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Artykuł wdrożeniowy
Implementation article

Wpływ mikrostarterów B i K na wielkość i jakość bulw ziemniaka

The influence of microstarters B and K on the volume and quality of potato tubers

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W latach 2016–2018 w Oddziale IHAR-PIB w Boninie oceniano wpływ zastosowania nawozów mikroelementowych Micro 1 B i Mikro 1 K jako nawożenie uzupełniające nawożenie podstawowe pod ziemniaki. Największy plon bulw uzyskano dla kombinacji, w której do nawożenia podstawowego zastosowano dodatkowo nawóz Micro 1 K. Na poletkach, na których aplikowano ten zestaw nawozów stwierdzono najwyższy wzrost plonu ogólnego, oraz plonu bulw dużych (powyżej 55 mm), przydatnych do przetwórstwa. Stwierdzono także korzystny wpływ mikrostartera Mikro 1 B na zawartość skrobi w bulwach.

Słowa kluczowe: ciemnienie bulw, Micro 1 B, Micro 1 K, nawozy, plon, skrobia

In 2016-2018, the IHAR-PIB Branch in Bonin assessed the effect of Micro 1 B and Micro 1 K micronutrient fertilizers as supplementary fertilizers to basic fertilization for potatoes. The highest tuber yield was obtained for the combination of basic fertilization and Micro 1K. In the plots where this set of fertilizers was applied, the highest increase in the total yield and the yield of large tubers (over 55 mm), useful for processing, was observed. It was also found that the Micro 1 B microstarter had a beneficial effect on the starch content in tubers.

Key words: darkening of tubers, fertilizers, Micro 1 B, Micro 1 K, starch, yield

Introduction

Macronutrients and micronutrients are involved in specific physiological reactions and are essential for proper development and yield formation in crop plants, including potatoes. Nutrient deficiency may inhibit development and slow down physiological processes, which further negatively impacts the size and quality of tuber yield (Stępień et al. 2009). Fertilization is one of the main agrotechnical treatments significantly influencing the size of yield and the quality of formed tubers (Szewczuk, 2009; Trawczyński, Prokop 2016). Because of the long growing season (longer than 130 days in late varieties) and high yield weight, potatoes require a good supply of nutrients throughout the growing season. A complex supply of easily assimilable nutrients has a significant effect on physiological processes, plant development, and the formation and growth of new tubers (Grzyś, 2004; Zarzecka, 2006). The efficiency of fertilization depends, among other things, on soil parameters (agronomic category, content of organic matter, nutrients, and pH), precipitation and air temperature during the growing season, and the type of fertilizers applied. One solution relies on special fertilizers, both foliar and those applied to soil (Trawczyński and Prokop, 2016). These fertilizers contain microelements which are components of enzymes that catalyze and regulate biochemical processes (Grzyś, 2004). Therefore, the deficiency of micronutrients has a critical effect on the yield quality and radically reduces its size (Czuba, 2000). The role of micronutrients has been significantly increasing in recent years, which is associated with the introducing more vigorous and higher-yielding varieties that have a greater demand for micronutrients. Another reason is an increase in soils with low content of available micronutrients and thus their deficiency in plants, reducing consumer value and fodder value of crops (Grzyś, 2004; Brown, 2004; Imas, Magen, 2004).

The study aimed to test the effect of special fertilizers, Micro 1 B and Micro 1 K, containing EDTA-chelated Mn and Zn, on the development of potato plants and the size and quality of tuber yield.

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Material and Methods

Field experiments were carried out in the IHAR -PIB Department in Bonin near Koszalin (West Pomeranian province, Poland) in 2016-2018. The effects of soil fertilization with Micro 1 B and Micro 1 K were determined for the medium-late variety Jelly of consumer quality. Specifically, the following variants of fertilization were tested:

— MB-1 – fertilization with Micro 1 B, dose 25 kg·ha^{-1}
— (Mg – 4.0 kg·ha^{-1}, SO_3 – 8.25 kg·ha^{-1}, B – 22.5 g·ha^{-1}, Mo – 2.5 g·ha^{-1}, Mn – 250 g·ha^{-1},
— Zn – 750 g·ha^{-1});
— MK-1 – fertilization with Micro 1 K, dose 25 kg·ha^{-1}
— (NH_4 – 1 kg·ha^{-1}, P_2O_5 – 7.5 kg·ha^{-1}, K_2O – 5.0 kg·ha^{-1}, SO_3 – 2.8 g·ha^{-1}, Mn – 100 g·ha^{-1}, Zn – 500 g·ha^{-1});
— NM – mineral fertilization with Yara Mila 14-14-21, dose 700 kg·ha^{-1}
— (98 – kg N·ha^{-1}, 98 kg – P_2O_5·ha^{-1}, 147 kg – K_2O·ha^{-1});
— NM + MB-1 – fertilization with Yara Mila 14-14-21 (700 kg·ha^{-1}) + MB-1 (25 kg·ha^{-1});
— NM + MB-1 – fertilization with Yara Mila 14-14-21 (700 kg·ha^{-1}) + MK-1 (25 kg·ha^{-1}).

Experiments were established on 22.5 m^2 plots (100 plants) in a randomized block design in four replicates on a field where winter wheat was previously grown. The soil on the experimental site was sandy loam characterized by different contents of basic macronutrients depending on the study year (Tab. 1).

Tabela 1
Table 1

Analiza gleby (lata 2016 – 2018)

Soil analysis (years 2016 - 2018)

Rok Year	pH w KCl pH in KCl	mg w 100 g gleby mg in 100 g soil						Próchnica organic matter [%]	Kategoria agronomiczna agronomic category
		P_2O_5		K_2O		MgO			
2016	5,9	18,6	wysoka high	16,0	wysoka high	6,1	wysoka high	2,3	glina piaszczysta sandy loam
2017	5,3	12,8	średnia medium	7,0	niska low	3,0	niska low	1,6	glina piaszczysta sandy loam
2018	5,5	20,1	bardzo wysoka very high	13,0	średnia medium	3,9	niska low	1,6	glina piaszczysta sandy loam

In August, the winter wheat harvest was followed by sowing white mustard as a forecrop (25 kg · ha^{-1}) and fertilization with urea at a dose of 23 kg N·ha^{-1}. Winter ploughing was done between late October and early November. The soil was cultivated in early April. In mid-April, Yara Mila 14-14-21 multi-component mineral fertilizer was applied at a dose of 700 kg·ha^{-1}, and mixed with the soil by double cultivation. Micro 1 B and Micro 1 K fertilizers were applied in rows in the last ten days of April directly before planting potato tubers on the study plots. About 20-25 days after planting, potatoes were hillered and the ridges were finally formed. After that the field was treated with Plateen 41.5 WG herbicide at a dose of 2.0 kg · ha^{-1}. Another weed control treatment was applied during the crop cover stage (BBCH 31 – 35), and Titus 25 WG at a dose of 60 g · ha^{-1} was used. During the growing season, depending on the scale of infestation, the crop was treated to control potato blight and potato beetle (Tab. 2).

Weather conditions (amount of rainfall and average daily air temperature) were monitored during the study period at the weather station in Bonin (Fig. 1, Fig. 2).

Weather conditions in Bonin varied between study years. 2016 was characterized by much lower precipitation in April-June, and higher precipitation in July and August than the multiannual data. In 2017 the amount of precipitation was highest, compared to the multiannual average (1981-2010). 2018 was dry: the precipitation was above the multiannual average only in July but was much lower in other months.

During the study period, lower mean daily air temperatures were recorded in 2017.

