

MINERAL FERTILIZATION VERSUS THE INTENSITY OF PHOTOSYNTHESIS AND TRANSPIRATION OF POTATO PLANTS

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Abstract. Macro- and microelements have an effect on the process of photosynthesis and transpiration. Foliar fertilizers increase the content of elements in leaves and affect the course of gas exchange. This work have presented the results of the study aimed to estimate the effect of soil (NPK 280 and 420 kg·ha⁻¹) and foliar (Basfoliar® 12-4-6, ADOB® Mn, Solubor® DF) fertilizer application on the intensity of gas exchange in potato plants of semi-early to late cultivars. In the research hypothesis it was assumed that macro- and microelements contained in foliar fertilizers will affect the intensity of process of photosynthesis and transpiration in the field conditions, which in consequence may affect the yield and quality of potato tubers. Measurements of photosynthesis and transpiration were made using the portable gas analyser LI-COR 6400 (DMP AG SA LTD). Readings for gas exchange parameters were performed at several days' intervals. The obtained high photosynthesis rate, reaching even up to 35.59 μmol CO₂·m⁻²·s⁻¹ in 2010, indicated a good general state of plants. The late cultivar Ślęza has shown the highest photosynthesis rate – 18.45 μmol CO₂·m⁻²·s⁻¹. No effect of differentiated rates of soil fertilizers on photosynthesis intensity was observed. In the experiment, potato cultivars and the applied rate of soil NPK fertilization of 280 kg·ha⁻¹ significantly differentiated transpiration intensity. For the semi-late cultivar, the lower rate of soil fertilization resulted in a higher intensity of the process of transpiration. Transpiration proceeded more dynamically after a period of heavy rainfalls. No effect of microelements contained in foliar fertilizers on processes of gas exchange has been indicated.

Key words: foliar fertilizer application, gas exchange, potato cultivars, soil fertilizer application

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INTRODUCTION

Plants retain in their tissues a small percentage of water they take up, and the other part they transpire to the atmosphere. Transpiration is expressed in relations to the leaf area unit and the time unit. Therefore the measurements are characterized by a high variation in time. From the botanical point of view, the intensity of transpiration and photosynthesis depend on leaf morphology and anatomy as well as changing weather conditions, exposure, humidity conditions and the cultivar [Demming and Björkman 1987, Kolbe and Beckmann 1997, Michałek and Sawicka 2005, Goffart *et al.* 2008, Olszewska 2009]. The growth of leaf blade limits stomatal conductance, thus reducing transpiration and photosynthesis [Hsiao 1973]. Stomatal conductance depends on many factors, such as temperature, humidity and intensity of radiation [Vos and Groenwold 1989]. The literature widely describes response on drought stress, soil salinity through the effect on gas exchange, whereas there are few reports in the available scientific literature about the relationship between rates of soil and foliar application, and the intensity of photosynthesis and transpiration in potato plant. According to Kolbe and Beckmann [1997], the concentrations of nitrogen, potassium and phosphorus in leaves is decreasing as they are getting older, whereas increases the concentration of magnesium and manganese. The maximal content of inorganic compounds in leaves was estimated at 40-60 days after emergences. According to many authors, nitrogen, potassium, magnesium, manganese and boron have an effect on processes of photosynthesis and transpiration [Grzyś 2004, Kalaji *et al.* 2004, Penston 2006, Verbruggen and Hermans 2013].

The aim of this study was to estimate the effect of foliar application of fertilizers with varied composition, used at two soil fertilization levels on gas exchange in potato plant. In the research hypothesis it was assumed that macro- and microelements contained in foliar fertilizers will affect the intensity of process of photosynthesis and transpiration under field conditions, which consequently may have an effect on the quantitative and qualitative yield of potato tubers. Its verification was conducted during three years of the study.

MATERIAL AND METHODS

The field study was carried out in 2008-2010 at the Production and Experimental Institute "Bałcyny" Sp. z o. o. in Bałcyny (53°35' N; 19°51' E) by the Department of Agrotechnology, Agriculture Management and Agribusiness, University of Warmia and Mazury in Olsztyn. The three-factorial experiment (repeated over 2008-2010) was established with the randomized split-plot method in three replications.

The first order factor was potato cultivars: Adam (semi-early, with a starch content of about 18.5%), Pasja Pomorska (semi-late, with an average starch content of 20%) and Ślęza (late, with a very high content of starch, on average 21.5%). The cultivars Pasja Pomorska and Ślęza are especially preferred by Polish starch industry [Lista Odmian Odmian COBORU 2000, 2003, 2005].

The second order factor comprised two levels of soil fertilization: A – 280 kg·ha⁻¹ (80 N, 80 P, 120 K); B – 420 kg·ha⁻¹ (120 N, 144 P, 156 K). Soil fertilizers in the form of potash salt (60%), granulated triple superphosphate (46%) and ammonium nitrate (34%) were applied in a single rate prior to potato planting.

