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PEA YIELD AND ITS COMPONENTS IN DIFFERENT CROP ROTATIONS

Vytautas SEIBUTIS, Irena DEVEIKYTĖ

Lithuanian Institute of Agriculture
Akademija, Kėdainiai district
E-mail: vytautas@lzi.lt

Abstract

The effects of the crop rotations (2-4 course) differing in duration on the formation of pea productivity elements and the yield were investigated in stationary field experiments in Dotnuva during 1997-2004.

Averaged experimental data showed that the highest pea yield (3.70 t ha^{-1}) was recorded in the three-course crop rotation (sugar beet-spring barley-pea), in the four-course (pea-winter wheat-sugar beet-spring barley) and two-course (pea-winter wheat) crop rotations the grain yield consistently declined and made up 3.65 and 3.43 t ha^{-1} (no significant yield reduction).

After different preceding crops the productivity of pea was similar: after sugar beet it was 3.70 t ha^{-1}, after spring barley and winter wheat the yield was 3.62 and 3.53 t ha^{-1}, respectively.

Shortening of the rotation had some effect on the formation of individual productivity elements of pea. Through shortening of the crop rotations from 4 to 2 courses the height of pea stems, number of pods per plant and number of seeds per plant significantly decreased.

Summarized data from the 1997-2004 experimental period indicate that the shortening of rotations and choice of preceding crops did not have any effect on pea seed yield but influenced the formation of pea productivity elements.

Key words: pea, yield, crop rotation.

Introduction

Pea (*Pisum sativum* L.) is a minor field crop grown only on about 14.9 thousand hectares corresponding roughly to 0.85 % of the cultivated field area in Lithuania /Statistics Lithuania, 2006/. Pea has always been regarded as a valuable plant because of its highly nutritive albuminous seeds and soil - improving properties /Stevenson, von Kessel, 1996b/. Rotation with pea needs an effective N_2 fixation, an adjusted crop rotation and adapted crop management practices to improve efficiency of nitrogen fixation and valorization /Unkovich, Pate, 2000/. For example, wheat derived an additional 8 kg N ha^{-1} from the residue of a preceding pea crop compared with a preceding wheat crop /Stevenson, von Kessel, 1996a/. Pea is grown for human consumption, animal feed or seed for sowing. Peas are often grown in a rotation with winter wheat /Payne et al., 2000; von Kessel, Hartley, 2000/, cereals and mixed with cereals /Salonen et al., 2005/. Growing barley after beans and reducing nitrogen fertilization, the yield was the same as growing barley after cereals /Kankanen et al., 1999/.

Recently, successful growing of semi-leafless peas has been started. They perform well alone, unmixed with cereals, as the short-stemmed and tendrils make them rather resistant to lodging, thus they are sometimes called non-lodging. Semi-leafless peas are becoming more popular among farmers than their predecessors – leafed peas. Because of high yields and the possibility to be cultivated alone, their crops are expanding rapidly /Pranaitis, Marcinkonis, 2005/.

Diversifying crop rotations by including a mixture of crop types has long been recognized as an effective means of reducing business risk. Each crop type has a different requirement for water, nutrients, and other resources, which affects the residual quantities available and, thus, the potential yield of subsequent crops. Growing a mixture of crop types can also produce other rotational benefits such as improved weed control, lower disease incidence, and improved soil quality, which may enhance the yields and grain quality of subsequent crops or reduce costs of production. Some agronomic studies have reported that yields of pulse and oilseed crops often display higher year-to-year variability than the yield of cereal grains /Lafond et al., 1993; Miller et al., 2001/. Crop diversity may also add value to cropping systems by increasing the efficiency of cereal crop production /Johnston et al., 2002; Zentner et al., 2002; Miller et al., 2003/.

The aim of this investigation was to study the influence of different short crop rotations on pea yield and its components.

Materials and Methods

Research on shortening of crop rotations was conducted at the Lithuanian Institute of Agriculture in Dotnuva during the period 1997-2004. The experiment was composed of 6 short crop rotations (2-4 courses) (Table 1).

