THE EFFECT OF INTERCROPPING ON CROP PRODUCTIVITY AND YIELD QUALITY OF OAT (Avena sativa L.)/ GRAIN LEGUMINOUS SPECIES (PEA – Pissum sativum L., LENTIL – Lens culinaris L.) CULTIVATED IN PURE STAND AND MIXTURES, IN THE ORGANIC AGRICULTURE SYSTEM

Elena Mirela Dusa, University Assistant, PhD
Vasilica Stan, Associate professor, PhD
Plant Sciences Department, Faculty of Agriculture, University of Agronomic Science and Veterinary Medicine, Bucharest, Romania

Abstract:

Intercropping is the simultaneous cultivation of two or more species on the same field, during a growing season, in order to produce a greater yield, by making use of resources that would otherwise not be utilized by a single crop. The researches are focused on the productivity and yield quality of oat and two species of grain leguminous (pea – *Pisum sativum* L. and lentil – *Lens culinaris* L.), in intercropping, in order to evaluate their adaptability to natural conditions of South Romania and to organic cultivation. The experiment was carried out in 2007-2009 period, in Moara Domneasca Experimental Field, on reddish preluvosoil, in randomized variants, in 4 replications. The seeds used for experiments were organic. Oat and grain leguminous were sown in alternating rows (1 row of oat, 1 row of pea/lentil), at 12.5 cm between rows. A series of parameters were determined as follows: yield components, yield, land equivalent ratio and seeds quality. In average, the oat intercropped with pea produced 14.02 q/ha, and the oat intercropped with lentil had 13.47 q/ha. In intercropping, the pea yield was 7.87 q/ha smaller than in the sole cropping (27.48 q/ha). The lentil intercropped with oat produced 7.69 q/ha. The highest value of LER (1.50) was obtained at oat-pea intercropping. At oat-lentil intercropping, LER value was 1.40. The highest protein yield was obtained at pea in sole cropping, i.e. 733 kg/ha. Within intercrops, the best protein yield was obtained in oat-pea intercropping (6.96 q/ha); for comparison, the oat-lentil intercropping produced 3.67 q/ha protein.

Keywords: intercropping, organic agriculture, oat, pea, lentil

Introduction

Nowadays, in the developed regions of the world, conventional agriculture, which is more and more pure crop-oriented, modifies landscapes and hurts ecosystems, including biodiversity. Thus, at both world and European levels, a new concern appeared, related to the connection between agricultural practices, environmental problems and long term stability of agricultural production systems.

Organic agricultural practices are generally more environmentally friendly than conventional agriculture, particularly with regard to lower pesticide residues, a greater resilience to drought and a richer biodiversity (Dabbert et al., 2000).

Intercropping can be seen as the practical application of diversity, competition and facilitation in arable cropping systems. Grain leguminous-cereal mixed intercrops are better at exploiting natural resources as compared to the sole crops of different plant species (Hauggaard-Nielsen et al., 2003, 2006). Grain leguminous can cover their nitrogen demand from atmospheric N_2 (Hauggaard-Nielsen et al., 2001, Trenbath, 1976) and therefore in intercropping with cereals compete less for soil mineral N.

Compared with grain leguminous-cereal intercropping, the grain leguminous from monoculture can be grown under organic agriculture conditions but they have some disadvantages. For example, pea plants from monoculture may often lodge heavily, making harvesting difficult and great yield losses can occur. When intercropping pea with cereals like oat as a standing support culture, lodging can be avoided (Lauk et al., 2006).

Several factors can affect growth of the species used in intercropping, including cultivar selection, seeding ratios, and competition between mixture components (Cabellero et al., 1995; Carr et al.; 2004; Droushiotis, 1989; Papastylianou, 1990).

Grain leguminous-cereal intercrops may produce higher grain and protein yields as compared to monoculture (Jensen, 1996; Hauggaard-Nielsen et al., 2001; Lauk et al., 2005) and show greater yield stability across years than when growing grain leguminous and cereals as monoculture (Ofori et al., 1987; Willey, 1979).

Furthermore, the level of weed infestation reported in grain leguminous monoculture is significantly reduced when these are intercropped with cereals (Rauber *et al.*, 2001).

In the conditions of Southern Romania part, the oat, pea and lentil plants are regarded as suitable grain leguminous for the organic agriculture system.

