping with cereals on the improvement of cereal supply with nitrogen and protein content in grain on a loamy soil in organic farming conditions.

Materials and Methods

The field experiment was carried out on a loamy Endocalcari-Epihypogleyic Cambisol during 2007-2009 at the Lithuanian Institute of Agriculture in Dotnuva (55°24'N, 23°50' E). The soil pH varied at about 7.5, humus content was 2.3%, available P 74-79 mg kg⁻¹ and K 135-140 mg kg⁻¹. Wheat (*Triticum aestivum* L.), barley, oats (*Avena sativa* L.) and triticale (x *Triticosecale* Wittm.) were grown as sole crops and intercrops

calculated according to the amount of nitrogen, by multiplying with 6.25 for pea and 5.7 for spring cereals. The LER values were calculated as follows (Mead & Willey 1980):

$$L_c = \frac{Y_{cerealIC}}{Y_{cerealSC}}; L_p = \frac{Y_{pealC}}{Y_{peaSC}}$$

and $LER = L_c + L_p$. $Y_{cerealIC}$ and Y_{pealC} are the intercrop yields and $Y_{cerealSC}$ and Y_{peaSC} are the sole crop yields of cereal and pea respectively. A LER value above one indicates a benefit of intercropping.

The experimental data were processed by analysis of variance (ANOVA) applying Least Significant Difference (LSD) test using the computer software Selekcija (Tarakanovas & Raudonius 2003).

Table 1. Temperature and precipitation during the winter and growing period

Tabela 1. Temperatura i padavine tokom zime i vegetacionog perioda

month mesec	mean air temperature / srednja temperatura vazduha (°C)			1924- 2009	precipitation per month / mesečna suma padavina (mm)			1924 - 2009
	2007	2008	2009		2007	2008	2009	
January	1.0	0.5	-2.8	-4.8	88.3	68.8	41.0	30.2
February	-7.4	2.2	-3.5	-4.5	25.7	31.1	18.7	25.3
March	5.2	2.6	0.9	-0.8	23.6	53.4	53.9	28.5
April	6.9	8.8	8.8	5.8	15.8	38.7	13.1	36.9
May	13.5	12.2	12.7	12.2	98.2	13.2	26.7	51.8
June	17.6	16.1	14.6	15.6	61.5	49.2	168.6	62.4
July	17.2	18.2	18.1	17.6	118.1	47.6	90.0	73.4
August	18.7	18.0	16.8	16.7	50.8	90.8	67.1	73.7
September	12.8	12.1	13.9	12.0	49.1	16.0	48.2	51.3
October	7.7	8.9	5.2	6.8	48.7	80.4	95.4	50.2

data by Dotnuva meteorology station / podaci meteorološke stanice Dotnuva

with field pea. 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 rates were calculated on the basis of 5.5, barley 4.7, oat 6.0, triticale 4.5 and pea 1.0 million seeds ha⁻¹ for sole crop. The crops were cultivated according to organic management practices.

The crops were harvested at complete maturity stage. Grain yield components were determined from plant samples taken before harvest. Grain dry matter (DM) yield was determined after threshing. Nitrogen was determined by Kjeldahl, while crude protein content was

The precipitation sums and the temperature means during experimental period are shown in table 1.

Results and Discussion

The number of the productive stems was significantly lower in the intercrops than in sole peas or cereals (Tab. 2) in all three years of experiment and naturally fluctuated between years. Number of pea grain in intercrops was also lower, therefore number of cereals grain per ear was higher in intercrops and number of wheat and triticale was significantly higher. In previous research on pea productivity on light loam soil, it was noticed that a stand density of 80-90 plants m⁻² was sufficient to produce a rather high yield (Auškalnis & Dovydaitis 1998).