Net plot size for peas was 43.5 m^2. The treatments were replicated four times. Replication treatments were arranged randomly.

According to the new classification of soils 1999 (LTDK-99), systematic units that have been coordinated with FAO-UNESCO World soil map legends, predominant soils of the experimental site are *Endocalcari-Endohypogleyic Cambisol* (Lietuvos dirvožemiai, 2001), humus content in the plough layer 2.28 %, pH_{KCl} 7.2, mobile phosphorus 142 mg kg^{-1} and mobile potassium 180 mg kg^{-1}.

Pea crop *(Pisum sativum* L.*)* of cv. 'Profi' (1 million seed ha^{-1}) was grown in the experiment.

Conventional crop cultivation technology linked with sustainable mineral fertilization was applied in the trial.

Chopped pea vines were spread on soil surface as fertilizer after harvesting. To accelerate straw mineralization, 10 kg of nitrogen per 1 ton of pea straw (D. M.) was applied after harvesting, and shortly afterwards stubble was broken at 10-12 cm depth. Two-three weeks after stubble breaking the soil was ploughed at 20-22 cm depth.

Pre-sowing soil tillage for all crops was identical – shallow loosening by a cultivator with a light harrow at 5-8 cm depth, the operation was performed twice. After pea sowing the soil was rolled by a Cambridge roller. Only PK mineral fertilization was applied ($P_{40}K_{40}$). PK fertilizers were broadcast before primary soil tillage. Herbicides were applied in all crops: pea was sprayed by Stomp 2.0 l ha^{-1} (pendimetaline 330 g l^{-1} a.i.). Insecticides were used according to the need.

Plant density was estimated upon emergence of crops (plants were counted in four places of plots on an area of 0.25 m^2). At the end of plant growing season plants were pulled from two 0.25 m^2 plots per each plot and sheaves were made from which we determined the number of productive stems, plant height and productivity of pods. For chemical composition and 1000 grain weight determination, 1 kg samples were taken from each plot after grain harvesting and cleaning.

Table 1. Experimental design
1 lentelė. *Tyrimų schema*

Crop rotation No. *Sėjomainos nr.*	Course No. and plant species *Rotacijos nario nr. ir augalo pavadinimas*	Crop rotation No. *Sėjomainos nr.*	Course No. and plant species *Rotacijos nario nr. ir augalo pavadinimas*	Crop rotation No. *Sėjomainos nr.*	Course No. and plant species *Rotacijos nario nr. ir augalo pavadinimas*
I	1. Peas / *Žirniai* 2. Winter wheat *Žieminiai kviečiai* 3. Sugar beet *Cukriniai runkeliai* 4. Spring barley *Vasariniai miežiai*	II	1. Peas / *Žirniai* 2. Winter wheat *Žieminiai kviečiai* 3. Spring barley *Vasariniai miežiai*	III	1. Peas / *Žirniai* 2. Winter wheat *Žieminiai kviečiai* 3. Winter wheat *Žieminiai kviečiai*
IV	1. Sugar beet *Cukriniai runkeliai* 2. Peas / *Žirniai* 3. Winter wheat *Žieminiai kviečiai*	V	1. Sugar beet *Cukriniai runkeliai* 2. Spring barley *Vasariniai miežiai* 3. Peas / *Žirniai*	VI	1. Peas / *Žirniai* 2. Winter wheat *Žieminiai kviečiai*

Quality assessment indicators of the primary production of the crop rotation pea crops – total nitrogen content (N) was determined by Kjeldahl method (LST 1523), P – by wet combustion, colorimetrical method using *Technikon* instrument, K and Ca – by flame photometry. All analyses were done at the Lithuanian Institute of Agriculture's laboratory of Chemical research.

The results thus obtained were statistically analyzed using ANOVA software /Tarakanovas, Raudonius, 2003/.

Results and Discussion

Average experimental data from the 1997-2004 period indicated that the highest stand density of pea crop (101 plants m^{-2}) was recorded in the three-course crop rotation (sugar beet- pea-winter wheat) (Table 2).