Material and methods

The aim of the research was to study the behavior of some field crops in intercropping, in the organic agriculture system and to observe the

complementarity between plant species and their yield output, thereby revealing the degree of interspecific competition. Also, of special interest is to observe how the yield potential and crop quality is affected by competition between oat and pea or lentil.

Site

The experiments were carried out in three subsequent years i.e. 2007-2009, in Moara Domneasca Experimental Field located in the central part of Romanian Plain, in the organic agriculture system. The representative soil for this part of the country belongs to the reddish preluvosoil type, presenting the following characteristics: loamy-clay texture; medium humus content in A horizon (2.77%) and relatively high in A/B horizon (about 1.2%); slight neutral-acid reaction in A horizon (pH 6.29-6.64); phosphorus content of 17 ppm PAL (poorly medium supplied); potassium content, of 184 ppm KAL (well supplied) (Mihalache et al., 2009).

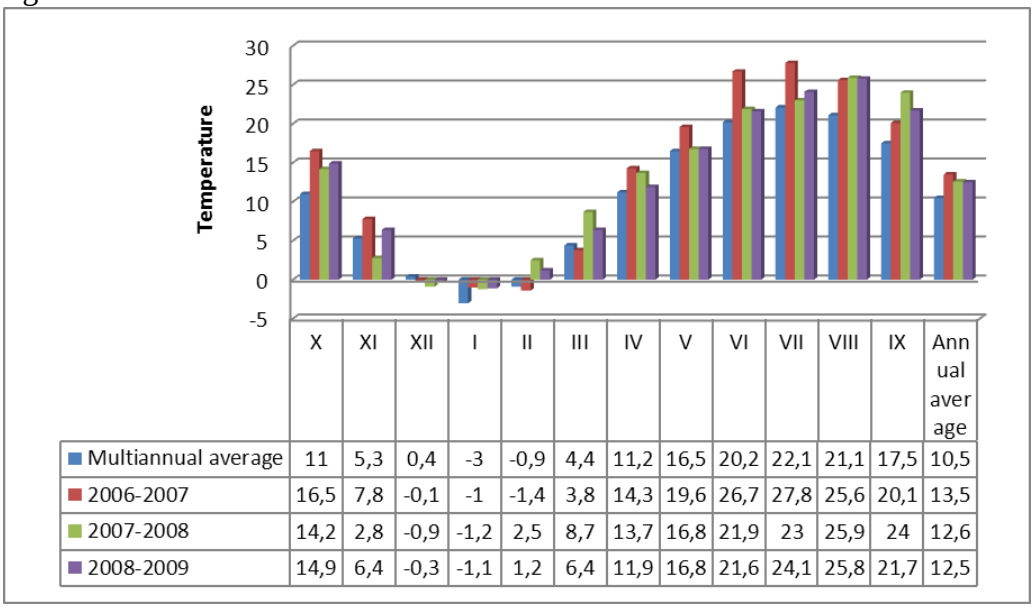
Experimental design and plant material

The experiment has been organized in blocks, in randomized variants, in 4 replications. The sown area of an experimental plot was 20 m² (width – 4 m, length – 5 m) (figure 1). A part of the organic material used for sowing came from the Didactic collection of the Field Crop Production Department from the Faculty of Agriculture (for example, the oat and lentil seeds) and pea (Kelvedon wonder cultivar) came from BBM Natura SRL, Braşov, Romania.

Fig.1. Oat-grain legumes intercropping experiment at Moara Domnească Experimental Field (Source: E.M. Duşa, 2009)

