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# YIELD AND COMMERCIAL TUBER QUALITY OF POTATOES GROWN UNDER TWO CROP PRODUCTION SYSTEMS IN DIFFERENT ENVIRONMENTAL CONDITIONS

*Summary*

*The experiment was carried out in the years 2014-2016 in two sites: Osiny-south-east Poland and Jadwisin- central Poland. In both places potatoes were grown under two crop production systems: organic and integrated. In Osiny the plantation was placed on heavier soil and in Jadwisn on lighter one. Six potato cultivars from different group of maturity were tested. The biggest impact on the tuber yield and its structure had a production system, followed by years and cultivars. A place of growing was the least important. The average yield obtained in an integrated system was higher by above 30% than in the organic system, the fact that much greater differences occurred on the lighter soil. Cultivar differences concerned only the share of large tubers. Site of growing affected only the total yield. The tested factors in the less way affected the commercial tubers quality. The share of tuber disorders was not strictly dependent on the production system and it can not be said that in the organic system tuber quality was worse.*
***Key words**: potato, cultivar, production system, yield, quality*

# PLON I JAKOŚĆ HANDLOWA BULW ZIEMNIAKÓW UPRAWIANYCH W DWÓCH SYSTEMACH PRODUKCJI W ZRÓŻNICOWANYCH WARUNKACH ŚRODOWISKA

*Streszczenie*

*Badania przeprowadzono w latach 2014-2016 w dwóch miejscowościach Jadwisin, woj. mazowieckie i Osiny, woj. lubelskie. W obu miejscowościach uprawiano ziemniaki w dwóch systemach produkcji, tj. ekologicznym i integrowanym. W Osinach uprawa prowadzona była na glebie kompleksu żytniego dobrego, w Jadwisinie na glebie kompleksu żytniego słabego. Badano 6 odmian ziemniaka należących do różnych grup wczesności. Stwierdzono, że największy wpływ na wielkość plonu bulw i jego strukturę miał system produkcji. Najmniejsze znaczenie miało miejsce uprawy. Średni plon uzyskany w systemie integrowanym był o ponad 30% wyższy niż systemie ekologicznym. Większe różnice między systemami uzyskano na glebie lżejszej. Różnice odmianowe dotyczyły tylko udziału w plonie bulw dużych. Miejsce uprawy różnicowało jedynie plon ogólny bulw. Badane czynniki w niewielkim stopniu wpływały na udział wad bulw. Nie można jednoznacznie stwierdzić, że w systemie ekologicznym jakość handlowa bulw była gorsza niż w systemie integrowanym.*
***Słowa kluczowe**: ziemniak, odmiana, system produkcji, plon, jakość*

## 1. Introduction

Consumers' interest in more secure and better controlled methods of agricultural production, in the foreground of which the organic and integrated farming should be placed results from the lost trust towards conventional food. The development of eco-friendly farming systems in the world in recent years is very dynamic [16]. This increase, however, is not the same and does not apply equally to all plants. One of the crop, whose share in organic and integrated farming is small, is potato, though, that it is still basic diet of a large number of people. This is due to the difficulty of cultivation of this species, mainly the protection against pathogens, specially *Phytophthora infestans* and Colorado potato beetle (*Leptinotarsa decelminatea*) [3, 8, 10] Factors that most limit the level of potato yields, specially in the organic system, result from big restrictions on the use of pesticides and in some soils deficit of nutrients appears as a result of non-mineral fertilizers. These limitations affect plant growth and consequently the yield [2, 4, 9, 15]. In addition to the production system, other factors such as soil quality, climatic conditions during the growing season and cultivar play a large role in shaping the level and quality of yield. The significance of cultivars in organic and integrated potato production has been described in earier publication [17, 18]. Agronomic requirements, however, not always go hand in hand with the requirements of consumers who expect mostly good quality product. Therefore, in addition to features that facilitate the cultivation, i.e. high resistance to pathogens, low requirements of soil and fertilizer, we should also take into account the commercial quality of the yield, i.e. the share of external and internal defects of tubers.

The aim of this study was to evaluate the role of a few factors such as: farming system, environmental conditions and cultivar on the yield and commercial quality of potato tubers.

