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INVESTIGATIONS OF PHOTOSYNTHETIC ACTIVITY PARAMETERS IN RELATION TO BERRIES YIELD OF SELECTED GRAPEVINE CULTIVARS

BADANIA PARAMETRÓW AKTYWNOŚCI FOTOSYNTETYCZNEJ WYBRANYCH ODMIAN WINOROŚLI W ODNIESIENIU DO ICH PLONOWANIA

Summary. Nine grapevine cultivars varying in fruit yield were tested for photosynthetic activity, chlorophyll content and leaf area during the 2010 growing season. Relationships between these parameters and berry yield were examined. Investigations revealed differences between the photosynthetic activity and other parameters of the selected grapevine cultivars. A high net photosynthetic rate was usually associated with high efficiency of CO_2 during photosynthesis, due to high stomatal conductance. However, a high net photosynthetic rate was not always related to high leaf area and berry yield. Specific leaf area did not vary between cultivars. Fruit production in some cultivars was positively related to photosynthetic activity, while in other cases plants focused on fruit development, hence low values of photosynthesis and/or low leaf area were recorded.

Key words: grapevine cultivars, net photosynthetic rate, stomatal conductance, internal CO_2 concentration, chlorophyll, leaf area

Introduction

Worldwide, grapes have become one of the most productive and important specialty crops. Grapevine fruits are widely used in juice and wine production in Europe. The wide range of grape cultivars makes it possible to select the ones which can survive in certain climatic conditions. We can also adjust cultivation activity to plant requirements. However, grapevine cultivars were found to reveal higher or lower grape yield independently of cultivation conditions, such as soil adjustments, watering and fertilization.

Formation of grape berries by plants may or may not be associated with plant photosynthetic activity, and consequently with various environmental stress factors. BEN--ASHERA et AL. (2006) found that yields of berries were not associated with higher soil salinity, but they observed a decline of the leaf area and the photosynthetic rate together with increasing salinity. The correlation between grapevine photosynthesis and fruit yield and quality is still not fully understood. DOWNTON et AL. (1987) observed that watering grapevine plants did not change the process of photosynthesis, while other authors reported that irrigation substantially increased photosynthesis and grape yields (SCHULTZ 1996, WILLIAMS 1996, ESCALONA et AL. 2003). MEDRANO et AL. (2003) suggested a close link between water availability and grape yield, mostly through water stress effects on photosynthesis. They also found that fruit quality was correlated with water availability, but not with photosynthetic activity. Another factor influencing fruit quality is heat. Air temperatures have increased in some world areas, posing a danger for crop production. Extreme temperatures may endanger berry quality and economic returns (SCHULTZ 2007). WANG et AL. (2010) observed a decline in photosynthetic rate of grapevine due to temperature increase as well as full recovery of the photosynthetic process after the withdrawal of stressful heat conditions. Similarly, KADIR et AL. (2007) observed, that some grape cultivars photosystem II is more thermostable than others on the basis of chlorophyll fluorescence investigations. Moreover, KADIR (2006) also found that grapevines with higher photosynthetic are more high temperature tolerant, and could be furthermore used in warmer regions.

The photosynthetic process is connected with many of the above-mentioned factors. If we decrease the negative effect of these factors or maintain similar conditions for all plants, the activity of this process will be associated mainly with individual cultivar features, such as chlorophyll content, leaf thickness connected with spongy mesophyll layer, etc. As mentioned above, the yield of berries may be associated with plant photosynthetic activity. Is it always a positive relationship? What about changes during different phases of plant development? The present study had the following objectives: (i) to determine changes of the photosynthetic activity and other parameters of nine grapevine cultivars at two investigation dates, (ii) to relate these parameters to leaf size and chlorophyll concentration, (iii) to examine whether the photosynthetic process is related to berry yields.

Materials and methods

Plant material

Plants are cultivated in field conditions. A collection of 158 grapevine cultivars has been maintained at the Agricultural Experimental Farm Baranowo of Poznań University of Life Sciences since 1982, and the above collection is registered at the Plant Breeding and Acclimatization Institute – National Research Institute. The main aim of this production is to maintain old grapevine cultivars as a gene bank, as well as to promote these cultivars among vineyard owners. Most of the cultivated cultivars can be used for juice and wine production.