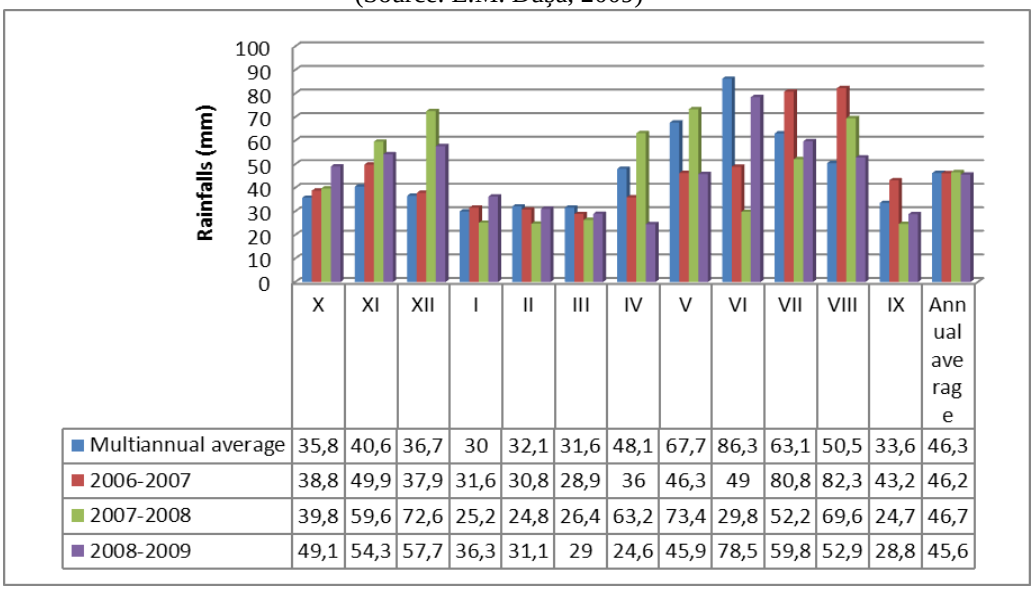
From a climate perspective, the area where the research took place is characterized by the appearance of a transitional form between dry steppe climate and sub-humid forest zone. The average maximum monthly temperature (27.8^{o}C) was reached in July (2006-2007 period), while the minimum temperature of -1.4^{o}C was registered in February (2006-2007).

The average annual precipitation for those three years is of 46.1 mm and the total rainfall in 2007, 2008 and 2009 period, during the crop growing season (March to July) were 241 mm, 245 mm and 237.8 mm respectively. The climatic conditions recorded at Moara Domneasca area are presented in the figures 1 and 2.



	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Annual average
Multiannual average	11	5,3	0,4	-3	-0,9	4,4	11,2	16,5	20,2	22,1	21,1	17,5	10,5
2006-2007	16,5	7,8	-0,1	-1	-1,4	3,8	14,3	19,6	26,7	27,8	25,6	20,1	13,5
2007-2008	14,2	2,8	-0,9	-1,2	2,5	8,7	13,7	16,8	21,9	23	25,9	24	12,6
2008-2009	14,9	6,4	-0,3	-1,1	1,2	6,4	11,9	16,8	21,6	24,1	25,8	21,7	12,5

Fig.2. Average air temperature registered at Moara Domnească Experimental Field (Source: E.M. Duşa, 2009)



	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Annual average
Multiannual average	35,8	40,6	36,7	30	32,1	31,6	48,1	67,7	86,3	63,1	50,5	33,6	46,3
2006-2007	38,8	49,9	37,9	31,6	30,8	28,9	36	46,3	49	80,8	82,3	43,2	46,2
2007-2008	39,8	59,6	72,6	25,2	24,8	26,4	63,2	73,4	29,8	52,2	69,6	24,7	46,7
2008-2009	49,1	54,3	57,7	36,3	31,1	29	24,6	45,9	78,5	59,8	52,9	28,8	45,6

Fig.3. Average rainfalls (mm) registered in Moara Domnească Experimental Field (Source: E.M. Duşa, 2009)

Oat, pea and lentil were sown in alternating rows (1 row of oat, 1 row of pea/lentil), at 12.5 cm between rows (figure 4). In intercropping, the oat had a density of 300 germinal seeds/m^2, the pea 80 germinal seeds/m^2 and lentil 150 germinal seeds/m^2.

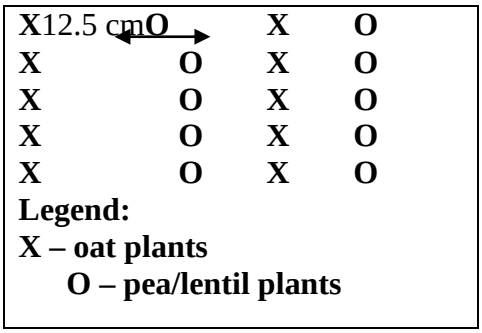


Fig. 4. Planting pattern of oat and lentil in intercropping system
(Source: E.M. Dusa, 2009)

Measurements

In these experiments, a program of phenological observation and biometrical measurements was developed and a series of parameters were followed, such as: agronomical parameters (yield components and seed yield), quality parameters (protein, starch and fat contents of the seeds) and competition parameters (land equivalent ratio).

