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Competitiveness and productivity of organically grown pea and spring cereal intercrops

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Abstract

Intercropping of cereals and grain legumes is a technology intended to enhance biodiversity in organic agroecosystems, increase and stabilize yields and make better use of plant growth resources. The experiments were designed to investigate the intercrops' yield advantage in different soil, climate and plant competition conditions in organic farming. Field trials were carried out during 2007–2010 at the Lithuanian Institute of Agriculture at three different soil sites: on a loamy *Endocalcari-Epihypogleyic Cambisol* (*CMg-p-w-can*) (Dotnuva), on a clay loam *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*) (Joniškėlis) and on a sandy loam *Hapli-Albic Luvisol* (*LVe-ha*) (Perloja). Pea (*Pisum sativum* L. (Partim)) and spring wheat (*Triticum aestivum* L. emend. Fiori et Paol.), spring barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.) and spring triticale (× *Triticosecale* Wittm.) were sown as intercrops (50:50 – a relative proportion of grain legume and spring cereal seeds) or as a sole crop. The result showed that weather and soil conditions during plant emerge determined the optimal productive density and created a basis for competition between the intercrop components. Spring cereals were dominant due to higher aggressivity index and competition rate compared with peas. Under various soils' conditions the aggressivity of cereals increased with increasing density of pea. In productive soils (Dotnuva, Joniškėlis), the highest competitive and suppressive power in the intercrops was exhibited by oats, in low productivity soils (Perloja) – the dominant species varied. Under the conditions of various soils, the production of pea intercrop with oats or barley was directly affected by cereals, while pea intercropped with wheat or triticale by the two components of the intercrop. In terms of grain yield, intercrops ranked as follows: pea/oats > pea/wheat, pea/triticale > pea/barley. In loamy soil (Dotnuva), these regularities were less consistent, therefore the advantages of intercrops' yield over sole crops' yield were negligible when the relative yield total (RYT) was > 1.0, except for the pea intercropped with barley. In Joniškėlis and Perloja, the relative yield total showed greater and more stable yield advantages of intercrops, except pea intercropped with triticale. The efficiency of intercrops stood out even more vividly in the treatments managed under organic cropping system for a longer period of time.

Key words: intercrop, *Pisum sativum*, *Poaceae*, yield, indices of competition.

Introduction

In intensive agricultural systems, crop diversity is reduced to one or very few species that are generally genetically homogeneous, the planting layout is uniform and symmetrical and external inputs are often supplied in large quantities. Such systems have clearly negative impacts on soil and water quality and on biodiversity conservation (Malezieux et al., 2009). However, increasing awareness of the link between agricultural practise, environmental issues and long-term stability of existing food production systems has put focus on the role that greater crop diversity in time (crop rotation) and space (field size and mixed cropping systems) may play in reducing the extent of these problems.

Intercropping, the simultaneous growth of more than one species in the same field (Willey, 1979), is the practical application of basic ecological principles. Its potential mechanisms and effects consist of competition (niche differentiation, resource use sharing, weed control), diversity (pest and disease control), facilitation (physical support, excretion of N and allellochemicals, modification of the rhizosphere) and associated diversity (habitats for natural predators, litter diversity enhances soil microbial diversity) (Hauggaard-Nilsen et al., 2008). The greatest intercrop advantages are attained when the species that are mixed differ markedly either morphologically, phenologically or physiologically (Andersen et al., 2007 b). The crops are not necessarily sown at the same time, and harvest time may also differ. However, the crops must co-occur for a significant period of their growth (Ofori, Stern, 1987). Intercrops can be combinations of annuals, perennials or a mixture of the two (or more) species (breed, type) (Anil et al., 1998). When two or more crops are growing together, each must have adequate space to maximize cooperation and minimize competition between them. Therefore, before making mixtures the following should be taken into account: spatial arrangement (Malezieux et al., 2009); plant density (Andersen et al., 2007 b; Neumann et al., 2007); maturity dates of the crops being grown (Anil et al., 1998), plant architecture (Brisson et al., 2004). In terms of density, intercropping systems range from replacement to additive. One of the most commonly used intercropping mixtures is the legume/nonlegume (usually cereal) combination (Ofori, Stern 1987; Anil et al., 1998; Hauggaard-Nilsen et al., 2008; Šarūnaitė et al., 2010).

The most important growth resources used by crops are light, water, and nutrients (Brisson et al., 2004). Aboveground parts of plants compete for light, belowground – for water and nutrients (Malezieux et al., 2009). Trenbath (1974) reported that an "ideal" leaf arrangement could be approached by a mixture of a tall erect-leaved genotype and a short, prostrate-leaved genotype. Therefore, a mixed crop better exploits the potential of light (Szumigalski, van Acker, 2008; Malezieux et al., 2009). Water is the most limiting factor for plant production and water is the medium that transports all other soil-based resources (Malezieux et al., 2009). Plants grown in mixed crops are different in root morphological and physiological plasticity: length density, surface, depth, root systems interpenetration (Hauggaard-Nilsen, Jensen, 2005).The components of the intercrops may be complementary in a spatial sense by exploiting different layers of the soil with their root systems (Brisson et al., 2004; Li et al., 2006). In Danish and German experiments the accumulation of phosphorous (P), potassium (K) and sulphur (S) was 20% higher in the intercrop (50:50 – a relative proportion of grain legume and spring cereals seeds) than in the respective sole crops (Hauggaard-Nielsen et al., 2009). The legume can provide N to the non legume directly trough mycorrizal links, root exudates, or decay of roots and nodules; or indirectly – during a spring period, where the legume fixes atmospheric dinitrogen (N_2), thereby reducing competition for soil NO_3^- with the non legume (Anil et al., 1998; Corre-Hellou et al., 2006). In mixed stands, the risk of N losses through leaching is substantially reduced in comparison to sole cropped pea (Neumann et al., 2007). Urbatzka et al. (2009) suggest that when pea was cultivated in mixture with cereals, the N utilization effect was higher than in pea pure stands and the N preceding crop effect of pea decreased. Intercropping has significant effects on microbiological and chemical properties in the rhizosphere, which may contribute to the yield enhancement by intercropping (Song et al., 2007).

The aim of this study was to determine the effects of intercropping pea and spring cereal (wheat, barley, oats and triticale) in organic cropping systems on three soil types, contrasting weather conditions on plant competition and yield performance.

Materials and methods

Site and soil. The field experiment was carried out in 2007–2010 at the Lithuanian Institute of Agriculture (Dotnuva), Joniškėlis Experimental Station and Perloja Experimental Station of the Lithuanian Institute of Agriculture. Experimental soil indicators are presented in Table 1.

