Potential of Legume-Cereal Intercropping for Increasing Yields and Yield Stability for Self-Sufficiency with Animal Fodder in Organic Farming

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Abstract

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Intercropping of grain legumes and cereals is a promising theme in organic farming for its potential for increasing and stabilizing yields, reducing weed pressure and sustaining plant health. On animal husbandry farms, pea-cereal mixtures may be an interesting crop harvested for green fodder as well as for feed concentrates. Increasing self-sufficiency with fodder is in agreement with the principles of organic agriculture, and it reduces the risks related to the import of soy protein that may be admixed with GM soya. In 2008–2011, plot trials (PT) with intercropped peas and spring cereals (wheat, barley) were conducted. Varieties and pea-cereal combinations were examined to find suitable varieties for intercropping, and the best pea to cereal ratio in the seed intercrop (pea to cereal ratios 80:20, 60:40, 40:60, 20:80). Results show that intercropping peas and spring cereals may be advantageous compared to monocultures. Pea-cereal intercrops produce high yields of green matter and concentrates especially when intercropped at the pea to cereal ratio of 60:40 and 40:60. In 2009, on five certified organic farms, controlled field trials (FT) were conducted with field pea (leaf type), spring barley and spring wheat in monocultures and intercrops (pea to cereal ratio 60:40). Forage yields were evaluated at pea growth phases BBCH-scale 79 and 83. Fresh yields of monocultures and intercrops were evaluated at grain harvest.

Keywords: barley; field trials; intercrop; organic agriculture; pea; wheat

Intercropping can be defined as the growth of two or more crops in the same space at the same time (Andrews & Kassam 1976). This technology may enable the intensification of a farming system, leading to increased general productivity and biodiversity in the intercropped fields as compared to monocultures of the individual intercropped species (Vandermeer 1989). In low-input and self-sufficient animal husbandry systems, the intercropping of cereals and legumes is an interesting method for producing high-quality roughage and concentrates. Due to the restricted use of mineral fertilisers, organic farming systems especially benefit from legume nitrogen (N) fixation. Further, intercropping can be advantageous for controlling plant diseases such as common bacterial blight and fungal rust (Boudreau & Mundt 1992; Fininsa 1996). In organic field trials, a disease reduction has been observed in intercrops of barley (*Hordeum vulgare* L.) with pea (*Pisum sativum* L.), faba bean (*Vicia faba* L.) and lupin (*Lupinus* sp.). Intercropping pea with barley reduced the level of ascochyta blight (*Mycosphaerella pinodes*) in the peas, and the levels of net blotch (*Pyrenophora teres*), brown rust (*Puccinia recondita*) and powdery mildew (*Blumeria graminis* f.sp. *hordei*) were reduced on the barley plants in every intercrop as compared to the barley monoculture (Kinane & Lyngkjaer 2002). The plant diversity in an intercrop generates the basis for a more diverse development of beneficial predators limiting pest propagation (Hauggaard-Nielsen & Andersen 2000). As pesticides are not allowed in organic farming, the weed, disease and pest-reducing effects make intercropping of cereals and legumes especially interesting in such farming systems.

In the past, legume-cereal intercropping (LCI) was a common part of the crop rotations on arable land in the Czech Republic (CR) (Šarapatka *et al.* 2009). Currently, however, LCI is not used to a great extent in the CR. This is generally due to agricultural intensification, when the benefits of LCI are outcompeted by cheap chemical inputs of fertilizers, pesticides and imported concentrates commonly based on cheap soy proteins. Organic farming systems are based on four basic principles of health, ecology, fairness and care (IFOAM 2007). The utilisation of local resources, and closed nutrient cycles aiming at self-sufficiency at a farm and district level, are logical consequences of the ecology principle. Hence, organic farmers aim at an increased production of protein and cereal crops to increase their self-sufficiency with animal fodder.

To support the adaptation of LCI in organic farming systems, it is necessary to test relevant intercrops under organic growing conditions. Further, it is important to record practical experience with LCI at the farm level with the machinery normally used. It is also important to find suitable combinations of crops and varieties, and their optimal ratio in the seed mixture. The main objective of this paper is to present results of growing monocultures and intercrops of peas and spring cereals under Czech conditions. This may support an expansion of legume cereal intercropping, to ensure a larger diversity in the crop rotations on arable land in the CR, especially in organic farming systems. Thereby, it may help Czech organic farmers to become more self-sufficient with fodder for their animals. Yield levels of green matter and grains will be presented and discussed.