The lowest stand density of the pea crop was registered in the three-course crop rotation (pea-winter wheat- winter wheat) 83 plants m^{-2}. Two-course crop rotations (pea-winter wheat) had significantly reduced number of productive pods (4.4 m^{-2}) and number of seeds per plant (18.2) as compared with the control four-course rotation. In the two-course (pea-winter wheat) and in the three-course (pea-winter wheat- winter wheat) crop rotations there was found significantly lower plant height as compared with the four-course rotation.

Table 2. The influence of different crop rotations on pea yield composition
2 lentelė. *Skirtingų sėjomainos rotacijų įtaka žirnių derliaus struktūros elementams*
Dotnuva, 1997-2004

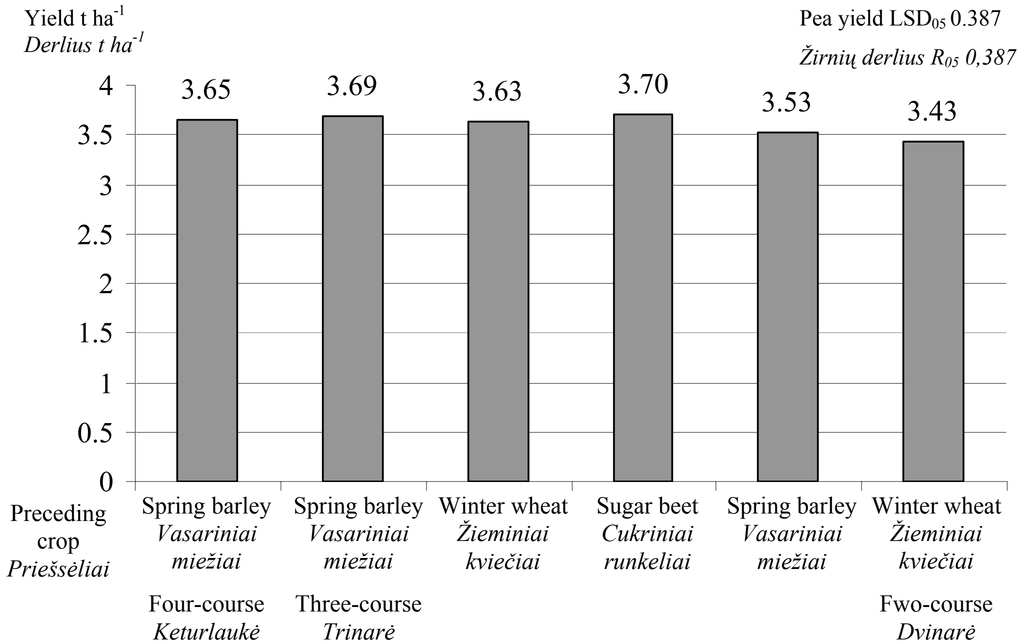
Crop rotation *Sėjomaina*	Number of plants per m^{-2} *Augalų skaičius m^{-2}*	Plant height cm *Augalų aukštis cm*	Number of pods per plant *Augalo ankščių skaičius*	Number of seeds per plant *Augalo sėklų skaičius*	1000 seed weight g *1000-čio sėklų masė g*
P-W-SB-B *Ž-K-CR-M*	94	75.8	5.1	20.4	203.8
P-W-B *Ž-K-M*	91	74.4	5.1	20.2	195.0
P-W-W *Ž-K-K*	83	71.4	4.8	19.4	201.4
SB-P-W *CR-Ž-K*	101	76.7	5.3	21.3	200.6
SB-B-P *CR-M-Ž*	92	76.9	5.2	20.8	199.1
P-W *Ž-K*	87	70.8	4.4	18.2	203.3
LSD_{05} / R_{05}	12.12	3.13	0.49	2.04	5.81
LSD_{01} / R_{01}	16.054	4.148	0.653	2.704	7.692

Note. Rotations are indicated using the first letters of crops: P – pea, W – wheat, B – barley, SB – sugar beet, WR – winter rape, SR – spring rape.
Pastaba. Sėjomainos augalai pažymėti pirmosiomis raidėmis: Ž – žirniai, K – žieminiai kviečiai, M - vasariniai miežiai, CR - cukriniai runkeliai, ŽR – žieminiai rapsai, VR – vasariniai rapsai.

