Yield and technological quality of ecological and low-input production of potatoes

Úroda a technologická kvalita ekologickej a low input produkcie zemiakov

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Abstract

The yield and other quantitative (number of plants, number of tubers, weight of tubers per 1 m^2) and qualitative parameters (content of vitamin C, starch, nitrogen and dry matter) of the *Solanum tuberosum* L. early variety "Collete" have been studied in ecological and low-input farming systems with two levels of organic fertilization during 2003-2005. The experiment was situated in water-protected zone of western Slovakia on Luvi-Haplic Chernozem. After harvest of forecrop in higher level of organic fertilization treatment catch crop – phacelia and mustard was grown. Highly significant differences in each studied parameters of potato tubers between certain years were ascertained, thus great influence of weather conditions on quality and quantity of potatoes was confirmed. Yields was highly significantly influenced also by farming systems, when in low-input system the average yield was 21.38 t ha^{-1} and in ecological system 20.02 t ha^{-1}. Green manure management did not influence yield significantly. In treatment without green manure the average yield 20.47 t ha^{-1} was reached with comparison to green manure application treatments 20.93 t ha^{-1}. In low-input system significantly higher C vitamin content (4.23 mg $100g^{-1}$) was ascertained compared to ecological one 3.53 mg $100g^{-1}$. Other qualitative parameters were more or less on the same level. We recommended both farming system for growing potatoes in water vulnerable zones and for better fulfil the Good Agricultural Practices in Slovak conditions.

Keywords: potatoes, *Solanum tuberosum* L., ecological and low-input farming systems, yield, potatoes quality

Rozšírený Abstrakt

V poľných podmienkach lokality Borovce bol skúmaný vplyv ekologického (ES) a low-input (LIS) systémov hospodárenia na pôde pri dvoch úrovniach organického hnojenia na výšku úrody a vybrané kvalitatívne znaky ľuľka zemiakového (*Solanum* *tuberosum* L.) veľmi skorej odrody „Collete“. Na rozdiel od low input systému hospodárenia, v ekologickom systéme nebola aplikovaná chemická ochrana plodín, ani priemyselné hnojivá v súlade s požiadavkami IFOAM. Pri oboch úrovniach organického hnojenia bolo na jeseň zaorané 30 t ha^{-1} maštaľného hnoja a pri vyššej úrovni organického hnojenia (B) bolo použité aj zelené hnojenie s výsevom 15kg ha^{-1} horčice a 15kg ha^{-1} facélie.

Lokalita Borovce (17°75´ v.d., 48°58´ s.š.) sa nachádza na juhozápadnom Slovensku, má kontinentálny charakter podnebia s priemernou ročnou teplotou 9,2 °C (za vegetáciu IV.-IX. 15,5 °C) a dlhodobým priemerom úhrnu zrážok 593 mm (z toho za vegetáciu IV.-IX. 358 mm). Územie sa vyznačuje veľkým kolísaním teplôt a nerovnomerným rozdelením zrážok. Dominantným pôdnym typom je černozem hnedozemná vytvorená na spraši (textúrne hlinitá až ílovitohlinitá; pH 5,5 - 7,2; stredný obsah humusu (1,8-2,0 %) a prístupného fosforu; dobrý obsah draslíka a vysoký obsah horčíka).

V oboch systémoch hospodárenia bola slama a ostatné pozberové zvyšky zaorané do pôdy a používalo sa klasické obrábanie pôdy. Ľuľok zemiakový bol pestovaný v 6 honovom osevnom postupe: hrach siaty – pšenica letná f. ozimná (po zbere pri B úrovni hnojenia aj medziplodina facélia vratičolistá + horčica biela v pomere 15 kg ha^{-1} + 15 kg ha^{-1}) – ľulok zemiakový (30 t ha^{-1} maštaľného hnoja) – jačmeň siaty f. jarná (s podsevom ďateliny lúčnej) – ďatelina lúčna - pšenica letná f. ozimná (po zbere pri B úrovni hnojenia aj medziplodina facélia vratičolistá + horčica biela v pomere 15 kg ha^{-1} + 15 kg ha^{-1}).