The following nine grapevine cultivars varying in berry yields were chosen to perform photosynthetic activity tests: green-berried grapevine cultivars – 'Michigan', 'Refren' (RF 16), and 'Vertes Csillaga'; and blue-black-berried cultivars – 'Baco Noir', 'Buffalo', 'Fredonia', 'Leon Millot', 'Maréchal Foch', and 'Rosette'. 15-year old plants were selected for the presented investigations which were conducted in Guyot system. In summer season premature lateral shoots were cut. The vineyard was not watered to obtain natural conditions of cultivation (total precipitation during the 2010 growing season was 422 mm). The soil in vineyard type was determined according soil outcrop as *luvisols*. Fertilization of the grapevine plantation was conducted according to the recommendations of HOFFMANN and KORSZUN (1990 a, 1990 b, 1992).

Analyses of photosynthetic activity and other parameters

The investigations were carried out during the growing season of 2010. Photosynthetic activity and other parameters were measured twice, during flowering (BBCH 65) and fruit formation (BBCH 73). The handheld photosynthetic system Ci 340aa (CID Bioscience Inc., Camas, USA) was used to evaluate net photosynthetic rate (A), stomatal conductance (gs) and internal CO_2 concentration (Ci). For these purposes, constant conditions of measurements in the leaf chamber were maintained – CO_2 inflow concentration at 340 $\mu mol \cdot mol^{-1}$ of air level, light 1000 $\mu mol \cdot m^{-2} \cdot s^{-1}$, chamber temperature 32°C. Investigations were performed for fully expanded leaves (5^{th} base leaf in the berries zone) which did not reveal any visual symptoms of mechanical damage or senescence. Measurements were taken during daytime hours – 10 a.m. – 2 p.m.

Chlorophyll $a + b$ content was measured using the dimethyl sulfoxide extraction method (SHOAF and LIUM 1976, HISCOX and ISRAELSTAM 1978). Leaf areas were measured using a Ci-202 leaf areameter (CID Bioscience Inc., Camas, USA). Specific leaf area (SLA) was also evaluated (GARNIER et AL. 2001).

Statistical analysis

The data were analysed with the aid of the statistical software STATISTICA 9.1. The results were analysed with a factorial ANOVA with cultivar and investigation date fixed factors. Tukey's test was employed to analyse the detailed differences between measured parameters. The graphical presentation of Tukey's test results was used in the presented study.

Results and discussion

Two-way ANOVA revealed that levels of the net photosynthetic rate, stomatal conductance and internal CO_2 were different for cultivars and dates of investigation (Table 1).

Increase of net photosynthetic rates between the first and the second dates of investigations was observed in all cultivars. The lowest level ($\alpha = 0.05$) of this parameter on the first date was recorded in leaves of 'Fredonia', while the highest was observed in 'Buffalo', 'Leon Millot' and 'Michigan'. On the second date of measurements, when berries started to form, we observed the highest values in 'Fredonia', 'Maréchal Foch' and 'Refren' (RF 16). The level of the net photosynthetic rate was comparable in leaves of 'Buffalo', 'Michigan', 'Rosette' and 'Vertes Csillaga'. 'Baco Noir' and 'Leon Millot' revealed statistically significantly lower levels than the above-mentioned groups (Fig. 1).

Table 1. Test statistics and significance levels of two-way ANOVA with cultivar and date of investigation fixed factors (*p = 0.001, **p = 0.01, ns – not significant)
Tabela 1. Statystyki testowe i poziomy istotności dwuczynnikowej analizy wariancji z odmianą i terminem badań jako czynnikami oddziałującymi na badane cechy (*p = 0,001, **p = 0,01, ns – nieistotne)