The third order factor was foliar fertilization: Basfoliar 2-4-6 (8 dm³·ha⁻¹), ADOB Mn (4 dm³·ha⁻¹), Solubor DF (2 dm³·ha⁻¹) and the control treatment – without foliar fertilization. Application of foliar fertilizers was performed once at the beginning of flowering (BBCH 61 scale). Composition of foliar fertilizers (weigh %): ADOB[®] Mn: Mn – 10.0, N – 6.5, Mg – 2.0; Solubor[®] DF: B – 17.5; Basfoliar[®] 12-4-6: N – 12.0, P₂O₅ – 4.0, K₂O – 6.0, MgO – 0.2, Mn – 0.01, Cu – 0.01, Fe – 0.01, B – 0.02, Zn – 0.005, Mo – 0.005 [ADOB 2014].

Each year, the experiment was established on Haplic Luvisol originating from boulder clay [IUSS Working Group WRB 2006]. Composite soil samples from each plot to a depth of 20 cm to determine the chemical properties of soil. On the experimental sites, soil pH ranged from 6.2 to 6.4 and soil nutrient levels ranged from 82 to 144 mg·kg⁻¹ P, 153 to 184 mg·kg⁻¹ K, 170 to 210 mg·kg⁻¹ Mn, 0.44 to 1.18 mg·kg⁻¹ B (Table 1). The District Chemical and Agricultural Station in Olsztyn was commissioned to make the soil analyses. Potato tubers were planted between 20th and 30th April. Potato was grown every year in the field after cereals, without organic fertilization. Tuber harvest were performed at the stage of potato full maturity, from the 20th to 30th September. Cultivation practices included two-time hilling and repeated spraying with pesticides. The herbicide Afalon Dispersive 450 SC in a dose of 2 dm³·ha⁻¹ was used to control dicotyledonous weeds, against potato blight – the fungicide with systemic action Ridomil Gold MZ 68 WG 2 kg·ha⁻¹ and Tattoo C 750 SC 2 dm³·ha⁻¹, at a later time, the preparation with Surface activity Antracol 70 WG 1.8 kg·ha⁻¹, Gwarant 500 SC 2 dm³·ha⁻¹. Neonikotynoid – Apacz 50 WG 40 g·ha⁻¹, Calypso 480 SC 0.08 dm³·ha⁻¹ and Mospilan 20 SP 80 g·ha⁻¹ were applied against Colorado potato beetle.

Table 1. Selected chemical properties of topsoil (0-20 cm) before the establishment of the experiment in successive years of the study

Tabela 1. Wybrane właściwości chemiczne warstwy uprawnej gleby (0-20 cm) przed założeniem doświadczenia w kolejnych latach badań

Year of study Rok badań	pH in 1 mol dm ³ KCl pH w KCl 1 mol dm ³	Available nutrients mg·kg ⁻¹ soil Formy przyswajalne, mg·kg ⁻¹ gleby		Available nutrients. mg·kg ⁻¹ soil Formy przyswajalne, mg·kg ⁻¹ gleby	
		P	K	Mn	B
2008	6.16	122	170	170	1.18
2009	6.27	82	153	193	0.86
2010	6.42	144	184	210	0.44

Measurements of photosynthesis and transpiration were made using the portable gas analyser LI-COR 6400 (DMP AG SA LTD). Gas exchange rates were determined at the constant CO₂ concentration amounting to 400 ppm and exposure of 1000 μmol·m⁻²·s⁻¹. The source of photons was the lamp “LED Light Source” emitting light with the main peak spectrum concentrated in the band 670 nm and the second which was smaller – 465 nm. Measurements were made in each plot on randomly selected 10 plants. Readings were performed on the youngest fully developed leave, in 5 replications. Measurements were performed three times: one day prior to fertilizer application, two and seven days after foliar application, and the study results were presented as average values.

The results were subject to statistical analysis using the analysis of variation. Differences between the treatments were assessed using Tukey’s test, assuming the

probability of error $P = 0.05$. Statistical analyses were made using the software STATISTICA 10 PL[®].

The course of meteorological conditions during measurements of gas exchange

Potato plant growth and development are determined on air temperature and precipitation which occur during the growth period. In the present study measurements of gas exchange were conducted three times, hence it was assumed right to discuss the weather conditions only during fifteen days covering measurements in individual years. The analysed days of the year 2008 were characterized by the lowest precipitation during the three years of the study, amounting to 18.1 mm, and the average air temperature 17.0°C. In 2008 the highest rainfall, amounting to 9.4 mm, was recorded during two days prior to the first measurement of gas exchange and 6.2 mm between the second and seventh day of the analysis of gas exchange rates (Fig. 1a). In 2009 there occurred the highest precipitation (63 mm) and the highest average air temperature (18.9°C). Moreover, high precipitation level (60 mm) was recorded between the second and seventh day of measurement of gas exchange, whereas there was no precipitation in 2009 before the first measurement of gas exchange (Fig. 1b). The analysed days of 2010 in turn were characterized by the total precipitation of 42.4 mm and the lowest air temperature 13.6°C (Fig. 1c). In 2010 there were only three days with rainfall during the period in question and 25 mm of rainfall was recorded two days before the first measurement of gas exchange.

