THE RATE OF PHOTOSYNTHESIS AND THE CONTENT OF PHOTOSYNTHETIC PIGMENTS OF WHEAT YOUNG PLANTS AT DIFFERENT NITROGEN CONCENTRATIONS IN NUTRIENT SOLUTION

F. Hnilička, V. Novák

Czech University of Agriculture, Faculty of Agronomy, Prague, Czech Republic

In laboratory conditions the trial has been repeatedly established to study the effect of five different nitrogen concentrations in the nutrient solution Hoagland No. 3 on the content of chlorophylls and rate of intensity in young plants of winter wheat, cv. Samanta. It follows from the results that in view of the content of photosynthetically active pigments (in the phase 14.DC the content of pigments ranged between 140 and 230 $mg.m^{-2}$ and in the phase 30.DC it ranged from 350 to 620 $mg.m^{-2}$) and intensity of photosynthesis (intensity of photosynthesis in the phase 14.DC was ranging from 1.642 to 3.025 $\mu mol.m^{-2}.s^{-1}$ and in the phase 30.DC between the values 9.049 and 10.767 $\mu mol.m^{-2}.s^{-1}$) in laboratory conditions, an optimum nitrogen concentration seems to be from 0.5 N to 2 N at the given intensity of light (490 $\mu mol.m^{-2}.s^{-1}$). Extremely low and high nitrogen concentrations had a negative impact not only on the content of photosynthetically active pigments, but also on the rate of photosynthesis. Relatively low values of immediate intensity of photosynthesis were caused particularly by relatively low content of chlorophylls in leaves which were not yet photosynthetically mature.

wheat; nitrogen concentration; photosynthesis

INTRODUCTION

Great attention has been devoted to photosynthesis, as a process standing at the beginning of all power engineering, because the rate of photosynthesis is an important factor which affects the production and the amount of biomass that is also a yield. In this view photosynthesis is a primary biological basis of the productivity of cultural plants (E v a n s , 1975).

Photosynthesis by its position in the plant metabolism affects in its consequence also the uptake, distribution and utilization of mineral substances (N á t r, 1992).

The process of photosynthesis alone is affected by a lot of factors, both external and internal ones. Important external factors can include solar radiation and air temperature. In the production process the effect of solar radiation and temperature is manifested the most on the change of intensity of photosynthesis (H o d y s o n, 1981; W i t t, P e e n i n g d e V r i e s, 1982). However, the plants in photosynthetic reactions use about 0.8% of all global radiation impacting on the Earth (S t r a š i l, 1998)

Except the solar radiation, the rate of photosynthesis is also affected by the mineral nutrition. One of the most important factors is enough available nitrogen forms in the environment. This element acts not only on the content of photosynthetically active pigments in leaves, but also on the production of photosynthetic apparatus and the rate of is ageing, as documented in the Kostrej's study (K o s t r e j et al., 1992).

Except the external factors an amount of chlorophyll and the course, rate of photosynthesis and subsequently accumulation of dry matter are influenced also by internal factors, such as: age of plant or its photosynthetic apparatus, respectively. G l e n k e l (1969) reports that the rate of photosynthesis is the lowest at the beginning of the growing season and is increasing gradually in dependence on ontogenesis.

Therefore, the authors concentrated in their study on the investigation of the effect of different nitrogen concentrations in nutrient solution as affected the photosynthetically active pigments in leaves, the course and rate of photosynthesis of wheat (*Triticum aestivum* L.) in laboratory conditions. In addition, we they studied a relationship between the amount of chlorophylls per unit of leaf area and immediate rate of photosynthesis in juvenile phases of wheat ontogenesis.

MATERIAL AND METHOD

In laboratory conditions in the years 1997 to 1999 the trials were repeatedly established to study the effect of various nitrogen concentrations in nutrient solution on the content of chlorophylls and the rate of photosynthesis in young plants of winter wheat, cv. Samanta.

Plants were cultivated in hydroponics in controlled light and temperature conditions of air-conditioned box of the Department of Botany and Plant Physiology, when light regime represented 16 hours of light at intensity of irradiation 490 μmol.m^{-2}.s^{-1} and by hours of darkness. Temperature was adjusted to 25 ± 1 °C and 20 ± 1 °C at night.

In the trial we studied the effect of five different nitrogen concentrations in nutrient solution Hoagland No. 3 (Table I): control variant (1 N) variant with a marked nitrogen deficit (0.1 N), variant with reduced nitrogen content (0.5 N), variant with increased nitrogen content in solution (2N and 4 N). The other properties of nutrient solution remained identical in all variants (pH 4.57, osmotic concentration 1.583).

In selected phases of ontogenesis (14.DC, 19.DC, 21.DC, 22.DC, 23.DC, 25.DC, 26.DC, 28.DC and 30.DC) the concentration of chlorophylls was determined in five upper leaves and immediate rate of photosynthesis of the third upper wheat leaf in three repetitions from each variant.

