SUGAR BEET YIELDING AND SUGAR CONTENT IN THE BACKGROUND OF POLISH REGIONS AND NUTRITIONAL FACTORS

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Investigation on production plantations (total 398) were conducted in 1992–2002 in two sugar beet cultivation regions (central and middle-eastern part of Big Valley strip). Plantations were divided into two groups of yield above or below average of plantation total in each region. The aim of the investigation was to determine individual contribution of nutritional factors in root yield and sugar content forming. Average root yield for the group of plantation yielding above mean yield was 47.4 t/ha, ranging from 39.7 to 65.0 t/ha in middle-eastern and 55.9 t/ha, ranging between 47.4 and 72,0 t/ha in central Poland. The corresponding values for sugar content were as follows: 15.8; 13.4–18.1; 18.0 and 14.7–21,0%. Average root yields for the group of plantation yielding were 31.1 t/ha ranging from 15.1 to 39.1 t/ha in middle-eastern and 37.7 t/ha, ranging between 18.0 and 47.3 t/ha. The corresponding values for sugar content were: 15.8; 13.7–19.0; 16.9 and 14.2–21.2%. To find individual part of nutrition factors in root yield and sugar content forming the obtained regression coefficients were summed up and the share of each of them was calculated in this sum. Higher determination (R^2 = 22.4 and 18.6% depending on the region) was found above the average for the group of yield. The role of nutritional factor differed depending on the yielding group. In the group of yield below average the most important was soil pH and potassium content in the soil. In the group of yield above average a big role was played by nitrogen and phosphorus fertilization.

sugar beet; sugar content; root yield; nutritional factor; production plantation

INTRODUCTION

In some countries of Western Europe root yield achieved high enough sugar content to be 10–12 t sugar per 1 ha. During last five years in Poland root yield of sugar beet reached 50–60% of its production compared with the best countries (France, the Netherlands, United Kingdom, Germany) (Anonymous, 2003). Pidgeon et al. (2001) evaluated that the potential level of sugar beet yielding as the result of solar radiation absorption should be in Poland about 13.6 t sugar/ha, whereas the real yield for the years 1990–1995 was 40%. It increased to nearly 50% of the possible yield. For a comparison, sugar yields per unit area in France, the Nertherlands and England are equal to 80–85% potential level of yielding. According to the mentioned authors, limiting factors of sugar beet yielding in Poland are first of all moisture conditions. Independently of production site economic parameters of sugar beet are determined by three groups of factors: genotype, environment and technology of production. Currently in Poland the majority of registered varieties in respect to economic features approach to varieties cultivated in Western Europe, while the set of environmental conditions less profitable than in the latter enables to plantator groups to obtain high (50–60 t/ha) and very high (above 60 t/ha) yields.

It results from now conducted studies that from among factors of production technology the more sound root and sugar yield are affected by sowing date and date of harvest, i.e. length of vegetation period, plant density and rate of nitrogen (Kozminski, Michalska, 1995; Pawelec, Malicki, 1987; Šroller, Běhal, 1981). The role of fertilization and plant nutrition factors in yield forming in sugar beet is recognized in the literature (Draycott et al., 1997; Scott, Jaggard, 1978). Agricultural practice shows however, that fertilization is treated as some kind of panaceum for errors made in production technology as well in observance of technological discipline (Wyszynski et al., 2002). Rate applied very often surpasses the real needs of sugar beet and fertilization recommendation (Klepacki, 1997; Krzymuski et al., 1993).

The aim of the work was to evaluate the role of plant nutrition factor in sugar beet group of plantations differing in yielding level.

MATERIAL AND METHODS

The studies were conducted in 1992–2002 in two sugar beet-growing regions in Poland, on total group of 398 plantations. Individualized regions under investigation were middle-eastern and central parts of Big Valleys

strip (central strip of Poland). Middle-eastern region characterizes with late start of vegetation and shorter vegetation period, bigger comminution of plantations and lower level of soil management. Soil conditions are also worse, there is prevalence of brown soils, sugar beet is usually grown in class IIIb and IVa soils (scale 1–8) of very good rye complex. In the group of plantations where the investigation was conducted, sugar beet in soil better than IIIa and IIIb class in middle-eastern region was cultivated on 45%, and in central one on about 80% surface designated for this crop. Weather conditions in both regions of investigation are in Tables 1 and 2. As is seen in time period under investigation more amount of rainfall was observed in central Poland, mean monthly sum of temperature was also a slight higher there.