Table 1. Main characteristics of the experimental soil at the 0–25 cm depth

Soil parameters	Dotnuva	Joniškėlis	Perloja
Soil group	*Endocalcari-Epihypogleyic Cambisol* (*CMg-p-w-can*)	*Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*)	*Hapli-Albic Luvisol* (*LVe-ha*)
Soil surface texture	loamy	clay loam	sandy loam
Humus %	2.3	2.2	1.8
pH	7.5	6.4	4.7
N_{total} g kg^{-1} of soil	1.51–1.61	1.25–1.33	0.95–0.99
Available P_2O_5 mg kg^{-1} of soil	74–79	140–150	67
Available K_2O mg kg^{-1} of soil	135–140	205–225	115
Bulk density Mg m^{-3}	1.4	1.5	1.4
Total porosity %	43–49	41–43	30–35

Experimental design and field management. The field experiments were carried out in 2007–2010. The following trial design was used for intercrops and sole crops: 1) pea (*Pisum sativum* L. (Partim), cv. 'Pinochio') – Ps, 2) pea/spring wheat (*Triticum aestivum* L. emend. Fiori et Paol., cv. 'Estrad') – PWi, 3) pea/spring barley (*Hordeum vulgare* L., cv. 'Aura') – PBi, 4) pea/oat (*Avena sativa* L., cv. 'Migla') – POi, 5) pea/spring triticale (× *Triticosecale* Wittm., cv. 'Nilex') – PTi, 6) spring wheat – Ws, 7) sprig barley – Bs, 8) oats – Os, 9) spring triticale – Ts. The experimental plots were laid out in a complete one-factor randomised block design in three replicates. Individual plot size was 2.5 × 12 m. 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 (50:50 – a relative proportion of grain legume and spring cereals seeds). Hauggaard-Nielsen et al. (2008) indicate that, a relative proportion of pea intercrop around 40–50% is needed in order to achieve a level of intraspecific competition. Wheat seed rate was

5.5, barley 4.7, oats 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.

Plant sampling and statistical analysis. The productive stem density was determined in the area of 0.25 m^2 in 4 places per plot before crop harvesting at maturity stage. The crops were harvested at complete maturity stage. Indices of plant competition: aggressivity (A) and competitive ratio (CR) (Willey, Rao, 1980), relative yield (RY) and relative yield total (RYT) (Weigelt, Jolliffe, 2003) on the basis of grain yield were calculated as follows:

$$Ac = Yic/(Ysc \times Fc) - Yip/(Ysp \times Fp), \quad (1),$$

$$CRc = (Yic/Ysc) / (Yip/Ysp), \quad (2),$$

$$RYc \text{ (for cereal)} = Yic/(Ysc), \quad (3),$$

$$RYp \text{ (for pea)} = Yip/(Ysp), \quad (4),$$

$$RYT = (RYc + RYp), \quad (5),$$

where Ac and CRc aggressivity and competitive ratio of cereals, of Yic and Yip are yields of cereals and pea in intercrops, Ysc and Ysp are yields of cereal and pea in sole cropping, Fc and Fp are the proportion of the area occupied by cereal and pea in the intercropping.

The experimental data were statistically processed using analysis of variance and correlation – regression analyses methods employing software *Anova*, software package *Selekcija* (Tarakanovas, Raudonius, 2003).

Meteorological conditions. Dotnuva. In April–May 2007, the temperature practically did not differ from the long-term mean. In May, the amount of rainfall was sufficient for plant growth (Table 2). June was slightly warmer, heavy rainfall occurred at the end of the month. In July, the rainy weather prevailed. The normally warm and humid weather dominated at the beginning of August. In April 2008, the weather was optimally wet. May was cool, windy and dry. The reserves of productive moisture reduced and conditions were close to critical for crop growth. In June, the warm and very dry weather conditions continued. After a prolonged dry period, the rainfall was very beneficial to plants. Warm and rainy weather prevailed in August. Rainy weather conditions delayed harvest. Warm, sunny and dry weather dominated during April 2009. Moisture shortage for spring cereals was felt already in the second half of May. June was cool and rainy. Rainfall amount was 2.7 times higher than the norm during the month. Rainy weather conditions continued in July. In May–July 2010, the temperature was +2ºC higher compared to the long-term mean; the amount of rainfall was about 60% higher than the long-term mean. In spring, moisture conditions delayed sowing. The germination and growing period was adverse for spring crop. As a consequence, the experiment had to be rejected that year.

Table 2. Crop growing conditions during the main vegetation period, 2007–2010

Place	Year	Sowing and germination period (15 04–15 05)	Main growth period (16 05–31 07)	Maturity stage and harvest period (01 08–31 08)
Dotnuva	2007	at sowing – dry, later – optimal	in the first half of vegetation – optimal, in the second half (July) – excessive moisture	dryish – normally wet
	2008	at sowing – optimal, later – dry	in the first half of vegetation – dryish, in the second half – dry	warm weather, excessive moisture
	2009	after sowing – dry	excessive moisture (June–July)	optimal
	2010	at sowing – excessive moisture	extremely moisture (June–July)	optimal
Joniškėlis	2007	optimal	in the first half of vegetation – optimal, in the second half (July) – excessive moisture	dry
	2008	after sowing – torrential rain, later – dry	in the first half of vegetation – droughty, in the second half – optimal	excessive moisture, torrential rain
	2009	dry	excessive moisture (June–July)	optimal with torrential rain
	2010	after sowing – excessive moisture	optimal	optimal
Perloja	2007	dry	at the beginning of vegetation – optimal, in the second half (July) – excessive moisture	very dry
	2008	dry	dry	dry
	2009	at sowing – very dry, later – optimal	at the beginning of vegetation – optimal, later – wet	dry
	2010	after sowing – excessive moisture	throughout the entire vegetation period – excessive moisture	excessive moisture

Joniškėlis. In 2007, the daily air temperature in April and May differed little from the average long-term data. Heavier rainfall occurred only in May. The growing period of the main crops (May–July 2007) was slightly warmer (+1.0ºC) compared with the long-term mean. The amount of rainfall in July exceeded the long-term mean by 37.8 mm. In 2008, the weather conditions stood out even more markedly by wet spring and dry first half of the summer and excessively wet end of summer compared with the long-term data. Abundant precipitation in March and especially April delayed spring cereal sowing. May and June, the period of intensive plant growth, were cooler and drier. In July, there was enough rainfall, and in August the amount of rainfall exceeded the long-term mean by 48.6 mm. In 2009, April and May were drier, the amount of rainfall was by 19.2 and 29.3 mm lower and the weather was negligibly warmer compared with the long-term mean data. High rainfall amount in June and July (80.9 and 107.6 mm, respectively) partly offset shortage of moisture. In 2010, during the vegetation period the weather conditions were close to normal, except for plant emergence period. Abundant amount of rainfall in May (by 23.7 mm higher compared with the long-term mean) and recurring torrential rain aggravated plant emergence. The second half of summer was warm and wet.

