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EVALUATION OF DIFFERENT POTATO FERTILIZATION REGIMES ON STARCH YIELD – PRODUCTION AND ECONOMIC ASPECTS

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Abstract

The article contains data concerning the production and economic aspects of producing starch from three starch potato cultivars, such as Adam, Pasja Pomorska and Ślęza. The considerations are based on an experiment conducted in 2008–2010 at the Experimental Station of the University of Warmia and Mazury in Olsztyn, situated in Bałcyny (N = 53°35'49''; E = 19°51'20,3'').

The study has shown that the cultivar Adam is the least economically useful starch potato, as it gives low starch yields, generates very high unit costs and presents the least favourable response to modifications in foliar fertilization that do not lead to the improvement of yielding. The lowest unit costs of producing starch occurred in the production of the potato cultivar Ślęza. Depending on the applied foliar fertilization treatments, the starch production unit costs decreased the most for the cultivar Pasja Pomorska, reaching the highest cost reduction level in the variant consisting of soil dressing *A* – 280 kg ha^{-1} NPK (80 N, 80 P, 120 K) and foliar fertilization variant *a* – Basfoliar 12-4-6 [8 dm ha^{-1}].

PRODUKCYJNO-EKONOMICZNA OCENA WPŁYWU RÓŻNYCH SPOSOBÓW NAWOŻENIA ZIEMNIAKA NA WYDAJNOŚĆ SKROBI

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Słowa kluczowe: nawożenie, skrobia, koszty, opłacalność, ziemniak.

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A b s t r a k t

W artykule ujęto dane dotyczące uwarunkowań produkcyjno-ekonomicznych skrobi trzech wybranych odmianach ziemniaka skrobiowego: Adam, Pasja Pomorska i Ślęza. Bazą były badania prowadzone w latach 2008–2010 w Stacji Doświadczalnej Uniwersytetu Warmińsko-Mazurskiego w Bałcynach (N = 53°35'49'; E = 19°51'20,3').

W badaniach wykazano, iż najmniej przydatną do uprawy w warunkach glebowo-klimatycznych Warmii, ze względu na najniższą wydajność skrobi, z punktu widzenia ekonomicznego, jest odmiana Adam, która generuje niskie plony skrobi, najwyższe koszty jednostkowe pozyskania oraz najmniej korzystnie reaguje na modyfikacje nawożenia dolistnego, nie skutkując poprawą plonowania. Najniższe koszty jednostkowe skrobi wystąpiły w produkcji ziemniaka odmiany Ślęza. W zależności od zastosowanych wariantów nawożenia dolistnego w odmianie Pasja Pomorska następowały największe spadki kosztu jednostkowego skrobi, który osiągnął najwyższą wartość redukcji kosztu w wariancie nawożenia doglebowego *A* – 280 kg ha^{-1} NPK (80 N, 80 P, 120 K) oraz w nawożeniu dolistnym *a* – Basfoliar 12-4-6 [8 dm ha^{-1}].

Introduction

Both in Poland and across the world, dynamic changes are taking place in dedicating agricultural plantations to some innovative purposes. Traditional cultivation of plants for food and feeds is often replaced by growing energy or industrial crops. Such transformations affect many agricultural plants, and especially potato. Potato is a versatile crop plant, which has gained popularity all over the world. In 2014, the global potato production exceeded 358 million tons, which is the highest yield volume in history. For comparison, 328 million tons of potato were harvested in 2000, and since then the potato production has been increasing steadily. The biggest potato producer is Asia (over 43% of the world's production), followed by Europe (nearly 38%) (FAOSTAT 2016). In Poland, however, potato production has been on the decrease, mainly because of the diminishing total acreage planted with potatoes, which cannot be offset by the higher yields per ha (Table 1). This trend in the Polish potato

Table 1

Changes in acreage, yield and crops of potato in the years 1990–2014 in Poland

Years	Production area [thous. ha]	Yield [t ha^{-1}]	Harvest [mln t]
1991–1995	1694	16.1	27.34
1996–2000	1292	18.1	23.37
2001–2005	813	18.1	14.68
2006–2010	525	19.0	9.88
2011	406	23.0	9.36
2012	373	24.2	9.04
2013	346	21.0	7.29
2014	277	27.8	7.70

Source: based on NOWACKI (2015)

production is a consequence of the process of replacing smaller plantations by larger ones, where potato production is intensified. In the past, the most popular cultivation technology was a low-input system, preferred by smaller farmers. Meanwhile, the sustainable and intensive technologies have been gaining ground. The organic system is not very popular in potato production (NOWACKI 2012). The same tendencies are likely to continue in the following years (*Rolnictwo w latach 2000–2013*).