McDonald (1995) reported a strong response of seed yield to growing season rainfall with yield increasing by 4.3 kg ha^{-1} for each additional millimetre increase in rainfall. Our study suggests that pea yield was more dependent on the different growing conditions of each year influenced by the weather factors. Pea yield varied markedly in separate years. The crop yielded best in 2004: in all crop rotations the yield amounted to on average 5.25 t ha^{-1}, while the lowest yield (2.60 t ha^{-1}) was recorded in 1999.

Average experimental data from the years 1997 to 2004 showed that pea yielded best (3.70 t ha^{-1}) in the three-course crop rotation (sugar beet-pea-winter wheat), a slightly lower yield (3.69 t ha^{-1}) and (3.65) was harvested in the three-course (pea-winter wheat-spring barley) and four-course (pea-winter wheat-sugar beet-spring barley) crop rotations, and the lowest yield (3.43 t ha^{-1}) in the two-course crop rotation (pea-winter wheat) (Figure). After different preceding crops the productivity of pea was similar: after sugar beet it was average 3.70 t ha^{-1}, after barley and wheat the yield was 3.62 t ha^{-1} and

3.53 t ha^{-1}, respectively. According to literature /Takeli, Ates, 2003/, seed yield in pea varied from 1.5-8.0 t ha^{-1}.



Yield of pea seeds in various crop rotations
Žirnių derlius skirtingose sėjomainose
Dotnuva, 1997-2004

Correlation data between pea yield indicators and actual yield are presented in Table 3. Analysis of the data suggests that significant and strongest (r = 0.78-0.99) correlations between the pea yield and the elements forming yield were identified in the two-course crop rotation. Slightly weaker correlations between the pea yield and its elements were established in the four-course crop rotation (r = 0.64-0.72). The yield of peas grown in the three-course crop rotation (sugar beet-barley-pea) was significantly influenced only by the number of plants. Averaged data indicated the weakest correlation between the pea grain yield and the number of seed. The number of reproductive nodes, plant height and seed number per pod had a significant ($P < 0.01$) and positive correlation with seed yield /Walton, 1991/. In the trials published by Gupta et al. (1984), the seed yield of peas was correlated with 100-seed weight.

Different crop rotations had a diverse effect on the amount of nitrogen, potassium, calcium and protein in pea grain production. Differences in pea grain chemical composition between the individual short crop rotations were low during the 2001-2004 experimental periods.

Table 3. Linear correlation coefficients of pea yield indicators in relation to yield
3 lentelė. *Žirnių grūdų derliaus formavimo elementų ir derliaus tiesinės koreliacijos koeficientai*

Dotnuva, 1997-2004

Crop rotation *Sėjomaina*	Number of plants per m^{-2} *Augalų skaičius m^{-2}*	Number of pods per plant *Augalo ankščių skaičius*	Number of seeds per plant *Augalo sėklų skaičius*	1000 seed weight g *1000-čio sėklų masė g*
P-W-SB-B *Ž-K-CR-M*	0.72**	0.65**	0.64**	0.66**
P-W-B *Ž-K-M*	0.71**	0.78**	0.65**	0.51
P-W-W *Ž-K-K*	0.60*	0.63**	0.51*	0.69**
SB-P-W *CR-Ž-K*	0.57*	0.75**	0.62**	0.78**
SB-B-P *CR-M-Ž*	0.72*	0.48	0.37	0.42
P-W *Ž-K*	0.78**	0.99**	0.88**	0.79**

* Correlation significant at 95 % probability level / *Ryšys patikimas esant 95 % tikimybės lygiui*
** Correlation significant at 99 % probability level / *Ryšys patikimas esant 99 % tikimybės lygiui*