Na úrodu a úrodotvorné prvky (počet rastlín na 1 m^2, počet hľúz na 1 m^2, hmotnosť hľúz na 1 m^2), ako i na všetky sledované znaky kvality (obsah vitamínu C, obsah škrobu, obsah dusíka a obsah sušiny) mal štatisticky vysoko preukazný vplyv ročník (Tabuľka 4, 5).

Úroda bola preukazne ovplyvnená aj pestovateľským systémom. V LIS sa dosiahlo 21.38 t ha^{-1} zemiakov a v ES 20,2 t ha^{-1}. Zelené hnojenie neovplyvnilo preukazne výšku úrody, ktorá bola v intervale 20,47 - 20,93 t ha^{-1} v prospech zeleného hnojenia (Tabuľka 4).

Z kvalitatívnych znakov bol preukazne vyšší obsah vitamínu C v hľuzách dopestovaných v low-input sústave hospodárenia (4.23 mg 100g^{-1}) v porovnaní s ekologickou sústavou (3.53 mg 100g^{-1}). Ostatné úrodové aj kvalitatívne znaky boli vyrovnané, čo znamená, že odroda Collete dokázala tieto znaky regulovať v oboch systémoch hospodárenia. Zelené hnojenie sa štatisticky preukazne prejavilo len pri úrodotvornom prvku hmotnosti hľúz na 1 m^2 (Tabuľka 4, 5).

Z hľadiska výšky a kvality produkcie boli istejšie a stabilnejšie úrody ako i lepšia kvalita dosiahnuté v low-input systéme pestovania. Kvalita produkcie je v oboch systémoch pestovania na rovnakej úrovni a spĺňa požiadavky konzumentov. Z dosiahnutých výsledkov vyplýva, že pre prax možno odporučiť oba systémy hospodárenia pre pestovanie ľuľka zemiakového veľmi skorej odrody Collete.

Navrhnuté systémy hospodárenia sú vhodné pre pestovanie zemiakov v zraniteľných oblastiach vôd ako aj pre plnenie podmienok správnej farmárskej praxe.

Kľúčové slová: ľuľok zemiakový, *Solanum tuberosum* L., ekologický a low-input systém hospodárenia, úroda, kvalita zemiakov

Introduction

Nowadays, the development of ecological farming intensively increases in almost all countries of the world. Ecological farms have significantly higher biodiversity, reduced energy consumption and cause less water pollution than intensive farms. Ecological farms have the total costs usually lower by 10 % - 25 % [28]. Moreover, ecological farming significantly positively influences soil physical, chemical and biological properties [6, 25, 26]. Better taste and health aspect of bio-products permanently increase consumers´ demand [9].

Generally, yields in ecological farming system are lower compared to conventional one. Since in ecological farming system are not used synthetic pesticides and artificial fertilisers, for their satisfactory yield have to be strictly kept all measurements supporting the optimal plants growing and development during the whole growing season. The most preferred measurements are: sufficient crop rotation, suitable plants varieties, optimizing of organic fertilization and other management practices, use of permitted chemicals for biological plant protection [8]. The most frequent causes of lower yields in ecological farming systems are: shortage of nutrient content during spring season, great competition of weed and insufficient plant protection against diseases and pests. Primary in pests control against Colorado Potato Beetles in ecological faming were acquired excellent results by use of bio-insecticide NOVODOR (86 % effectiveness) [23]. Good results were acquired also by use of physical methods of pests control, when open flame performed better than hot water steam and pneumatic collector with 56 % efficiency [24].

Ecological farming is low-input in use of external farming inputs, but it is a high-input for the knowledge and skills needed. Low-input system is characterized by reduced fertilization (40 % - 50 % of conventional system), regulated application of liquid manure and dung-water, and minimized soil cultivation.

Pimentel et al. [20] stated principles that underline a low-input sustainable agricultural system: 1) adapting the agricultural system to the environment of the region, including soil, water, climate and biota present at the site; 2) optimizing the use of biological and chemical/physical resources in the agroecosystem.

Aim of this research was to compare the influence of different farming systems (ecological and low-input) by two levels of organic fertilization on yield and selected quantitative and quality parameters of early variety of potatoes “Collete”.