Table 2 collates information on changes in the use of harvested potatoes in Poland. Noteworthy is a very big increase in the amount oftubers dedicated to industrial processing, from 11.5% in the 2005/2006season to 25.2% in the 2015/2016 season, which has induced very big changes in the economic and production aspects of potato cultivation DZWONKOWSKI i in. 2015).

Table 2

Distribution of domestic potato yields [%]

Season	Distribution targets						
	losses and damage	seed potatoes	animal feed	self-supply of farmer	sold for human consumption	industrial processing	export
2005/06	11.0	10.6	35.3	12.4	19.0	11.5	0.2
2015/16	7.7	8.6	15.2	15.6	26.9	25.2	0.8

Source: based on DZWONKOWSKI i in. (2015)

The total output of potato starch produced in the European Union is 1.95 million tons, of which 656,000 tons come from Germany. Germany is the biggest starch producer in the EU, followed by the Netherlands, France, Denmark and Poland (EMMANN et al. 2012). In 2015, the situation was slightly different, namely 28% of starch potato was produced in Germany, 24% in the Netherlands, 13% in Poland, 12% in Denmark and 11% in France (*Bundesverband*... 2016). In Germany, starch producers are mostly found in the following lands: Niedersachsen, Bayern and Brandenburg (UNIKA 2011). Many experts claim that the potato starch market will decrease down to the 80–85% of today's production output, which will anyway meet the demand (EMMANN et al. 2012). This tendency has been manifested by a decline in the acreage seeded with starch potato in Germany, which started back in 2001. Since that year, the total area of starch potato plantations has fallen from 95,000 ha to 86,000 ha (TOP AGRAR 2010). In 2015, the total area of fields allocated to starch potato cultivation in Germany declined to the record lowest level, i.e. to 52 796 ha (*Bundesverband*... 2016).The reason is the steadily decreasing subsidies allocated to starch potato production and processing (EMMANNET al. 2012). Until 2011, starch producing companies could take advantage of higher prices, which allowed them to go through the transition period (DREETZ 2011). Potato production in Poland has been steadily declining, mainly due to the decreasing demand by agriculture and in response to the lower market demand. In 2015, potatoes were grown on 279.000 ha (MRIRW 2016).

The aim of this paper is to discuss the impact of different fertilization regimes applied to starch potato on the effectiveness and costs of starch production.

Materials and Methods

The results presented and discussed in this paper originate from a controlled field experiment set up at the Agricultural Research Station in Bałcyny (N = 53°35'49'; E = 19°51'20,3'') and conducted in 2008–2010. A multiple (repeated over years) three-factorial experiment with three replications was set up according to the method of random split-plot sub-blocks on grey-brown podsolic soil developed from boulder clay. The area of each plot planted with potatoes was 24 m^2, of which 18 m^2 was harvested.

Potatoes were planted in the last ten days of April. Tubers (class CA material) were planted at 40-cm intervals, in rows spaced at 62.5 cm, hence the plant density was 40.000 plants per hectare.

Each year, potatoes were grown in a field previously cropped with cereals, without organic fertilization. They were harvested at the full ripeness stage, in the last ten days of September. The cultivation treatments consisted of double earthing-up and several pesticide sprays. Dicotyledonous weeds were controlled with the herbicide AfalonDyspersyjny 450 S.C. dosed at 2 dm ha^{-1}. Potato blight was prevented by using the systemic fungicides Ridomil Gold MZ 68 WG 2 kg ha^{-1} and Tattoo C 750 SC 2 dm ha^{-1}, while surface acting preparations Antracol 70 WG 1.8 kg ha^{-1} and Gwarant 500 SC 2 dm ha^{-1} were appliedon a later date. Colorado beetle was controlled with the neonicotinoids Apacz 50 WG 40g ha^{-1}, Calypso 480 SC 0.08 dm ha^{-1} and Mospilan 20 SP 80 g ha^{-1}.

