

CULTIVAR-ENVIRONMENTAL DETERMINANTS OF POTATOES YIELDING UNDER ORGANIC SYSTEM

Summary

In the years 2005-2013 experiments concerning yielding of potato under organic system in two places of different soil-climatic conditions were conducted. During 9 years in 3-year cycles, 22 cultivars from different group of maturity were tested. It was stated that the yield depended mostly on climatic conditions in years of investigation and cultivars. The place of growing had no statistical influence. An average yield on heavier soil was 211 but on lighter one- 221 dt·ha⁻¹. Most of tested cultivars yielded in range 200-300 dt·ha⁻¹. On heavier soil the stability of yielding was grater. It was stated the different reaction of cultivars from different maturity groups. Early and mid-early cultivars achieved higher yields on lighter soil, but late cultivars – on heavier one.

Key words: potato, cultivar, yield, organic system

ODMIANOWO-ŚRODOWISKOWE UWARUNKOWANIA PLONOWANIA ZIEMNIAKÓW W SYSTEMIE EKOLOGICZNYM

Streszczenie

W latach 2005-2013 przeprowadzono badania dotyczące plonowania roślin ziemniaka uprawianych w systemie ekologicznym w dwóch miejscowościach o zróżnicowanych warunkach klimatyczno-glebowych. W ciągu 9 lat, w cyklu 3-letnim, przebadano 22 odmiany z różnych grup wczesności. Stwierdzono, że plony zależały głównie od warunków atmosferycznych panujących w latach badań i od odmiany. Samo miejsce uprawy nie miało istotnego znaczenia. Średni plon uzyskany na glebie mocniejszej wynosił 211, a na glebie lżejszej 221 dt·ha⁻¹. Większość odmian plonowała w zakresie od 200 do 300 dt·ha⁻¹. Stabilność plonowania była większa na glebie mocniejszej. Stwierdzono zróżnicowanie reakcji odmian w poszczególnych grupach wczesności. Odmiany wczesne i średnio wczesne plonowały lepiej w Jadwisinie, natomiast odmiany późniejsze w Osinach.

Słowa kluczowe: ziemniak, odmiana, plon, system ekologiczny

1. Introduction

At the Institute of Plant Breeding and Acclimatization - National Research Institute in Jadwisin the research on the potato cultivation in different production systems, including organic system are conducted. Experiments related to the organic cultivation of potato underway since 2005. Research are conducted in two places located in different parts of Poland, under different soil and climatic conditions. One place is Experimental Station of the IUNG in Osiny near Pulawy (south-eastern Poland), the second Jadwisin-central Poland. The aim of the research is to assess, among others, yielding potato grown in the organic system under different climate and soil conditions as well as to evaluate the usefulness of the different varieties to specific environmental conditions. From the literature on the study of the potato crop in the organic system it is known that the yields obtained in organic system can be from 10 to 50% lower compared to conventional ones [2, 6, 9, 11, 12, 13, 14] and in very unfavorable conditions even 70% [20]. The lower level of yielding is caused by the reduction or total ban on the use of pesticides and mineral fertilizers in this system, which generally results in lower yield and its diminutive [3, 13]. The reaction of cultivars is also different [17, 19]. On the basis of the research results conducted in two locations in Poland in the three-year cycles the differences in yielding potato crops grown in the organic

system, depending on such factors as: soil, climatic and cultivar can be analyzed. We can also make the ranking of studied factors and a closer look at the individual cultivars and compare their response to growing in the same production system, but in different environments. Making some generalizations, which is also one of the objectives of our work is possible.

2. Materials and methods

The study was conducted in two locations with different climate and soil conditions. In Osiny (south-east Poland) potatoes were grown on the very good rye complex soil, in Jadwisin on good rye complex soil. In both experimental places the crop rotation was adapted to the soil conditions. The research was conducted in 3-year cycles. During the nine years 22 potato varieties belonging to different groups of earliness were tested. Choosing a variety to organic cultivation their greatest resistance to both viruses (virus Y and leafroll virus) and fungus (*Phytophthora infestans*) were taken into account. Assessing the tuber yield was related to the climatic conditions prevailing in the localities, ie temperature and precipitation (Table 1). The characteristics of tested cultivars are given in table 2.