Material and methods

The yield and selected quantitative and qualitative parameters of the *Solanum tuberosum* L. early variety “Collete” growing in ecological and low-input farming systems with two levels of organic fertilization have been studied in the field experiment. The method of randomised blocs in four replications was used during 2003-2005 in locality Borovce. Experimental site is located at maize-barley growing region at western part of Slovakia (E 17°75’, N 48°58’) in water-protected zone.

The locality has continental climate with average annual temperature 9.2 °C (during growing season IV.-IX. 15.5 °C) and annual precipitation 593 mm (during growing season IV.-IX. 358 mm). The area is characterized by very unstable temperature and irregularly distributed precipitation. Main soil type is Luvi-Haplic Chernozem on carbonate loess with loamy – to clay-loamy texture; neutral – to slightly acid reaction (pH 5.5-7.2); medium content of humus (1.8 % - 2.0 %) and available phosphorus; good content of potassium and high content of magnesium). Soil-climatic data are summarized in Table 1.

Evaluated systems:

ES – Ecological system of crop production. The direction and practices in accordance of IFOAM (International Federation of Organic Agriculture Movements) have been applied. The farm yard manure, straw, crops residues and green manure were incorporated into soil. Farmyard manure was used ones per six-crop rotation in potato phase of rotation with dose 30 t ha^{-1}. Chemical fertilizers and common chemical control were excluded. Only permitted insecticide (Novodor) and fungicide (Kuprikol) were used.

LIS – Low-input system. Straw and crop residues were incorporated into soil with supplementing of consumed PK nutrient by chemical fertilizers. Farmyard manure (FYM) was used only in potato phase of rotation with dose 30 t ha^{-1}. Low level of nitrogen fertilizers was used to all growing crops (to winter wheat 40 kg, to common pea 10 kg and to spring barley 30 kg nitrogen per hectare). Integrated pest management was also used.

In both evaluated systems the same basic tillage (conventional mouldboard plough and rotative cultivator Amazone KG-301) and management practices of organic matter (incorporation of FYM, straw, crop residues and green manure) were used. PK fertilization in LIS was made according to input-output balance. In the first year, the fertilization doses were applied according planned yield for winter wheat 7 tons, for spring barley 6 tons, for pea 4 tons, for potatoes 20 tons and for meadow clover up to 10 tons per hectare. The following years the fertilization doses were adjust according yield of forecrop sequence calculated according to Bízik et al. [2], Bujnovský and Ložek [3].

Green manure management treatments - without green manure (treatments A) and with green manure (treatments B) were used in six-crop rotation as follows: common pea – winter wheat (after crop harvest in B treatments of fertilization was grown catch crop – phacelia and mustard with sowing rate 15 kg ha^{-1} + 15 kg ha^{-1}) – potato (30 t ha^{-1} farmyard manure) – spring burley (with under seeding meadow clover) – meadow clover – winter wheat (after crop harvest in B level of fertilization was grown catch crop – phacelia and mustard with sowing rate 15 kg ha^{-1} + 15 kg ha^{-1}).

In both farming systems followed quantitative parameters were evaluated: the yield of potato tubers was calculated from each replication plots. The number of plants per $1m^2$, the number of tubers per $1m^2$, the weight of tubers per $1m^2$; samples were taken once from each replication. Qualitative parameters: content of vitamin C, starch, nitrogen and dry matter. The data were subjected to analysis of variance ANOVA (software Statgraphic).

Results and discussion

The weather conditions highly significantly influenced all studied quantitative and qualitative parameters for potato growing and crops yields (Tables 3-5).

Average annual temperature and annual precipitation in studied years 2003-2005 and also their long-term average values (years 1951-1980) are presented in Table 2. Years 2003 and 2004 were characterized by very dry growing season, when in year 2003 the total precipitation reached only 58 % compared to long-term average values (1951-1980) and in year 2004 even only 56 %. Moreover, during growing season in year 2003 the average temperature was by 3.1 °C (17 %) higher compared to long-term average. Pospišil et al. [21] stated that potatoes have significant moisture demand and minimal precipitation per growing season should be 350-450 mm, regularly distributed mainly in critical potato growth phases - germination, tubers formation and their growing. Optimum demand of total precipitation is 600 mm - 800 mm per year and 65 % - 75 % relative air moisture during growing season. If deficit of precipitation occurred, the use of irrigation is needed mainly in maize and sugar beet growing region. Similarly Nagy et al. [17] on the base of synthesis of 39 years results ascertained that in the sub humid area the irrigation of potatoes constitutes a resolute method in the achievement of constantly high production per ha.