All calculations were made in line with the Polish agricultural bookkeeping methodology (GORAJ 2000), including the classical division into direct and indirect costs, which enabled us to calculate basic categories of costs and revenue according to the following scheme (AUGUSTYŃSKA-GRZYMEK et al. 2009):

1. Direct costs (DC).
2. Indirectcosts (IC).
3. Total costs (TC).
4. Unit productioncosts (UC).

The unit costs of tractors and machinery as well as the costs of conducting individual agrotechnical treatments were calculated according to the methods used at the Institute for Building, Mechanization and Electrification of Agriculture in Poland (MUZALEWSKI 2007). The calculations of agricultural machinery costs included the costs of using machines owned by the Experimental Station in Bałcyny: an URSUS C-385 tractor, URSUS C-360 tractor, John Derre 6930 tractor, Kverneland 7-farrow plough, Kverneland 5-farrow plough, drag spike-tooth harrow with 10 points, N-035 fertilizer spreader, S 227 plant seeder, P430/2weeder, Krukowiak ORP/2500/18/PHN sprayer, Anna potato combine, and an HW 6011 dump trailer. The analysis of economic effectiveness was conducted on the basis of the records of treatments and type of implements used in these treatments, as well as determined inputs of labour, power and inputs of materials. The hourly wage was set according to the remuneration system at the Experimental Station.

Starch yield. After harvest, the following were determined: total potato tuber yield, percentage content of starch in potato tubers (the weighing method on a Sengbusch weighing balance), and starch yield as a function of total yield and percentage starch content. Based on starch yields in particular fertilization variants, a starch yield increase was calculated relative to the zero variant h.

For the economic assessment, three-year average starch yields were taken as the main assessment criterion. The results were analyzed statistically using analysis of variance. The Tukey's test was applied to evaluate the inter-treatment variation, assuming the probability of error to be p=0.05. All analyses were accomplished with the help of STATISTICA 10® software.

The following factors were considered:

I. The first factor consisted of potato cultivars: Adam (medium early), Pasja Pomorska (medium late) and Ślęza (late).

II. The second factor included levels of soil fertilization:

A – 280 kg ha^{-1} NPK (80 N, 80 P, 120 K),

B – 420 kg ha^{-1} NPK (120 N, 144 P, 156 K).

The soil fertilizing treatments were composed of potassium salt (60%), granulated triple superphosphate (46%) and ammonium saltpetre (34%), applied once prior to potato planting.

III. The third factor corresponded to foliar fertilization:

a – Basfoliar 12-4-6 [8 dm ha^{-1}],

b – ADOB Mn [4 dm ha^{-1}],

c – Solubor DF [2 dm ha^{-1}],

d – ADOB Mn + Solubor DF [2 + 1 dm ha^{-1}],

e – ADOB Mn + Basfoliar 12-4-6 [2 + 4 dm ha^{-1}],

f – Basfoliar 12-4-6 + Solubor DF[4 + 1 dm ha^{-1}],

g – Basfoliar 12-4-6 + ADOB Mn + Solubor DF [2.7 + 1.3 + 0.7 dm ha^{-1}],
h – control treatment – no foliar fertilization.

The foliar fertilizers were applied once, at the early inflorescence phase (BBCH 61].

Results and Discussion

Starch is a natural, renewable biopolymere, the demand for which arises from its use as raw material in production of beverages, sweets, fat reducing products, paper, cardboard paper, pharmaceuticals, textiles, feeds and many other products (FACHAGENTUR 2014). Technology-wise, the best raw material for making starch products is potato starch. The physical and chemical structure of potato starch makes it easily modifiable by various physical and chemical factors. However, it should be remembered that cereal starch can successfully compete with and virtually always replaces potato starch as raw material (DZWONKOWSKI 2007). In the future, the use of potato starch will depend on the costs of producing this sugar, at all stages of its manufacture, i.e. from the cultivation of starch plants, their transport and processing to the making of starch and any by-products.