In the statistical analysis the variance analysis was applied using ANOVA. The significance of differentiation was assessed by Student's t test.

Table 1. Weather conditions during vegetation period (temperature (T) and rainfall (R)) in years of investigation for two localizations

Month		May		June		July		August		September	
Year	Place	(R)	(T)	(R)	(T)	(R)	(T)	(R)	(T)	(R)	(T)
2005	Jadwisin	70,6	12,6	36,3	14,7	67,4	19,6	12,3	16,2	25,3	14,9
	Osiny	71,5	12,6	85,2	14,8	62,5	19,2	65,6	16,0	30,6	14,4
2006	Jadwisin	50,4	12,8	50,9	15,9	9,2	21,9	156,1	17,0	11,5	14,8
	Osiny	58,0	13,9	19,2	17,7	20,7	22,4	129,8	17,9	8,7	15,0
2007	Jadwisin	78,4	13,1	109,6	15,7	54,1	17,6	74,3	17,8	103,7	10,8
	Osiny	79,8	15,8	62,8	19,1	49,0	19,3	26,6	19,2	86,2	11,2
2008	Jadwisin	62,9	13,6	43,5	17,1	68,8	18,1	80,9	17,7	48,8	11,6
	Osiny	83,3	13,5	42,3	18,2	93,6	18,8	72,2	17,0	61,2	12,4
2009	Jadwisin	80,8	12,3	72,4	17,3	85,6	21,3	83,1	17,4	18,8	14,7
	Osiny	63,2	13,7	95,8	16,6	69,0	20,1	82,9	18,4	21,9	14,8
2010	Jadwisin	166,8	12,4	64,0	16,5	152,5	18,6	105,3	18,5	71,3	11,1
	Osiny	110,2	14,3	47,8	18,3	42,6	22,1	118,5	20,3	104,8	12,3
2011	Jadwisin	33,1	13,2	44,8	17,5	278,1	17,0	57,1	17,5	18,5	13,7
	Osiny	60,5	14,8	54,4	19,4	250,1	18,5	36,2	18,7	3,1	14,4
2012	Jadwisin	52,4	13,9	96,6	15,6	92,2	18,8	87,2	17,4	26,9	12,8
	Osiny	35,3	15,6	68,9	17,7	114,3	21,4	93,9	19,0	19,4	15,0
2013	Jadwisin	130,0	15,7	105,4	17,2	17,1	18,7	97,7	18,2	94,0	10,9
	Osiny	85,4	15,6	37,4	19,7	30,3	19,8	7,1	19,8	47,6	12,1

Source: own work

Table 2. Characteristics of tested cultivars

Years	Cultivar	Maturity group	Resistance to Phytophthora infestans
2005-2007	Drop	very early	3
	Gracja	early	3
	Korona	early	3
	Bartek	mid early	5
	Triada	mid early	4
	Syrena	mid late	5
	Zeus	mid late	6
2008-2010	Berber	very early	3
	Mitek	very early	3
	Owacja	early	4
	Vitara	early	3
	Agnes	mid early	5
	Tajfun	mid early	5
	Fianna	mid late	5
Ursus	late	6,5	
2011-2013	Flaming	very early	2
	Viviana	very early	2
	Eugenia	early	3
	Vineta	early	2
	Finezja	mid early	4,5
	Gustaw	mid late	5,0
	Medea	late	6,5

Source: own work

3. Results

3.1. The significance differentiation of tested factors

The analysis of variance showed the significance of differentiation such factors as: years of research, variety and interaction of years with the place of cultivation. There was no significance diversity of the place of growing, and its interaction with cultivars as well as cultivars and years of research, which means that the response of cultivars to the place of cultivation, and the climatic conditions in different years was the same. The largest share of the total variability had years of research and their interaction with the place of growing (Table 3).