MATERIAL AND METHODS

Field experiments in plot trials. In 2008–2011, field experiments with plot trials (PT) were carried out in the experimental fields of Agritec, Ltd. in Rapotín (RA) in Šumperk District in Central Moravia. In 2009–2011, the same experiment was carried out under certified organic conditions on two locations in the area of Ekofarma Čechovi in Postřelmov (PO-1 and PO-2), close to Rapotín. In the years 2008–2011, a total of 9 trials were carried out (Table 1). The experimental design was a randomized block design.

The plot trial in RA (PT-RA) and PO (PT-PO) had three replications and 24 treatments (Table 2). The treatments were monocultures and intercrops of peas (varieties Bohatyr, leafy and Terno, semi-leafless) and cereals (spring wheat variety Sirael, spring barley variety Pribina). Bohatyr was selected because leafy varieties produce more green matter, and suppress weeds more efficiently due to shading. Pribina and Sirael were selected because they are short stemmed with good lodging resistance, which is especially important when the cereals were combined with Bohatyr, which climbs heavily on the cereals and easily causes lodging. Terno was selected to test a field pea variety that might be less susceptible to lodging. Terno is a commonly used field pea variety in the CR. The seed intercrops were pea to cereal ratios of 80:20, 60:40, 40:60 and 20:80 (Table 2) in a replacement design. The size of each experimental plot was 13 m^2, and the plot harvest area was 10 m^2.

In the plot trial, grain yields were recorded by an experimental combiner. All grains from the harvest plots were collected, and weighed after drying with cold air circulation. Fresh yields were calculated as the amount of peas, cereals and impurities. The impurities were dominated by parts of weed plants. Net yields were calculated as grain weight after removal of impurities. The mixtures were fractionated into peas and cereals.

To determine land use efficiency, the land equivalent ratio (LER) was measured (Mead 1990). LER values were calculated as

$$LER = (Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb}) = L_a + L_b$$

where:
Y – yield (kg/ha)
Y_{ab} – yield of crop A when intercropped with crop B
Y_{aa} – yield of crop A in monoculture
Y_{ba} – yield of crop B when intercropped with crop A
Y_{bb} – yield of crop B in monoculture
L_a, L_b – partial LERs of crops A and B

The LER is the sum of the fractions of the intercropped yields divided by the monoculture yields.

Table 1. Plot trial – site information and weather data (1961–1990)

Site	Position	Altitude (m a.s.l.)	Temperature (°C)	Precipitation (mm/year)
RA	49°59'37''N, 17°1'33''E	350		
PO-1	49°54'55''N, 16°53'56''E	280	7.45	693.0
PO-2	49°54'56''N, 16°52'31''E	330		

RA – Rapotín; PO-1, PO-2 – Postřelmov

Table 2. Plot trials – composition of monoculture and intercrop treatments of peas and cereals

Treatment	Abbreviation	Crop 1	Variety	Ratio (%)	Crop 2	Variety	Ratio (%)
1	B100	pea	Bohatyr	100	wheat	Sirael	0
2	B20S80			80			20
3	B40S60			60			40
4	B60S40			40			60
5	B80S20			20			80
6	S100			0			100
7	T100	pea	Terno	100	wheat	Sirael	0
8	T20S80			80			20
9	T40S60			60			40
10	T60S40			40			60
11	T80S20			20			80
12	S100			0			100
13	B100	pea	Bohatyr	100	barley	Pribina	0
14	B20P80			80			20
15	B40P60			60			40
16	B60P40			40			60
17	B80P20			20			80
18	P100			0			100
19	T100	pea	Terno	100	barley	Pribina	0
20	T20P80			80			20
21	T40P60			60			40
22	T60P40			40			60
23	T80P20			20			80
24	P100			0			100

The LER value shows the area under intercropping needed to give equal amounts of yield as the monoculture crops, at the same management level (Vandermeer 1989). A LER value above 1 shows that intercropping is more efficient than monocultures of the crops that constitute the intercrop mixture. Net yields of fractionated peas and cereals were used to calculate LER.

Field trials on organic farms. Field trials (FT) with intercrops and monocultures of field pea and spring cereals were carried out on five certified organic farms with various production systems (Tables 3 and 4) in 2009. Selected varieties were field pea Bohatyr (leaf type), spring barley Pribina and spring wheat Sirael. These varieties were selected for the reasons described above. A pea to cereal ratio of 60:40 (replacement design) was chosen because this ratio was expected to give the highest yields of green matter (Huňady, unpublished results). Green matter yields were the most important outputs of the farm level trials, and grain yields were recorded only on three out of the five farms included.