RESULTS AND DISCUSSION

Assessment of the intensity of photosynthesis and transpiration of potato plants

The first study determining the content of chlorophyll in potato with the use of the chlorophyll meter SPAD 502 was conducted by Vos and Bom [1993]. The authors examined the effect of nitrogen rates and indicated the necessity of differentiation of cultivars and other nutritional factors. Kalaji *et al.* [2004], Shulka *et al.* [2007] came to similar conclusions, while analysing the effect of nitrogen fertilization on chlorophyll content. Gianquinto *et al.* [2004] report that the differences in chlorophyll content result from larger amounts of chlorophyll in the cultivars which mature earlier.

When comparing the photosynthesis rate in individual years of the study based on the three measurements made, potato plants in 2010 had the most favourable conditions. Photosynthesis rate in 2010 reached the highest value (more than $35.59 \mu\text{mol CO}_2 \text{ m}^{-2} \cdot \text{s}^{-1}$), whereas the lowest value was observed in 2008, on the level not exceeding $4.54 \mu\text{mol CO}_2 \text{ m}^{-2} \cdot \text{s}^{-1}$ (Fig. 2). The study conducted in the years 2008 and 2010 did not prove a significant effect of the cultivar, soil and foliar application of fertilizers on the course of photosynthesis. Whereas in 2009, the effect of the variation effect was indicated. The cultivar Ślęza showed the highest photosynthesis intensity in two days after the foliar application. This rate was higher by 4.47 and $4.58 \mu\text{mol CO}_2 \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ in comparison with the cultivars Pasja Pomorska and Adam (Fig. 4). The other factors and interactions did not have significant effect on this feature. The air temperature and precipitation in the discussed decade were the highest, which could affect the intensity of photosynthesis, all the more because the optimal temperature for potato photosynthesis stays within the range from 16 to 25°C [Hammes and Jager 1990]. According to the study by Germ *et al.*

[2007] in potato plants the photosynthesis intensity was at the similar level $19.85 \pm 8.28 \mu\text{mol CO}_2 \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. Rykaczewska *et al.* [2004] did not prove a difference between potato cultivars in photosynthesis intensity, which was on the level $7.1 \mu\text{mol CO}_2 \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. Lazarević *et al.* [2014] proved a relationship between photosynthesis intensity and the cultivar, which shaped on the level $11.46 \pm 13.06 \mu\text{mol CO}_2 \cdot \text{m}^{-2} \cdot \text{s}^{-1}$.

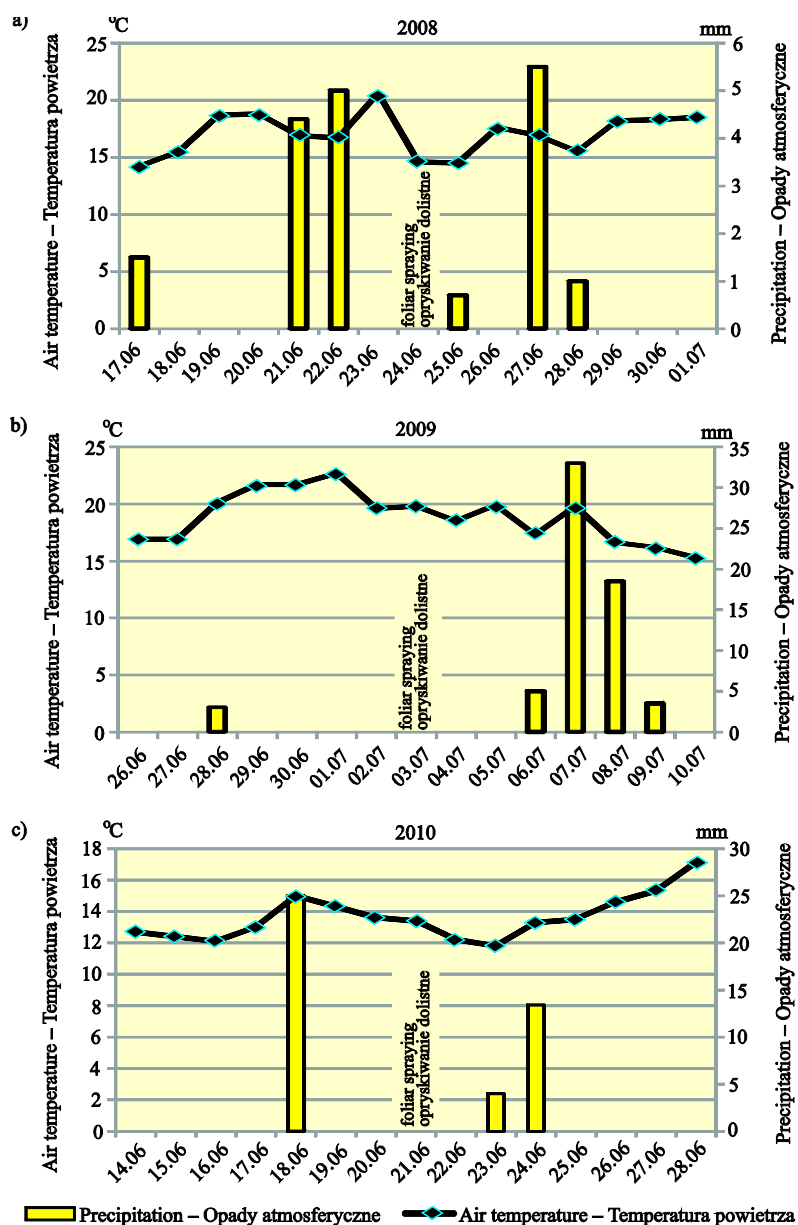


Fig. 1. Precipitation and air temperature during the study
 Rys. 1. Suma opadów atmosferycznych i temperatury powietrza w czasie prowadzenia badań