Table 3. Statistics analysis

Sources of variation	Squares sum	Significance
Years	4099	++
Place	18,9	-
Cultivar	1823	++
Years x Place	3845	++
Place x Cultivar	491	-
Years x Cultivar	1068	-

+ significant for $\alpha \leq 0,05$, ++ significant for $\alpha \leq 0,01$, - non significant

Source: own work

3.2. Tuber yield depending on place of growing

In the first series of experiment (2005-2007) significant differences in the yield of tubers between 2 locations and between years was found. On average, for the three years of research higher yields were obtained for Osiny. In Jadwisin, on sandy soil the yields were lower. Particularly high differences related to the years 2005 and 2006. In 2007 the yield was however lower in Osiny. An average for 3 years the yield for Jadwisin accounted $139 \text{ dt}\cdot\text{ha}^{-1}$ and for Osiny $205 \text{ dt}\cdot\text{ha}^{-1}$. The highest yield (average for 2 places) was achieved in 2007 (Table 4).

In second series significant differences between place of growing and between years were also found. In this series the situation was inverse. Higher yields were obtained in Jadwisin than in Osiny. The average difference amounted almost $100 \text{ dt}\cdot\text{ha}^{-1}$. The highest difference in favor of Jadwisin was in 2009, the lowest in 2010. For both places the highest yield was noticed in 2009 (Table 5).

In third series statistical difference was only found between tested years. There were no differences between locations. In the years 2011 and 2012 an average yield for cultivars was higher in Jadwisin than in Osiny. Inverse situation had place in 2013. The biggest difference between places was noticed in 2012. The average for two places was the lowest in 2013 (Table 6).

Table 4. Tuber yield (dt·ha⁻¹) depending on place of growing for years 2005-2007 (mean for 7cultivars)

Years	Place	Tuber yield dt·ha ⁻¹	Difference in favor of Osiny dt·ha ⁻¹	Mean for years	LSD
2005	Jadwin	73	95	121	44
	Osiny	168			
2006	Jadwisin	124	124	186	
	Osiny	248			
2007	Jadwisin	220	-20	210	
	Osiny	200			
Mean	Jadwisin	139	66		
	Osiny	205			
LSD for place		35			

Source: own work

Table 5. Tuber yield (dt·ha⁻¹) depending on place of growing for years 2008-2010 (mean for 8 cultivars)

Years	Place	Tuber yield dt·ha ⁻¹	Difference in favor of Osiny dt·ha ⁻¹	Mean for years	LSD for years
2008	Jadwisin	320	-120	260	40
	Osiny	200			
2009	Jadwisin	342	-136	275	
	Osiny	206			
2010	Jadwisin	241	-42	220	
	Osiny	199			
Mean	Jadwisin	301	-99		
	Osiny	202			
LSD for place		50			

Source: own work

Table 6. Tuber yield (dt·ha⁻¹) depending on place of growing for years 2011-2013 (mean for 7 cultivars)

Years	Place	Tuber yield dt·ha ⁻¹	Difference in favor of Osiny dt·ha ⁻¹	Mean for years	LSD for years
2011	Jadwisin	258	-59	224	45
	Osiny	199			
2012	Jadwisin	258	-69	223	
	Osiny	189			
2013	Jadwisin	141	+ 49	165	
	Osiny	190			
Mean	Jadwisin	219	-26		
	Osiny	193			
LSD for place		-			

Source: own work

3.3. Cultivar differences

During the nine years 22 potato cultivars belonging to different groups of earliness were tested. It was stated the significance of their diversity in terms of the tuber yield. In first series 7 cultivars were tested. The highest yield, an average for 2 places was obtained for cultivars Bartek and Triada, the lowest for Drop and Gracja. Cultivars extremely differing in the level of yields in both localities were Korona and Bartek. Yield stability of individual cultivars estimated on the base of the standard deviation was also varied. The greatest stability was obtained for cultivars: Drop and Gracja, the lowest for cultivar Bartek (Table 7).

In the second series (2008-2010) eight cultivars of different maturity were examined. In this group of cultivars smaller diversity of yield was observed. An average for two locations the lowest yield was noticed for cultivar Fianna.

In this series the greatest stability was obtained for cultivar Ursus, the smallest for cultivar Vitara (Table 8).