On each farm, 2.5 ha of suitable land were used for the experiment and divided into five sub-plots of 0.5 ha where the above-mentioned varieties were grown as monocultures and pea-cereal intercrops (60:40). On Postřelmov farm, the experimental field was divided into four blocks with different treatments of weed harrowing. On the other farms, the whole experimental field was weed harrowed once, at pea height 5 cm. Yield data from Postřelmov farm are only presented for the treatment with one harrowing at pea height 5 cm. Because the plot size used for comparing the five monoculture and intercrop treatments was still very large (0.625 ha), we do not expect this reduction in plot size to impact the results notably. Weed harrowing was conducted across seed rows (perpendicular to the direction of sowing).

In all farm trials, green matter yields were recorded twice, at pea green ripening (BBCH-scale 79, Meier 2001) and at early pea ripening (BBCH 83, 30% of pods ripe). The first sampling occurred from July 9 to July 23 and the second from July 23 to August 6. At each sampling, three samples of aboveground plant

Table 3. Field trials (FT) – information about location, climate and soil conditions on five certified organic test farms; temperature and precipitation data from the period (1961–1990), relevant for the municipality where the farm is located

Locality (farm)	Location (coordinates)	Altitude (m a.s.l.)	Temperature (°C)	Mean precipitation (mm/year)	Soil type
FT-MA (BEMAGRO, Inc.)	district Český Krumlov, region South Bohemia (48°41'22''N, 14°35'6''E)	690	7.0	624	Alumic Cambisol
FT-HL (AGROFYTO, Ltd.)	district Vsetín, region Zlín, Central Moravia (49°10'52''N, 18°3'40''E)	450	6.6	780	Dystric Cambisol
FT-CI (Farma Číhalín)	district Třebíč, region Vysočina, East Moravia (49°15'56''N, 15°47'53''E)	489	7.0	560	Haplic Stagnosol
FT-SA (Biofarma Sasov)	district Jihlava, region Vysočina, East Moravia (49°22'38''N, 15°36'8''E)	525	6.9	596	Dystric Cambisol
FT-PO main trial (Ekofarma Čechovi)	district Šumperk, region Olomouc, Central Moravia (49°54'51''N, 16°53'56''E)	280	7.5	693	Albo-gleyic Luvisol

MA – Malonty; HL – Horní Lideč; CI – Číhalín; SA – Sasov u Jihlavy; PO – Postřelmov

material were taken from each plot. Each of these samples was composed of two subsamples taken at two random harvest plots of 0.5 m^2, cut by hand with the help of metal frame. The samples were identified and weighed both in the field and at the laboratory. After weighing, the three samples were pooled and thoroughly mixed. A representative sample of 1.5 kg was taken and dried at 60°C for 24 h. This drying did not produce completely dry material, but stabilised hay samples with a water content of 8–11%.

Fresh grain yields were measured on three farms, FT-MA, FT-SA and FT-PO. Grain yields in kg/m^2 were measured by the farmers, using normal combiners, weighing the trailer and measuring the harvested area.

Table 4. Field trials – overview of production systems on the organic farms hosting the field experiment

Farm (locality)	Production system	Farm land (ha)	Arable land (ha)	Preceding crop exp. field	Manuring exp. field
BEMAGRO, Inc. (MA)	cash crops: rye, spelt, winter wheat animal production: beef cattle, dairy cows	2200	500	spelt	compost
AGROFYTO, Ltd. (HL)	cash crops: red clover and grasses for seed production fodder crops: feedstuff for dairy cows animal production: organic milk, dairy cows	855	163	winter triticale	not manured
Farma Číhalín (CI)	cash crops: rye and wheat, poppy animal production: suckler cows, beef cattle	85	60	mustard	compost
Biofarma Sasov (SA)	cash crops: potatoes, camelina, hemp, buckwheat fodder crops: legume-cereal intercrops (LCI) animal production: slaughter pigs, beef cattle Charolais	500	250	spring wheat	not manured
Ekofarma Čechovi (PO)	cash crops: spelt, wheat, barley, spelt for seed production and grass seeds fodder crops: LCI animal production: beef sheep	166	151	wheat	not manured

MA – Malonty; HL – Horní Lideč; CI – Číhalín; SA – Sasov u Jihlavy; PO – Postřelmov

The water concentration was not recorded. Samples of about 3 kg per treatment were dried with cold air circulation, and fractionated into cereals and peas. Shares of peas and cereals to calculate LER values (see below) are reported at a standard water content of 14%.

Statistical methods. The statistical significance of differences between treatments in yields of hay and grains was analysed by one-way analysis of variance (ANOVA). The significance of the treatment effect was assessed by Fisher LSD test and Dunnett's test, using the Statistica 12.0 software. The levels of significance are reported as $P < 0.05$.