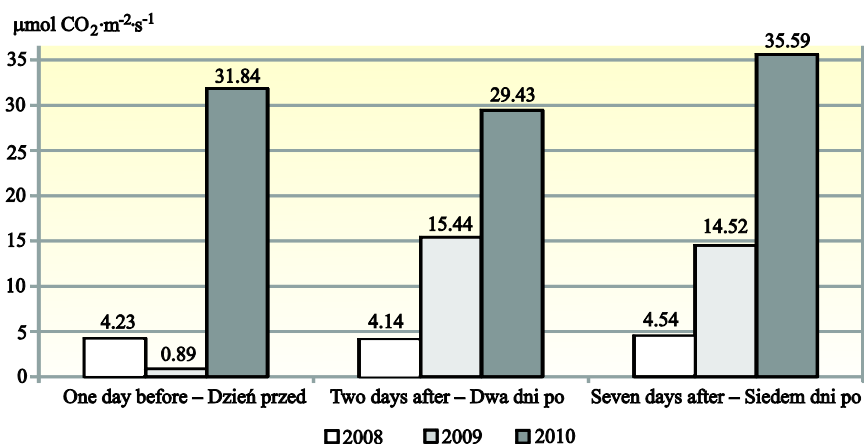


Fig. 2. The course of photosynthesis during the years of research

Rys. 2. Przebieg fotosyntezy w czasie lat badań

The study of transpiration rates was carried out during the three years of the study. Due to the high diversification of the weather conditions, each year of the study was treated separately. In 2010 the lowest transpiration rate amounted to $0.15 \text{ mmol H}_2\text{O} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$, and in 2009 it was $3.33 \text{ mmol H}_2\text{O} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$, in measurements carried out seven days after the foliar fertilizer application (Fig. 3). According to the study by Germ *et al.* [2007] concerning the drought stress in potato plants, the intensity of transpiration was at the similar level, amounting to $6.68 \pm 0.24 \text{ mmol H}_2\text{O} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. Lazarević *et al.* [2014] proved a relationship between the transpiration intensity and the cultivar, which reached the value $4.13 \pm 5.31 \text{ mmol H}_2\text{O} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$.

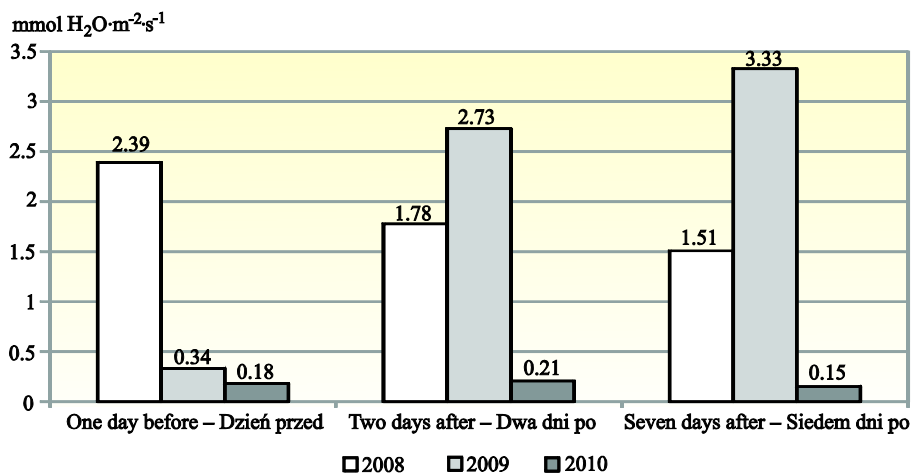
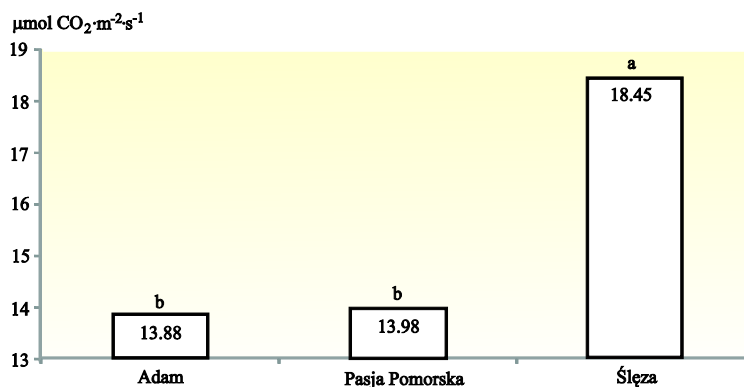