During the vegetation period, when needed, there were effectuated hoeing and weeding works, to remove weeds. There were not applied organic or mineral fertilizers on the field; after harvesting, the vegetal residues were crushed and incorporated into the soil. Also, during the vegetation period were not observed significant attacks of pests or pathogens.

The land equivalent ratio (LER) was calculated using the following formula:

$$LER = Y_{i.c.1}/Y_{s.c.1} + Y_{i.c.2} / Y_{s.c.2}$$

where:

$Y_{i.c.1}$ - crop 1 yield in intercropping;

$Y_{i.c.2}$ - crop 2 yield in intercropping;

$Y_{s.c.1}$ - crop 1 yield in sole crop;

$Y_{s.c.2}$ - crop 2 yield in sole crop.

When LER values are higher than 1, means that there is an advantage of intercropping in terms of the use of resources for the plant growth compared to sole cropping. When LER values are lower than 1, means that sole cropping use the resources more efficiently in comparison with intercropping (Sullivan, 1998).

Results and discussions:

Yield components

In average, on 3 years of experimentation, the number of spikelet/panicle was higher at the oat from the sole crop, i.e. 34.5 and fluctuated between years, and in intercropping, the highest number of spikelet was obtained at the oat intercropped with pea i.e. 32.6. The number of oat grains/panicle was also lower in intercropping, especially at the oat grown in intercropping with lentil (table 1). The 1000 grain weight (TGW) varied between 23.7 g at the oat intercropped with lentil and 25.4 g at the oat from the sole crop.

Table 1. Yield components at oat, in sole crop and in intercropping

Yield components	Oat sole crop	Oat-pea intercropping	Oat-lentil intercropping
		Average 2007-2009	
Panicle length (cm)	21.8	21.4	20.5
Number of spikelet/panicle	34.5	32.6	30.5
Number of grains/plant	47.6	46.1	41.6
Number of grains/spikelet	1.4	1.5	1.4
Grain mass/panicle (g)	1.4	1.4	1.2
TGW (g)	25.4	24.7	23.7

The lentil plants from the sole crop formed in average, the highest number of pods/plant i.e. 25.2, while in intercropping with oat, the plants formed a number of 20.9 pods/plant. The smallest number of grains/pod was found at lentil plants in intercropping with oat, respectively 1.1 grains. At the lentil plants from the sole crop the TGW value was of 34.3 g and at those from intercropping with oat, of 31.7 g (table 2).

In average, in the sole crop, pea plants formed a number of 4 pods/plant and in intercropping with oat formed 3.5 pods/plant. Also, the highest number of grains/pod resulted at pea plants from the sole crop, respectively 4.8 grains and TGW ranged between 162.8 g at pea intercropped with oat and 163.7 g at pea in the sole crop (table 2).

Table 2. Yield components at lentil and pea plants, in sole crop and in intercropping

Productivity compounds	Lentil	Oat-lentil	Pea	Oat-pea
	Sole crop	intercropping	Sole crop	intercropping
		Average 2007-2009		
Plant height (cm)	39.7	37.9	50.6	47.6
Number of pods/plant	25.2	20.9	4.0	3.5
Number of grains/plant	26.8	22.8	18.9	15.8
Number of grains/pod	1.3	1.1	4.8	4.5
Grain mass/plant (g)	1.0	0.9	2.7	2.1
TGW (g)	34.3	31.7	163.7	162.8

Yield, land equivalent ratio and the above ground biomass

The yield obtained at oat – lentil and oat – pea intercropping (table 3), in the experimental conditions of Moara Domneasca, show that, in intercropping, the productivity was different from the sole crop.

Thus, in average over three years of experimentation, the oat from the sole crop produced 17.78 q/ha. Compared with the control, the yield of the oat in intercropping was lower, i.e. of 13.74 q/ha in intercropping with lentil and of 13.93 q/ha, in intercropping with pea.

At the lentil plants from the control (sole crop), the yield was of 11.83 q/ha, and in intercropping with oat, the lentil produced 7.69 q/ha, 4.14 q/ha lower than the control.

In the sole crop, the pea plants produced 27.48 q/ha, and when the pea was intercropped with the oat, the yield was of 19.61 q/ha, 7.87 q lower than the control.

Overall, at oat-lentil intercropping the total yield was of 21.16 q/ha, and at oat-pea intercropping of 33.54 q/ha.