RESULTS AND DISCUSSION

Field experiments in plot trials. In the trial plots, grain yields were recorded by experimental equipment. The weed regulation was more efficient. This helps to explain the generally much higher grain yields in the plot trial (Table 5 and 6) as compared to the farm level grain yields (Table 7).

Leafy pea variety Bohatyr and semi-leafless pea variety Terno. Wheat and barley. For the purposes of comparison of the grain yields of both intercropped pea varieties (Bohatyr, Terno) and both cereals (wheat, barley) the obtained net yields of all intercropped treatments were recalculated into the yields that would be obtained if the pea varieties and wheat or barley were sown as monocultures – in the amount corresponding to the pea to cereal ratio 100:0 (for pea) and 0:100 (for cereal).

The results show that the difference between the average recalculated grain yields of leafy variety Bohatýr (3.75 t/ha) and semi-leafless variety Terno (3.90 t/ha) was 4.0% and was not statistically significant (Figure 1). Also the difference between average LER values of both pea varieties was not statistically significant.

The lower yields of pea leafy variety Bohatyr can be attributed, among other things, to increased lodging of plants and subsequently to harvest losses.

The difference between the average recalculated yields of wheat (4.33 t/ha) and barley (3.81 t/ha) was

Table 5. Plot trials – net yields of grain (t/ha) of pea-cereal intercrops, 2008–2011

Treatment	Crop 1	Variety	Ratio (%)	Yield of pea	Crop 2	Variety	Ratio (%)	Yield of cereal	Yield in total
1	pea	Bohatyr	100	3.48	wheat	Sirael	0	0.00	3.48
2			80	2.88			20	1.11	3.99
3			60	2.25			40	1.92	4.17
4			40	1.62			60	2.54	4.16
5			20	0.82			80	3.16	3.98
6			0	0.00			100	3.57	3.57
7	pea	Bohatyr	100	3.55	barley	Pribina	0	0.00	3.55
8			80	2.60			20	1.03	3.62
9			60	1.97			40	1.75	3.71
10			40	1.57			60	2.11	3.67
11			20	0.81			80	2.41	3.21
12			0	0.00			100	2.69	2.69
13	pea	Terno	100	3.41	wheat	Sirael	0	0.00	3.41
14			80	2.72			20	0.79	3.50
15			60	2.17			40	1.74	3.91
16			40	1.63			60	2.40	4.03
17			20	0.93			80	3.07	4.01
18			0	0.00			100	3.70	3.70
19	pea	Terno	100	3.26	barley	Pribina	0	0.00	3.26
20			80	2.57			20	0.86	3.42
21			60	2.11			40	1.59	3.70
22			40	1.62			60	1.95	3.57
23			20	0.93			80	2.36	3.29
24			0	0.00			100	2.65	2.65

Table 6. Plot trials – LER (land equivalent ratio) of pea-cereal intercrops, 2008–2011

Treatment	Ratio (%)	Year				Mean
		2008	2009	2010	2011	2008–2011
Bohatyr-Sirael	80:20	1.57	0.98	1.13	1.09	1.13
	60:40	1.26	0.99	1.15	1.22	1.15
	40:60	1.16	1.05	1.13	1.21	1.14
	20:80	1.09	1.04	1.11	1.17	1.11
Bohatyr-Pribina	80:20	1.06	0.91	1.03	1.28	1.09
	60:40	1.06	0.97	1.22	1.35	1.19
	40:60	1.07	1.10	1.22	1.33	1.22
	20:80	1.00	1.02	1.23	1.15	1.13
Terno-Sirael	80:20	1.52	0.95	1.05	0.94	1.04
	60:40	1.39	1.02	1.11	1.11	1.12
	40:60	2.13	1.17	1.11	1.11	1.24
	20:80	1.24	1.12	1.14	1.10	1.13
Terno-Pribina	80:20	1.55	0.94	1.14	1.11	1.13
	60:40	1.35	1.11	1.28	1.32	1.26
	40:60	1.29	1.22	1.25	1.28	1.26
	20:80	1.43	1.20	1.22	1.20	1.23

13.7% and was statistically significant (Figure 1). In terms of yields, it was more advantageous to grow wheat than barley in pea-cereal intercrop.

The difference between average LER values of intercropped wheat (1.13) and barley (1.19) was also statistically significant but the LER of barley, on the contrary, was higher than the LER of wheat. This fact can be explained by the generally lower yields of barley compared to wheat. The differences between the yields of wheat and barley were very significant.

The recalculated yields of pea and cereal separately when intercropped at four different pea to cereal ratios (80:20, 60:40, 40:60, 20:80) were higher than the real yields of pea and cereal monocultures (100:0, 0:100). The difference in yields between the monoculture of Terno variety and the intercropped one was statistically significant. This indicates that intercropping may have a positive influence on yields of both pea and cereal when intercropped.