Fig. 3. The course of transpiration during the years of research

Rys. 3. Przebieg transpiracji w czasie lat badań



Source of variation Źródła zmienności	Sum square Suma kwadratów	Degrees of freedom Stopnie swobody	F Rozkład	Probability Prawdopodobieństwo
Cultivars – Odmiany	218.49	2	6.28	0

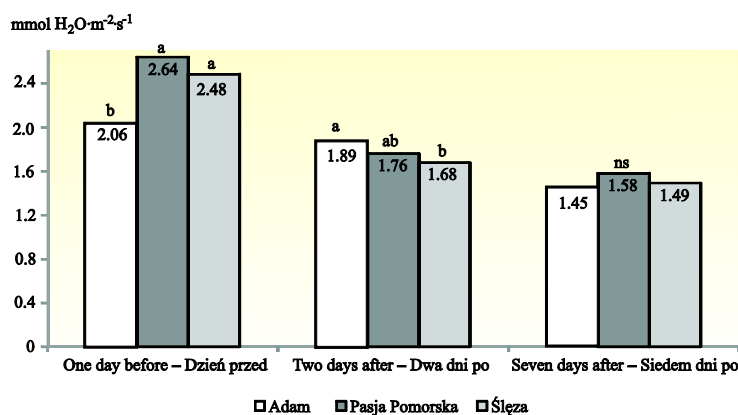
a, b – values marked with the same letter do not differ significantly at $P = 0.05$ – wartości oznaczone tymi samymi literami nie różnią się istotnie przy $P = 0,05$

Fig. 4. The effect of cultivars on photosynthesis rates two days after foliar application of fertilizers in 2009

Rys. 4. Wpływ odmian na przebieg fotosyntezy dwa dni po nalistnym zabiegu nawożenia w 2009 r.

The course of transpiration in all the years of the study was closely connected with the potato cultivar. In 2008 the transpiration level on the first day prior the foliar fertilizer application was dependent on the potato cultivar. The cultivars Pasja Pomorska and Ślęza were characterized by a higher rate of gas exchange as compared with the semi-early cultivar Adam, by 0.58 and 0.43 mmol H₂O·m⁻²·s⁻¹, respectively (Fig. 5). This was the highest transpiration rate measured one day prior to foliar fertilizer application during the three years of this study. Within 48 hours prior to the measurement, precipitation amounted to 9.4 mm. A negative relationship between the intensity of gas exchange and the rate of foliar fertilizer application was proved (Fig. 6). A significant difference was found on the treatment with the cv. Pasja Pomorska fertilized with the lower rate of fertilizers, where the highest transpiration rate was observed.

Next transpiration measurement in the same year of the study performed two days after the foliar application showed a significantly higher level of gas exchange rate in the cv. Adam, exceeding the cv. Ślęza by 0.22 mmol H₂O·m⁻²·s⁻¹ (Fig. 5). Transpiration measurement seven days after the foliar fertilizer application did not show differences between the cultivars or the effect of fertilizer rates and fertilization methods (Fig. 5).



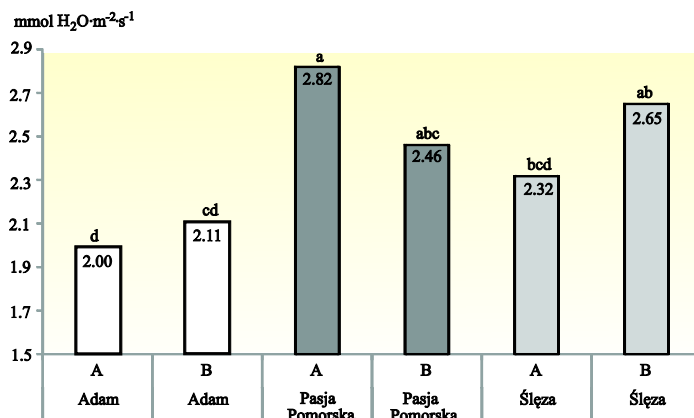
Source of variation – Cultivars Źródła zmienności – Odmiany	One day before foliar application of fertilizers – Dzień przed nalistnym zabiegiem nawożenia	Two days after foliar application of fertilizers – Dwa dni po nalistnym zabiegu nawożenia
SS – Suma kwadratów	2.94	0.38
DF – Stopnie swobody	2	2
F – Rozkład	10.86	3.86
P – Prawdopodobieństwo	0	0.03

a, b – for explanatios, see Fig. 4 – objaśnienia pod rys. 4

ns – non-significant differences – różnice nieistotne

Fig. 5. The effect of variety on transpiration rates before and after foliar application of fertilizers in 2008

Rys. 5. Wpływ odmiany na przebieg transpiracji przed i po nalistnym zabiegu nawożenia w 2008 r.