In middle-eastern region investigation was conducted in 1992–1995 with 185 plantations and in central one in 2000–2002 with 211 ones. In each region analyzed plantations were divided into 2 groups : yielding above or below average for all plantations in the region. Each plantation has a special document, operation sheet that comprised detailed characteristics of the environment as well as production technology used. At harvest the samples of roots and soil were taken from each plantation. There were determined sugar content in roots and potassium and phosphorus content as well as pH_{KCl} in soil. Plantations were analyzed at harvest, while root yield data were received from sugar factory. Data analysis was performed separately for each of investigation cycles and plantation groups. Arithmetic means of studied features were calculated according to the class distribution for given interval of factor levels. Three levels of soil content in phosphorus and potassium (low, medium and high) as well as 3 pH values (below 5.5, 5.5–6.5 and above 6.5) were segregated. While analyzing the effect of NPK 3 rate intervals were segregated in kg of N, P_2O_5 and K_2O per ha. The method of multiple linear regression was used for statistical evaluation of the influence of 6 analyzed factors upon yield and sugar content in roots. Regression function was estimated for data of plantation group of bigger or lower than average in particular region yield. To evaluate individual role of nutrition factor in root yield and sugar content forming obtained regression coefficients summed up and the percentage share in this sum for each of analyzed factor was found out.

Table 1. Monthly rainfall (mm) in growing season during 1992–1995 and 2000–2002 and water requirements after Dziezyc et al. (1987)

	April	May	June	July	August	September	October	Sum
Middle-eastern Poland								
1992	62.9	36.5	46.1	55.8	19.6	110.6	52.7	384.2
1993	29.5	22.1	70.8	93.7	38.6	80.5	24.6	359.8
1994	79.2	63.6	28.7	7.1	61.4	56.6	77.8	374.4
1995	48.5	53.8	99.0	54.0	50.8	115.4	14.8	436.3
Means 1969–1994	33.0	54.0	76.0	86.0	71.0	56.0	48.0	424.0
Central Poland								
2000	5.1	42.9	27.2	142.1	51.3	51.9	4.9	325.4
2001	87.7	60.9	71.4	114.2	67.2	102.1	24.5	528.0
2002	9.8	157.6	81.0	68.2	73.0	44.0	74.6	508.2
Means 1980–1999	38.0	55.0	70.0	76.0	64.0	49.0	37.0	389.0
Rainfall requirements after Dziezyc (mm)								
	18	65	74	85	78	54	34	408

Table 2. Average monthly temperatures of air (°C) in growing season during 1992–1995 and 2000–2002

	April	May	June	July	August	September	October
Middle-eastern Poland							
1992	6.0	13.2	17.1	18.9	19.7	16.7	4.8
1993	8.0	15.8	14.7	15.9	15.2	10.4	7.3
1994	8.8	12.0	15.0	21.1	17.8	14.3	5.8
1995	7.3	12.1	17.5	19.2	17.1	12.5	8.7
Means 1969–1994	6.8	12.6	16.0	17.4	16.7	12.5	7.2
Central Poland							
2000	12.0	15.2	18.0	16.9	18.3	11.6	11.4
2001	8.0	14.4	15.4	20.5	19.2	12.1	11.0
2002	8.7	18.1	18.7	23.2	22.1	13.6	8.4
Means 1980–1999	8.1	14.3	17.4	19.1	18.7	14.0	9.2

RESULTS AND DISCUSSION

Variability in middle-eastern region of Poland in both plantation groups of higher and lower yield was bigger than in central one. In this region root yield was higher by 8.4 t/ha in the group of plantations that yielded above the average and 6.6 t/ha in the one yielding below average as compared to middle-eastern region. Higher yield as well as lower value of indices that characterize yielding variability speak about higher levelling of production environment in central region (cultivation in better soil). Nitrogen fertilization on plantation in both groups of yield was higher in middle-eastern region, while root yield was lower. Fertilization with phosphorus and potassium in both regions was a bit less on plantations of yielding below average. In this yield group plantations were characterized by lower pH. It was in both group of yielding lower in middle-eastern region. Soil rich in phosphorus and potassium was higher in central region for both group of plantations.