For the pea variety Bohatyr, some differences in performance were noted between the pea-wheat and pea-barley intercrops. The average net yield of pea-wheat intercrop for four years was 4.08 t/ha (Table 5). This is notably higher than for the pea-barley intercrop, which yielded 3.56 t/ha on average. There were no statistically significant differences between LER values (1.16 and 1.14) found (Table 6).

For the pea variety Terno, there were also notable differences between the pea-wheat (3.86 t/ha) and pea-barley (3.49 t/ha) intercrops (Table 5).

LER values must be interpreted with caution. In the plot trials, both positive and negative LER values

Table 7. Field trials (FT) – net yields of intercrop components and monocultures (t/ha), and shares (%) of peas and cereals in grain samples from three organic farms

Farm	Bohatyr – Sirael			Bohatyr – Pribina			Bohatyr	Sirael	Pribina
	pea	cereal	in total	pea	cereal	in total	pea	cereal	cereal
FT-PO	1.11	0.06	1.17	0.80	0.16	0.96	0.60	1.92	2.19
FT-SA	1.84	0.06	1.90	1.68	0.61	2.29	1.37	1.57	3.81
FT-MA	0.74	0.16	0.90	0.91	0.52	1.43	0.53	1.89	2.70
Average shares (t/ha)	1.23	0.09	1.32	1.13	0.43	1.56	0.83	1.79	2.90
Average shares (%)	92	8	100	72	28	100	100	100	100

PO – Postřelmov; SA – Sasov u Jihlavy; MA – Malonty

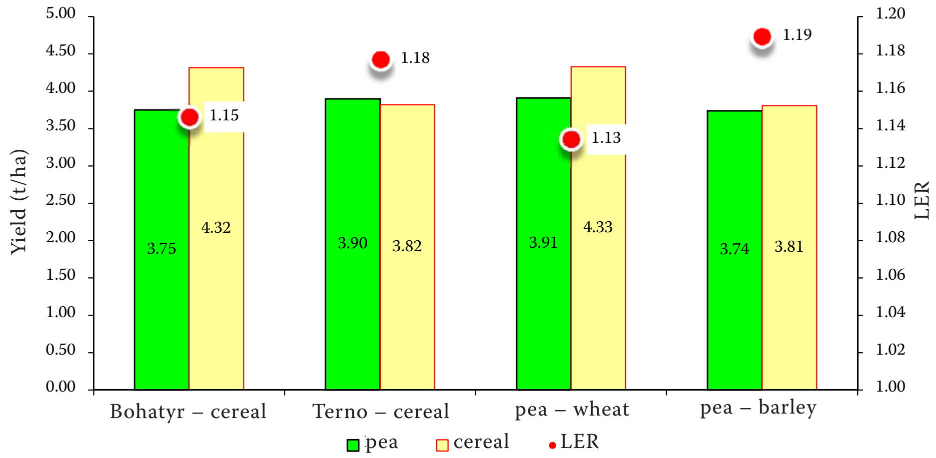

Figure 1. Plot trials (PT) – net average yields of grain (t/ha) of pea and cereal intercropped at four different pea to cereal ratios (80:20, 60:40, 40:60, 20:80), 2008–2011; yields were recalculated to the pea to cereal ratio of 100:0 (pea) and 0:100 (cereals)
LER – land equivalent ratio

were found for the pea-cereal intercrops, indicating both positive and negative effects of intercropping (Table 6). In 2008, the LER for B80S20 was as high as 1.57, but only 0.98 in 2009. The highest value was found in a season with lower pea yields due to a virus disease. This shows that remarkably high LER values may indicate not only a positive effect of intercropping, but also that the crop yield was not satisfactory for any reason. The LER value can be affected by the low yield of one of two crops in the mixture. The LER can therefore be influenced by higher disease attack, higher weed pressure, adverse weather conditions etc. This finding is consistent with the results of Chargoy (2004).

The optimal seed ratio of intercrop components. The largest benefit of intercropping was obtained when the components were both sown at pea to cereal ratios 40:60 and 60:40. The LER values were 1.21 and 1.18, respectively (Figure 2).

Average yields of pea-cereal intercrops and pea and cereal monocultures were statistically compared by Dunnett's test.

Statistically significant differences were found between yields of treatments with seed ratios 40:60 (3.86 t/ha) and 60:40 (3.87 t/ha) compared to pea monoculture as the control mean (3.42 t/ha).