## 2. Materials and methods

Material for the research comes from field experiments conducted in the years 2014-2016 on two types of soils: at experimental station of the Institute of Soil Science-Osiny (south-eastern Poland) on the heavier soil (plow soil with elements of black degradated soil), and at the Institute of Plant Breeding and Acclimatization-Jadwisin (central Poland) on lighter soil: pseudopodsolic formed from light loamy sands.

In both places potatoes were grown in 2 crop production systems: organic and integrated. Potatoes were planted on third decade of April and harvested on second decade of September. The two systems differed in fertilization, weed control and insect control practices (Table 1).

Six potato table cultivars were chosen for this experiment based on maturity class and resistance to late blight.

At harvest time, tuber yield, tuber size distributions (<35 mm, 35-60 mm and >60 mm) and share of external and internal disorders: common scab, black scarf, green tubers, pest damages, deformation and rust spot and hallow hearts were assessed. External disorders was assessed as a percent of infected or damaged tubers from all the sample. Internal disorders as a number of damaged tubers.

Data were analyzed using the ANOVA program, with means separated by Student's t-test.

Tukey test was used to test the difference between the average values at a significance level $\alpha < 0.05$.

Weather conditions during vegetation period for both places are given in table 2.

## 3. Results

### 3.1. Statistical analysis

There were significant differences in most of the examined parameters characterizing the total yield, tuber size distribution and share of tuber disorders. A production system, next year and cultivar had the biggest influence on tested parameters. Site of growing had smaller impact. There were a few significant interactions between tested factors. Most of them concerned production system and site and years (table 3).

Table 1. Agronomic inputs in organic and integrated systems in 2 sites
*Tab.1. Zabiegi agrotechniczne stosowane w systemie ekologicznym i integrowanym w dwóch miejscowościach*

| Crop production practice | Organic system Jadwisin | Integrated system Jadwisin | Organic system Osiny | Integrated system Osiny |
|---|---|---|---|---|
| Fertilization | Cow composted manure applied in spring: 280 dt ·ha$^{-1}$ + mustard as a catch crop | Manure – 250 dt ha$^{-}$ N: 80 kg ha$^{-1}$ P: 55 kg ha$^{-1}$ K: 130 kg ha$^{-1}$ | Compost – 300 dt ha$^{-1}$ + catch crop | Manure – 250 dt ha$^{-1}$ N: 75kg ha$^{-1}$P:60 kg ha$^{-1}$ K:105 kg ha$^{-1}$ |
| Weed control | Only mechanical tillage | Mechanical tillage + herbicides | Only mechanical tillage | Mechanical tillage + herbicides |
| Colorado potato beetle control | Biological insecticide (*Bacillus thuringiensis*) | Chemical insecticides | Biological insecticide (*Bacillus thuringensis*) | Chemical insecticides |
| Late blight control | Copper fungicides | Chemical fungicides | Copper fungicides | Chemical fungicides |

*Source: own work / Źródło: opracowanie własne*

Table 2. Total monthly rainfall (P) and mean monthly temperatures (T) during the vegetative growth period in the years 2014-2016 for Jadwisin and Osiny
*Tab. 2. Sumy miesięcznych opadów (P) oraz średnich temperatur powietrza (T) dla okresu wegetacji w latach 2014-2016 dla dwóch miejscowości*

| Year | Place | April | | May | | June | | July | | August | | September | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | P (mm) | T ($^0$C) | P (mm) | T ($^0$C) | P (mm) | T ($^0$C) | P (mm) | T ($^0$C) | P (mm) | T ($^0$C) | P (mm) | T ($^0$C) |
| 2014 | Jadwisin | 61,1 | 10,3 | 41,3 | 14,1 | 69,8 | 15,8 | 23,5 | 21,5 | 79,2 | 18,2 | 11,9 | 14,8 |
| | Osiny | 67,5 | 10,2 | 170,5 | 13,4 | 99,4 | 15,7 | 56,2 | 20,6 | 105,5 | 18,4 | 17,8 | 14,5 |
| 2015 | Jadwisin | 27,8 | 8,3 | 39,5 | 12,9 | 15,4 | 17,5 | 62,3 | 19,6 | 8,6 | 22,5 | 36,6 | 15,1 |
| | Osiny | 29,4 | 8,2 | 108,7 | 12,6 | 29,2 | 16,8 | 52,1 | 19,8 | 4,3 | 22,4 | 40,1 | 15,5 |
| 2016 | Jadwisin | 92,2 | 15,3 | 85,4 | 18,7 | 103,6 | 19,6 | 61,4 | 18,4 | 9,5 | 15,7 | 92,2 | 15,3 |
| | Osiny | 87,5 | 15,0 | 75,6 | 18,2 | 95,7 | 19,9 | 60,5 | 18,5 | 10,9 | 15,8 | 87,5 | 15,0 |