Table 3 contains a complex specification of the effects of potato fertilization on the starch yield, depending on the variants of foliar and soil nutrition of the three cultivars analyzed in our experiment, the highest starch yields were produced by cv. Ślęza. Starch yields obtained from tubers of this cultivar in both soil fertilization variant *A* – 280 kg ha^{-1} NPK (80 N, 80 P, 120 K) and variant *B* – 420 kg ha^{-1} NPK (120 N, 144 P, 156 K) were higher than from tubers of the other cultivars. The highest starch yield [9.18 mg ha^{-1}] was achieved in soil fertilization variant *B* – 420 kg ha^{-1} NPK (120 N, 144 P, 156 K) and foliar fertilization variant *f* – Basfoliar 12-4-6 + Solubor DF [4 + 1 dm ha^{-1}]. Slightly less starch, 9.15 mg ha^{-1}, was found in soil fertilization variant *B* – 420 kg ha^{-1} NPK (120 N, 144 P, 156 K) and foliar fertilization variant *g* – Basfoliar 12-4-6 + ADOB Mn + Solubor DF [2.7 + 1.3 + 0.7 dm ha^{-1}]. The lowest productivity was achieved by cv. Adam, which gave the lowest starch yield of 5.08 mg ha^{-1} in soil fertilization variant *A*– 280 kg ha^{-1} NPK (80 N, 80 P, 120 K) and foliar fertilization variant *c* – Solubor DF [2 dm ha^{-1}]. The data in table 3 demonstrate that the cultivars responded differently to modifications in foliar fertilization, but it was only cv. Pasja Pomorska grown in soil fertilization variant *A* – 280 kg ha^{-1} NPK (80 N, 80 P, 120 K) that produced a higher starch yield when supplied foliar fertilization according to variant *a* – Basfoliar 12-4-6 [8 dm ha^{-1}].

Table 3

Effect of different potato fertilization variants on starch yield

Specification	Cultivar	Variants of foliar fertilization*	Variants of soil fertilization							
			a	*b*	*c*	*d*	*e*	*f*	*g*	*h*
Starch yield [Mg ha^{-1}]	Adam	*A*	5.38	5.21	5.08	5.39	5.34	5.5	5.28	5.52
Starch yield gain** [Mg ha^{-1}]			-0.14	-0.31	-0.44	-0.13	-0.18	-0.02	-0.24	–
Starch yield [Mg ha^{-1}]		*B*	5.62	5.48	5.75	5.76	5.51	5.88	5.79	5.71
Starch yield gain** [Mg ha^{-1}]			-0.09	-0.23	0.04	0.05	-0.20	0.17	0.08	–
Starch yield [Mg ha^{-1}]	Pasja Pomorska	*A*	7.60	7.19	7.33	7.36	7.28	7.49	7.45	7.15
Starch yield gain** [Mg ha^{-1}]			0.45	0.04	0.18	0.21	0.13	0.34	0.30	–
Starch yield [Mg ha^{-1}]		*B*	7.03	6.77	7.28	7.46	6.85	7.12	6.99	7.38
Starch yield gain** [Mg ha^{-1}]			-0.35	-0.61	-0.10	0.08	-0.53	-0.26	-0.39	–
Starch yield [Mg ha^{-1}]	Ślęza	*A*	8.75	8.32	8.86	8.57	9.06	8.95	8.58	8.61
Starch yield gain** [Mg ha^{-1}]			0.14	-0.29	0.25	-0.04	0.45	0.34	-0.03	–
Starch yield [Mg ha^{-1}]		*B*	8.84	8.78	8.6	8.99	8.78	9.18	9.15	9.10
Starch yield gain** [Mg ha^{-1}]			-0.26	-0.32	-0.50	-0.11	-0.32	0.08	0.05	–
$LSD_{(0.05)}$ of cultivars – 0.17; cultivar x soil fertilization – 0.25; other factors and non-significant interactions										