When pea varieties were evaluated separately, no significant differences were found between yields of the intercropped variety Bohatyr and yield of Bohatyr as monoculture.In contrast, significant differences were found between yields of Terno variety intercropped using pea to cereal seed ratios of 60:40 and 40:60, and yield of Terno variety grown as monoculture.

Significant differences were observed between yields (3.62, 3.86, 3.87 and 3.64 t/ha) of all intercrop treatments (pea to cereal ratios 20:80, 40:60, 60:40 and 80:20) in comparison with cereal monoculture as the control mean (3.15 t/ha). These results were

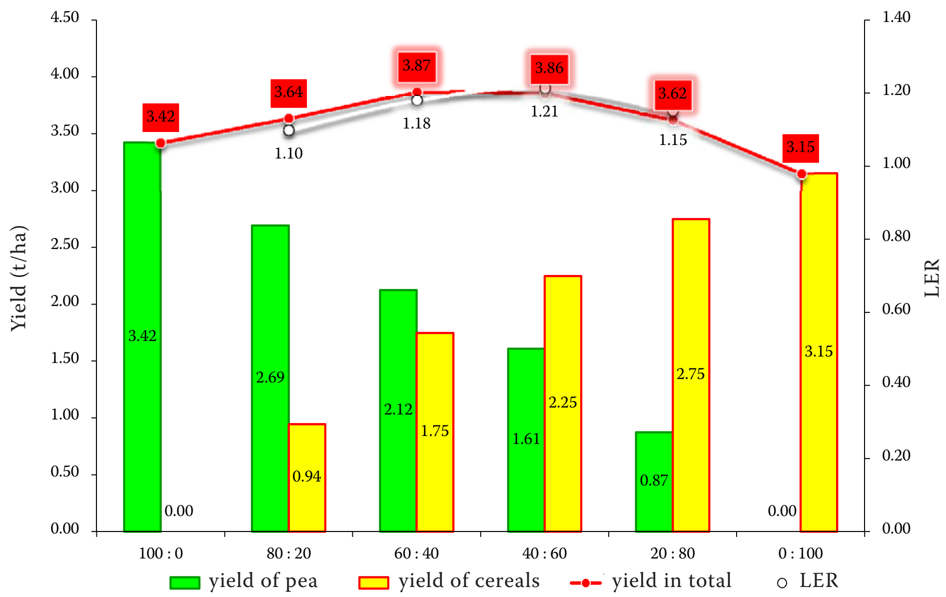

Figure 2. Plot trials (PT) – net average yields of grain (t/ha) of pea and cereal monocultures and intercrops on the basis of seed ratios, 2008–2011
LER – land equivalent ratio

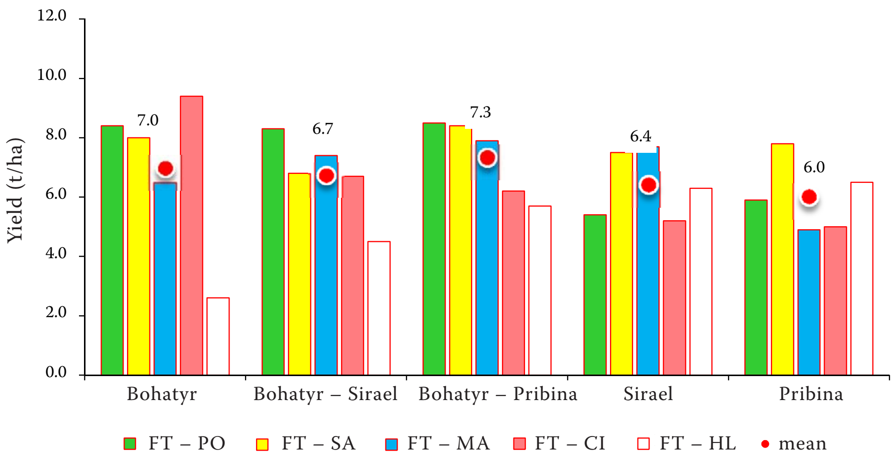

Figure 3. Field trials (FT) – hay yields (dried at 60°C for 24 h) harvested at pea green ripe growth stage (BBCH 79) on five organic farms in 2009
PO – Postřelmov; SA – Sasov u Jihlavy; MA – Malonty; CI – Číhalín; HL – Horní Lideč