In third series also eight cultivars were tested. In this series the smallest differentiation of yielding was stated. There were no significant differences between cultivars. The difference in the level of yields in both locations were the smallest.

In this series the greatest stability was obtained for cultivar Flaming , the lowest for cultivar Finezja (Table 9).

Table 7. Yielding of cultivars depending on place of growing (mean for years 2005-2007)

Cultivar/Place	Jadwisin	Osiny	Mean	Standard deviation	LSD for cultivars
Drop	107	99	103	60	63
Gracja	110	135	123	60	
Korona	118	232	175	91	
Bartek	176	307	242	102	
Triada	184	236	210	77	
Syrena	124	205	164	70	
Zeus	152	225	189	78	

Source: own work

Table 8. Yielding of cultivars depending on place of growing (mean for years 2008-2010)

Cultivar/Place	Jadwisin	Osiny	Mean	Standard deviation	LSD for cultivars
Agnes	290	230	260	52	67
Berber	269	132	201	79	
Fianna	240	142	191	79	
Milek	264	194	229	73	
Owacja	321	219	270	85	
Tajfun	341	249	295	80	
Ursus	322	254	288	39	
Vitara	361	194	278	103	

Source: own work

Table 9. Yielding of cultivars depending on place of growing (mean for years 2011-2013)

Cultivar/Place	Jadwisin	Osiny	Mean	Standard deviation	LSD for cultivars
Eugenia	258	216	237	66	-
Finezja	235	278	257	96	
Flaming	235	226	231	47	
Gustaw	201	222	211	75	
Medea	172	222	197	79	
Vineta	251	226	239	77	
Viviana	186	206	196	78	

Source: own work

Table 10. Cultivars distribution on groups of different yielding

Cultivars yielding above 300 dt·ha ⁻¹		Cultivars yielding between 200-300 dt·ha ⁻¹		Cultivars yielding below 200 dt·ha ⁻¹	
Jadwisin	Osiny	Jadwisin	Osiny	Jadwisin	Osiny
Owacja, Tajfun, Ursus, Vitara	Bartek	Agnes, Berber, Eugenia, Fianna, Finezja, Flaming, Gustaw, Milek, Vineta	Agnes, Eugenia, Finezja, Flaming, Gustaw, Korona, Medea, Owacja, Syrena, Tajfun, Triada, Ursus, Vineta, Viviana, Zeus	Bartek, Drop, Gracja, Korona, Medea, Syrena, Triada, Viviana, Zeus	Berber, Drop, Fianna, Gracja, Milek, Vitara

Source: own work

The average yield obtained from both organic plantations for all varieties was 221 dt·ha⁻¹ in Jadwisin and 211 dt·ha⁻¹ on in Osiny. Yield stability in different years was higher in Osiny. An average for cultivars ranged from 168 dt·ha⁻¹ to 248 dt·ha⁻¹. In Jadwisin it was much wider and ranged from 73 dt·ha⁻¹ to 342 dt·ha⁻¹.

The highest yields (average for the years of research and the place) was obtained for varieties: Tajfun, Ursus, Vitara, Agnes, Owacja, Finezja (above 250 dt·ha⁻¹). The lowest for cultivars Drop and Gracja-less than 150 dt·ha⁻¹. Most varieties yielded in range 200-300 dt·ha⁻¹. Despite the lack of significance of interaction of cultivars with the place of growing it could be seen diversified their response to soil and climatic factors. Some varieties reaching the highest yields in Osiny gave some of the lowest yields in Jadwisin and vice versa. The yielding coefficient variation for all cultivars was 19.8%.

Table 10 shows the distribution of cultivars into 3 groups in terms of the yield in the range: above 300, 200-300 and less than 200 dt·ha⁻¹. As can be seen from the data presented in the table, in Jadwisin cultivar diversity was greater than in Osiny, where most of the cultivars included in the range of 200-300 dt·ha⁻¹. Only 7 cultivars ranked in the extreme groups. In Jadwisin, only 9 cultivars included in the group with an average yield, the other were in the 2 extreme groups (Table 10).