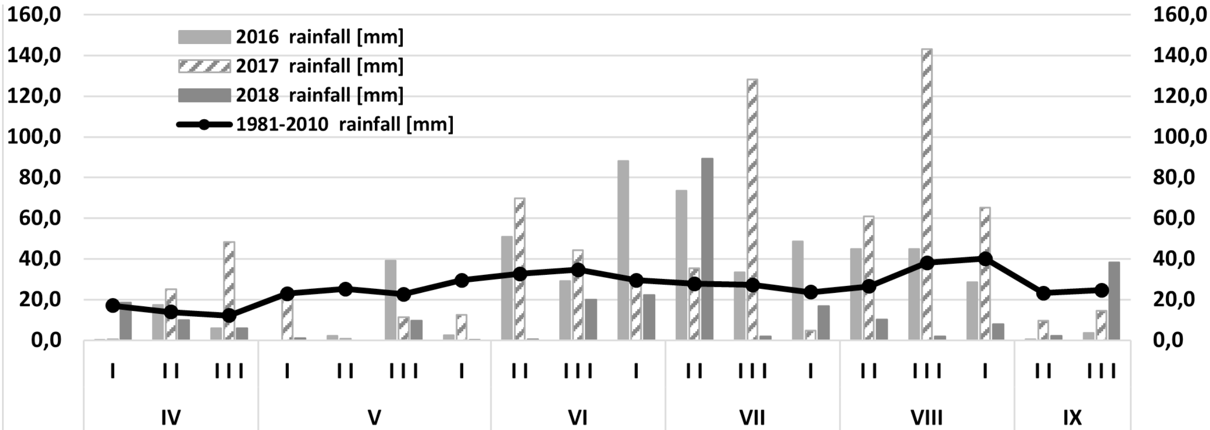
Tabela 2
Table 2

Wykaz środków ochrony roślin stosowanych w doświadczeniu w latach 2016–2018

List of pesticides used in experiment in the years 2016–2018

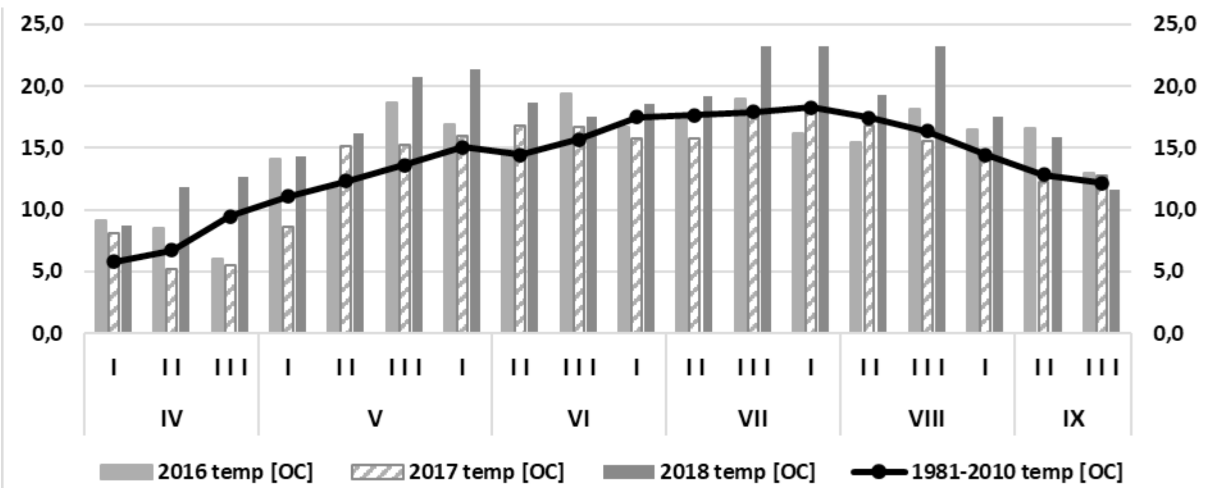
Środek ochrony roślin plant protection product	2016	2017	2018
Herbicydy Herbicides	Plateen 41,5 WG (2,0 kg) Titus 25 WG (60 g)*	Plateen 41,5 WG (2,0 kg) Titus 25 WG (60 g)	Plateen 41,5 WG (2,0 kg) Titus 25 WG (60 g)
Insektycydy Insecticides	SpinTor 240 SC (0,15 l) Actara 25 WG (80 g) Nomolt 150 SC (0,25 l)	Actara 25 WG (80 g)	Actara 25 WG (80 g)
Fungicydy Fungicides	Infinito 687,5 SC (1,6 l) Pyton Consento 450 SC (2,0 l) Infinito 687,5 SC (1,6 l) Infinito 687,5 SC (1,6 l) Quantum 69 WG (2,0 kg) Curzate Top 72,5 WG (2,0 kg) Dithane NeoTec 75 WG (2,0 kg) Altima 500 SC (0,4 l)	Infinito 687,5 SC (1,6 l) Infinito 687,5 SC (1,6 l) Orvego 525 SC (0,8 l) Revus 250 SC (0,6 l) Drum 45 WG+Ranman Top 160 SC (0,2 kg+0,5 l) Drum 45 WG+Ranman Top 160 SC (0,2 kg+0,5 l) Ranman Top 160 SC (0,5l) Banjo Forte 400 SC (08 l)	Infinito 687,5 SC (1,6 l) Infinito 687,5 SC (1,6 l) Pyton Consento 450 SC (2,0 l) Pyton Consento 450 SC (2,0 l) Ranman Top 160 SC (0,5l)

** w nawiasach podano dawkę środka zastosowaną na 1 hektar*
in parentheses dose per hectare is given



Rys. 1 Sumy opadów w latach 2016-2018 w porównaniu do wielolecia (1981-2010).