Insufficient weather conditions in years 2003-2004 had negative effect on crop yield, which was statistically significantly the lowest (13.67 t ha^{-1}) just in extreme year 2003. In year 2005, which was considered as climatically normal (considering amount of precipitation and average temperature during growing season and during whole year long as well), were reached significantly the highest yields (30.73 t ha^{-1}) of early variety of potatoes “Collete” (Table 4). The influence of weather conditions on the variability of potatoes crop was reported by other authors [8, 10, 27].

The yield of green manure (phacelia and mustard) incorporated into soil in autumn was in average 7.24 t ha^{-1} in years 2002-2003 (Table 3). Lower average yield of catch crop was reached in ecological system (5.52 t ha^{-1}) compared to low-input system, where the yield was 9.91 t ha^{-1}, what corresponds to doses of fertilizers and ways of plant protection in studied farming systems. Very low yields of catch crops in year 2003 in ecological system 0.97 t ha^{-1} and in low-input system 1.04 t ha^{-1} were probably caused by significant deficit of precipitation (the precipitation in August was only 16.0 mm and in September 19.3 mm), and also by very high average temperatures in August (22.36 °C) and September (15.55 °C).

The yields and the values of other studied parameters of potato tubers are presented in Table 4 and their statistical evaluation is in Table 5.

Generally, the yield of *Solanum tuberosum* L. tubers in ecological farming is 20-50 % lower compared to other systems. According to Lehocká et al. [12] the highest influence on potatoes yields had weather conditions, potatoes variety, and farming systems what is in agreement with our results. In the years 2003-2005 average yield of potato tubers was 20.70 t ha^{-1}. Weather conditions during evaluated years had highly significant influence on yields (Table 4). Yield was highly significantly influenced also by farming systems, when in low-input system the average yield was 21.38 t ha^{-1} and in ecological system 20.02 t ha^{-1}, what is in agreement with the results of other authors respectively trials comparing the yields of different farming systems [10, 11, 14, 22, 28].

Green manure management did not influence potatoes yields significantly. In treatment without green manure (A) average yield 20.47 t ha^{-1} was reached and at higher level of organic fertilization (B) 20.93 t ha^{-1} (Table 4). Ložek et al. [16] stated that potatoes require organic fertilization at least in doses 30-40 t ha^{-1} of farmyard manure incorporated to soil in autumn. Average consumption of nutrients per production of 1000 kg potato tubers is 5 kg N, 1 kg P, 7 kg K, 11.5 kg Ca, 0.7 kg Mg.

Average plants number per 1 m^2 in years 2003-2005 was 3.81. Studied farming systems influenced this parameter highly significantly, and lower plants number was ascertained in ecological system 3.67 plants m^{-2} compared to low-input system 3.96 plants m^{-2}. No significant differences between green manure management practices were found (range 3.83-3.79 plants m^{-2}). Significant interaction of farming systems with organic fertilization revealed that different farming systems influenced number of potato plants per 1 m^2 also at different fertilization levels (Table 5).

In evaluated parameters number and weight of potato tubers per 1 m^2 were not ascertained statistically significant differences between farming systems (Table 4, 5). Whereas in parameter number of tubers per 1 m^2 no significant difference between studied levels of green organic fertilization was found, in parameter the weight of tubers per 1 m^2 it was ascertained significantly higher weight 2.34 kg m^{-2} of tubers at treatment without green manure (A) compared to higher level of organic fertilization (B) 2.18 kg m^{-2}. Also statistically significant interaction of years with green manure fertilization revealed that weather conditions influenced potato tubers weight per 1 m^2 at certain levels of organic fertilization differently.