Source of variation Źródła zmienności	Sum square Suma kwadratów	Degrees of freedom Stopnie swobody	F Rozkład	Probability Prawdopodobieństwo
Cultivars × soil fertilization Odmiany × nawożenie doglebowe	0.99	2	3.69	0.04

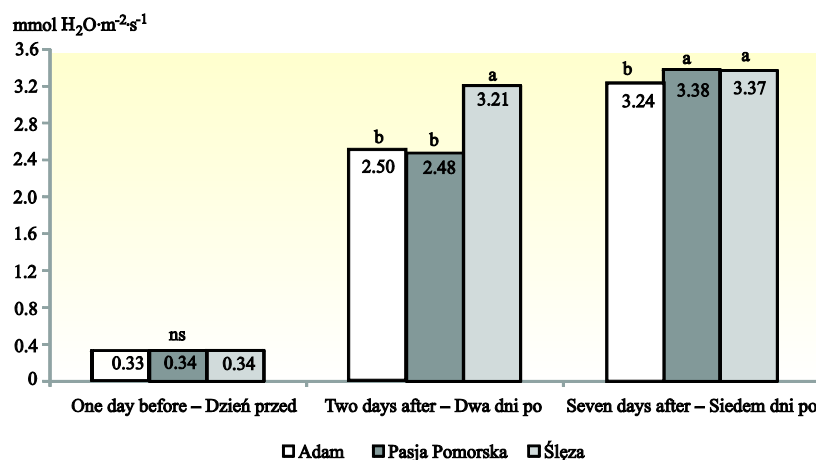
a, b – for explanatios, see Fig. 4 – objaśnienia pod rys. 4

A – NPK 280 kg·ha⁻¹; B – NPK 420 kg·ha⁻¹

Fig. 6. The effect of cultivar and soil fertilization on transpiration rates before foliar application of fertilizers in 2008

Rys. 6. Wpływ odmiany i nawożenia doglebowego na przebieg transpiracji przed nalistnym zabiegiem nawożenia w 2008 r.

In 2009, one day prior to the foliar fertilizer application, the transpiration measurement did not indicate significant differences between cultivars, as well as between rates and fertilization methods (Fig. 7). This was also a period without precipitation, lasting to the second measurement of gas exchange rates. The cv. Ślęza showed the highest transpiration intensity two days after the foliar application. Its transpiration intensity exceeded the cv. Adam by $0.71 \text{ mmol H}_2\text{O}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ and the cv. Pasja Pomorska by $0.73 \text{ mmol H}_2\text{O}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (Fig. 7). Seven days after the foliar application, the cultivars Pasja Pomorska and Ślęza had significantly higher transpiration rate. This was the highest transpiration rate during the three years of this study, measured seven days after the foliar application of fertilizers, at the same time the highest of the three measuring times. Precipitation during four days preceding the measurement amounted to 60 mm. A negative relationship between the gas exchange intensity and the rate of foliar fertilizer applied was proved (Fig. 8). A significant difference in the course of transpiration was found, similar to the year 2008, in the cv. Pasja Pomorska which showed the highest transpiration rate at the lower rate of fertilizers. In the cultivar Pasja Pomorska a higher fertilization rate resulted in a lower transpiration rate. The measurement performed seven days after the foliar application also showed the highest transpiration rate ($3.59 \text{ mmol H}_2\text{O}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) obtained from the control treatment (without foliar fertilizers) at the foliar NPK application $280 \text{ kg}\cdot\text{ha}^{-1}$, and the lowest ($3.16 \text{ mmol H}_2\text{O}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) with the NPK rate $420 \text{ kg}\cdot\text{ha}^{-1}$. The difference was $0.43 \text{ mmol H}_2\text{O}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (Fig. 9).



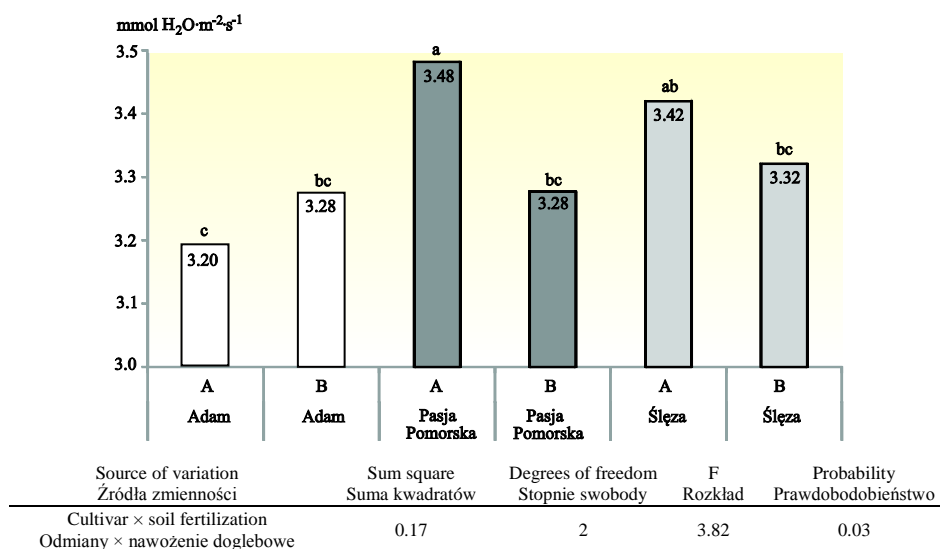
Source of variation – Cultivars Źródła zmienności – Odmiany	Two days after foliar application of fertilizers – Dwa dni po nalistnym zabiegu nawożenia	Seven days after foliar application of fertilizers – Siedem dni po nalistnym zabiegu nawożenia
SS – Suma kwadratów	5.50	0.21
DF – Stopnie swobody	2	2
F – rozkład	4.10	4.76
P – Prawdopodobieństwo	0.03	0.02