To extract pigments from leaves into acetone and to subsequent spectrophotometry the methodological guidelines according to Š e s t á k, Č a t s k ý et al. (1966) were used. The size of an analysed sample of leaf blade on the content of pigments was 2 g of fresh weight. To calculate the concentration of chlorophylls in extract the relationships after N y b o m (1955) were used.

Immediate rate of wheat photosynthesis was measured by an apparatus LCA-4 in air-conditioned box at intensity of irradiation 490 μmol.m^{-2}.s^{-1} and temperature 25 ± 1 °C.

The principle of this method consists in the detection of change in the concentration of carbon dioxide in atmosphere surrounding assimilating object (Š e s t á k, Č a t s k ý et al., 1966).

The results obtained were statistically evaluated using computer program Statgraphic on the significance level $\alpha = 0.05$.

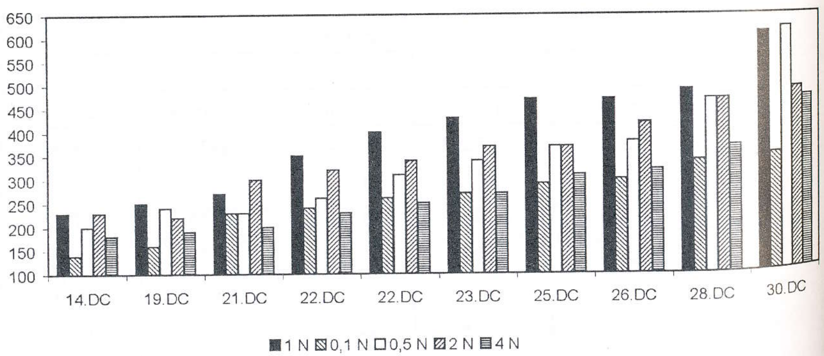
I. Variants of Hoagland's nutrient solution No. 3

Substance (mg.l^{-1})	N concentration in solution				
	1	0.1	0.5	2	4
	variant 1	variant 2	variant 3	variant 4	variant 5
$Ca(NO_3)_2$	0.821	0.12293	0.61465	0.821	0.821
KNO_3	0.506	0	0	0.506	0.506
KH_2PO_4	0.136	0.136	0.136	0.136	0.136
$MgSO_4$	0.120	0.120	0.120	0.120	0.120
NH_4NO_3	0	0	0	0.6006	1.8018
KCl	0	0.3737	0.3737	0	0
$CaCl_2$	0	0.93079	0.27513	0	0
Citrate Fe	1 ml	1 ml	1 ml	1 ml	1 ml
Microelements after Benson in the dose 1 ml					

RESULTS AND DISCUSSION

It is evident from the results obtained that the content of chlorophyll during ontogenesis manifested the tendency of growth because the lowest content was found in the phase when the fourth leaf appeared (from 140 to 230 $mg.m^{-2}$) and to the beginning of shooting it increased to the values between 350 and 620 $mg.m^{-2}$. The results obtained are in accordance with K a r c z m a r c z y k et al. (1993). It is evident from Fig. 1 that e.g. in the phase 14.DC the content of chlorophylls ranging from 140 $mg.m^{-2}$ in the variant 0.1 N and to 230 $mg.m^{-2}$ in the variants 1 N and 2 N. In the phase of the third visible tiller the content of chlorophylls ranged between 270 $mg.m^{-2}$ (in the variant 0.1 N and 4 N) and 430 $mg.m^{-2}$ (variant 1 N). At the beginning of shooting the lowest amount of chlorophylls was found in the variant with a marked deficit of nitrogen – 0.1 N, in which the content of chlorophylls was measured amounting to 350 $mg.m^{-2}$. On the contrary, the highest content of chlorophylls in mg per 1 m^2 was in the variant with half concentration of nitrogen – 0.5 N (620 $mg.m^{-2}$).

It follows from Fig. 1 that insufficient concentration of nitrogen in medium caused statistically significant decrease of the chlorophyll content in wheat leaves (Table II). In this variant (0.1 N) total decrease of the content of pigment by 35 % occurred compared with the control variant (1 N). Also the variant with extremely high concentration of nitrogen in solution (4 N) reduced the total content of chlorophylls, the measured content of pigments reached 70% of the values obtained in the control variant.