Similarly as studied yields parameters all qualitative parameters were significantly influenced by climatic conditions in studied years. Many authors presented in their results significant influence of year on qualitative parameters of potatoes [1, 13, 18, 19].

C vitamin content in potatoes was in certain years highly significantly different, and its average content was 3.88 mg $100g^{-1}$. Also farming systems had significant influence on C vitamin content, when in low-input system it reached 4.23 mg $100g^{-1}$ and in ecological one 3.53 mg $100g^{-1}$. Between the levels of organic fertilization were not found significant differences (Table 4, 5). Diviš [4] and Diviš and Zlatohlávková [5] quoted that the C-vitamin content was more affected by variety, years than by farming methods.

Average starch content in potatoes was 16.38 %. Significant differences in starch content were ascertained only between years 2003-2004 and 2004-2005. Lower starch content (16.16 %) but without statistical significance was in ecological farming system compared to low-input system (16.59 %). Similarly, no significant differences between levels of organic fertilization were found in potatoes starch content (Table 4, 5).

Nitrogen content in potatoes was in certain years highly significantly different, and its average content was 15552 mg kg^{-1} (1.55 %). Between different farming systems and levels of organic fertilization were not found statistically significant differences (Table 4, 5). Generally, higher content of nitrogen (but not in nitrate form) is favourable in consumer and fodder potatoes, mainly for high biological value of potato proteins, which consists of around 70 % tuberin and 30% tuberinin. From biological point of view, the potato protein is one of the most valuable for high content of essential amino acids [7].

Climatic conditions influenced also dry matter content, which was in warm and dry years 2003 and 2004 significantly higher (22.69 % and 23.48 %) compared to climatically normal year 2005 (20.36 %). There were no significant differences between studied farming systems, when in low-input system average dry matter content was 22.24 % and in ecological one 22.12 % in years 2003-2005. Similarly, between levels of organic fertilization were not found significant differences, and in lower level of organic fertilization (A) was dry matter content 22.33 % compared to higher level (B) 22.02 %.

Compared to our results, Lehocká et al. [13] and Žák et al. [27] ascertained lower content of dry matter (20.09 %) and starch (16.71 mg kg^{-1}) in potato tubers from ecological farming system compared to low-input system (24.21 % respectively 17.13 mg kg^{-1}). However, C vitamin content (2.28 mg $100g^{-1}$) and nitrogen content (21300 mg kg^{-1}) were more favourable in ecological farming system compared to low-input (1.57 mg $100g^{-1}$ respectively 20700 mg kg^{-1}). They stated that nitrogen content in potato tubers significantly depended on used doses of nitrogen fertilisers.

On the base of results obtained in this study we can conclude, that evaluated qualitative parameters, beside C vitamin content, in ecological system nearly reached the level of low-input system, when nitrogen content in ecological system was 15740 mg kg^{-1}, i.e. by 2.6 % higher than in low input system 15363 mg kg^{-1}. Starch content in ecological system was by 2.6 % lower (16.16 mg kg^{-1}) than in low-input system 16.59 mg kg^{-1}. Dry matter content was in ecological system by 0.5 % lower (22.12 %) compared to low-input system (22.24 %). The difference between ecological and low-input farming system in C vitamin content was 20 %, when in ecological system it was 3.53 mg $100g^{-1}$ and in low-input system 4.23 mg $100g^{-1}$. Similar results are presented also by Lehocká et al. [15].

Conclusions

In years 2003-2005 the influence of different farming systems and two levels of organic fertilization on yield and chosen qualitative parameters of potato tubers was studied on experimental basis VÚVR Piešťany in Borovce. From the results obtained in this study we can conclude:

- All evaluated parameters of potato tubers variety "Collete" grown in ecological and low-input system were statistically significantly influenced by weather conditions in studied years.
- The yield of tubers was highly significantly higher in low-input system than in ecological one.
- In low input system were found highly significantly more plants on $1m^2$ compared to ecological one.
- Green manure management did not influence yield significantly.
- Beside C vitamin content, which was significantly higher in low-input system, other qualitative parameters were not significantly different between studied farming systems.
- The quality of potatoes grown in ecological farming system nearly reached the quality of potatoes grown in low-input system.
- Results obtained in this study had shown that it is worth to use in practise both farming systems for potato tubers growing. However, more stabile and certain yield of potatoes was reached in low-input-system, but the quality of production was on similar level in both systems. Indeed, ecological and low-input growing of potatoes has positive influence on environment.