Sugar content in sugar beet root was higher in central region, independently of yielding level. It was due to more profitable production conditions. Noteworthy is higher sugar content in plantation group of the yield above average in central region, what confirmed finding of Le Bail (1994) that high production level and its quality do not counteract each to other. In middle-eastern region sugar content was similar in both groups of yielding (Table 3).

In both regions big range of nitrogen rate was observed, independently of the size of yield. In group of yielding above average rate of N up to 120 kg/ha was applied by 5 and 10% of plantators, respectively. About 40–48% plantations used rate 120–200 kg/ha, while rate of N above 200 kg/ha was applied on 42% and 52% of fields, depending on region (Table 4). In the group of yield above average a yield increment in middle-eastern region between rate up to 120 kg and above 200 kg/ha was about 3.5 t/ha, while in central one it was higher, 5 t/ha (Table 4). In the group that yielded below average, rate of N up to 120 kg/ha was used in 14 and 29% of plantations, 121–200 kg/ha in 43 and 41%, and above 200 kg/ha in 30 and 29% of plantations, depending on a region. Yield increment in this group of plantations for rate up to 120 kg N/ha and above 200 kg N/ha was similar, 3–3.2 t/ha (Table 4). The highest increment of root yield due to fertilization with phosphorus was found in middle-eastern region, which was characterized by low content in this mineral element (Tables 4 and 5). Root yield increment due to potassium fertilization was higher in both regions in group of plantations above average. Sugar content decreased with increased rate of N,

Table 3. Averages, minimum, maximum and variation coefficients of root yield, sugar content and nutrition factors in dependence on region and groups of plantations

Groups and number of plantations			Yield of root (t/ha)	Rate (kg/ha)			pH	Content in soil (mg/100g)		Sugar content (%)
				N	P_2O_5	K_2O		P_2O_5	K_2O	
		Middle-eastern Poland								
95	Yield above average	average	47.4	206.9	105.6	117.4	5.7	11.8	15.6	15.8
		standard deviation	17.9	17.7	110.3	203.6	0.4	10.6	4.5	0.03
		variation coefficient	0.38	0.09	1.04	1.73	0.06	0.90	0.29	0.00
		minimum	39.7	201.0	72.0	72.0	5.3	7.5	16.2	13.4
		maximum	65.0	226.0	228.0	360.0	5.8	22.5	22.5	18.1
92	Yield below average	average	31.1	189.3	81.6	92.6	5.3	11.1	14.2	15.8
		standard deviation	6.3	58.0	44.5	64.0	0.8	5.5	6.1	1.09
		variation coefficient	0.20	0.31	0.55	0.69	0.16	0.50	0.43	0.07
		minimum	15.1	68.0	0.0	0.0	3.8	3.5	5.0	13.7
		maximum	39.3	365.0	295.0	360.0	7.5	22.5	27.5	19.0
		Central Poland								
112	Yield above average	average	55.9	188.0	93.9	128.1	6.3	16.2	18.4	18.0
		standard deviation	6.2	58.0	37.2	46.2	0.8	5.0	6.3	1.29
		variation coefficient	0.11	0.31	0.40	0.36	0.12	0.31	0.34	0.07
		minimum	47.4	66.0	35.0	14.0	4.3	3.5	5.0	14.7
		maximum	72.0	345.0	320.0	285.0	7.9	22.5	27.5	21.0
99	Yield below average	average	37.7	167.4	89.8	125.9	5.9	15.1	16.4	16.9
		standard deviation	6.9	68.6	38.5	57.0	1.0	6.1	6.3	1.62
		variation coefficient	0.18	0.41	0.43	0.45	0.16	0.40	0.38	0.10
		minimum	18.0	48.0	30.0	36.0	3.9	3.5	5.0	14.2
		maximum	47.3	373.0	205.0	312.0	7.7	22.5	27.5	21.2

whereas there was no strictly oriented effect on this feature in the case of fertilization with phosphorus and potassium. Independent of investigation region and group of yielding increasing pH value enhanced root yield. Phosphorus and potassium content in soil affected the yield in central region in plantation group above average. In middle-eastern region in plantation group below average the magnitude of yield was influenced by soil potassium content (Table 5). The lack of relationship between soil content in phosphorus and potassium and the level of used rate of mineral elements in both region independent of group of yielding should be noted (Table 6). Bigger phosphorus and potassium rates were applied in plantation characterized by high soil content in these elements. Nitrogen rate was higher in plantation group of higher pH value.