* details in the Methods, ** relative to technology *h*

Production costs are generated by many production factors, most of which can be extensively manipulated by theproducer, except the weather conditions. In the reported experiment, the total costs of potato cultivation were in a range of 6.4 thousand PLN ha^{-1} to over 7.4 thousand PLN ha^{-1} (Table 4). The difference was a result of the differences in the price of seed potatoes and the applied soil fertilization variant. Economically speaking, however, the unit costs of producing the raw material are much more important. Our calculations proved that the lowest unit costs of producing starch were obtained for c. Ślęza grown in soil fertilization variant *A* – 280 kg ha^{-1} NPK (80 N, 80 P, 120 K), where they equalled 797 zł Mg $^{-1}$. The highest unit production costs were generated by growing cv. Adam in fertilization variant *B* – 420 kg ha^{-1} NPK (120 N, 144 P, 156 K), where they were slightly higher than in variant *A* – 280 kg ha^{-1} NPK (80 N, 80 P, 120 K). The unit production costs of growing the third tested cultivar, Pasja Pomorska, reached the same level as the production costs of the average starch yield for the whole experiment. In general, the total costs of potato cultivation(materials seeds, mineral fertilization, crop protection, cost of operating tractors and machines, labor costs, agricultural tax, other indirect costs), depending on the type of production, are high and range from 8.5 to nearly 17 thousand PLN ha^{-1} (NOWACKI 2015).

Table 4

Costs of starch production from selected starch potato cultivars including soil fertilization [PLN ha^{-1}]

Cultivar	Adam		Pasja Pomorska		Ślęza		Średnio	
Fertilizaion variant	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
Starch yield [Mg ha^{-1}]	5.3	5.7	7.4	7.1	8.7	8.9	7.1	7.2
Direct costs in total:	3513.77	3974.77	3729.77	4190.77	4053.77	4520.83	3765.77	4229.34
– seed potatoes	2052.00	2052.00	2268.00	2268.00	2592.00	2592.00	2304.00	2304.00
– mineral fertilization	917.77	1378.77	917.77	1378.77	917.77	1384.83	917.77	1381.34
– plant protection	544.00							
Indirect costs in total:	2888.14							
– labour of tractors and machines	2229.58							
– labour in puts	271.00							
– agricultural tax	125.00							
– other indirect costs (+10%)	262.56							
Total costs	6401.91	6862.91	6617.91	7078.91	6941.91	7408.91	6653.91	7117.48
Unit costs PLN/ Mg $^{-1}$	1198.92	1206.15	899.27	995.68	797.01	829.76	931.97	983.14

Table 5

Specification of unit costs of the starch production in different fertilization variants of selected starch potato cultivars [PLN Mg $^{-1}$]

Soil fertilizaion variant	Foliar fertilization variants								
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	Mean
Adam									
A	1190.4	1232.0	1256.6	1187.5	1200.7	1162.5	1212.4	1146.6	1198.9
B	1221.6	1255.4	1190.3	1191.2	1247.3	1165.7	1185.2	1189.1	1206.1
Mean	1206.0	1243.7	1223.5	1189.4	1224.0	1164.1	1198.8	1167.9	1202.5
Pasja Pomorska									
A	871.1	922.7	900.3	899.0	910.4	882.4	888.3	915.4	899.2
B	1007.3	1048.1	969.8	948.7	1034.8	993.0	1012.7	949.3	995.6
Mean	939.2	985.4	935.1	923.9	972.6	937.7	950.5	932.4	947.4
Ślęza									
A	793.7	836.4	781.4	809.9	767.3	774.7	809.0	797.8	797.0
B	837.7	845.0	858.7	823.3	844.2	805.5	809.0	805.5	829.7
Mean	815.7	840.7	820.0	816.6	805.8	790.1	809.0	801.6	813.6
Mean for cultivars									
A	919.4	965.3	935.9	935.7	921.6	909.1	935.8	928.2	931.9
B	1007.3	1048.1	969.8	948.7	1034.8	993.0	1012.7	949.3	983.1
Mean	963.4	1006.7	952.9	942.2	978.2	951.1	974.2	938.8	985.5