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Table 1: Soil and climate characteristics of the experimental site
Tabuľka 1: Pôdno-klimatická charakteristka záujmového územia

Parameter (1)		Value (2)
Locality (18)		Borovce (E 17°75', N 48°58')
Above sea level (3)		167 m
Growing region (4)		Maize – burley (5)
Climatic conditions (6)		Continental (7)
Average temperature (8)	For the years (9)	9.2°C
For vegetation period (10)	15.5°C	
Average rainfall (11)	For the years (9)	593 mm
	For vegetation period (10)	358 mm
Soil type (12)		Luvi-Haplic chernozem (13)
Texture (19)		Loamy – to sandy-loamy (20)
pH/KCl		5.5 – 7.2
Available nutrients content (14)	P (Egner method)	187-234 mg kg^{-1} (average)(15)
	K (Schachtschabel method))	173-219 mg kg^{-1} (good) (16)
	Mg (Mehlich II method))	255-307 mg kg^{-1} (high) (17)
	Humusu (Tyurin method)	1.8 – 2.0 % (average) (15)

(1) ukazovateľ, (2) hodnota, (3) nadmorská výška, (4) výrobná oblasť, (5) kukurično-jačmenná, (6) charakter podnebia, (7) kontinentálny, (8) priemerná teplota vzduchu, (9) za rok, (10) za vegetáciu, (11) priemerný úhrn zrážok, (12) pôdny typ, (13) Černozem hnedozemná, (14) obsah živín prístupných pre rastliny, (15) stredný, (16) dobrý, (17) vysoký, (18) lokalita, (19) pôdny druh, (20) hlinitá až piesočnato-hlinitá

Table 2: Weather conditions in years 2003-2004
Tabuľka 2: Poveternostné podmienky v pokusných rokoch 2003-2004

Month (1)	x (1951-1980)		2003		2004		2005	
	°C	mm	°C	mm	°C	mm	°C	mm
I.	-1.8	32	-1.65	40.9	-3.06	50.6	-0.48	39.9
II.	0.2	33	-1.06	9.4	1.28	27.4	-2.36	51.6
III.	4.2	32	5.17	0.9	4.42	49.4	3.01	7.0
IV.	9.4	43	9.94	16.5	11.65	14.4	11.45	91.2
V.	14.1	54	18.73	28.7	14.05	15.4	15.62	33.5
VI.	17.7	80	22.26	33.9	17.94	72.9	18.18	33.7
VII.	18.9	76	21.67	95.7	20.06	15.9	20.44	90.3
VIII.	18.4	68	22.94	16.0	20.70	44.6	18.93	98.8
IX.	14.5	38	15.88	19.3	15.01	38.9	16.41	42.3
X.	9.6	42	8.00	57.9	12.22	61.4	10.89	10.2
XI.	4.6	51	6.68	34.5	5.20	46.5	3.68	48.0
XII.	0.3	46	0.88	30.6	0.96	33.3	-0.33	69.5
`x I. – XII.	9.2	-	10.85	-	10.06	-	9.62	-
`x IV. - IX.	15.5	-	18.61	-	16.60	-	16.84	-
∑ I. – XII.	-	593	-	384.3	-	470.7	-	616.0
∑ IV. – IX.	-	359	-	210.1	-	202.1	-	389.8

(1) mesiac

Table 3: The yield of catch crop – green manure (t ha^{-1})
Tabuľka 3: Úroda medziplodiny na zelené hnojenie (t ha^{-1})

Variant/year (1)	2002	2003	2004	Total (3)	Average (2)
ES A	10.84	0.94	3.63	15.41	5.14
ES B	10.80	1.00	5.91	17.71	5.90
Average (2) ES	10.82	0.97	4.77	16.56	5.52
LIS A	11.18	1.04	9.51	21.73	7.24
LIS B	10.90	1.04	19.78	31.72	10.57
Average (2)LIS	11.04	1.04	14.65	26.73	8.91
Average ES + LIS	10.93	1.01	9.71	21.65	7.21