*Source: own work / Źródło: opracowanie własne*

Table 3. Significance of differences in parameter means
*Tab. 3. Istotność zróżnicowania badanych czynników*

| Tested parameters | Total yield | Share of small tubers (<35 m) | Share of medium tubers (35-60 m) | Share of large tubers (>60mm) | Mass of 1 tuber | Cammon scab (%) | Black scarf (%) | Deformations (%) | Pest damages (%) | Green tubers (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Production system | ++ | ++ | ++ | ++ | ++ | ++ | - | - | ++ | + |
| Site | ++ | _ | _ | _ | _ | _ | _ | | + | _ |
| Cultivar | _ | ++ | - | ++ | ++ | + | ++ | - | - | - |
| Years | ++ | - | - | ++ | _ | + | - | ++ | - | ++ |
| System x Cultivar | - | - | - | - | - | - | - | - | - | - |
| Cultivar x years | - | - | - | - | - | - | - | - | - | - |
| System x site | ++ | - | - | - | + | ++ | ++ | - | + | |
| System x years | - | - | - | - | - | - | - | - | - | ++ |
| Cultivar x site | - | - | - | - | - | - | - | - | - | - |
| Site x years | + | ++ | - | - | + | ++ | + | - | ++ | _ |

*++ = significant at α ≤0.05; + = significant at α ≤0.01; - = non significant* *Source: own work / Źródło: opracowanie własne*

## 4. Influence of tested parameters on tuber yield and tuber size distribution

Production system significantly differentiated the values of all yield parameters. In the integrated system higher values were achieved for total yield, share of large tubers and mass of 1 tuber. The share of small and medium tuber was higher in organic system. The biggest differences in favor of integrated system concerned the share of large tubers (52,9 %), total yield (33,1 ) and mass of 1 tuber (28,2%), (tab. 4).

The tested cultivars were not significantly different in terms of the level of the total yield. There were also no significant interactions between tested factor, that means the same reaction of cultivars on production system, site of growing and years. There were, however, significant differences in tuber size distribution, specially the share of small and large tubers.

The years of investigations significantly influenced the total yield and share of large tubers. The highest yield in both places was obtained in 2016 and the lowest in 2015. The share of big tubers was higher in 2015 and 2016 compared to 2014.

The site of growing significantly influenced only the total yield. The higher yield was achieved in Jadwisin. There were no significant differences in the tubers size distribution (table 6).

There was significant interaction between site of growing and production system in relation to total yield. In Jadwisin, the difference between integrated and organic system was very high- 42,1% but in Osiny only 20,6%.

## 5. Influence of tested parameters on tubers quality

Crop production system significantly influenced such tubers disorders as: common scab, pest damages and green tubers. In the integrated system there was higher share of common scab, and green tubers. The share of pest damages however was higher in organic system. The share of black scurf and the level of deformations was the same in both systems (table 7).

Table 4. Influence of crop production system on tuber yield and tuber size distribution (mean for 2 sites, 6 cultivars and 3 years)
*Tab. 4. Wpływ systemu produkcji na plon bulw i jego strukturę (średnio dla 2 miejsc uprawy, 6 odmian i 3 lat badań)*

| Production system | Total yield (dt·ha $^{-1}$) | Share of small tubers (<35 mm) (%) | Share of medium tubers (35-60 mm) (%) | Share of large tuber ( >60 mm) (%) | Mass of 1 tuber (g) |
|---|---|---|---|---|---|
| Organic | 262a | 4,6a | 87,5a | 7,9a | 77,4a |
| Integrated | 392b | 2,2b | 81,0b | 16,8b | 108,4b |
| Decrease in relation to integrated system (%) | 33,1 | - | - | 52,9 | 28,2 |