Parameter Parametr	Cultivar Odmiana	Date of investigation Termin badania	Interaction Interakcja
Net photosynthetic rate Aktywność fotosyntezy netto	177.45*	1 410.95*	95.55*
Stomatal conductance Przewodność aparatów szparkowych	226.19*	1 258.25*	271.76*
Internal CO_2 concentration Wewnętrzne stężenie CO_2	23.34*	61.00*	26.90*
Chlorophyll *a* + *b* Chlorofil *a* + *b*	45.93*	33.07*	27.80*
Leaf area Powierzchnia liści	11.78*	1.70^{ns}	0.12^{ns}
Specific leaf area (SLA) Specyficzna powierzchnia liści	3.50**	14.70*	3.58**

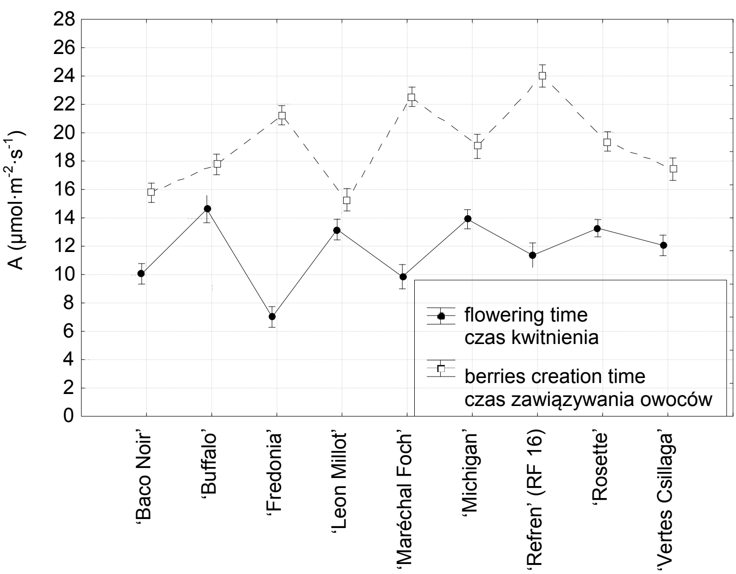

Fig. 1. Net photosynthetic rate of nine grapevine cultivars at two dates of measurements
Rys. 1. Aktywność fotosyntezy netto dziewięciu odmian winorośli w dwóch terminach pomiarów

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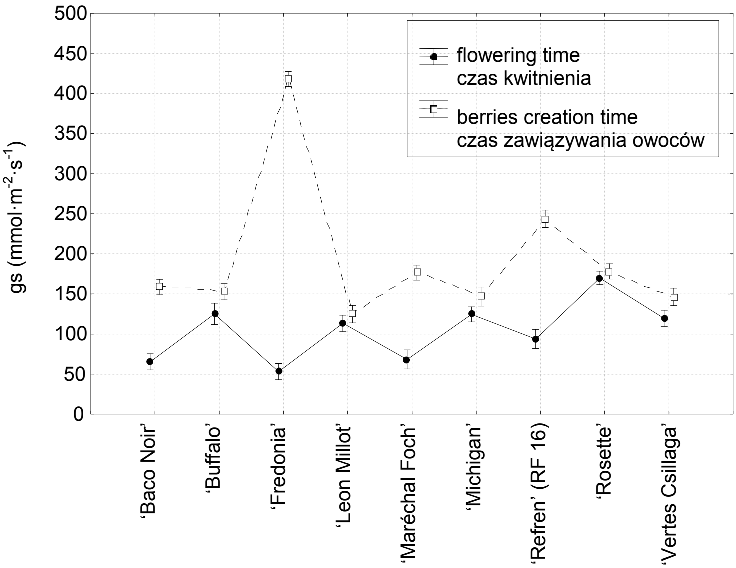

Fig. 2. Stomatal conductance of nine grapevine cultivars at two dates of measurements
Rys. 2. Przewodność aparatów szparkowych dziewięciu odmian winorośli w dwóch terminach pomiarów