Performed analysis of data concerning the effect of N, P and K fertilization in production plantations as well as soil content in P_2O_5 and K_2O and its pH showed no relationship between the level of applied rate of fertilizer and soil content in these nutrition elements. It explains the lack of strictly oriented effect of analyzed nutrition factors upon root yield. Also it points the lack of knowledge and discipline in using these technology production factors.

Evaluated relationship between yield and nutrition factor of plants indicated their determination of root yield size to be 10.6 to 22.4% as depended on yielding group and investigation region. Bigger determination (R^2) was found for group yielded above, 22.4% and 18.5% in middle-eastern and central region, respectively. In comparable region of investigation determination (R^2) for group yielding below average was 10.6 and 12.4, respectively. Assuming total effect of 6 analyzed nutrition factors upon root yield in Fig. 1, the ranking was presented that confirms the lack of univocal influence of studied nutrition factors on sugar beet yielding. Results of the performed analysis point to various effects of nutrition factor in region and group of yield. As it results from Fig. 1, the most yield limiting factor in the group of low yield are pH and potassium content depending on the region. Whereas in group that yielded above average very important is nitrogen and phosphorus fertilization.

In root yield forming of sugar beet in Poland apart from environmental factors (radiation, moisture conditions) large importance has obeying technological discipline. On example of forming nutritional factors of plants on plantations were proved great technological reserves in improving yields.

Table 4. Root yield and sugar content on plantations in dependence on nitrogen, phosphorus and potassium fertilization

Rate (kg/ha)	Middle-eastern Poland				Central Poland			
	root yield (t/ha)	sugar content(%)	fields		root yield (t/ha)	sugar content (%)	fields	
			number	%			number	%
Plantations with yields above average								
N								
≤ 120	44.8	16.4	5	5.3	53.7	18.0	11	9.8
121–200	47.5	16.0	38	40.0	55.9	18.1	54	48.2
> 200	48.4	15.7	52	54.7	58.7	17.9	47	42.0
P_2O_5								
≤ 80	44.9	15.8	34	35.8	53.6	18.2	44	39.3
81–160	47.4	15.9	52	54.7	55.9	17.9	65	58.0
> 160	53.0	16.1	9	9.5	54.9	17.7	3	2.7
K_2O								
≤ 80	46.0	15.7	30	31.6	53.4	18.2	13	11.6
81–160	47.4	15.8	45	47.4	55.9	18.2	80	71.4
> 160	49.6	16.2	20	21.1	57.4	17.3	19	17.0
Plantations with yields below average								
N								
≤ 120	28.5	16.6	13	14.1	36.1	16.8	29	29.3
121–200	31.1	15.8	43	46.7	37.7	17.2	41	41.4
> 200	31.5	15.6	36	39.1	39.3	16.6	29	29.3
P_2O_5								
≤ 80	31.0	15.6	53	57.6	37.5	17.4	45	45.5
81–160	31.1	16.2	36	39.1	37.7	16.5	48	48.5
> 160	31.7	15.7	3	3.3	43.1	16.5	6	6.1
K_2O								
≤ 80	31.0	15.5	41	44.6	38.1	16.5	19	19.2
81–160	31.1	16.0	39	42.4	37.7	17.2	60	60.6
> 160	33.4	16.4	12	13.0	38.1	16.5	20	20.2

Table 5. Root yield and sugar content on plantations with yields above and below average in dependence on pH and contents of available soil K_2O and P_2O_5