Table 3. Seeds yield and the land equivalent ratio (LER) at oat, lentil and pea, in sole crop and in intercropping (2007-2009 average)

Type of crop	Yield (q/ha)			Total yield (q/ha)	LER			Total LER
	Oat	Lentil	Pea		Oat	Lentil	Pea	
Oat (sole crop)	17.78	-	-	17.78	-	-	-	-
Lentil (sole crop)	-	11.83	-	11.83	-	-	-	-
Pea (sole crop)	-	-	27.48	27.48	-	-	-	-
Oat-lentil	13.47	7.69	-	21.16	0.76	0.64	-	**1.40**
Oat-pea	13.93	-	19.61	33.54	0.79	-	0.71	**1.50**

Regarding the land equivalent ratio (table 4), the highest value, i.e. 1.50 was obtained at oat-pea intercropping. At oat-lentil intercropping, the LER value was of 1.40. These results show that, in sole crop, would be necessary 40%, respectively 50% more land areas, to obtain the same yields like in intercropping.

Chemical composition

Regarding the chemical composition, it could be highlight that, at oat, the moisture content at harvesting ranged between 11.01%, in intercropping with pea and 11.50%, in sole crop. At lentil, the grain moisture was of 11.30-11.35% and the pea had a moisture content of 13.05% in sole crop and of 12.77% in intercropping with oat.

Chemical analysis showed less important differences between variants regarding protein and fat content. So, the protein content of oat seeds was very close in all 3 variants, respectively between 12.40% and 12.71%. The lentil seeds accumulated 25.95% protein in sole crop, and 26.11% in intercropping with oat. Finally, at pea seeds from the sole crop it

was determined a content of 26.68% protein and in intercropping with oat, 26.60%.

On the other hand, at oat, the fat content varied between 4.22% and 4.30% at those 3 experimental variants. At lentil, it was determined in average a content of 1.08% fats, in sole crop and of 0.77% in intercropping with oat. For pea, the contents of fats were of 1.35% in sole crop and of 1.38%, in intercropping with oat (table 5).

Table 5. Chemical composition of oat, lentil and pea seeds, in sole crop and in intercropping (2007-2009 average)

Type of crop	Moisture (%)	Protein (% d.m.)	Fat (% d.m.)
Oat (sole crop)	11.50	12.71	4.30
Lentil (sole crop)	11.30	25.95	1.08
Pea (sole crop)	13.05	26.68	1.35
Oat (intercropping with lentil)	11.12	12.40	4.25
Oat (intercropping with pea)	11.01	12.62	4.22
Lentil (intercropping with oat)	11.35	26.11	0.77
Pea (intercropping with oat)	12.77	26.60	1.38

The highest protein yield/ha of 7.33 q/ha was obtained at pea in sole crop. Between intercrops, the best protein/ha yield resulted on oat-pea intercropping, respectively 6.96 q/ha; through comparison, at oat-lentil intercropping, the protein yield was of 3.67 q/ha (table 6).

Table 6. Protein yield at oat, lentil and pea, in sole crop and in intercropping (2007-2009 average)

Type of crop	Seed yield (q/ha)			Total yield	Protein yield (q/ha)			Total protein
	Oat	Lentil	Pea	(q/ha)	Oat	Lentil	Pea	yield (q/ha)
Oat (sole crop)	17.78	-	-	17.78	2.25	-	-	2.25
Lentil (sole crop)	-	11.83	-	11.83	-	3.06	-	3.06
Pea (sole crop)	-	-	27.48	27.48	-	-	7.33	7.33
Oat-lentil	13.47	7.69	-	21.16	1.67	2.00	-	**3.67**
Oat-pea	13.93	-	19.61	33.54	1.75	-	5.21	**6.96**

Conclusion

Intercropping changed the yield components in oat. The yield components of oat were reduced more when it was intercropped with lentil than in intercropping with pea, the number of grains/plant being the most affected. Also, both lentil and pea were affected by the intercropping system. At lentil, the number of pods/plant and the number of grains/plant were lower than at pea.

The yield of sole crops was higher than their intercrop yields. The grain yield of oat was less affected by intercropping, being reduced with 4.31 q/ha in case of oat-lentil intercropping and with only 3.85 q/ha when oat was intercropped with pea. Intercropping reduced the grain yield of lentil by 65% and of pea by 71%. That means that the leguminous were shadowed by the oat plants and the plants from the mixture competed for light, water and nutrients.

All combinations from this research showed superior land efficiency of intercropping in comparison with the sole crops, especially oat-pea intercropping who recorded higher values, i.e. 1.50. That means a 50% area advantage of intercrops over sole cropping.