Perloja. In 2007, April was dry and there was a shortage of moisture for legume seed swelling. In May, the amount of rainfall totalled 51 mm, which made plant emergence hard. In June, the conditions for plant growth were optimal. In July, the torrential rains washed off nutrients from the soil. In 2008, the spring was cool. Although there was enough moisture in the soil, the temperature in April and May was by 1.2–1.3ºC lower compared with the long-term mean. In the third ten-day period of April, frosts occurring every night inhibited cereal emergence. April was somewhat cool and dry; rain appeared only in the middle of the month. July and August were slightly cooler; the amount of rainfall was by 20% lower than the long-term mean. In 2009, April was warmer but very dry. May was wet and warm, June was noted for excessive moisture (the amount of rainfall was twice as high). After the rainy June, July was also by on average 26% wetter and slightly warmer, compared with the long-term mean. August was normally warm but drier. In 2010, the spring stood out by wet weather. May was especially wet, with the amount of rainfall 2.7 higher compared with the long-term mean. The summer was warm and wet. The rain, occurring almost daily, impeded crop growth and maturation.

Results and discussion

Productive density. Intercropping advantages may be influenced by both plant density and relative frequency of the intercrop components (Subkowicz, Tendziagolska, 2005). Number of plants in mixtures varied and depended on the site, soil, year, crop species and cultivation method. The highest productive density of peas in a sole crop and in the dual-component intercrop was established in the trials in Dotnuva (loamy soil), lower in Joniškėlis (clay loam) and Perloja (sandy loam) (Table 3). The share of pea plants in the total plant productive density structure was similar and made up 8.2–24.4% (32–64 plants m^{-2}) in Dotnuva, 5.3–24.6% (15–57 plants m^{-2}) in Joniškėlis, and 7.1–30.2% (20–55 plants m^{-2}) in Perloja. The mixed crops formed in Dotnuva had higher and more stable productive density (239–415 plants m^{-2}), compared with Joniškėlis and Perloja sites (139–339 plants m^{-2} and 94–397 plants m^{-2}, respectively). Comparison of various mixtures showed the highest stand density in Dotnuva in pea/wheat (277–415 plants m^{-2}) and pea/barley (265–389 plants m^{-2}), in Joniškėlis in pea/oats (229–329 plants m^{-2}) and pea/wheat (232–339 plants m^{-2}), in Perloja in pea/oats (271–397 plants m^{-2}) dual-component intercrops.

The plant density formed in Joniškėlis and Perloja was largely determined by the site-specific soil characteristics and weather conditions. With pre-sowing tillage, not every year we succeed in creating adequate moisture to air ratio in the seedbed for satisfactory seed emergence. Peas were found to be especially sensitive to this. In the dry spring of 2009, in Joniškėlis and Perloja the emergence and establishment of peas, whose seeds require more moisture for swelling, was hard. While in 2010, due to excess moisture, the cohesion and penetration resistance of heavy soil increased during the drying process, which resulted in the formation of crust. This weakened seed-bed aeration. That year the plant emergence was poor, and the emerged plants were weak and produced a poor root system, which impeded plants' nutrition and weakened their competitive power.

Table 3. Productive density in sole crops and in dual-component intercrops, plants m^{-2}

Treat-ment	Crop component	Dotnuva			Joniškėlis				Perloja			
		2007	2008	2009	2007	2008	2009	2010	2007	2008	2009	2010
Ps	pea	126	99	102	91	98	63	71	90	100	70	63
PWi	pea	48	50	46	27	31	47	29	52	46	29	20
	wheat	367	227	300	313	230	185	212	242	260	231	121
	total	415	277	346	339	261	232	241	294	306	260	141
PBi	pea	38	50	32	29	36	47	34	55	29	30	20
	barley	305	215	357	232	233	185	129	127	114	138	74
	total	343	265	389	261	269	232	163	182	143	168	94
POi	pea	57	64	52	29	30	37	15	28	30	30	32
	oats	311	198	266	227	299	192	270	369	308	331	239
	total	368	262	318	256	329	229	285	397	338	361	271
PTi	pea	46	42	56	32	57	49	33	36	30	38	20
	triticale	279	197	239	233	184	150	106	225	247	305	183
	total	325	239	295	265	241	199	139	261	277	343	203
Ws	wheat	584	327	522	443	352	293	330	397	326	190	127
Bs	barley	462	338	395	353	299	274	300	228	284	288	139
Os	oats	499	373	454	346	396	259	372	484	285	341	310
Ts	triticale	415	307	382	411	358	267	298	394	334	305	290
LSD_{05}		41.6	44.9	60.1	84.2	53.5	61.3	80.4	42.6	37.4	36.1	25.5

Note. Intercrops: PWi – pea/spring wheat, PBi – pea/spring barley, POi – pea/oat, PTi – pea/spring triticale; sole crops: Ps – pea, Ws – spring wheat, Bs – spring barley, Os – oats, Ts – spring triticale.

In later plant growth stages, the total productive stand density was influenced by the weather conditions and interaction (competition) between components of the mixture. In Joniškėlis, in mixed crops with increasing number of productive stems of cereals from 106 to 313 plants m^{-2}, pea density significantly declined ($r = -0.528$, $P < 0.05$). Literature sources indicate that during vegetation the number of peas declined by 6–10% until harvesting (Шпаар и др., 2000).

Grain productivity. In 2007, in Dotnuva comparison of intercrops with sole pea showed that significantly lower productivity was of pea/oats and oats/triticale intercrops, also lower than that of sole stands of these cereals (Table 4). The best yielding were pea/wheat and pea/barley intercrops. In 2008, cereal yield declined by on average 40.4% due to the dry vegetation period (May–July received only 110 mm of rainfall), there were no significant differences between the treatments. Productive moisture reserves declined and were close to critical for plants to grow; this had greater adverse effect on cereals compared with peas. Cereals suppressed peas less. The highest sole crops' grain productivity was of those crops that were less sensitive to pre-crops, soil productivity and the weather conditions. Oats were best yielding. In many cases, pea sole crop yielded better than intercrops or sole cereal crops, except for pea/oats mixture. In 2009, the rainy weather in June and July was also adverse for the development and maturation of cereals. The average productivity of crops varied little compared with the year 2008. Significantly higher yield was produced by sole oat crop, and that of wheat and triticale tended to decline, compared with pea yield. Positive significant role of intercrops was revealed. Mixed crops, except for pea/oats mixture were higher yielding than respective sole crops.