Stomatal conductance revealed similar patterns as net photosynthetic rates on the first date of investigations. Although 'Rosette' cultivar exhibited a higher level than other cultivars, it was not associated with such a high level of net photosynthetic rate (Fig. 2). On the second date, we observed an extreme level of stomatal conductance in 'Fredonia' cultivar leaves which was not related to such an extreme increase in net photosynthesis (Fig. 1). It can be explained by not very high effectiveness of the CO_2 assimilation process due to a high internal CO_2 level (Fig. 3). A high stomatal conductance level was connected with a high photosynthetic rate in 'Refren' (RF 16) cultivar. Although 'Maréchal Foch' cultivar did not reveal the highest stomatal conductance level, quite a high level of net photosynthesis was noted. This was associated with high efficacy of the CO_2 assimilation process, which was confirmed by a low internal CO_2 level. A similar tendency was observed in the case of 'Buffalo', 'Michigan', 'Rosette' and 'Vertes Csillaga' cultivars (Figs. 1, 2, 3). Although on the second date 'Baco Noir' revealed a similar level of stomatal conductance as 'Buffalo' cultivar, the expected increase of net photosynthetic rate did not occur. This was probably due to inadequate CO_2 efficiency of the photosynthetic process, as indicated by the internal CO_2 level (Fig. 3). 'Leon Millot' was one of the cultivars which did not reveal a strong increase of the photosynthetic process between the two dates of investigations. This was due to similar levels of stomatal conductance and CO_2 assimilation (Figs. 2 and 3).

High effectiveness of the photosynthetic process should result in higher leaf area/biomass production. This is especially true for 'Refren' (RF 16) cultivar. Although 'Buffalo' and 'Leon Millot' cultivars did not reveal very high photosynthetic activities, a comparatively high leaf area was observed (Fig. 4). This kind of relationship – high

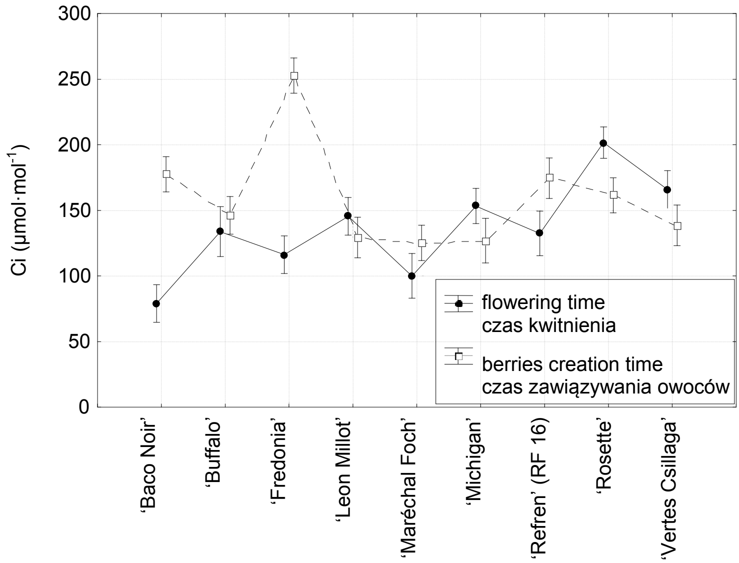

Fig. 3. Internal CO_2 concentration of nine grapevine cultivars at two dates of measurements

Rys. 3. Wewnętrzne stężenie CO_2 dziewięciu odmian winorośli w dwóch terminach pomiarów