The seed quality was not significantly affected by intercropping in comparison with sole cropping, the differences being very small. The highest protein yield was registered at pea in sole crop. In intercropping, the best protein yield was obtained at oat-pea intercropping, i.e. 6.96 q/ha.

In the experimental conditions of Moara Domneasca, oat-pea intercropping behaved best, being obtained the highest grain yield and the highest protein content.

The extension of those crops in production is conditioned by the land weed infestation level and pest control, and also by maintaining and raising agricultural land fertility through organic agriculture measures (incorporation of crop residues; crop rotation with grain legumes; organic manure management).

References:

Dabbert, S., M. Stolze, A.M. Häringaud, A. Piorr. A policy relevant assessment of the environmental impacts of organic farming. In: Alföldi, T., W. Lockeretz, U. Niggli. Proceedings of the 13th International IFOAM Scientific Conference, Zurich, Switzerland, 148-151, 2000.

Caballero, R., E. L. Goicoechea, and P. J. Hernaiz. Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of vetch. Field Crops Research, 41.2: 135-140, 1995.

Carr, P. M., Horsley, R. D., & Poland, W. W. . Barley, oat, and cereal–pea mixtures as dryland forages in the northern Great Plains. Agronomy Journal, 96(3), 677-684, 2004.

Droushiotis, D. N. . Mixtures of annual legumes and small-grained cereals for forage production under low rainfall. J. Agric. Sci. 113.2: 249-253, 1989.

Duşa, E.M., Gh.V., Roman. Researches regarding the productivity of oat-lentil intercropping in the organic agriculture system. Research Journal of Agricultural Science, 41(1), 22-26, 2009.

Hauggaard-Nielsen, H., P. Ambus, E. S. Jensen. Interspecific competition, N use and interference with weeds in pea-barley intercropping. Field Crops Research, 70:101–109, 2001.
Hauggaard-Nielsen, H., P. Ambus, E. S. Jensen. The comparison of nitrogen use and leaching in sole cropped versus intercropped pea and barley. Nutrient Cycling in Agroecosystems, 64:289–300, 2003.
Hauggaard-Nielsen, H., M. K. Andersen, B. Jørnsgaard, E. S. Jensen. Density and relative frequency effects on competitive interactions and resource use in pea-barley intercrops. Field Crops Research, 95:256–267, 2006.
Jensen, E. S.. Grain yield, symbiotic N_2 fixation and interspecific competition for inorganic N in pea-barley intercrops. Plant and Soil, 182:25–38, 1996.
Lauk, E., R. Lauk. The yields of legume – cereal mixes in years with high – precipitation vegetation periods. Latvian Journal of Agronomy, 8:281-285, 2005.
Lauk, R., E. Lauk. Yields in vetch-wheat mixed crops and sole crops of wheat. Agronomy Research, 4:37–44, 2006.
Ofori, F., W.R. Stern. Cereal-legume intercropping systems. Advances in Agronomy, 41:41–90, 1987.
Mihalache, M., L. Ilie, D.I. Marin. Research concerning theeffect of management systems on physical and chemical properties of reddish preluvosoil from Moara Domneasca experimental field. Annals of the University of Craiova, Agriculture – Montanology – Cadastre Series, XXXIX: 428-432, 2009.
Papastylianou, I.. Response of pure stands and mixtures of cereals and legumes to nitrogen fertilization and residual effect on subsequent barley. Journal of Agricultural Science, Cambridge, 115, 15-22, 1990.
Rauber, R., K. Scmidtke, H. Kimpel-Freund. The performance of pea (*Pisum sativum* L.) and its role in determining yield advantages in mixed stands of pea and oat (*Avena sativa* L.). Agronomy and Crop Science, 187:137-144, 2001.
Trenbath, B. R.. Plant interactions in mixed crop communities. R. I. Papendick, P. A. Sanchez, G. B. Triplett, editors. Multiple cropping. American Society of Agronomy Special Publication, 27:129-170, 1976.
Stefanic G.. Indrumar pentru prelucrarea statistica a rezultatelor din experientele mono-, bi- si trifactoriale din agricultura si biologia solului. Soil Science, vol. XLIV, 2010.
Willey, R. W.. Intercropping – Its importance and research needs. Part 1. Competition and yield advantages. Field Crop Abstract, 32: 1–10, 1979.