Table 4. The influence of different crop rotations on pea seed quality indicators
4 lentelė. *Skirtingų sėjomainos rotacijų įtaka žirnių sėklų kokybės elementams*

Dotnuva, 2001-2004

Crop rotation *Sėjomaina*	N	P	K	Ca	Crude protein *Žali baltymai*
			%		
P-W-SB-B *Ž-K-CR-M*	3.70	0.547	1.08	0.203	23.1
P-W-B *Ž-K-M*	3.63	0.540	1.12	0.221	22.7
P-W-W *Ž-K-K*	3.63	0.538	1.12	0.206	22.7
SB-P-W *CR-Ž-K*	3.71	0.560	1.11	0.223	23.2
SB-B-P *CR-M-Ž*	3.74	0.555	1.13	0.201	23.4
P-W *Ž-K*	3.49	0.534	1.11	0.211	21.8
LSD_{05} / R_{05}	0.116	0.03	0.022	0.02	0.701
LSD_{01} / R_{01}	0.160	0.041	0.031	0.027	0.969

Nitrogen and protein contents in pea grain in the two-course crop rotation (pea-winter wheat) were recorded to be significantly lower as compared with the four-course rotation. Potassium content in pea grain production in all three and two-course crop rotations investigated was found to be significantly higher than in the four-course crop rotation. In the three-course crop rotation (sugar beet-pea-winter wheat) a significantly higher content of calcium was identified as compared with the four-course rotation.

Conclusions

1. Choice of preceding crops and shortening of rotations had some effect on the formation of individual productivity elements of peas. Through shortening of crop rotations from 4 to 2 courses the height of pea stems, number of pods per plant and number of seeds per plant significantly decreased.

2. Shortening of rotations from 4, 3 to 2 courses and choice of preceding crops did not have statistically significant effect on the pea seed yield.

3. Shortening of rotations resulted in an increase in potassium and calcium contents in pea grain, whereas nitrogen, phosphorus and protein contents tented to decrease.

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ŽIRNIŲ DERLIUS IR JO KOMPONENTAI SKIRTINGOSE SĖJOMAINOSE

V. Seibutis, I. Deveikytė

Santrauka

1997-2004 m. stacionariniame lauko bandyme Dotnuvoje tirta skirtingų (2-4 nariai) sėjomainos rotacijų parinkimo įtaka žirnių biometriniams rodikliams ir derlingumui.

Vidutiniais tyrimų duomenimis, didžiausias žirnių derlius (3,70 t ha^{-1}) gautas trilaukėje sėjomainoje (cukriniai runkeliai, miežiai, žirniai). Keturlaukėje (žirniai, žieminiai kviečiai, cukriniai runkeliai, miežiai) ir dvilaukėje (žirniai, žieminiai kviečiai) sėjomainose žirnių grūdų derlius nuosekliai mažėjo – atitinkamai 3,65 ir 3,43 t ha^{-1} (neesminis derliaus mažėjimas).

Žirnius auginant po skirtingų priešsėlių, derlingumas buvo panašus: po cukrinių runkelių – 3,70 t ha^{-1}, po vasarinių miežių ir žieminių kviečių – atitinkamai 3,62 ir 3,53 t ha^{-1}.

Nustatyta, kad sėjomainos rotacijų trumpinimas bei priešsėlių parinkimas lėmė skirtingą žirnių produktyvumo elementų formavimąsi. Trumpinant rotacijas nuo 3 iki 2 laukų, iš esmės sumažėjo augalo aukštis, ankščių bei sėklų skaičius.

1997-2004 m. atliktų tyrimų duomenimis, sėjomainos rotacijų trumpinimas ir priešsėlio parinkimas neturėjo didelės įtakos žirnių sėklų derliui, bet lėmė skirtingą žirnių produktyvumo elementų formavimąsi.

Reikšminiai žodžiai: žirniai, derlius, sėjomaina.