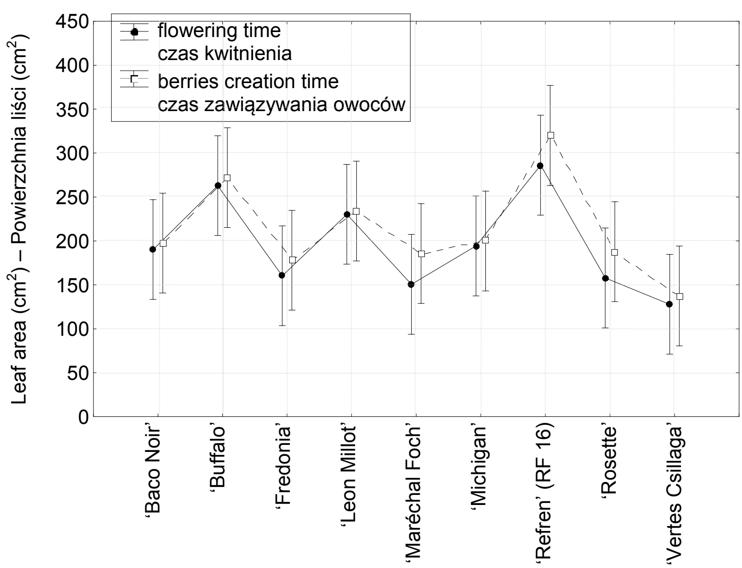

Fig. 4. Leaf area of nine grapevine cultivars at two dates of measurements

Rys. 4. Powierzchnie liści dziewięciu odmian winorośli w dwóch terminach pomiarów photosynthetic rate and large leaves – was previously observed in some genotypes of wheat (CRAVER and NEVO 1990, MORGAN and LECAIN 1991). However, some investigators have reported an inverse relationship between leaf size and photosynthetic rate (SIROHI and GHILDIYAL 1975, RAWSON et AL. 1983, LECAIN et AL. 1989). It was suggested that a smaller leaf area could be compensated by enhanced activity per unit of leaf area (RAWSON et AL. 1983). This kind of relation was recorded in the case of 'Maréchal Foch' and 'Rosette' cultivars (Figs. 1 and 4). Variability in the specific leaf area (SLA) parameter was not so clear. We can only observe some tendencies due to the lack of statistically significant differences between certain cultivars. The lowest level of SLA was recorded in 'Rosette' and 'Maréchal Foch' cultivars (Fig. 5).

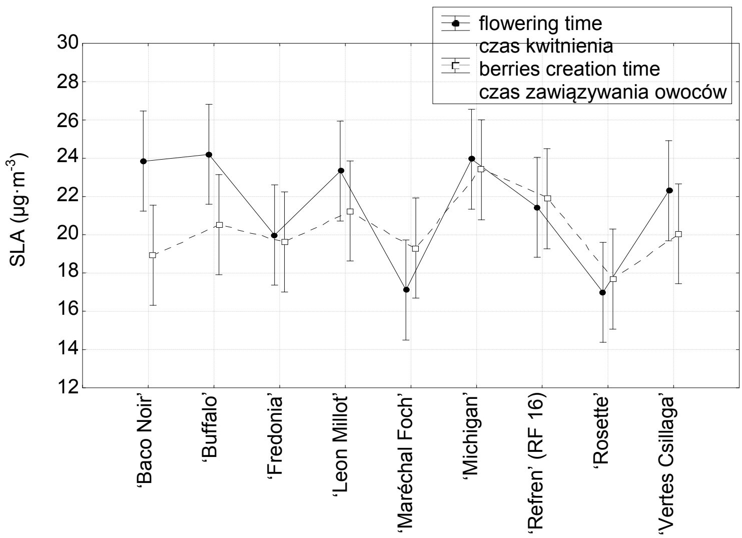

Fig. 5. Specific leaf area (SLA) of nine grapevine cultivars at two dates of measurements
Rys. 5. Specyficzna powierzchnia liści (SLA) dziewięciu odmian winorośli w dwóch terminach pomiarów

Photosynthetic activity should be related to chlorophyll content. An increase of chlorophyll content between the two investigation dates was noticeable in leaves of 'Buffalo', 'Fredonia', 'Maréchal Foch' and 'Rosette' cultivars. The remaining cultivars revealed a decrease or maintenance at a similar level of all chlorophyll forms. The recorded high chlorophyll content on the second date of investigations was related to a comparatively high level of net photosynthetic rate in leaves of 'Maréchal Foch', while a very high level of photosynthetic activity of 'Refren' (RF 16) cultivar was not associated with a very high level of chlorophyll. This might suggest very high efficiency of the photosynthetic process due to high stomatal conductance and high CO_2 effectiveness. By contrast, the high leaf chlorophyll level recorded for 'Rosette' cultivar did not correlate with a similar level of photosynthesis. The remaining cultivars mostly exhibited a positive relationship between the chlorophyll content and photosynthetic activity (Figs. 1 and 6).