Table 2. The grain yield components in pea and spring cereals crop structure
 Tabela 2. Komponente prinosa zrna u strukturi useva stočnog graška i jarih strnih žita

treatment varijanta	number of productive stems broj produktivnih stabala (m ⁻²)			grain number per ear/legume stem broj zrna po klasu/stablu (m ⁻²)			thousand grain weight masa 1000 zrna (g)		
	2007	2008	2009	2007	2008	2009	2007	2008	2009
pea + wheat grašak + pšenica									
pea grašak	48	50	46	10	9	7	219	221	196
wheat pšenica	367	227	300	39	42	40	39	40	28
pea + barley grašak + ječam									
pea grašak	38	50	32	8	9	6	111	108	213
barley ječam	305	215	357	23	19	24	52	48	44
pea + oat grašak + ovas									
pea grašak	57	64	52	9	11	5	199	215	195
oat ovas	311	198	266	48	48	60	28	36	33
pea + triticale grašak + tritikale									
pea grašak	46	42	56	13	8	8	227	219	223
triticale tritikale	279	197	239	44	44	49	38	40	40
sole crops / pojedinačni usevi									
pea grašak	126	99	102	20	13	15	239	220	233
wheat pšenica	584	327	522	33	36	37	36	38	31
barley ječam	462	338	395	21	21	25	45	50	43
oat ovas	499	373	454	44	40	46	28	39	34
triticale tritikale	415	307	382	38	38	46	36	37	37
LSD _{0.05}									
pea grašak	10.6	9.86	11.8	1.74	2.52	2.05	0.59	1.92	20.4
spring cereal jara strna žita	42.2	43.7	63.3	4.51	4.65	3.24	1.60	0.19	0.26

The results obtained during the tree experimental years showed that the productivity of spring cereal sole crops or cereal and pea intercrops depended on the species of cereals and cultivation conditions (Tab. 3).

The productivity of spring wheat and barley intercrops in the 2007 was significantly higher compared with that of the other intercrops and cereal sole crops, except for spring wheat (Tab. 3). The fact that intercropping of legumes and cereals produced higher yields than sole cereal crops without nitrogen fertilization was noticed

by several researchers (Jensen 1996, Lauk & Lauk 2005). The cultivation conditions were different in experimental years, therefore the results varied. In the year 2008, yields of cereal intercrops were lower than in the 2007, because the climatic conditions were droughty in the summer of 2008. Oat and pea intercrop grain yield was the highest and the productivity of barley intercrop was insignificantly lower compared with the other intercrops. In 2009, yields of cereal intercrops were lower than in the 2007, however higher than in 2008. In 2009, the intercrops were more

Table 3. Grain yield and crude protein content and yield in intercrops and in sole pea or spring cereals
 Tabela 3. Prinos zrna i sadržaj i prinos sirovih proteina u združenom i čistom usevu stočnog graška i
 jarih strnih žita

treatment varijanta	grain yield prinos zrna (kg ha ⁻¹)			crude protein content sadržaj sirovih proteina (%)			crude protein yield prinos sirovi proteini (kg ha ⁻¹)		
	2007	2008	2009	2007	2008	2009	2007	2008	2009
peas+wheat grašak+pšenica	4491	2139	2225	16.1	14.5	14.3	689	311	319
peas grašak	722	559	369	22.9	23.1	23.7	165	130	88
wheat pšenica	3769	1580	1854	13.9	11.6	12.4	524	181	231
pea+ barley grašak+ječam	3951	1851	2448	16.7	15.7	12.3	611	291	302
peas grašak	649	783	265	23.1	22.4	23.6	150	175	63
barley ječam	3302	1068	2183	14.0	10.8	11.0	461	116	239
pea + oat grašak+ ovas	3010	2379	2277	15.2	13.8	11.9	423	332	271
peas grašak	634	514	188	23.4	23.6	22.8	150	121	43
oat ovas	2376	1865	2089	11.5	11.4	10.9	275	211	228
pea+triticale grašak+tritikale	3567	2089	2549	18.1	13.2	14.6	545	275	374
peas grašak	838	414	310	23.0	22.9	23.3	193	96	72
triticale tritikale	2729	1675	2239	12.9	10.9	13.5	352	179	302
sole crops / pojedinačni usevi									
pea	4232	2342	2236	22.7	23.3	23.6	960	549	530
grašak									
wheat	4650	2210	2149	11.3	10.1	11.6	527	247	249
pšenica									
barley	3304	2114	2332	12.8	9.50	10.4	421	181	242
ječam									
oat	3241	2924	2526	11.1	10.6	10.0	359	268	253
ovas									
triticale	3773	2341	2039	11.6	9.80	12.0	439	257	245
tritikale									
*LSD _{0.05}	373.7	565.8	275.4	1.04	0.94	0.96	61.5	125.0	70.6

*for total yield / za ukupni prinos

productive than sole cereal crops, except pea and oat intercrop and the most productive was pea and triticale intercrop. Some researchers noted that the yield of the intercrops was more stable than that of sole crops (Corre-Hellon et al. 2006). In our experiment, pea and barley intercrop in two years out of three produced higher yield compared with the sole barley crop, however we could not conclude that this intercrop yielded more stably.