Table 4. Grain yields of pea and spring cereals grown as sole crops and in dual-component intercrops
Dotnuva, 2007–2009

Treatment	Crop component	2007	2008	2009	Average
		grain yield kg ha^{-1}			
Ps	pea	4231.7	2342,2	2235.7	2936.5
PWi	pea	722.2	559.3	369.8	550.4
	wheat	3769.2	1580.2	1854.4	2401.3
	total	4491.4	2139.5	2224.9	2951.9
PBi	pea	648.8	783.3	264.9	565.7
	barley	3302.1	1068.2	2183.1	2184.5
	total	3950.9	1851.5	2448.0	2750.1
POi	pea	634.2	514.3	187.0	445.2
	oats	2376.0	1864.9	2088.8	2109.9
	total	3010.2	2379.2	2276.8	2555.4
PTi	pea	837.8	414.3	310.1	520.7
	triticale	2729.7	1675.4	2238.6	2214.6
	total	3567.5	2089.7	2548.7	2735.3
Ws	wheat	4649.9	2209.9	2149.0	3002.9
Bs	barley	3303.6	2114.2	2332.1	2583.3
Os	oats	3241.3	2923.9	2525.7	2897.0
Ts	triticale	3773.3	2341.4	2038.9	2717.9
LSD_{05}		373.72	565.77	275.36	743.12

Note. Explanations of abbreviations under Table 3.

Averaged data (2007–2009) suggest that according to productivity the dual-component intercrops were ranked in the following order: pea/wheat > pea/triticale, pea/barley > pea/oats.

The data from the Joniškėlis site show that in heavy loam *Cambisol* crop productivity was by on average 20.5% higher compared with that of crops grown in the Dotnuva site (Table 5). Clay soils have high capillary water capacity; therefore plants are not so readily affected by droughts (Tausojamoji žemdirbystė…, 2008). The rough structure of these soils was more favourable for cereals than for peas.

In 2007, uneven distribution of precipitation did not have any major negative effect on crop productivity. Best yielding were sole crops of oats and triticale and pea/wheat intercrops. In many cases, sole cereal crops were higher yielding than intercrops. Of all research years, peas yielded worst in 2008. More distinct symptoms of drought damage on plants were noted in the first ten-day period of June. The productivity of all sole cereal crops and pea/barley, pea/triticale and pea/oats intercrops was significantly higher than that of sole pea crop. The highest grain productivity was recorded for pea/oats intercrop, it outyielded sole oat crop. With growing intercrops for the second time (2009 and 2010) in the crop rotation and changing competition environment cereal productivity was stabilised. The advantages of intercrops stood out more markedly. In the spring of 2009, due to the drought all crops emerged poorly and were the thinnest compared with other experimental periods. Excessive moisture content in June–July, which is the period when peas intensively grow aboveground mass, strengthened their competitive power against cereals, which resulted in higher pea productivity compared with cereals. The highest productivity like in 2008 was demonstrated by the pea/oats crop. All intercrops were higher yielding than the respective sole cereal crops and in many cases higher yielding than sole pea crop. Significantly lower grain productivity was exhibited by sole barley and triticale and pea/triticale intercrop, compared with sole pea crop. In 2010, similar trends of cereal productivity persisted. According to grain productivity, all intercrops surpassed respective sole cereal crops. Significantly higher productivity was recorded for pea/oats and pea/triticale crops. Averaged data (2007–2010) indicated that according to productivity intercrops were ranked in the following order: pea/oats > pea/wheat, pea/triticale > pea/barley.

The findings of research done in Perloja suggested that average cereal productivity was by 45.6% lower than in Dotnuva and by 54.8% lower than in Joniškėlis (Table 6). This resulted from the low productivity of those sites' soils: limited organic matter and nutrient content, high water permeability and acid reaction (Žėkaitė, 2010). In the less favoured farming areas better yielding were crops less sensitive to soil and environmental conditions. In the initial years of the experiment 2007 and 2008, all intercrops produced a yield increase compared with cereals. Pea/oats mixture yielded best. In later years (2009 and 2010) due to contrasting weather conditions, the data were less consistent. High yielding were sole oats and triticale crops, however, the productivity of their mixtures with peas was lower. In both years, there was evident advantage of pea/barley mixture over sole barley crop. Averaged data (2007–2010) suggest that according to productivity mixed crops were ranked in the following order: pea/oats > pea/wheat, pea/triticale > pea/barley.

Table 5. Grain yields of pea and spring cereals grown as sole crops and in dual-component intercrops
Joniškėlis, 2007–2010

Treatment	Crop component	2007	2008	2009	2010	Average
		grain yield kg ha^{-1}				
Ps	pea	3843.3	1957.5	2921.0	2864.6	2896.6
PWi	pea	1041.0	376.7	951.9	811.6	795.3
	wheat	3442.4	2020.0	2144.4	2285.9	2473.2
	total	4483.3	2396.7	3096.4	3097.6	3268.5
PBi	pea	391.4	376.7	776.2	1051.6	649.0
	barley	3375.3	2306.7	2027.6	1836.0	2386.4
	total	3766.7	2683.3	2803.8	2887.6	3035.4
POi	pea	217.8	376.7	576.1	561.1	432.9
	oats	4152.1	4096.7	2881.9	4219.2	3837.5
	total	4369.9	4473.3	3458.0	4780.4	4270.4
PTi	pea	973.5	966.7	1797.5	1225.4	1240,8
	triticale	2783.2	1960.0	710.4	2548.7	2000.6
	total	3756.7	2926.7	2507.9	3774.1	3241.4
Ws	wheat	3770.0	3626.7	3085.8	3069.0	3387.9
Bs	barley	4230.0	3086.7	2468.6	2197.8	2995.8
Os	oats	4686.7	3903.3	3127.3	4103.1	3955.1
Ts	triticale	4506.7	2976.7	2126.5	3272.1	3220.5
LSD_{05}		844.71	678.33	386.45	318.16	611.8

Note. Explanations of abbreviations under Table 3.

Table 6. Grain yields of pea and spring cereals grown as sole crops and in dual-component intercrops
Perloja, 2007–2010

Treatment	Crop component	2007	2008	2009	2010	Average
		grain yield kg ha^{-1}				
Ps	pea	748.1	2000.0	1570.0	780.0	1274.5
PWi	pea	356.8	572.3	310.3	160.0	349.9
	wheat	933.2	1287.7	1629.7	950.0	1200.2
	total	1350.0	1860.0	1940.0	1110.0	1550.0
PBi	pea	465.7	483.4	331.7	250.0	382.7
	barley	554.3	1186.6	1178.3	390.0	827.3
	total	1020.0	1670.0	1510.0	640.0	1210.0
POi	pea	310.0	418.3	354.0	290.0	343.1
	oats	1309.1	2031.7	1760.2	1560.0	1665.3
	total	1619.1	2450.0	2114.2	1850.0	2008.3
PTi	pea	249.1	422.2	375.7	170.0	304.3
	triticale	1170.9	1247.8	1707.3	890.0	1254.0
	total	1420.0	1670.0	1980.0	1060.0	1558.3
Ws	wheat	1370.0	1680.0	1980.0	770.0	1450.0
Bs	barley	720.0	1320.0	1380.0	490.0	977.5
Os	oats	1430.0	1570.0	2460.0	2160.0	1905.0
Ts	triticale	1270.0	1610.0	2330.0	1680.0	1722.5
LSD_{05}		148.01	291.63	267.42	203.51	414.50

Note. Explanations of abbreviations under Table 3.