	Middle-eastern Poland				Central Poland			
	root yield (t/ha)	sugar content(%)	fields		root yield (t/ha)	sugar content (%)	fields	
			number	%			number	%
Plantations with yields above average								
pH_{KCl}								
≤ 5.5	46.3	15.9	39	41.1	52.4	18.4	17	15.2
5.5–6.5	47.4	15.8	37	38.9	55.9	18.1	49	43.8
> 6.5	48.5	15.7	19	20.0	57.6	17.7	46	41.1
Content of P_2O_5								
Low	46.2	16.1	43	45.3	52.5	18.8	10	8.9
Medium	47.4	15.55	28	29.5	55.9	18.3	42	37.5
High	47.9	15.75	24	25.3	56.4	17.7	60	53.6
Content of K_2O								
Low	46.9	16.1	39	41.1	52.8	18.3	25	22.3
Medium	47.4	15.7	32	33.7	55.9	18.0	39	34.8
High	47.6	15.5	24	25.3	57.4	17.9	48	42.9
Plantations with yields below average								
pH_{KCl}								
≤ 5.5	30.8	15.8	56	60.9	35.0	17.2	37	37.4
5.5–6.5	31.1	15.9	24	26.1	37.7	16.7	30	30.3
> 6.5	31.4	16.1	12	13.0	40.1	16.8	32	32.3
Content of P_2O_5								
Low	30.7	16.1	49	53.3	37.6	17.8	23	23.2
Medium	31.1	15.6	21	22.8	37.7	16.5	29	29.3
High	33.2	15.5	22	23.9	38.7	16.7	47	47.5
Content of K_2O								
Low	29.6	15.7	44	47.8	37.7	17.2	34	34.3
Medium	31.1	16.1	33	35.9	37.7	16.6	37	37.4
High	35.3	15.7	15	16.3	38.2	16.9	28	28.3

Table 6. Mean rate of potassium, phosphorus and nitrogen applied in plantations of stated interval K_2O and P_2O_5 content and soil pH in dependence on level of yielding

Regions	Plantations of root yield					
	above average			below average		
	Interval content of K_2O and P_2O_5					
	low	medium	high	low	medium	high
	Applied rates of K_2O (kg/ha)					
Middle-eastern Poland	110.5	117.4	129.0	75.55	92.60	103.20
Central Poland	128.0	114.4	139.2	118.7	128.6	130.9
	Applied rates of P_2O_5 (kg/ha)					
Middle-eastern Poland	94.3	105.6	119.0	80.2	81.6	91.2
Central Poland	90.8	84.7	100.8	72.4	82.5	102.8
	Soil pH_{KCl}					
	< 5.5	5.6–6.5	> 6.5	< 5.5	5.6–6.5	> 6.5
	Applied rates of N (kg/ha)					
Middle-eastern Poland	197.9	206.9	212.1	191.9	189.3	191.4
Central Poland	163.6	192.1	192.6	172.1	162.7	166.2