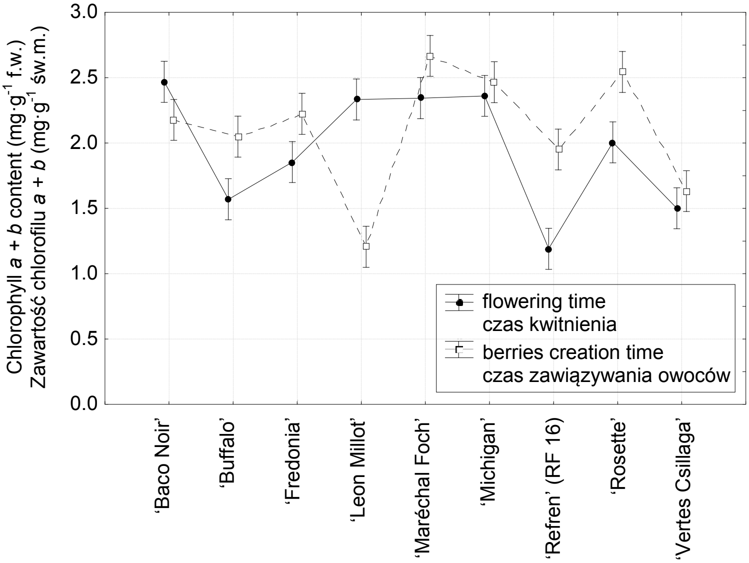

Fig. 6. Chlorophyll *a* + *b* content in leaves of nine grapevine cultivars at two dates of measurements
Rys. 6. Zawartość chlorofilu *a* + *b* w liściach dziewięciu odmian winorośli w dwóch terminach pomiarów

The recorded high photosynthetic activity was not always correlated with the highest berry yields. This was especially true for 'Refren' (RF 16) cultivar, where the highest photosynthetic activity was recorded and one of the lowest fruit development levels. A similar tendency could be observed for 'Fredonia' cultivar (Table 2, Fig. 1). A high grain yield has been observed together with high biomass production in some crop species, e.g. maize (GHILDIYAL and SINHA 1977). By contrast, GHILDIYAL (1992) and SHARMA-NATU et AL. (2004) observed an increase of biomass production without any effect on mung bean yield. 'Rosette' and 'Maréchal Foch' cultivars showed moderate fruit production, similarly to their photosynthetic activity level. 'Buffalo' and 'Michigan' cultivars were characterised by the highest yield of berries, while their photosynthetic activity was not so high. SHARMA-NATU and GHILDIYAL (2005) suggested that increased yield production could be attributed to reduced investment in leaves and other vegetative structures. It seems that plants focused on fruit production. Some earlier investigations revealed that plants change priorities during their lifetime, e.g. cereals send assimilates to roots, and plants from the Fabaceae family distribute them to flowers and fruits (LARCHER 2003). The lower rate of photosynthesis during the flowering and berry development phase could have been connected with faster leaf senescence due to nitrogen transport required for fruit and grain formation (GHILDIYAL and SINHA 1971, SINHA and GHILDIYAL 1971, RAO and GHILDIYAL 1985, GHILDIYAL and SIROHI 1986, SINGH 1990, PANDEY et AL. 2001).

Table 2. Mean values of berries yield of selected cultivars
Tabela 2. Średnie wartości plonowania winogron poszczególnych odmian

Cultivar Odmiana	Mean yield from plant – Średni plon z rośliny (kg)
'Baco Noir'	0.62
'Buffalo'	1.16
'Fredonia'	0.22
'Leon Millot'	0.85
'Maréchal Foch'	0.84
'Michigan'	1.05
'Refren' (RF 16)	0.57
'Rosette'	0.88
'Vertes Csillaga'	0.81

Conclusions

The investigations revealed differences between the photosynthetic activity and other parameters between the examined grapevine cultivars. High net photosynthetic rates were usually associated with high efficiency of CO_2 during the process of photosynthesis due to high stomatal conductance. However, high net photosynthetic rates were not always correlated with high leaf area. Specific leaf area did not vary between cultivars. Fruit formation was in some cultivars positively related to photosynthetic activity, while in some cases cultivars were focused on the berry creation process, hence low values of photosynthesis and/or low leaf area were recorded.