Even in organic agriculture it is difficult to obtain comparative values for protein contents of different cereals. Analysis of data showed

that crude protein concentration of the intercropped cereals was improved compared to sole cereal crops in all experimental years, but was estimated lower than in sole pea (Tab. 3). Differences in protein content in different cereals were recorded. The highest positive influence was achieved for intercropped triticale grain. In all three experimental years, protein concentration was significantly higher than that in sole triticale. The lowest influence was observed in intercropped oat and the protein concentration was insignificantly higher than that in sole oat.

Fig. 1. Land equivalent ratio (LER) for pea-cereal intercrops based on grain and crude protein yields
Slika 1. Površinski ekvivalentni odnos (LER) za združeni usev graška i pšenice zasnovan na prinosu sirovih proteina

The yield of crude protein in the intercrops varied between experimental years. Although the protein yield depended greatly on grain yield of crops, the yield of crude protein was determined to be lower in crops in 2008 and 2009 than in 2007. However, the yield of crude protein was increased in pea and cereal intercrops compared with cereal sole crops. 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.

The efficiency of resource use in intercropping relative to sole crop from intercropping expose LER values (Fig. 1) based on grain yield. Total LERs above 1.00 were found in case of barley in 2007 and 2009, of wheat in 2009 and of triticale in 2009 intercrops, which shows the advantage of these mixtures over sole crops. Other cases in terms of total LER showed some disadvantage of intercrops. LERs calculations based on crude protein yield strengthen demonstrate that intercrops produce more per area than its sole cereal crops.

Conclusions

The productivity of spring cereal sole crops or pea and cereal intercrops depended on the species of cereals and varied depending on different year's cultivation conditions. Grain productivity in some cases was estimated to be higher in intercrops, however it could not be concluded that pea/cereals intercrops yielded stably in three experimental years. However, protein content in the grain of cereals grown in intercrops was positively affected by pea and cereal intercrops. Pea-cereal intercrops can increase land use productivity.

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Uticaj združene setve stočnog graška i jarih strnih žita na prinos zrna i sadržaj sirovih proteina

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Izvod: Prednost združenih useva je u povoljnim biološkim odnosima između useva i njihovog različitog iskorišćenja raspoloživih resursa za rast. Ovaj eksperiment je imao za cilj da istraži uticaj stočnog graška kao združenog useva sa žitaricama na poboljšanje dostupnosti azota žitaricama i sadržaja proteina u zrnu na ilovastom zemljištu u uslovima organske poljoprivrede. Eksperiment je izveden u periodu 2007-2009. u Poljoprivrednom institutu Litvanije u gradu Dotnuva (55°24'N, 23°50'E). Grašak (*Pisum sativum* L.) i jara pšenica (*Triticum aestivum* L.), jari ječam (*Hordeum vulgare* L.), ovas (*Avena sativa* L.) i tritikale (x *Triticosecale* Wittm.) bili su posejani kao združeni usevi 50:50 ili kao čisti usevi. Dobijeni trogodišnji rezultati pokazuju da su produktivnost i kvalitet jarih strnih žita kao čisti ili kao združeni usev zavisili od vrste žita i varirali su u zavisnosti od agrotehničkih uslova u različitim godinama. Produktivnost zrna u nekim slučajevima je procenjena kao viša u združenom usevu, međutim nije bila stabilna u tri godine eksperimenta. Kao združeni usev, grašak je imao pozitivan uticaj na koncentraciju i sadržaj proteina u zrnu žita.

Ključne reči: grašak, jara strna žita, prinos, proteini, združeni usevi