a, b – for explanatios, see Fig. 4 – objaśnienia pod rys. 4

ns – ni – non-significant differences – różnice nieistotne

Fig. 7. The effect of cultivar on transpiration rates before and after foliar application of fertilizers in 2009

Rys. 7. Wpływ odmiany na przebieg transpiracji przed i po nalistnym zabiegu nawożenia w 2009 r.

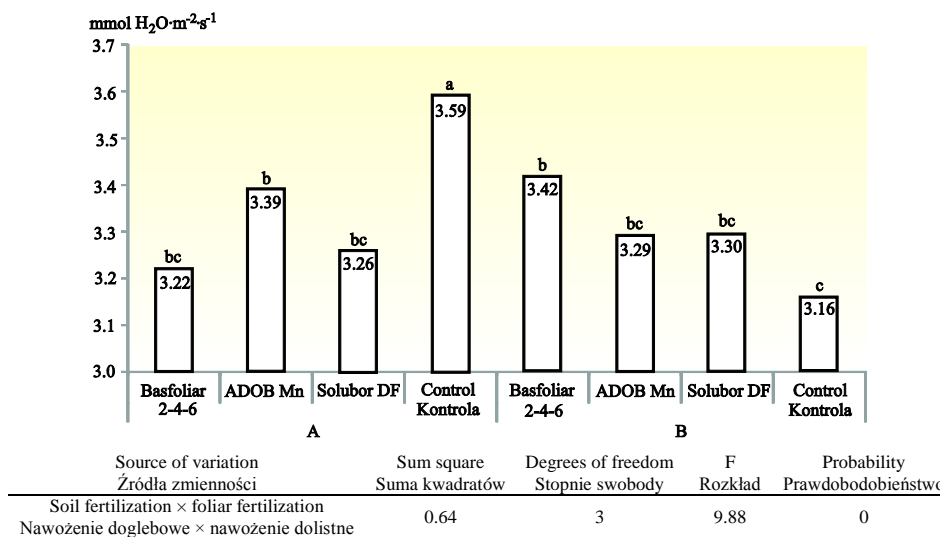


a, b – for explanatios, see Fig. 4 – objaśnienia pod rys. 4

A – NPK 280 kg·ha⁻¹; B – NPK 420 kg·ha⁻¹

Fig. 8. The effect of cultivar and soil fertilization on transpiration rates seven days after foliar application of fertilizers in 2009

Rys. 8. Wpływ odmiany i nawożenia doglebowego na przebieg transpiracji siedem dni po nalistnym zabiegu nawożenia w 2009 r.



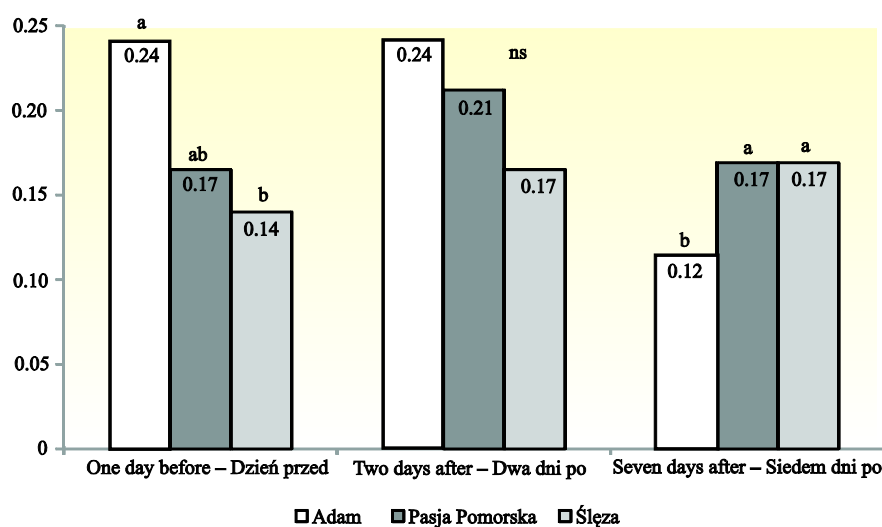
a, b – for explanatios, see Fig. 4 – objaśnienia pod rys. 4

A – NPK 280 kg·ha⁻¹; B – NPK 420 kg·ha⁻¹

Fig. 9. The effect of soil and foliar fertilization on transpiration rates seven days after foliar application of fertilizers in 2009

Rys. 9. Wpływ nawożenia doglebowego i dolistnego na przebieg transpiracji siedem dni po nalistnym zabiegu nawożenia w 2009 r.