Table 5 contains detailed data regarding the unit starch production costs, including the division into the variants of soil and foliar fertilization. The three cultivars responded in a highly diverse manner to the individual variants of fertilization. The lowest average unit cost was calculated for cv. Ślęza. The same cultivar was distinguished by attaining the lowest unit cost of all computed values, which equaled 767.3 zł Mg $^{-1}$ in soil fertilization variant *A* – 280 kg ha^{-1} NPK (80 N, 80 P, 120 K) and foliar fertilization *e* – ADOB Mn + Basfoliar 12-4-6 [2 + 4 dm ha^{-1}].

Economically speaking, it is important to know how individual factors affect the unit costs. The following set of data (Table 6) shows differences in the levels of unit costs calculated per Mg $^{-1}$ of starch. Large differences can be seen between the unit costs derived for the control and a specific fertilization variant among the soil and foliar fertilization techniques. The biggest decrease

Table 6

Specification of differences in unit costs of starch production between the control and foliar fertilization at a given soil fertilization variant for selected starch potato cultivars [PLN Mg $^{-1}$]

Soil fertilizaion variant	Foliar fertilization variants								
	a	*b*	*c*	*d*	*e*	*f*	*g*	control	mean
Adam									
A	43.9	85.4	110.0	40.9	54.1	15.9	65.8	0.0	52.3
B	32.5	66.2	1.2	2.1	58.1	-23.4	-3.9	0.0	17.0
Mean	38.2	75.8	55.6	21.5	56.1	-3.8	31.0	0.0	34.6
Pasja Pomorska									
A	-44.3	7.3	-15.1	16.4	-5.0	-32.9	-27.1	0.0	16.2
B	58.0	98.7	20.5	-0.6	85.5	43.7	63.3	0.0	46.3
Mean	6.9	53.0	2.7	-8.5	40.2	5.4	18.1	0.0	15.0
Ślęza									
A	-4.1	38.6	-16.4	12.1	-30.5	-23.1	11.2	0.0	-0.8
B	32.2	39.5	53.2	17.8	38.7	0.0	3.5	0.0	23.5
Mean	14.0	39.1	18.4	14.9	4.1	-11.6	7.4	0.0	11.4
Mean for cultivars									
A	-8.8	37.1	7.7	7.4	-6.6	-19.1	7.6	0.0	3.7
B	58.0	98.7	20.5	-0.6	85.5	43.7	63.3	0.0	46.3
Mean	24.6	67.9	14.1	3.4	39.5	12.3	35.5	0.0	25.0

in unit costs versus the control was found for cv. Pasja Pomorska in soil fertilization variant *A* – 280 kg ha^{-1} NPK (80 N, 80 P, 120 K) and foliar fertilization *a* – Basfoliar 12-4-6 [8 dm ha^{-1}], where it reached over 44 PLN Mg $^{-1}$. In the other fertilization variants applied to the same cultivar, a decline in unit costs was also quite evident, ranging from 27 to 32 PLN Mg $^{-1}$, which in both cases occurred in soil fertilization variant *A* at 280 kg ha^{-1} NPK (80 N, 80 P, 120 K). Among the other cultivars, unit costs were decreased for cv. Ślęza in the same soil fertilization variant as reported for cv. Pasja Pomorska, i.e. variant A 280 kg ha^{-1} NPK (80 N, 80 P, 120 K). The unit costs were particularly lowered when combined with foliar fertilization variant *e* – ADOB Mn + Basfoliar 12-4-6 [2 + 4 dm ha^{-1}]. In this combination, the decrease was over 30 PLN Mg $^{-1}$ compared to the control unit cost.