Fig. 1 Rainfall in the period 2016-2018 compared to the multi-year period (1981-2010).



Rys. 2 Średnie dobowe temperatury powietrza w latach 2016-2018 w porównaniu do wielolecia (1981-2010).

Fig. 2 Average daily air temperatures in the period 2016-2018 compared to the multi-year (1981-2010).

Air temperatures were highest in 2018, also compared to the multiannual average (tab. 3).

Three weeks before harvest, the haulm was destroyed through mechanical and chemical methods. Haulm was disintegrated and treated with Reglone 200 SL at a dose of 3.0–4.0 l·ha^{-1}. Potatoes were harvested in the last ten days of September. Tubers harvested from the central ridge of each plot were evaluated for:

— total yield,
— structure of marketable yield and yield of large tubers (10 consecutive plants from the central ridge),
— darkening of raw tubers. One week after harvest, 10 medium-size tubers were cut along the top-stolon axis and arranged on white filter paper. After 4 hours, tubers were assessed using a 1-9 scale, where 9 is no discolouration, and 1 is the strongest darkening.
— starch content was assessed 4 weeks after harvest using Reihman's scales (two samples from each plot, each sample approx. 2 kg of medium-size tubers). Two measurements were taken for each sample, and the mean value was used for data analysis. Measurements were repeated if the difference between them was greater than 0.5%.

The significance of differences was verified using Tukey's test at α=0.05 and statistical software (ARM 2020).

Results

Tuber yield

The highest total tuber yields for different tested variants of fertilization were obtained in 2016. Yields in other study years were significantly lower (Tab. 3).

Tabela 3
Table 3

Ogólny plon bulw (t·ha^{-1}) w zależności od roku badań i wariantu nawożenia

The total tuber yield (t·ha^{-1}) depending on the year of assessment and the variant of fertilization

Rok Year	Kombinacja Variant					Średnio Average
	MB – 1	MK – 1	NM	MB – 1+ NM	MK – 1+ NM	
2016	45,20	57,38	63,28	59,00	69,40	58,85
2017	38,58	37,63	55,35	55,38	56,48	48,68
2018	44,45	47,55	54,73	56,35	55,25	51,67
Średnio Average	42,74	47,52	57,78	56,91	60,38	

NIR $_{(0,05)}$/LSD$_{(0,05)}$ dla/for:
kombinacji/variants = 6,014;
lat/years = 3,971;
kombinacje x lata/variants x years = 10,417;
lata x kombinacje/years x variants = 8,880

Considering all fertilization variants, the highest total tuber yield was found for basic mineral fertilizer in combination with Micro 1 K (MK – 1 + NM).

The highest marketable yield of tubers (diameter larger than 30 mm) was also found for 2016 (Tab. 4). Yields in other study years were significantly lower. The highest yield was obtained for fertilization variant MK – 1 + NM.

The highest yield of large tubers (diameter larger than 55 mm), suitable for processing into chips and crisps, was found for the fertilization variant MK – 1 + NM (Tab. 5). Yield size varied depending on the fertilization variant and study year. The share of large tubers in the total yield was highest in 2017, and it ranged from 81.4% for the MB – 1 variant to 97.2% for the MB – 1 + NM variant. Despite differences in weather conditions, tested variants of fertilization positively affectedthe share of large tubers suitable for processing. The mean share of large tubers in the total yield between 2016 and 2018 ranged from 62.8% (MB – 1 variant) to 80.7% (MK – 1 + NM variant).

Starch content

The content of starch in tubers differed significantly between fertilization variants (Tab. 6). It was highest for the MB – 1 variant and the basic NM variant. The content of starch also differed between study years and was highest in 2017.