In dual-component intercrops with increasing productive density of cereals and their share in the yield the total yield of the intercrops increased in Dotnuva (r = 0.650, P < 0.05; r = 0.969, P < 0.01, respectively), in Joniškėlis (r = 0.576, P < 0.05; r = 0.916, P < 0.01, respectively) and in Perloja (r = 0.701, P < 0.01; r = 0.942, P < 0.01, respectively). In heavy loam *Cambisol*, with increasing number of peas (from 15–57 plants m^{-2}) in the dual-component intercrops, both cereal share in the yield and total yield declined (r = −0.721, P < 0.01; r = −0.668, P < 0.01, respectively). Research done in other regions (Dotnuva, Perloja) showed that the effect of pea density (or share in the yield) on the total productivity of dual-component intercrops was insignificant. This might have been determined by lower pea density variation range.

Statistical analysis indicated that the yield of pea/oats intercrop correlated with the share of oats yield (r = 0.991, P < 0.01) ranging from 1309.1 to 4219.2 kg ha^{-1}. The productivity of pea/barley intercrop correlated with barley productivity (variation range – 390.0–3375.3 kg ha^{-1}; r = 0.971, P < 0.01) and its density (variation range 74–357 plants m^{-2}; r = 0.659, P < 0.05). Whereas the productivity of peas grown in mixed crop with wheat or triticale correlated with both components of the intercrop. With increasing pea productivity in intercrop from 160.0 to 1041.0 kg ha^{-1}, and that of wheat from 933.2 to 3769.2 kg ha^{-1}, the total yield increased statistically significant (r = 0.825, P < 0.01 and r = 0.984, P < 0.01, respectively). The correlation of yield indicators of pea/triticale mixture (productivity variation range for peas – 170.0–1797.5 kg ha^{-1}, triticale – 890.0–2783.2 kg ha^{-1}) was slightly weaker (r = 0.637, P < 0.05 and r = 0.842, P < 0.01, respectively).

Intensity of competition. Competition between plants is one of the many ecological processes that form plant community composition, variation dynamics and productivity. Various indexes are used to express it, which enable establishment of intensity and effect of competition. Aggressivity (A) and competition rate (CR) indicators are most often used to determine intensity of competition (Weigelt, Jolliffe, 2003). Agressivity of cereal (Ac) is presented in Table 7. If aggressivity value is higher than 0 the species in the crop dominates, if this value is lower than 0 the species is being chocked (Willey, Rao, 1980).

Aggressivity indicator of cereals in intercrops depended not only on cereal species but also on soil and weather conditions. In productive soils, Dotnuva (2007, 2008) and Joniškėlis (2007, 2010) of all spring cereals oats dominated in dual-component intercrops. Peas were least chocked by barley in Dotnuva (2008, 2009) and triticale (2007, 2009, 2010) and wheat (2008, 2010) than in Joniškėlis. In less productive soils (Perloja) Ac indicator was not stable and markedly varied between the plant species. Due to the limited resources, plants respond to the weather conditions more sensitively and the winners are those plants that grow in more favourable conditions. Statistical analysis showed that under the conditions of various soils, cereal aggressivity in the pea/wheat, pea/oats and pea/triticale intercrops depended on pea density (20–52, 15–64 and 20–57 stems m^{-2} respectively) (r = 0.726, $P < 0.05$; r = 0.713, $P < 0.05$; r = 0.669, $P < 0.05$, respectively).

Table 7. Cereal aggressivity (Ac) and competition rate (CRc) in organically grown dual-component annual intercrops

Treatment	Year	Dotnuva		Joniškėlis		Perloja	
		Ac	CRc	Ac	CRc	Ac	CRc
PWi	2007	1.06	4.75	0.56	3.37	1.16	1.43
	2008	0.80	2.99	0.40	2.89	1.27	2.68
	2009	1.10	5.22	1.09	2.13	0.73	4.16
	2010	–	–	0.37	2.63	1.35	6.01
PBi	2007	1.09	6.52	0.96	7.84	1.48	1.24
	2008	0.20	1.51	0.91	3.88	0.73	3.72
	2009	0.92	7.90	1.50	3.09	0.79	4.04
	2010	–	–	0.57	2.28	0.61	2.48
POi	2007	1.25	4.89	1.22	15.63	0.20	2.21
	2008	1.17	2.90	1.15	5.45	1.49	6.19
	2009	1.41	9.89	1.26	4.67	0.53	3.17
	2010	–	–	0.85	5.25	−0.16	1.94
PTi	2007	0.78	3.65	0.38	2.44	0.91	2.77
	2008	0.70	4.05	1.52	1.33	0.66	3.67
	2009	1.99	7.92	−0.17	0.54	0.87	3.06
	2010	–	–	0.26	1.82	0.36	2.43

Note. Explanations of abbreviations under Table 3.

In 2009, the year of excessive moisture, in Dotnuva and Joniškėlis, the highest Ac value was established (except pea/triticale intercrops) and cereal yield accounted for the largest share in the intercrop's productivity. The droughty year 2008 (Dotnuva) was less favourable for cereals, which resulted in the lowest cereal yield and less severe competition for peas. The lowest aggressivity of cereals and the highest competitive ability of peas were determined in 2010 in Joniškėlis and Perloja. Negative aggressivity values of cereals were established only in those cases when due to the weather conditions it was impossible to achieve the target plant density and grain yield (Joniškėlis pea/triticale, 2009 and Perloja pea/oats, 2010). Literature sources suggest that peas produce more above ground mass in the second half of the growing season, unlike cereals (Andersen et al., 2007 a) that take the dominant position already in the initial growth stages. In intercrops, at early growth stages it is possible to reduce cereal competitiveness by increasing the number of leguminous plants and their share in intercrops, as well as by shifting sowing time and methods (Hauggard-Nielsen et al., 2009) and proper choice of species and cultivars.