*Source: own work / Źródło: opracowanie własne*

Table 5. Influence of years on tuber yield and tuber size distribution (mean for 2 systems, 2 sites and 6 cultivars)
*Tab. 5. Wpływ lat badań na plon bulw i jego strukturę (średnio dla 2 systemów produkcji i 6 odmian)*

| Years | Total yield (dt·ha $^{-1}$) | Share of small tubers (<35 mm) (%) | Share of medium tubers (35-60 mm) (%) | Share of large tuber (>60 mm) (%) | Mass of 1 tuber (g) |
|---|---|---|---|---|---|
| 2014 | 334b | 4,3a | 86,4a | 9,3a | 91,2a |
| 2015 | 288a | 3,4a | 82,8a | 13,8b | 89,6a |
| 2016 | 353c | 2,4a | 83,2a | 14,4b | 95,8a |

*a, b, c-statistically different groups*

*Source: own work / Źródło: opracowanie własne*

Table 6. Influence of growing site on tuber yield and tuber size distribution (mean for 2 systems, 3 years and 6 cultivars)
*Tab. 6. Wpływ miejsca uprawy na plon bulw i jego strukturę (średnio dla 2 systemów uprawy, 3 lat badań i 6 odmian)*

| Site of growing | Total yield (t·ha $^{-1}$) | Share of small tubers (<35 mm) (%) | Share of medium tubers (35-60 mm) (%) | Share of large tuber (>60mm) (%) | Mass of 1 tuber (g) |
|---|---|---|---|---|---|
| Jadwisin | 37,7a | 3,7a | 84,6a | 11,7a | 94,3a |
| Osiny | 27,7b | 3,0a | 83,8a | 13,1a | 89,5a |
| Decrease in relation to Jadwisin (%) | 26,5 | - | - | - | 3,1 |

*Source: own work / Źródło: opracowanie własne*

Table 7. Influence of crop production system on tuber disorders (mean for 2 sites, 6 cultivars and 3 years)
Tab. 7. Wpływ systemu produkcji na udział wad bulw (średnio dla 2 miejsc uprawy, 6 odmian i 3 lat badań)

| Production system | Common scab (%) | Black scarf (%) | Deforma tions (%) | Pest dama ges (%) | Green tubers (%) |
|---|---|---|---|---|---|
| Organic | 19,9a | 9,2a | 6,8a | 2,7a | 1,7a |
| Integrated | 42,1b | 11,6a | 9,3a | 0,4b | 9,3b |

*Source: own work / Źródło: opracowanie własne*

Table 8. Influence of cultivar on tuber disorders (mean for 2 sites, 2 production systems and 3 years)
*Tab. 8. Wpływ odmiany na udział wad bulw (średnio dla 2 miejsc uprawy, 2 systemów produkcji i 3 lat badań)*

| Cultivar | Common scab (%) | Black scarf (%) | Deformations (%) | Pest damages (%) | Green tubers (%) |
|---|---|---|---|---|---|
| Lord | 35,8ab | 6,8a | 6,9a | 1,5a | 7,9a |
| Ignacy | 34,8ab | 10,8ab | 6,8a | 1,3a | 4,5a |
| Michalina | 41,1b | 12,8ab | 5,4a | 1,0a | 3,7a |
| Jurata | 25,6a | 19,2b | 10,1a | 1,2a | 2,8a |
| Malaga | 27,3a | 8,4a | 11,2a | 1,4a | 8,0a |
| Oberon | 21,4a | 4,2a | 8,0a | 3,0a | 7,1a |

*Source: own work / Źródło: opracowanie własne*

Table 9. Influence of growing site on tuber disorders (mean for 2 systems, 3 years and 6 cultivars)
*Tab. 9. Wpływ miejsca uprawy na udział wad bulw (średnio dla 2 systemów uprawy, 3 lat i 6 odmian).*

| Site | Common scab (%) | Black scarf (%) | Deformations (%) | Pest damages (%) | Green tubers (%) |
|---|---|---|---|---|---|
| Jadwisin | 28,8a | 11,9a | 8,8a | 2,3a | 5,1a |
| Osiny | 33,1b | 8,8a | 7,2a | 0,7b | 5,9a |