Tabela 4
Table 4

Plon handlowy (t·ha^{-1}) w zależności od roku badań i wariantu nawożenia

The marketable yield (t·ha^{-1}) depending on the year of assessment and the variant of fertilization

Rok Year	Kombinacja Variant					Średnio Average
	MB – 1	MK – 1	NM	MB – 1+ NM	MK – 1+ NM	
2016	43,48	55,53	62,23	55,63	67,93	56,96
2017	38,58	37,40	55,35	55,38	56,48	48,64
2018	41,48	46,30	52,80	54,95	52,68	49,64
Średnio Average	41,18	46,41	56,79	55,32	59,03	

NIR $_{(0,05)}$/LSD$_{(0,05)}$ dla/for: kombinacji/variants = 5,912;
lat/years = 3,903;
kombinacje x lata/variants x years = 10,239;
lata x kombinacje/years x variants = 8,728

Tabela 5
Table 5

Plon bulw dużych (t·ha^{-1}) w zależności od roku oceny i wariantu nawożenia

The yield of large tubers (t·ha^{-1}) depending on the year of assessment and the variant of fertilization

Rok Year	Kombinacja Variant					Średnio Average
	MB – 1	MK – 1	NM	MB – 1+ NM	MK – 1+ NM	
2016	29,68	42,20	50,80	30,43	54,08	41,44
2017	31,40	32,08	46,65	53,83	54,25	43,64
2018	19,45	21,73	35,05	39,10	37,90	30,65
Średnio Average	26,84	32,00	44,17	41,12	48,74	

NIR $_{(0,05)}$/LSD$_{(0,05)}$ dla/for: kombinacji/variants = 5,469
lat/years = 3,611;
kombinacje x lata/variants x years = 9,472;
lata x kombinacje/years x variants = 8,074

Tabela 6
Table 6

Procent skrobi w zależności od roku oceny i wariantu nawożenia

Percent of starch depending on the year of assessment and the variant of fertilization

Rok Year	Kombinacja Variant					Średnio Average
	MB – 1	MK – 1	NM	MB – 1+ NM	MK – 1+ NM	
2016	15,563	15,400	14,313	14,363	15,213	**14,970**
2017	17,100	16,775	17,050	15,750	16,175	**16,570**
2018	15,513	15,100	16,125	15,788	15,550	**15,615**
Średnio Average	**16,058**	**15,758**	**15,829**	**15,300**	**15,646**	

NIR $_{(0,05)}$/LSD$_{(0,05)}$ dla/for: kombinacji/variants = 0,669;
lat/years = 0,442;
kombinacje x lata/variants x years = 1,159;
lata x kombinacje/years x variants = 0,988

Enzymatic darkening

The analysis of enzymatic darkening of tubers did not reveal significant differences between experimental variants (Tab.7). However, there were differences in this feature between study years. Four hours after dissections, no signs of darkening were found only for tubers harvested in 2018 when precipitation was lowest, and air temperatures were highest.

Tabela7
Table 7

Ciemnienie enzymatyczne bulw w zależności od roku oceny i wariantu nawożenia

Tuber enzymatic darkening depending on the year of assessment and the variant of fertilization

Rok Year	Kombinacja Variant					Średnio Average
	MB – 1	MK – 1	NM	MB – 1+ NM	MK – 1+ NM	
2016	8,945	8,950	8,950	8,850	8,925	8,924
2017	8,575	8,525	8,600	8,650	8,600	8,590
2018	9,000	9,000	9,000	9,000	9,000	9,000
Średnio Average	8,840	8,825	8,850	8,833	8,842	

NIR $_{(0,05)}$/LSD$_{(0,05)}$ dla/for: lat/years = 0,055
1 oznacza ciemnienie najsilniejsze, a 9 brak ciemnienia
1 is a darkening of the strongest, and 9 no darkening

Discussion

The development of potato plants and tuber yield were significantly influenced not only by the type of soil and fertilization but also by weather conditions during the growing season (Fig. 1 and 2). According to Chmura et al. (2013), the yield of medium-late (including the Jelly variety used in the experiment) and late potatoes depends on the total precipitation. These authors reported that lower precipitation during the first phase of growth (May-June) and higher precipitation in July-August promote higher tuber yield. In our experiment, this was the case in 2016 when the total precipitation was lower in April-June and higher during the second phase of growth. In 2017, high amounts of precipitation did not promote high yield. The least favourable conditions for the growth of potato plants and tuber yield were recorded in 2018, a year characterised by a significant shortage of rainfall and high air temperatures. Borówczak (2012) reported that a low amount of rainfall during the formation of tubers and their growth influence yield size, but also the suitability of tubers for industrial processing. The lowest share of large tubers (diameter larger than 55 mm) was found in 2018 for each tested variant.