The competitive ratio is an important tool to know the degree with which one crop competes with the other. Willey and Rao (1980) reported that CR gives a better measure of competitive ability of the crops and can prove a better index as compared with aggressivity. The highest and stable cereal competition rate (CRc) was established in Dotnuva site (in pea/wheat and pea/triticale intercrop). The lowest competition rate as well as aggressivity index were exhibited in the year 2008 (except pea/triticale), which was less favourable for cereal growth; however, the highest competition rate was noted in 2009, which was less favourable for peas. The most consistent variation of this indicator was observed in Joniškėlis: the highest CRc ratio was recorded for oats in the pea/oats intercrop, while the lowest ratio was established for triticale in pea/triticale intercrop. In Joniškėlis, the highest CRc was determined in 2007. In Dotnuva and Joniškėlis, the relationship between pea productivity in the intercrops and CRc was inverse: with increasing CRc, pea productivity declined (r = −0.762, $P < 0.01$; r = −0.675, $P < 0.01$, respectively). Under the conditions of various soils this relationship was more distinct in the pea/triticale intercrop (r = −0.602, $P < 0.05$). In the pea/barley intercrop, with increasing number of pea stems (20–55 stems m^{-2}) the CRc declined (r = −0.697, $P < 0.01$). Interspecific competition improves the growth of the dominant species, nutrient uptake, productivity at the expense of the other species growing in the intercrop (Zhang, Li, 2003).

Effect of competition. Relative yield (RY) value defines the ratio between the yield of crops grown in an intercrop and the yield of the same crops grown as a sole crop (Weigelt, Jolliffe, 2003). Cereals yielded best in intercrops in Dotnuva, where relative yield value of cereals (RYc) amounted to 0.51–1.10 (Fig.). This ratio was the highest in 2007 and 2009 and differed little between the different intercrops. Peas were strongly outcompeted in intercrops, therefore their yield compared with that of sole pea crop was considerably lower, relative yield (RYp) value amounted to 0.12–0.33. In the dry year 2008, which was least favourable for cereals, this value was the highest (0.18–0.33). The highest RYp of peas was in intercrops with wheat (2007, 2008, 2009), with triticale (2007, 2009) and with barley (2008). Relative yield total (RYT) value stood out more distinctly (0.91–1.24) in 2009, the year with excessive moisture. The highest and stable (in 2007 and 2009 years it was >1.0) RYT value was established for barley intercropped with peas, while the lowest relative yield total value was recorded for pea/oats (0.86–0.91). When RYT >1 there is an intercropping advantage in terms of improved use of environmental resources for plant growth (Weigelt, Jolliffe, 2003). In Joniškėlis, the RYc value of intercropped cereals was 0.33–1.05, of peas (RYp) – 0.06–0.62. When intercrops had been grown in the crop rotation for the second time (2009 and 2010), relative yields of cereals and peas became more stable and RYp of peas increased. The highest relative yield of peas was produced when they had been intercropped with triticale (2007, 2008, 2009, and 2010) and wheat (2007, 2009).

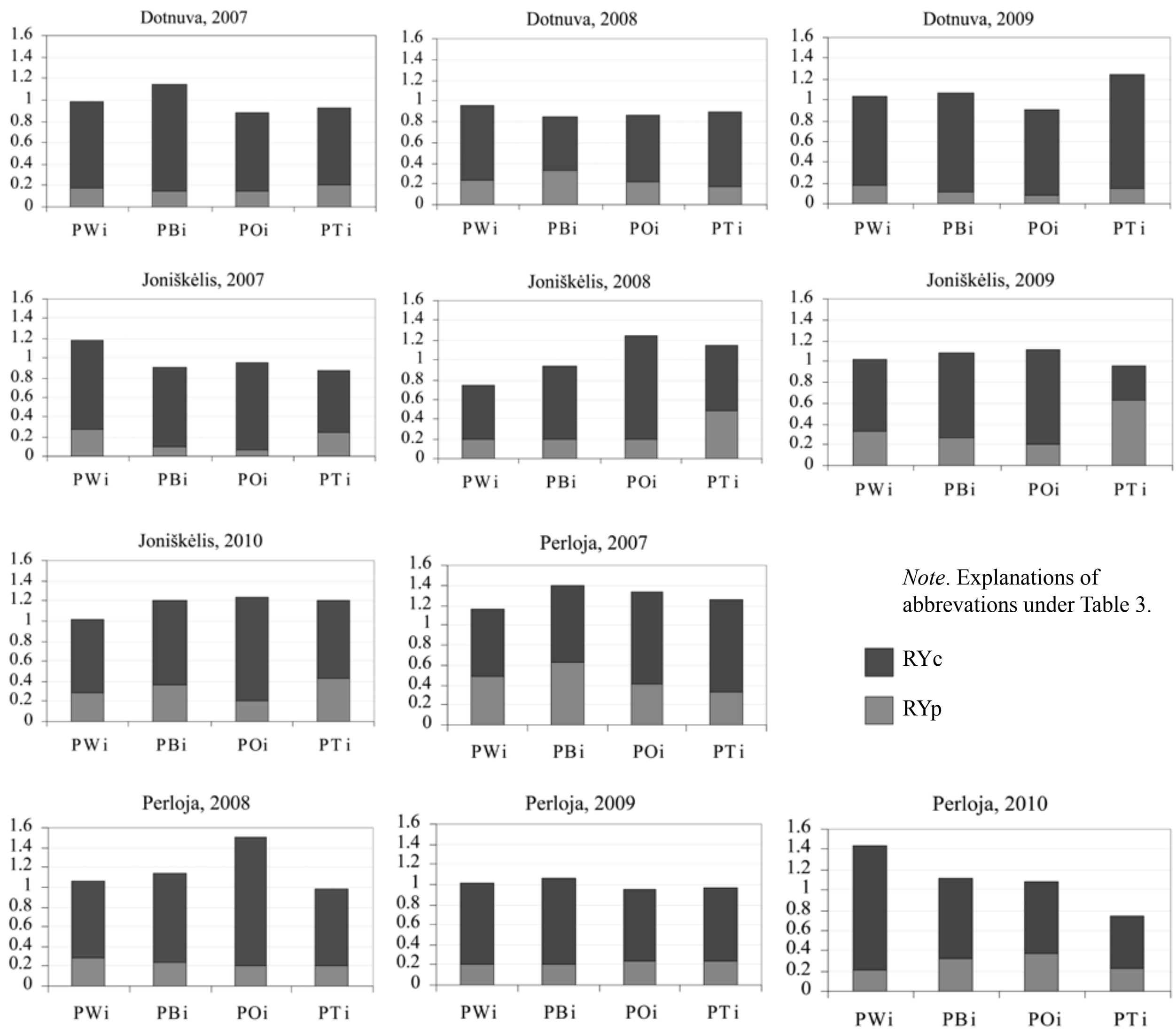

Figure. Cereals and legumes relative yield (RY) and relative yield total (RYT) of the intercrops on a grain yield basis

In Joniškėlis, the RYT value demonstrated a more marked positive effect of the intercrops compared with the findings from Dotnuva site. Comparison of intercropped cereals evidenced oats to yield best when intercropped with peas. The RYT was higher than 1.0 of pea/oats (2008, 2009, and 2010), pea/wheat (2007, 2009, and 2010) and pea/barley (2009, 2010), pea/triticale (2008, 2010). The highest RYT was in 2009 and 2010.