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References

Ben-Ashera J., Tsuyukib I., Bravdoc B.-A., Sagihaa M., 2006. Irrigation of grapevines in saline water: I. Leaf area index, stomatal conductance, transpiration and photosynthesis. Agric. Water Manage. 83: 13-21.

Craver B.F., Nevo E., 1990. Genetic diversity of photosynthetic characters in native populations of *Triticum dicoccoides*. Photosynth. Res. 25: 119-128.

Downton W.J.S., Grant W.J.R., Loveys B.R., 1987. Diurnal changes in the photosynthesis of field grown grape vines. New Phytol. 105: 71-80.

Escalona J.M., Flexas J., Medrano H., 2003. From leaf photosynthesis to grape yield: influence of soil water availability. Vitis 42, 2: 57-64.

Garnier E., Shipley B., Roumet C., Laurent G., 2001. A standardized protocol for the determination of specific leaf area and leaf dry matter content. Funct. Ecol. 15: 688-695.

GHILDIYAL M.C., 1992. Effect of urea on photosynthesis and yield in mung bean. J. Agron. Crop Sci. 168: 91-94.
GHILDIYAL M.C., SINHA S.K., 1971. Variability in photosynthesis and nitrogen fixation in mung bean and cowpea cultivars. In: Physiological studies on pulses. Ed. G.S. Sirohi. IARI, New Delhi: 38-42.
GHILDIYAL M.C., SINHA S.K., 1977. Physiological analysis of heterosis in *Zea mays* L. I. Changes in sugars and starch contents in relation to grain development. Indian J. Exp. Biol. 5: 899-904.
GHILDIYAL M.C., SIROHI G.S., 1986. Photosynthesis in wheat as influenced by leaf position, time of the day and presence of the sink. Wheat Inf. Serv. 65: 38-42.
HISCOX J.D., ISRAELSTAM G.F., 1978. A method for the extraction of chlorophyll from leaf tissue without maceration. Can. J. Bot. 5: 1332-1334.
HOFFMANN M., KORSZUN S., 1990 a. Dynamika pobierania makroskładników przez winorośl odm. Skarb Pannonii rozmnażanej z sadzonek zielnych w pierwszym roku uprawy. Rocz. AR Pozn. 217, Ogrodn. 18: 19-31.
HOFFMANN M., KORSZUN S., 1990 b. Wymagania pokarmowe winorośli odm. Skarb Pannonii w pierwszym roku uprawy. Pr. Kom. Nauk Roln. Kom. Nauk Leśn. PTPN 69: 43-52.
HOFFMANN M., KORSZUN S., 1992. Uprawa kilku odmian winorośli w nieogrzewanym tunelu foliowym. Rocz. AR Pozn. 238, Ogrodn. 20: 29-38.
KADIR S., 2006. Thermostability of photosynthesis of *Vitis aestivalis* and *V. vinifera*. J. Am. Soc. Hortic. Sci. 131: 476-483.
KADIR S., VON WEIHE M., AL-KHATIB K. 2007. Photochemical efficiency and recovery of photosystem II in grapes after exposure to sudden and gradual heat stress. J. Am. Soc. Hortic. Sci. 132: 764-769.
LARCHER W., 2003. Physiological plant ecology. Springer, Berlin.
LECAIN D.R., MORGAN J.A., ZERBI G., 1989. Leaf anatomy and gas exchange in nearly isogenic semi dwarf and tall winter wheat. Crop Sci. 29: 1246-1251.
MEDRANO H., ESCALONA J.M., CIFRE J., BOTA J., FLEXAS J., 2003. A ten-year study on the physiology of two Spanish grapevine cultivars under field conditions: effects of water availability from leaf photosynthesis to grape yield and quality. Funct. Plant Biol. 30, 6: 607-619.
MORGAN J.A., LECAIN D.R., 1991. Leaf gas exchange and related leaf traits among 15 winter wheat genotypes. Crop Sci. 31: 443-448.
PANDEY R., SHARMA-NATU P., GHILDIYAL M.C., 2001. Irrigation decrease loss of leaf nitrogen and rubisco during pod development in chickpea. J. Agron. Crop Sci. 187: 177-183.
RAO T.R.K., GHILDIYAL M.C., 1985. Analysis of photosynthetic source and sink relationship in mungbean (*Vigna radiate* L.) Wilczek. Indian J. Plant Physiol. 28: 135-144.
RAWSON H.M., HINDMARSH J.H., FISCHER R.A., STOCKMAN Y.R., 1983. Changes in leaf photosynthesis with plant ontogeny and relationships with yield per year in wheat cultivars and 120 progeny. Aust. J. Plant Physiol. 10: 503-514.
SCHULTZ H.R., 1996. Water relations and photosynthetic response of two grapevine cultivars of different geographical origin during water stress. Acta Hortic. 427: 251-266.
SCHULTZ H.R., 2007. Climate change and world viticulture. Cost Action 858 Workshop: Vineyard under environmental constraints: adaptation to climate change. Abiotic stress ecophysiology and grape functional genomics. University of Łódź, Poland.
SHARMA-NATU P., GHILDIYAL M.C., 2005. Potential targets for improving photosynthesis and crop yield. Curr. Sci. (Bangalore) 8, 12: 1918-1928.
SHARMA-NATU P., PANDURANGAM V., GHILDIYAL M.C., 2004. Photosynthetic acclimation and productivity of mung bean cultivars under elevated CO_2 concentration. J. Agron. Crop Sci. 190: 81-85.
SHOAF T.W., LIUM B.W., 1976. Improved extraction of chlorophyll *a* and *b* from algae using dimethyl sulfoxide. Limnol. Oceanogr. 21: 926-928.