(1) rok, (2) priemer, (3) spolu

Table 4: Values of technological quality of potato tubers
Tabuľka 4: Hodnoty znakov technologickej kvality ľuľka zemiakového

Potato tubers (1)								
factors (2)	yield (3)	number of plants per 1 m^2 (4)	number of tubers per 1 m^2 (5)	weight of tubers per 1 m^2 (6)	vitamin C content (7)	starch content (8)	nitrogen content (9)	dry mater content (10)
units (11)	(t ha^{-1})	pieces (12)		kg	mg100 g^{-1}	mg kg^{-1}	mg kg^{-1}	%
total average (12)	20.70	3.81	38.14	2.26	3.88	16.38	15552	22.18
years (14)								
2003	13.67	4.06	32.38	1.37	2.72	16.03	18497	22.69
2004	17.71	3.63	39.13	2.17	4.97	18.08	12075	23.48
2005	30.73	3.75	42.94	3.23	3.96	15.02	16083	20.36
farming systems (15)								
ES	20.02	3.67	36.97	2.20	3.53	16.16	15740	22.12
LIS	21.38	3.96	39.50	2.32	4.23	16.59	15363	22.24
fertilization (16)								
A	20.47	3.83	39.25	2.34	3.69	16.40	15474	22.33
B	20.93	3.79	37.04	2.18	4.07	16.36	15629	22.02
years x farming systems (17)								
2003 ES	13.06	3.88	32.88	1.32	2.45	15.87	18663	22.69
2003 LIS	14.27	4.25	31.88	1.43	2.98	16.20	18331	22.69
2004 ES	17.46	3.50	36.25	2.11	4.25	17.72	12166	22.84
2004 LIS	17.96	3.75	42.00	2.24	5.69	18.44	11948	24.13
2005 ES	29.53	3.63	41.25	3.18	3.89	14.90	16391	20.83
2005 LIS	31.93	3.88	44.63	3.28	4.02	15.14	15775	19.90
years x fertilization (18)								
2003 A	13.45	4.13	34.88	1.43	2.57	16.07	18663	22.60
2003 B	13.88	4.00	29.88	1.32	2.87	16.00	18331	22.77
2004 A	17.84	3.50	40.38	2.37	4.73	18.06	11897	23.47
2004 B	17.57	3.75	37.88	1.97	5.21	18.10	12253	23.49
2005 A	30.12	3.88	42.50	3.22	3.78	15.07	15862	20.92
2005 B	31.34	3.63	43.38	3.24	4.13	14.97	16304	19.81
farming systems x fertilization (19)								
ES A	19.91	3.58	37.75	2.30	3.44	16.33	15662	22.40

ES B	20.12	3.75	35.80	2.10	3.62	15.99	15818	21.84
LIS A	21.03	4.08	40.75	2.38	3.94	16.47	15286	22.27
LIS B	21.74	3.83	38.25	2.56	4.53	16.72	15441	22.20
years ([4])								
Hd 0.05	0.98	0.21	6.41	0.16	0.63	1.71	868.27	2.13
Hd 0.01	1.48	0.32	9.72	0.25	0.95	2.60	1313.20	3.23
farming systems ([15])								
Hd 0.05	0.80	0.17	5.23	0.13	0.51	1.40	709.31	1.74
Hd 0.01	1.21	0.26	7.93	0.20	0.78	2.12	1074.67	2.64
fertilization ([16])								
Hd 0.05	0.80	0.17	5.23	0.13	0.51	1.40	709.31	1.74
Hd 0.01	1.21	0.26	7.93	0.20	0.78	2.12	1074.67	2.64
replication ([20])								
Hd 0.05	1.13	0.24	7.40	0.19	0.73	1.98	1003.12	2.46
Hd 0.01	1.71	0.37	11.22	0.29	1.10	3.00	1519.82	3.74