In the last year of the study (2010) differences between cultivars in the process of transpiration were indicated one day prior to the foliar application. The cultivar Adam was characterized by the highest transpiration rate ($0.24 \text{ mmol H}_2\text{O}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$), and cv. Ślęza by a significantly lower. Two days prior the first measurement, 25 mm of rain fell. Nonetheless, the rate of transpiration did not exceed $0.24 \text{ mmol H}_2\text{O}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. At the second time of measurement, the differences were non-significant, and seven days after the foliar application, the lowest rate was recorded in the cultivar Adam (Fig. 10). The effect of the other experimental factors and their interaction with the transpiration rates proved to be significant. Rykaczewska *et al.* [2004] also indicated varied transpiration intensity, and the differences between the cultivars amounted to even $2.0 \text{ mmol H}_2\text{O}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$.



Source of variation – Cultivar Źródła zmienności – Odmiany	One day before foliar application of fertilizers – Dzień przed nalistnym zabiegiem nawożenia	Seven days after foliar application of fertilizers – Siedem dni po nalistnym zabiegu nawożenia
SS – Suma kwadratów	0.09	0.03
DF – Stopnie swobody	2	2
F – Rozkład	3.90	7.75
P – Prawdopodobieństwo	0.03	0

a, b – for explanations, see Fig. 4 – objaśnienia pod rys. 4

ns – ni – non-significant differences – różnice nieistotne

Fig. 10. The effect of cultivar on transpiration rates before and after foliar application of fertilizers in 2010

Rys. 10. Wpływ odmiany na przebieg transpiracji przed i po nalistnym zabiegu nawożenia w 2010 r.

The measurements carried out in field conditions broaden our knowledge in plant physiology concerning the rates of gas exchange at the application of soil and foliar fertilizers.

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CONCLUSIONS

1. The high rate of photosynthesis showed a good general condition of the plants. The highest photosynthesis rate was observed in the late cultivar Ślęza, two days after the foliar application of fertilizer. No effect of macroelements contained in soil fertilizers on the course of photosynthesis has been proved.

2. Heavy precipitation preceding the measurement of transpiration rate may have contributed to achieving the highest transpiration rate of potato plants in 2009.

3. Transpiration intensity was dependent on the potato cultivar. The cultivar Pasja Pomorska cultivated on the lower rate of the foliar fertilizer responded with a higher transpiration rate.

4. No effect of the foliar fertilizers Basfoliar® 12-4-6, ADOB® Mn, Solubor® DF containing magnesium, manganese and boron, on the process of photosynthesis and transpiration has been shown.

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NAWOŻENIE MINERALNE A INTENSYWNOŚĆ FOTOSYNTETY I TRANSPIRACJI ROŚLIN ZIEMNIAKA

Streszczenie. Makro- i mikropierwiastki wpływają na proces fotosyntezy i transpiracji. Nawozy dolistne zwiększają zawartość pierwiastków w liściach i mają wpływ na przebieg wymiany gazowej. W pracy przedstawiono wyniki badań, których celem było określenie wpływu nawożenia doglebowego NPK 280 i 420 kg·ha⁻¹ oraz dolistnego (Basfoliar® 12-4-6, ADOB® Mn, Solubor® DF) na intensywność wymiany gazowej w roślinach ziemniaka, odmian średnio wczesnych do późnych. W hipotezie badawczej przyjęto, że makro- i mikropierwiastki zawarte w nawozach dolistnych wpłyną na intensywność procesu fotosyntezy i transpiracji w warunkach polowych, co w konsekwencji może oddziaływać na wydajność i jakość bulw ziemniaka. Pomiary fotosyntezy i transpiracji wykonano za pomocą przenośnego analizatora gazowego LI-COR 6400 (DMP AG SA LTD). Odczyty dla parametrów wymiany gazowej dokonywano w odstępach kilkudniowych. Uzyskany wysoki wskaźnik fotosyntezy, dochodzący nawet do 35.59 μmol CO₂·m⁻²·s⁻¹ w 2010 roku, świadczył o dobrej ogólnej kondycji roślin. Największym wskaźnikiem fotosyntezy wykazała się odmiana późna Ślęza – 18.45 μmol CO₂·m⁻²·s⁻¹. Nie zaobserwowano wpływu zróżnicowanych dawek nawozów doglebowych na intensywność fotosyntezy. W przeprowadzonym doświadczeniu odmiany ziemniaka oraz zastosowana dawka nawozów doglebowych NPK 280 kg·ha⁻¹ istotnie różnicowały intensywność transpiracji. Dla średnio późnej odmiany mniejsza dawka nawożenia doglebowego bardziej zintensyfikowała proces transpiracji. Transpiracja przebiegała bardziej dynamicznie po okresie obfitych opadów atmosferycznych. Nie wykazano wpływu mikropierwiastków zawartych w nawozach dolistnych na procesy wymiany gazowej.

Słowa kluczowe: nawożenie doglebowe, nawożenie dolistne, odmiany ziemniaka, wymiana gazowa

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