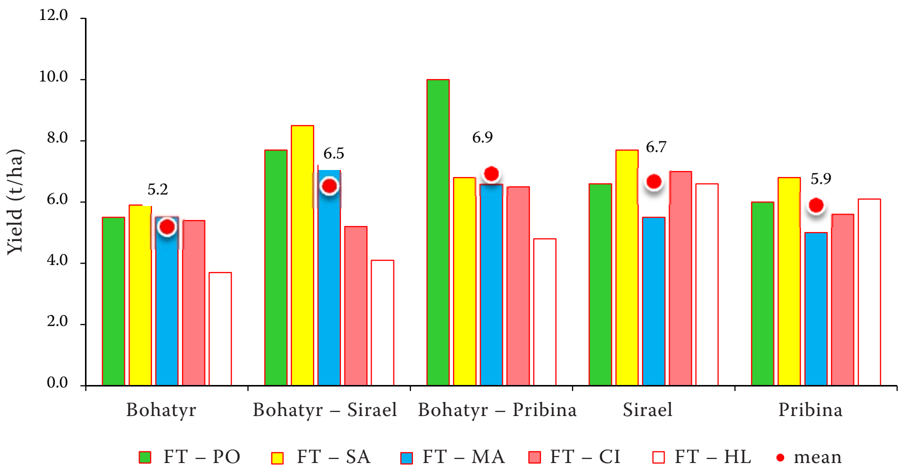

Figure 4. Field trials (FT) – hay yields (dried at 60°C for 24 h) harvested at pea growth stage BBCH 83 (t/ha) on five organic farms in 2009
PO – Postřelmov; SA – Sasov u Jihlavy; MA – Malonty; CI – Číhalín; HL – Horní Lideč

valid separately for wheat and for barley and also for their intercrops.

Field trials on organic farms. The project funding of the farm level experiments lasted only 1.5 years and reliability of the results is therefore limited. Nevertheless, some relevant results were obtained because the experiments were carried out on relatively large plots of organic farms with common farm machinery and in the operation mode.

At the first sampling (pea growth stage BBCH 79), the hay yields (60°C) varied from 6.0 to 7.3 t/ha (Figure 3). The highest yields (7.3 t/ha) were produced by the pea-barley intercrop,. This was 105% of the pea monoculture yield (7.0 t/ha). This finding is in accordance with the results presented by Abrahamsen & Eltun (2001). By contrast, pea-wheat yielded 96% of the pea monoculture yield. The overall highest yield, 9.4 t/ha, was produced by pea monoculture on the Číhalín farm

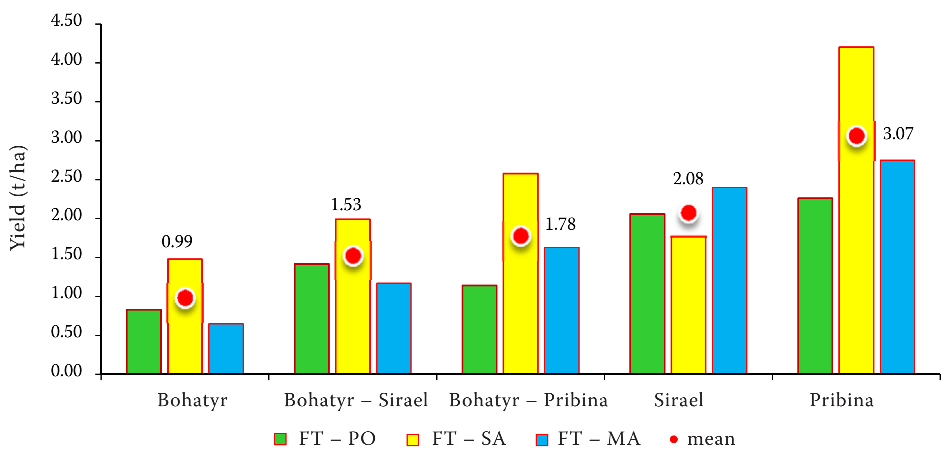

Figure 5. Field trials (FT) – fresh yields of grain (t/ha) on three organic farms, measured by the farmers in 2009
PO – Postřelmov; SA – Sasov u Jihlavy; MA – Malonty; CI – Číhalín; HL – Horní Lideč

(FT-CI). The cereal monocultures produced somewhat lower hay yields than pea monoculture and intercrops at the first sampling, between 6.0 and 6.4 t/ha.

Compared to pea monocultures, the other treatments were not statistically significantly different (Figure 3). No strong results for statistical significance can be expected when farms are used as replications, since the growing conditions varied too much, e.g. with respect to altitude (Table 3) and fertilization (Table 4).

At the second sampling (pea growth stage 83), the hay yields (60°C) were generally lower due to the development of the crop towards ripening (Figure 4). Especially the pea-barley intercrop yielded well – 6.9 t/ha, which was 33% more than the yield of pea monoculture (5.2 t/ha). This intercrop also produced the overall highest yield on the Postrelmov farm (FT-PO) – 10.0 t/ha.