In both places it was observed variation in the level of yield of cultivars from different groups of earliness. On the lighter soil in Jadwisin slightly higher yield compared to Osiny achieved early and mid early cultivars but lower late cultivars. (Table 10).

4. Discussion

Analysis of the impact of environmental factors on the tuber yield showed his greatest dependence on years of research. Discussing the influence of the vegetation conditions in years on the yield we can not ignore the impact of this factor on the disease development, mainly late blight, which causes the greatest losses in yield [1, 3]. Analyzing the weather in different years we can reconfirm the principle that the so-called „blight years”, ie. high yields of potatoes are in the years of high rainfall. This particularly applies to conventional crops where it is possible to use pesticides and fertilizers. In organic farming the situation is more complicated. Therefore, the yield of plants in the organic system is more dependent on climatic conditions than in the conventional [20].

To protect the potato plants against late blight in organic farming copper fungicides are permitted but their effectiveness is not as high as other fungicides. Also limits on the use of copper exists, and in some countries a total ban [5]. Analyzing the weather conditions in different years of the study should it noted that in the first series of studies in 2005-2007 the lowest yield was recorded in 2005, particularly related to light soil in Jadwisin. The main reason for such low yields lay in long periods of drought conditions during vegetation period.

Also in 2006, a shortage of rainfall in June and July had a negative impact on the yield of plants in both places. Very low yield was obtained in 2005, also in the organic system on the heavier soil in Osiny. The highest yields, on average, for the place was obtained in 2007, when the distribution of

rainfall during the growing season was the most preferred. In 2008-2010, the highest yields, on average, for the localization and the crop production system was achieved in 2008, when the amount of rainfall during the growing period was sufficient for potatoes and potato blight threat not high. The lowest yield was in 2010, in which the excess rainfall during the growing season and the rapid development of the late blight was the main reason for the yields decrease.

In the third series of studies in 2011-2013, ie the most profitable year for the yield of potatoes in the two places was the year 2012 when the air temperature, and the amount and distribution of rainfall during the growing season were the best. The worst conditions occurred in 2013, when it was cold and very wet spring (especially in Jadwisin) and thereafter in fully vegetation in July the drought occurred.

In addition to the climatic conditions a big role, especially in organic farming plays a variety, mainly its resistance to *Phytophthora infestans* fungus that causes late blight. Varieties with higher resistance are less exposed to complete destruction with strong pathogen infection than susceptible varieties [7, 8, 10, 18]. Very early and early cultivars are characterized by low resistance to *Phytophthora infestans* but in organic farming they are common due to the ability to faster rate yielding and, escape from late blight. Late cultivars are more susceptible to infection of pathogen at a later stage of development, but they also have a greater resistance to disease.

In our study, there was no strict relationship between resistance to *Phytophthora infestans* and the tuber yield but we can find a certain dependence. Top yielding cultivars (average of two places) were cultivars: Tajfun, Ursus, Owacja and Vítara. The first two cultivars are characterized by increased resistance to the pathogen (5 and 6,5), and two more are also quite high, as early variety that its resistance is 4 and 3. From many years, we can also observe the relationship between place, ie soil quality and the tuber yield in different group of earliness. Early cultivars seem achieve higher yields on the lighter soil and later on the heavier soil.

In conclusion, it should be stressed very important role of environmental conditions, in particular climatic conditions for yielding level of potato tubers grown in the organic system. The earlier studies conducted by the author have shown that in years with unfavorable weather conditions, greater losses in yield can be expected in organic system than in conventional [15, 20].

5. Conclusions

1. The yield of potatoes grown in the organic system depended greatly on weather conditions in the years of research and cultivar. The place of growing itself was less important. The highest yields were obtained in the years of the best distribution of rainfall during the growing season.
2. It was stated very large cultivar differences in tuber yield. The interaction of cultivars with place of growing has

not been proven but the reaction of some genotypes was different. Most varieties yielded in the range of 200-300 dt·ha⁻¹, the least in the range of above 300 dt·ha⁻¹. On stronger soil yield stability was higher than on lighter one.

3. The reaction of cultivars from different maturity groups was diverse. Early and mid early cultivars yielded higher in Jadwisin but later cultivars in Osiny.

6. References

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