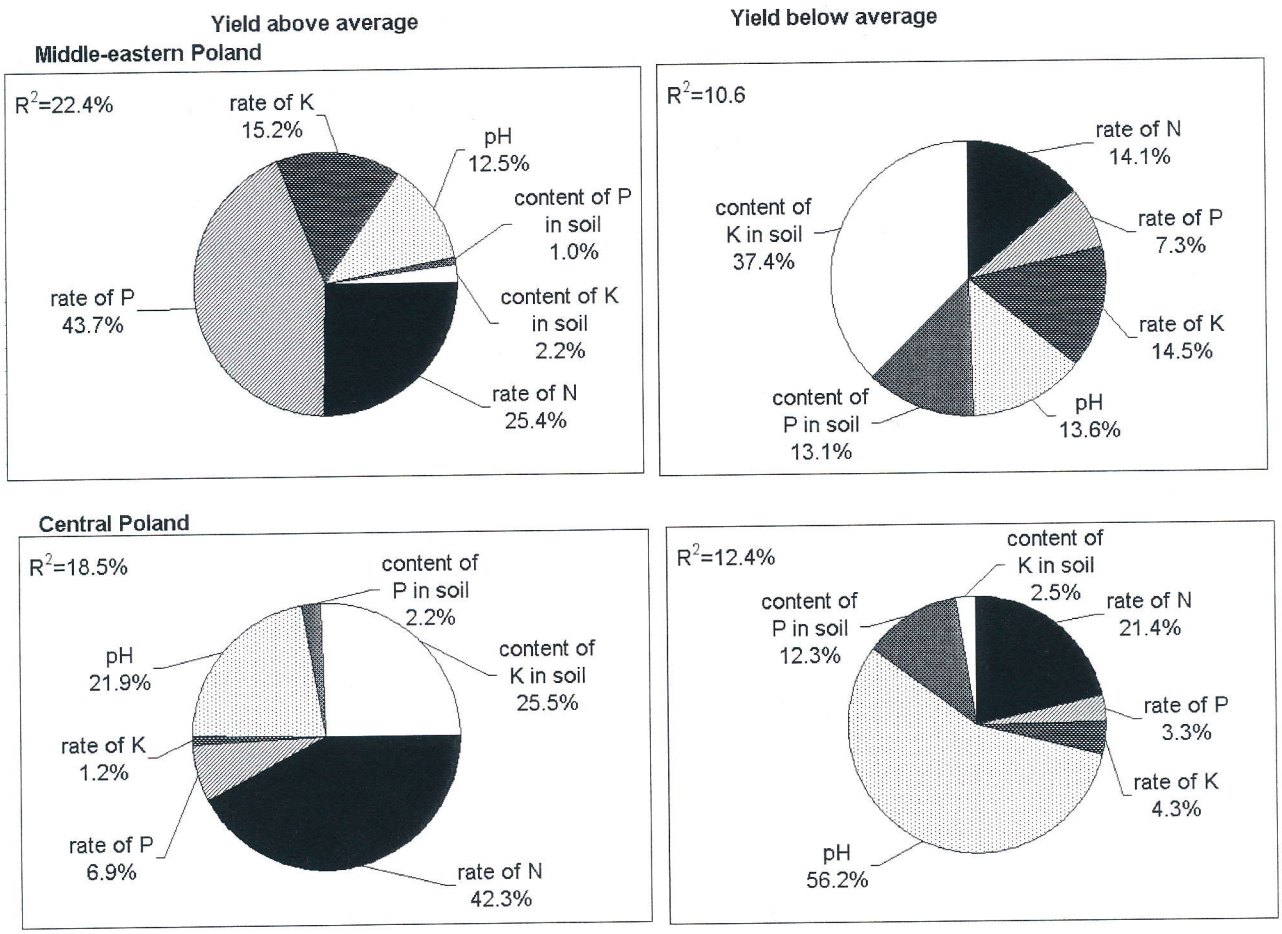

Fig. 1. Contribution of plant nutrition factor in root yield forming in dependence on yield groups in investigation regions

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Výnos cukrovky a cukernatost na pozadí polských oblastí a nutričních faktorů.

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Pokusy na produkčních pozemcích (celkem 398) se prováděly v letech 1992–2002 ve dvou řepařských oblastech (střední a středovýchodní část pásu Velké údolí). Pozemky jsme rozdělili do dvou skupin podle výnosu nad průměrem a pod průměrem celkového výnosu v každé oblasti. Cílem výzkumu bylo určit přínos jednotlivých nutričních faktorů na výnos bulvy a cukernatost. Nadprůměrný výnos bulvy pro skupinu s nadprůměrným výnosem byl 47,4 t/ha, v rozmezí 39,7 až 65,0 t/ha, ve středovýchodní části a 55,9 t/ha, v rozmezí 47,4 až 72,0 t/ha, ve středním Polsku. Odpovídající hodnoty pro výnos cukru byly: 15,8; 13,4 až 18,1; 18,0 a 14,7 až 21,0 %. Průměrné výnosy bulev pro skupinu pozemků s nižším výnosem byly 31,1 t/ha, v rozmezí 15,1 až 39,1 t/ha, ve středovýchodní části a 37,7 t/ha, v rozmezí 18,0 až 47,3 t/ha, ve středním Polsku. Odpovídající hodnoty výnosu cukru byly: 15,8; 13,7 až 19,0; 16,9 a 14,2 až 21,2 %. Ke zjištění jednotlivých složek nutričních faktorů ve výnosu bulvy a tvorbě cukru byly vypočítány regresní koeficienty a podíl každého z nich se započítal do této hodnoty. Vyšší hodnoty (R^2, 22,4 a 18,6 % v závislosti na oblasti) byly zjištěny pro skupinu s nadprůměrným výnosem. Role nutričního faktoru se lišila podle výnosu skupiny. Ve skupině s podprůměrným výnosem byla nejdůležitější hodnota pH půdy a obsah draslíku v půdě. Ve skupině s nadprůměrným výnosem hrálo důležitou roli hnojení dusíkem a fosforem.

cukrovka; cukernatost; výnos bulvy; nutriční faktor; produkce pozemků

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