SINGH R. 1990. Assimilation and partitioning of carbon and nitrogen during growth and development of grain legumes. In: Proceedings of the International Congress Plant Physiology. Eds. S.K. Sinha, P.V. Sane, S.C. Bhargava, P.K. Agrawal. Society for Plant Physiology and Biochemistry, New Delhi: 261-267.

SINHA S.K., GHILDIYAL M.C., 1971. Transamination of glutamic acid during germination, growth and seed development in Bengal gram. Phytochemistry (Amst.) 10: 2959-2963.

SIROHI G.S., GHILDIYAL M.C., 1975. Varietal differences in photosynthetic carboxylases and chlorophylls in wheat varietes. Indian J. Exp. Biol. 13: 42-44.

WANG L.J., FAN L., LOESCHER W., DUAN W., LIU G.-J., CHENG J.-S., LUO H.B., LI S.-H., 2010. Salicylic acid alleviates decrease in photosynthesis under heat stress and accelerates recovery in grapevine leaves. Plant Biol. 10: 34-44.

WILLIAMS L.E., 1996. Grape. In: Photoassimilate distribution in plants and crops: source-sink relationships. Ed. E. Zamski. Dekker, New York: 851-881.

BADANIA PARAMETRÓW AKTYWNOŚCI FOTOSYNTETYCZNEJ WYBRANYCH ODMIAN WINOROŚLI W ODNIESIENIU DO ICH PLONOWANIA

Streszczenie. Badania aktywności fotosyntezy, zawartości chlorofilu i powierzchni liści były prowadzone w 2010 roku na dziewięciu odmianach zróżnicowanych pod względem plonowania jagód. W pracy analizowano również powiązania pomiędzy tymi parametrami. Badania wykazały różnice w poziomach parametrów aktywności fotosyntetycznej pomiędzy wybranymi odmianami winorośli. Wysoki poziom aktywności fotosyntezy netto był zwykle powiązany z dużą wydajnością CO_2 w trakcie procesu fotosyntezy, w związku z dużą przewodnością aparatów szparkowych. Aktywność fotosyntezy i wielkość liści nie były ze sobą powiązane. Specyficzna powierzchnia liści nie była zróżnicowana pomiędzy odmianami. W przypadku niektórych odmian stwierdzono powiązanie wysokich poziomów aktywności fotosyntezy z obfitym plonowaniem, podczas gdy inne odmiany wykazywały słabe plonowanie i/lub małe powierzchnie liści.

Słowa kluczowe: odmiany winorośli, aktywność fotosyntezy netto, przewodność aparatów szparkowych, wewnętrzne stężenie CO_2, chlorofil, powierzchnia liści

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