The use of Micro 1 B and Micro 1 K fertilizers to supplement basic fertilization (Yara Mila 14-14-21, dose 700 kg·ha-1) positively affected the total yield, marketable yield, and yield of large tubers suitable for industrial processing.. The highest increase in the yield of large tubers was found in 2017 and 2016 for fertilization with Micro 1 K. It was 5.7 t·ha^{-1} for marketable yield, more than 6.1 t· ha^{-1} for the total yield of tubers, and more than 7 t· ha^{-1} for the yield of large tubers compared to 2018 and other variants of fertilization.

This positive effect of Micro 1 K fertilizer on the yield size might be associated with the supplementation of potassium and phosphorus. Grzebisz and Härdter (2006), Grzebisz (2011), and Grześkowiak (2013) reported that potato responds with an increase in yield to balanced potassium fertilization. A significant effect of potassium on yield in potato has also been confirmed in studies by Stępień et al. (2005, 2009) and Trawczyński (2005).

Starch is an important product used by the food, pharmaceutical and paper industries (Sznajder and Tarant, 2002, Dzwonkowski, 2010). Its role is increasing because of the search for new prospective applications and the pursuit of products safe for the environment. In addition, in biotechnology and in the chemical industry, starch as a natural, renewable and biodegradable raw material is increasingly replacing petroleum-based polymers (Kołodziejczyk et al., 2013). Our experiment revealed a significant positive effect of fertilization on the starch content, depending on the tested variant, study year, and the interaction between years and the tested variants of fertilization. The highest content of starch was found for the MB – 1 + NM variant in 2017. Puła and Skowera (2004) and Wojciechowski et al. (2013) reported that the increase in starch content in tubers is promoted by high levels of rainfall during tuber formation. Our findings apparently support this thesis. Kołodziejczyk (2014) concluded that in addition to the amount of rainfall, the accumulation of starch is significantly influenced by the distribution of rainfall and temperature across the growing season. Wierzbicka (2012) also reported that the accumulation of starch might additionally depend on temperature during the final period of the growing season. The content of starch in tubers depends on the potato variety (Jabłoński, 2005, Styszko and Kamasa, 2006). Wierzbicka (2011) concluded that starch content also depends on the length of plant growth and the size of tubers. This conclusion was confirmed by Styszko et al. (2001), who reported a positive correlation between starch content and the duration of the growing season but found a negative correlation between tuber size and protein content.

One of the parameters determining the suitability of tubers for processing, especially into chips and crisps, is the darkening of flesh. According to Leszczyński (2000), darkening results from the oxidation of tyrosine and chlorogenic acid in the presence of polyphenol oxidase. However, according to Kołodziejczyk (2014), tuber darkening may also be a variety-specific feature, although environmental conditions may play an important role in this process. Among the factors influencing tuber darkening, Ciećko et al. (2005) included potassium fertilization, while Trawczyński (2012) emphasized that this process may be associated with the type of fertilizer. Our experiment did not reveal any significant differences in tuber darkening between different types of fertilization. However, there were differences in this feature between study years. The lowest scores for tuber darkening were found in 2018, a year characterised by moderate amount of rainfall and relatively high air temperatures during the end of the growing season. Our findings are generally consistent with those reported by Sawicka (2000), Kołodziejczyk et al. (2005), and Osowski et al. (2017).

Conclusions

1. Weather conditions in individual study years had the strongest effect on the size of tuber yield.
2. Compared to mineral fertilization (NM), supplementary fertilization with Micro 1 K had a positive effect on the total yield, marketable yield, and the yield of large tubers.
3. The highest increase in the yield of large tubers was found in 2017 and 2016 for fertilization with Micro 1 K. It was 5.7 $t \cdot ha^{-1}$ for marketable yield, more than 6.1 $t \cdot ha^{-1}$ for the total yield of tubers, and more than 7 $t \cdot ha^{-1}$ for the yield of large tubers in 2018 compared to other variants of fertilization.
4. The experiment revealed a significant positive effect of fertilization on the starch content, depending on the tested fertilization variant, study year, and the interaction between years and the tested variants. The highest content of starch in tubers was found for the MB – 1 variant.
5. The degree of tuber darkening was significantly influenced by the distribution of rainfall and temperature across the growing season. The lowest scores for tuber darkening were found in 2018, a year characterised by moderate rainfall and relatively high air temperatures at the end of the growing season.

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