On low productivity soils (Perloja), the advantage of intercropped pea/cereal stands over sole crops was even more evident. They were distinguished by higher RYc value, of cereals – 0.53–1.29 and peas – 0.20–0.62, compared with the other experimental sites. The RYc value of individual cereal species varied in the intercrops and depended on the year. The RYT value of pea/wheat and pea/barley was higher than 1.0 for 4 years and that of pea/oats for 3 years out of 4. In Joniškėlis and Perloja, the RYT value was significantly determined by increased RYc of cereals ($r = 0.543$, $P < 0.05$; $r = 0.759$, $P < 0.01$, respectively). No significant relationships were established in the Dotnuva site.

Conclusions

1. The weather and soil conditions during plant emerge determined the optimal productive density and created a basis for competition between the intercrop components. Comparison of various mixtures showed that the highest stand densities were in pea/wheat (Dotnuva, Joniškėlis), pea/barley (Dotnuva) and in pea/oats (Joniškėlis, Perloja) dual-component intercrops. The share of pea plants in the total plant productive density structure was similar and made up 8.2–24.4% (32–64 plants m^{-2}) in Dotnuva, 5.3–24.6% (15–57 plants m^{-2}) in Joniškėlis, and 7.1–30.2% (20–55 plants m^{-2}) in Perloja.

2. Averaged data (2007–2010) indicated that according to productivity intercrops can be ranked in the following order: pea/oats > pea/wheat, pea/triticale > pea/barley (Joniškėlis, Perloja) and pea/wheat > pea/triticale, pea/barley > pea/oats (Dotnuva). Results obtained in the conditions of various soils showed that when peas were grown mixed with oats or barley, their productivity was directly correlated with cereals yield ($r = 0.991$, $P < 0.01$; $r = 0.971$, $P < 0.01$, respectively). Whereas the productivity of peas grown in mixed crop with wheat or triticale correlated with both components: yields of cereals ($r = 0.825$, $P < 0.01$ and $r = 0.984$, $P < 0.01$, respectively) and pea ($r = 0.637$, $P < 0.05$ and $r = 0.842$, $P < 0.01$, respectively) of the intercrop.

3. In the dual-component intercrops, due to higher aggressivity index and competition rate, spring cereals were dominant compared with peas. In productive soils (Dotnuva, Joniškėlis) of all spring cereals oats dominated in dual-component intercrops. In less productive soils (Perloja) aggressivity index was not stable and markedly varied between the plant species. Cereal aggressivity in the pea/wheat, pea/oats and pea/triticale intercrops depended on pea density (20–52, 15–64 and 20–57 stems m^{-2}, respectively) ($r = 0.726$, $P < 0.05$; $r = 0.713$, $P < 0.05$; $r = 0.669$, $P < 0.05$, respectively). During the main crop growing period, when the development rate of the intercropped plant species does not coincide, the weather conditions more favourable for one or another intercropped species can influence the degree of competition.

4. On a loamy *Cambisol* (Dotnuva) intercropping yield advantage (relative yield total (RYT) > 1.0) over the sole crops was of pea/barley (2007, 2009), pea/wheat and pea/triticale (2009) stands. In clay lom *Cambisol* (Joniškėlis) the RYT was higher than 1.0 of pea/oats (2008, 2009, and 2010), pea/wheat (2007, 2009, and 2010), pea/barley (2009, 2010) and pea/triticale (2008, 2010). Low productivity sandy loam *Luvisol* (Perloja) were distinguished by higher relative yield (RY) value, of cereals (RYc) – 0.53–1.29 and peas (RYp) – 0.20–0.62, compared with the other experimental sites. The RYT value of pea/wheat and pea/barley was higher than 1.0 for 4 years and that of pea/oats for 3 years out of 4. The advantages are even more distinct under application of organic cropping practices for a longer period of time.

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References

Andersen M. K., Hauggaard-Nielsen H., Høgh-Jensen H., Jensen E. S. Competition for and utilisation of sulfur in sole and intercrops of pea and barley // Nutrient Cycling in Agroecosystem. – 2007 (a), vol. 77, No. 2, p. 143–153

Andersen M. K., Hauggaard-Nielsen H., Weiner J., Jensen E. S. Competitive dynamics in two-component intercrops // Journal of Applied Ecology. – 2007 (b), vol. 44, p. 545–551

Anil L., Park J., Phipps R. H., Miller F. A. Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK // Grass and Forage Science. – 1998, vol. 53, p. 301–317

Brisson N., Bussiere F., Ozier-Lafontaine H. et al. Adaptation of the crop model STICS to intercropping. Teoretical basis and parametrisation // Agronomie. – 2004, vol. 24, p. 409–421

Corre-Hellou G., Fustec J., Crozat Y. Effect of root depth penetration on soil nitrogen competitive interactions and dry matter production in pea-barley intercrops given different soil nitrogen supplies // Plant and Soil. – 2006, vol. 282, No. 1–2, p. 195–208

Hauggard-Nielsen H., Gooding M., Ambus P. et al. Pea-barley intercropping for efficient symbiotic N_2-fixation, soil N acquisition and use of other nutrients in European organic cropping systems // Field Crop Research. – 2009, vol. 113, iss. 1, p. 67–71

Hauggaard-Nielsen H., Jensen E. S. Facilitative root interactions in intercrops // Plant and Soil. – 2005, vol. 274, p. 237–250

Hauggaard-Nielsen H., Jørnsgaard B., Kinane J., Jensen E. S. Grain legume-cereal intercropping: the practical application of diversity, competition and facilitation in arable and organic cropping systems // Renewable Agriculture and Food Systems. – 2008, vol. 23, p. 3–12

Li L., Sun J., Zhang F. et al. Root distribution and interactions between intercropped species // Oecologia. – 2006, vol. 147, No. 2, p. 280–290

Malezieux E., Crozat Y., Dupraz C. et al. Mixing plant species in cropping systems: concepts, tools and models // Agronomy for Sustainable Development. – 2009, vol. 29, p. 43–62

Neumann A., Schmidke K., Rauber R. Effects of crop density and tillage system on grain yield and N uptake from soil and atmosphere of sole intercropped pea and oat // Field Crops Research. – 2007, vol. 100, p. 285–293

Ofori F., Stern W. R. Cereal-legume intercropping systems // Advances in Agronomy. – 1987, vol. 41, p. 41–90