Although starch production in Poland encounters many obstacles, the starch production industry – after a period of potato starch production quotas in the EU (until 2013) – is now overcoming the crisis. Moreover, the rise in prices for starch on the global market can stimulate the production of potato starch in Poland and contribute to improved profitability of starch potato plantations (NOWACKI 2015). Also, the subsidies to starch potato cultivation in the amount of 400 euro/ha planned to be paid until 2020 will strengthen the competitive advantage of potato starch production. This situation should level off continual fluctuations on the starch potato market, also because of the obligatory contracts, which many potato farmers see as an opportunity (KOROLEWICZ 2015). The production of starch potato is most heavily burdened by the costs of using tractors and other machinery, which in our experiment accounted for 30 to 34% of the total production costs and reached similar values in other research (TURSKA 2014). The second biggest cost is represented by the purchase of seed potatoes, which can reach from 53.9 to 56.6% of direct cost (SKARŻYŃSKA 2010). In our experiment, this cost was around 58 to 64% of direct costs, but it can be lowered if farmers buy larger batches of seed potatoes, or make purchases as formal or even informal consortia of producers.

From the point of view of a producer, alternative costs play an important role in the "setting-up" of production. Comparison of costs and economic profits as well as the production management aspects related to the production of starch potato and other agricultural crops enable the farmer to make a good decision. Regarding the costs of setting up and running a plantation of starch potatoes, they are 3- to 4-fold as high as the analogous costs of starting a plantation of such crops as winter triticale, which in a study of Dubis et al. (DUBIS et al. 2015) equalled 2.2–2.5 thousand PLN ha^{-1}. Compared with spring barley, the total costs of starch potato cultivation were 4- to 5-fold higher (ŻUK-GOŁASZEWSKA et al. 2013). On the other hand, they were just less than 100% higher than the costs related to the cultivation of winter oilseed rape (GUGAŁA et al. 2015). The actual results depend on the intensity of plant production, as this factor determines costs of the inputs. What certainly distinguishes the cultivation of starch potato from the production of the other crops mentioned above is the input of the labour of tractors and machines, which – as already suggested – is decisive for the profitability of starch potato production.

Nowacki (NOWACKI 2012) concluded that potato production must be intensified because any extensive system of its production generates losses. In integrated or organic systems of production, the outcome will be profitable for the farmer only when higher prices for the produced potatoes are guaranteed. Irrigation may become an important treatment in potato production, as it is able to generate a yield increase of as much as 100%. It needs to be added that 1 mm of water used for irrigation raises the tuber yield by around 70.1 kg ha^{-1} (RĘBARZ and BORÓWCZAK 2006).

The prospects of starch potato and potato starch production in Poland will mostly depend on the pressure produced by cereal starch production and on the system of subsidies on the cereals market and subsidies allocated to starch (REMBEZA 2002). With prices of cereals falling, the market prices for potatoes must be compensated for by higher subsidies dedicated to starch. Otherwise, potato starch production will not be profitable.

Conclusions

The experimental results lead to the conclusion that the tested starch potato cultivars responded in a highly differentiated way to the treatments, in terms of both starch yields and the associated economic output. The analysis of the data derived from the experiment substantiates the following conclusions:

– the highest starch yields in the field experiment were obtained from cv. Ślęza; they were about 3 Mg ha^{-1} higher than the starch yield produced by the lowest-yielding cultivar Adam;

– the cultivar Pasja Pomorska in the variant with soil fertilization *A* – 280 kg ha^{-1} NPK (80 N, 80 P, 120 K) generated the highest increase in starch yield, which was the highest in foliar fertilization variant *a* – Basfoliar 12-4-6 [8 dm ha^{-1}];

– economically speaking, the cultivar Adam was the least useful one, as it produces very low starch yields, generates high unit production costs and presents the least favourable response to modifications in foliar fertilization;

– the lowest unit costs of starch production were calculated for cv. Ślęza, and this result repeated in nearly all fertilization variants;

– in response to the applied foliar fertilization variants, cv. Pasja Pomorska demonstrated economically highly desirable decrease in the unit costs of starch production, which was the biggest in soil fertilization variant *A* – 280 kg ha^{-1} NPK (80 N, 80 P, 120 K) and foliar fertilization *a* – Basfoliar 12-4-6 [8 dm ha^{-1}].

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