*Source: own work / Źródło: opracowanie własne*

Table 10. Influence of years on tuber disorders (mean for 2 systems, 2 sites and 6 cultivars)
*Tab. 10. Wpływ lat badań na udział wad bulw (średnio dla 2 systemów uprawy, 2 miejsc i 6 odmian)*

| Years | Common scab (%) | Black scarf (%) | Deformations (%) | Pest damages (%) | Green tubers (%) |
|---|---|---|---|---|---|
| 2014 | 25,2a | 9,2a | 9,8a | 1,0a | 10,0a |
| 2015 | 36,8b | 11,5a | 6,3a | 2,1a | 1,0b |
| 2016 | 37,6b | 7,7a | 15,2b | 5,2a | 3,1b |

*Source: own work / Źródło: opracowanie własne*

The cultivar significantly influenced the percent of tubers infected by common scab and black scarf. Cultivar Oberon was the least infected cultivar by two mentioned infections (table 8).

The site of growing significantly influenced the common scab infection and pest damages. Higher infection of common scab was noticed in Osiny but pest damages in Jadwisin (table 9).

The climatic conditions during vegetation period significantly influenced following disorders: common scab, deformations and green tubers. The infection of common scab was lower in 2014 compared to 2015 and 2016. The share of deformation was the higher in 2016 and share of green tubers in 2014 (table 10).

It was significant interaction between site and production system in relation to common scab. In Jadwisin the lowest infection was in 2014 but in Osiny the infection was the highest in this year. In Jadwisin an average from three years infection was similar in both systems but in Osiny the infection in integrated system was almost 3 times higher. The infection of black scarf in Jadwisin was higher in integrated system but in Osiny in organic one. In the experiment the internal disorders (rust spot and hallow hearts) were also assessed but only in one cultivar two tubers with rust spot was found, so this is not included in the calculation.

## 6. Conclusions

A production system, followed by years and cultivars had the biggest impact on the tuber yield and its structure. A place of growing was the least important. The average yield obtained in an integrated system was higher by above 30% than in the organic system, the fact that much greater differences occurred on the lighter soil. Cultivar differences concerned only the share of large tubers. Site of growing affected only the total yield. The tested factors in the less way affected the commercial tubers quality. The share of tuber disorders was not strictly dependent on the production system and it can not be said that in the organic system tuber quality was worse.

## 7. Discussion

Both the potato tuber yield, its structure and tuber quality depend on many factors. The main includes soil and climatic conditions, varietal and agronomic inputs. Among the agronomic factors, production system plays an important role. In Poland, as in the world, primary production system is a conventional one but next to this are more and more eco-friendly: organic and integrated systems.

In the literature there is most common comparison of organic crops with conventional and given decrease yield between these systems ranges from 10 to even 70% in favor of the conventional system [1, 6, 15, 21]. Less work concern the comparison of the organic with integrated systems. In addition to the documented reduction in the total yield in the organic system, the authors emphasize the tuber diminishment in comparison to integrated [7, 13, 17].

From eco-friendly grown potatoes we expect generally improved flavor and better nutritional value at the expense of slightly worse appearance. Using in these systems organic manuring, crop rotation rich in perennial plants, green fertilizers contributes to increasing infection of certain diseases such as common scab or black scarf, as well as create better conditions for the development of soil pests [5, 12, 14]. Analysis of the impact of environmental factors on the tuber yield showed its great dependence on years of research. The yield of plants in the organic system is more dependent on climatic conditions than in the conventional and then in integrated systems [21]. The effect of tested factors on the yield and its structure is rather well-known and explicable i.e. higher yields in the integrated system com-

pared to organic and higher yields in more favorable 2016 and 2014 years compared to 2015. It is more difficult to explain the difference in the yield between the sites of cultivation. On the heavier soil we expect generally higher yields. Unfortunately, in the study it was found an inverse relationship. This was specially under integrated systems. It is difficult to explain but it should be stressed very unfavorable weather conditions especially in 2014 in this site.

There was no significant varietal differences, although the comparison concerned cultivars from different groups of earliness, which generally differentiates the most the yield. In many our previous studies of other cultivars, these differences were always significant [18, 21].

For most of the tubers disorders there were differences between both: production system, cultivars, as well as the site of cultivation system. Such differentiation is confirmed by previous work [1, 11, 19]. But it is generally difficult to say in which system the commercial tuber quality was better. The occurrence of certain tuber defects was higher in the organic system, while others in the integrated system. The same situation concerned the growing site and years of research. So you can not explicitly state that the commercial tuber quality from organic system was worse.

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