([1]) Ľulok zemiakový, ([2]) faktory, ([3]) úroda hľúz, ([4]) počet rastlín na 1 m^2, ([5]) počet hľúz na 1 m^2, ([6]) hmotnosť hľúz na 1 m^2, ([7]) obsah vitamínu C, ([8]) obsah škrobu, ([9]) obsah dusíka, ([10]) obsah sušiny, ([11]) jednotky, ([12]) kusy, ([13]) celkový priemer, ([14]) roky, ([15]) systémy hospodárenia, ([16]) hnojenie, ([17]) roky x systémy, ([18]) roky x hnojenie, ([19]) systémy x hnojenie, ([20]) opakovanie

Table 5: Statistical evaluation of studied parameters by analysis of variance
Tabuľka 5: Štatistické vyhodnotenie hodnotených znakov zemiaka analýzou rozptylu

Potato tubers ([1]) factors ([2])	yield ([3])	number of plants per 1 m^2 ([4])	number of tubers per 1 m^2 ([5])	weight of tubers per 1 m^2 ([6])	vitamin C content ([7])	starch content ([8])	nitrogen content ([9])	dry mater content ([10])
years (R) ([11])								
SS ([12])	2544.99	1.62	91554	27.74	40.69	77.84	3.36E8	83.95
df ([13])	2	2	2	2	2	2	2	2
F ([14])	989.07	13.00	8.32	365.45	38.08	9.85	167.06	6.87
	1-2++	1-2++	1-2+	1-2++	1-2++		1-2++	
						1-2+		1-3+
P ([15])	1-3++	1-3+	1-3++	1-3++	1-3++		1-3++	
						2-3++		2-3+
	2-3++			2-3++	2-3++		2-3++	
farming systems (S) ([16])								
SS	22.46	1.02	88.02	0.16	5.97	2.23	1.70E6	0.17
df	1	1	1	1	1	1	1	1

F	17.46	16.33	1.60	4.23	11.17	0.56	1.69	0.02
P	1-2++	1-2++	-	-	1-2+	-	-	-
fertilization (H) (17)								
SS	2.49	0.02	58.52	0.32	1.72	0.01	2.88E5	1.16
df	1	1	1	1	1	1	1	1
F	1.93	0.33	1.06	8.48	3.23	0.005	0.28	0.19
P	-	-	-	1-2+	-	-	-	-
replications (O) (18)								
SS	68.05	2.39	5.72	0.93	0.32	6.67	9.51E6	4.49
df	3	3	3	3	3	3	3	3
F	17.74	12.77	0.03	8.18	0.20	0.57	3.14	0.24
P	1-3++ 1-4++ 2-3+ 2-4++	1-2++ 1-3+ 1-4++ 3-4+	-	1-4+ 2-4++ 3-4+	-	-	1-3+	-
residual dispersion (19)								
SS	7.71	0.37	329.87	0.22	3.20	23.69	6.04E5	36.63
df	6	6	6	6	6	6	6	6
in total (20)								
SS	2802.25	15.31	3915.97	33.76	72.43	153.92	3.81E8	220.35
df	47	47	47	47	47	47	47	47
interactions (21)								
R x H	-	-	-	+	-	-	-	-
R x O	+	-	-	-	-	-	-	-
S x H	-	+	-	-	-	-	-	-
H x O	-	-	-	+	-	-	-	-
R x S x H	-	+	-	-	-	-	-	-
R x S x O	+	-	-	-	-	-	-	-
R x H x O	+	++	-	+	-	-	-	-

(12) sum of squares, (13) degree of freedom, (14) F-test value, (15) significance
(1) Ľulok zemiakový, (2) faktory, (3) úroda hľúz, (4) počet rastlín na 1 m², (5) počet hľúz na 1 m², (6) hmotnosť hľúz na 1 m², (7) obsah vitamínu C, (8) obsah škrobu, (9) obsah dusíka, (10) obsah sušiny, (11) roky, (12) suma štvorcov, (13) počet stupňov voľnosti, (14) hodnota F-testu (vypočítaná), (15) preukaznosť, (16) systémy hospodárenia, (17) hnojenie, (18) opakovanie, (19) reziduálny rozptyl, (20) spolu, (21) interakcie