Song Y. N., Zhang F. S., Marschner P. et al. Effect of intercropping on crop yield and chemical and microbiological properties in rhizosphere of wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and faba bean (*Vicia faba* L.) // Biology and Fertility of Soils. – 2007, vol. 43, p. 565–574

Subkowicz P., Tendziagolska E. Competition and productivity in mixture of oats and wheat // Journal of Agronomy and Crop Science. – 2005, vol. 191, iss. 5, p. 377–385

Szumigalski A., van Acker R. C. Land equivalent ratios, light interception, and water use in annual intercrops in the presence or absence of in-crop herbicides // Agronomy Journal. – 2008, vol. 100, iss. 4, p. 1145–1153

Šarūnaitė L., Deveikytė I., Kadžiulienė Ž. Intercropping spring wheat with grain legume for increased production in an organic crop rotation // Žemdirbystė-Agriculture. – 2010, vol. 97, No. 3, p. 51–58

Tarakanovas P., Raudonius S. Agronominių tyrimų duomenų statistinė analizė taikant kompiuterines programas *Anova*, *Stat*, *Split-Plot* iš paketo *Selekcija* ir *Irristat*. – Akademija, Kauno r., 2003, 58 p. (in Lithuanian)

Tausojamoji žemdirbystė našiuose dirvožemiuose: monografija /sudaryt. S. Maikštėnienė [Sustainable agriculture on productive soils: monograph (summary)]. – Akademija, Kėdainių r., 2008, 344 p. (in Lithuanian)

Trenbath B. R. Biomass productivity of mixture // Advances in Agronomy. – 1974, vol. 26, p. 177–209

Urbatzka P., Graβ R., Haase T. et al. Fate of legume-derived nitrogen in monocultures and mixtures with cereals // Agriculture, Ecosystems and Environment. – 2009, vol. 132, p. 116–125
Weigelt A., Jolliffe P. Indices of competition // Journal of Ecology. – 2003, vol. 91, p. 707–720
Willey R. W. Intercropping – its importance and research needs. Part 1. Competition and yield advantages // Field Crop Abstract. – 1979, vol. 32, p. 1–10
Willey R. W., Rao M. R. A competitive ratio for quantifying competition between intercrops // Experimental Agriculture. – 1980, vol. 16, p. 117–125
Zhang F., Li L. Using competitive and facilitative interactions in intercropping systems enhances crop productivity and nutrient-use efficiency // Plant and Soil. – 2003, vol. 248, p. 305–312
Žėkaitė V. Weed competition in the cereal mixture and monocrops differing in competitive power (summary) // Vagos. – 2010, No. 88 (41), p. 44–49 (in Lithuanian)
Шпаар Д. (ред.), Эльлмер Ф., Постников А. и др. Зернобобовые культуры. – 2000, Минск, 264 с. (in Russian)

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Ekologiškai augintų žirnių ir vasarinių miglinių javų mišrių pasėlių konkurencingumas bei produktyvumas

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Santrauka

Augalų auginimas mišriuose pasėliuose žemės ūkio praktikoje suteikia potencialių privalumų naudojant vietinius išteklius, mažinant gamybos sąnaudas ir didinant agrosistemų tvarumą. Lauko bandymai vykdyti 2007–2010 m. Lietuvos žemdirbystės institute įvairiuose dirvožemiuose: giliau karbonatingame sekliai glėjiškame vidutinio priemolio rudžemyje (RDg8-k2), *Endocalcari-Epihypogleyic Cambisol* (*CMg-p-w-can*) Dotnuvoje, sekliai karbonatingame giliau glėjiškame sunkaus priemolio rudžemyje (RDg4-k2), *Endocalcari-Endohypogleyic Cambisol* (*CMg-n-w-can*) Joniškėlyje bei paprastajame pajaurėjusiame priesmėlio išplautžemyje (IDe-p), *Hapli-Albic Luvisol* (*LVe-ha*) Perlojoje, siekiant įvertinti mišrių pasėlių derlingumo pranašumą skirtingomis dirvožemio, klimato ir konkurencingumo sąlygomis, taikant ekologinės žemdirbystės sistemą. Sėjamasis žirnis (*Pisum sativum* L. (Partim)) bei vasarinis kvietys (*Triticum aestivum* L. emend. Fiori et Paol.), vasarinis miežis (*Hordeum vulgare* L.), sėjamoji aviža (*Avena sativa* L.) bei vasarinis kvietrugis (× *Triticosecale* Wittm.) auginti mišriuose pasėliuose (pupinių bei miglinių javų sėklų santykis 50:50) ir gryni. Tyrimų rezultatai parodė, kad meteorologinės ir dirvožemio sąlygos augalų dygimo metu lėmė optimalų produktyvųjį tankumą ir sudarė pagrindą konkurencijai tarp pasėlio komponentų. Mišriuose pasėliuose dėl didesnio agresyvumo rodiklio ir konkurencingumo santykio vasariniai migliniai javai buvo dominuojantys, palyginti su žirniais. Esant įvairiems dirvožemiams, didėjant žirnių tankumui miglinių javų agresyvumas didėjo. Derlinguose dirvožemiuose (Dotnuvoje, Joniškėlyje) mišriuose pasėliuose iš vasarinių miglinių javų dažniausiai dominavo avižos, mažiau derlinguose (Perlojoje) dominuojančios rūšys įvairavo. Esant įvairiems dirvožemiams, žirnius auginant mišinyje su avižomis arba miežiais, jų derlingumą tiesiogiai lėmė tik miglinių javų, o žirnių, augintų mišriame pasėlyje su kviečiais arba kvietrugiais, – abiejų mišinio komponentų derlius. Mišrūs pasėliai pagal mažėjantį derlingumą pasiskirstė taip: žirnių ir avižų mišinys > žirnių ir kviečių mišinys, žirnių ir kvietrugių mišinys > žirnių ir miežių mišinys. Vidutinio sunkumo priemolio dirvožemyje (Dotnuvoje) šie dėsningumai buvo mažiau nuoseklūs, todėl mišrių pasėlių derliaus pranašumas prieš vienarūšių, kai suminis santykinis derlius (RYT) > 1,0, buvo nežymus, išskyrus žirnių ir miežių mišinį. Joniškėlyje ir Perlojoje RYT atskleidė didesnį ir stabilesnį mišrių pasėlių (išskyrus žirnių ir kvietrugių pasėlio) derliaus pranašumą. Ekologinę žemdirbystę taikant ilgesnį laiką, mišrių pasėlių efektyvumas dar labiau išryškėjo.

Reikšminiai žodžiai: mišrūs pasėliai, *Pisum sativum*, *Poaceae*, derlius, konkurencijos indeksai.