The differences between treatments at the second sampling were not statistically significant (Figure 4).

In the farm trials, the grain yields at final seed harvest were generally very low, partly due to the weather in July, when precipitation exceeded the normal July period average across the major part of the Czech Republic. This led to lodging in peas and subsequently even in cereals; it also caused that the cereals were covered by lodged peas, which in certain cases slowed down or halted further development of cereals. The percent of cereals in the harvested seed was therefore lower than expected from the seed ratio (40%). For the three farms where grain yields were recorded, the average fresh yield was 1.53 t/ha for the pea-wheat intercrop, and 1.78 t/ha for pea-barley (Figure 5). This was less than the average yield of cereal monocultures, but well above the average of the pea monoculture.

As reported by Jensen *et al.* (2008), it is also of special interest that intercropping may reduce weed infestation, especially on soils with high weed pressure. However, the amounts of impurities in the grain samples, mainly plant parts from creeping thistle (*Cirsium arvense* /L./ Scop.), were significant. The samples contained between 5 and 15% of impurities (by weight). After removing the impurities, net yields with a standard water content of 14% were calculated.

Based on the net yields of fractionated intercrop components (Table 7), LER values may be calculated. Relatively high values were obtained, ranging from 1.39 to 1.91. However, this should not be interpreted as if intercropping were efficient to obtain high grain yields in these trials, because the yield levels were generally very low, and the cereal component in the intercrops, especially wheat, suffered from competition with pea. Mead (1990) stated that there are some limitations in the use of LER.

The fractionated grain yields show that intercropping increases the pea yields as compared to the pea monoculture (Table 7). This may so because the pea utilizes the cereals for climbing. Hence, if the purpose is to grow field peas, e.g. for concentrate, intercropping seems clearly advantageous, as increased grain yields were found on all farms. If the purpose is a maximally high grain yield, cereal monocultures yielded better than intercrops in this trial. This was due to the suppression of cereals by lodging caused by pea.

CONCLUSIONS

It may be concluded from average yields in 2008–2011 that pea-cereal intercropping influences yield stabilization in comparison with monocultures. The results also show that pea grown in intercrops in organic farming might have a high yield potential under favourable conditions. This is in line with the conclusions of Awal *et al.* (2006), who stated that a successfully composed intercrop may utilise available growth resources such as light, water and nutrients more efficiently than monocultures, resulting in higher yields and greater ecological and economic stability.

The outcomes obtained clearly demonstrate that under organic growing conditions, with reduced options for controlling weeds, pests and diseases, crop yields are highly variable in space and time. In field experiments on organic farms, longer time periods than one or two seasons are required to produce reliable data. However, the project funding of the farm level experiments lasted for only 1.5 years. In spite of the short experimental period, the study has produced some valuable knowledge.

When selecting crop varieties and pea to cereal ratio for intercropping, it is important to take into account the purpose of growing – whether the intercrop is grown for green fodder or for concentrates. It is necessary to consider agricultural technology, protection from weeds, diseases and pests, and to clarify the requirements for the composition of fodder (e.g. the ratio between protein and energy content) as Pozdíšek *et al.* (2010) reported.

Depending on the chosen aim of the production, legume-cereal intercropping may be utilised to maximize green matter yields (leafy pea variety), to increase the yields of protein/peas if peas are the main goal of production, and to increase the yields of grains (peas-cereals) if concentrates are the main goal of production. Such concentrates may be harvested as dry grain or with a higher water content and used as a silage concentrate.

The pea-cereal intercrop may give high yields of grains for concentrates, with a significant positive intercropping effect as shown by relatively high LER values. But LER values must be interpreted with caution and should not be used unless yield levels are reasonable.

In trials the pea to cereal ratios of 40:60 and 60:40 appeared to be optimal for growing in the intercrop in terms of yields and land use efficiency.

If the humidity is higher and therefore the growth of pea is intensive, then there is a risk of overlaying cereals by pea plants and thereby stopping further development of cereals. This can play an important role, especially in the case of growing the intercrops for concentrates. In this case it appears more appropriate to use the semi-leafless pea varieties and to reduce the risk of crop lodging. According to Mikić *et al.* (2011) semi-leafless pea varieties significantly enhanced standing ability and equally efficient dry matter production in comparison with normal-leafed genotypes. A leafy pea variety will climb too heavily, even on short-stemmed cereal varieties, and cannot be recommended to produce mixed pea-cereal concentrates. However, if the purpose is green fodder for hay or silage, pea-cereal intercrops with a leafy pea variety may be quite successful. Leafy pea variety is more suitable for intercropping and higher pea ratio (60% and more) in the intercrop if the production aim is to obtain green matter for silage production.

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