1. Content of chlorophylls ($mg.m^{-2}$)

x-axis – phase of ontogenesis, y-axis – content of chlorophylls ($mg.m^{-2}$)

II. Differences in average content of chlorophylls ($mg.100\ cm^{-2}$) and intensity of photosynthesis ($\mu mol.m^{-2}.s^{-1}$)

Differences in average content of chlorophylls ($mg.m^{-2}$)			Differences in average intensity of photosynthesis ($\mu mol.m^{-2}.s^{-1}$)		
Variant	average measurement values of all measurements	homogeneous groups	variant	average measurement values of all measurements	homogeneous groups
0.1 N	250	*	0.1 N	4.746	*
4 N	277	*	0.5 N	5.330	* *
0.5 N	342	*	4 N	5.554	* * *
2 N	353	* *	1 N	5.923	* *
1 N	397	*	2 N	6.221	*

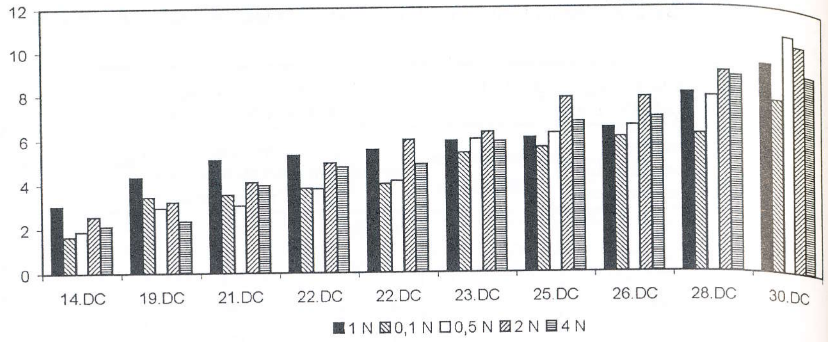
T-method; $\alpha = 0.05$

The highest increase of the content of photosynthetically active pigment was recorded in the variant 0.5 N in which the amount of chlorophylls increased from 200 $mg.m^{-2}$ to 620 $mg.m^{-2}$. On the other side, the lowest increase in the amount of pigments per 1 m^{-2} of leaf area in the variant with nitrogen deficit in the nutrient medium, because in this variant (0.1 N) the content of pigments rose from the value 140 $mg.m^{-2}$.

When evaluating the effect of nitrogen concentration in solution on the content of chlorophylls in wheat leaf, it can be said that the lowest content was recorded in the variant with a marked deficit of nitrogen in solution (0.1 N), as it is documented in R e p k a ' s study (1986).

Except the determination of chlorophylls in leaves, an immediate intensity of photosynthesis was also measured in laboratory conditions.

When investigating intensity of photosynthesis of young wheat plants a growth of intensity of photosynthesis during ontogenesis was evident. The lowest intensity of photosynthesis was found in the phase of the fourth leaf (1.642 to 325 $\mu mol.m^{-2}.s^{-1}$) and on the contrary, the highest was in the phase 30.DC (9.049 to 10.767 $\mu mol.m^{-2}.s^{-1}$). Within the given developmental phase intensity of photosynthesis was relatively stable in the different variants of the trial, as documented by Fig. 2. Photosynthetic non-maturity of leaves or a low content of chlorophylls in juvenile phases of growth, resp., were a limiting factor of intensity of photosynthesis (see Fig. 1), because it is generally reported in literature that at the values ranging between 100 and 250 $mg.m^{-2}$ chlorophyll compensation point occurs. In fully photosynthetically mature leaves 400 to 600 g of chlorophylls per 1 m^2 of leaf area occur.



2. Rate of photosynthesis (μmol.m^{-2}.s^{-1})

x-axis – phase of ontogenesis, y-axis – rate of photosynthesis

The given condition was fulfilled in all variants, except the variant 0.1 N at the beginning of shooting.

It can be said that intensity of photosynthesis has a growing tendency in juvenile phases of plant development that can be recorded in all nitrogen concentrations in nutrient solution. The results obtained correspond to the conclusions made by Genkel (1969), Rea, Cale (1991) and Hejnák et al. (1998).

It is evident from Fig. 2 that intensity of photosynthesis changed in dependence on nitrogen concentration in solution. The highest growth of the values of photosynthesis intensity can be found in the variant 0.5 N when immediate rate of photosynthesis grew from 1.877 μmol.m^{-2}.s^{-1} in the phase of the fourth leaf to the value 10.767 μmol.m^{-2}.s^{-1} at the beginning of shooting. The growth of intensity of photosynthesis during plant ontogenesis of wheat was also recorded in the variant with a marked deficit of nitrogen in nutrient solution (0.1 N). The measured values of immediate intensity of photosynthesis was the lowest in the variant 0.1 N compared with the other variants, because at the beginning of the growing season, that is in the phase 14.DC the rate of photosynthesis was 1.642 μmol.m^{-2}.s^{-1} and at the beginning of shooting it amounted to 7.799 μmol.m^{-2}.s^{-1}.

Significant decrease of intensity of photosynthesis in the variant with nitrogen deficit (0.1 N) by 17.19 % compared with the variant 1 N, as reported in Table II, was caused by the fact that plants did not produce a sufficient amount of chlorophylls. It can be said in harmony with Repka (1986), Heitholt et al. (1995) and Hejnák et al. (1998) that nitrogen deficit is significantly decreasing the intensity of photosynthesis.

Except the marked deficit of nitrogen in nutrient solution, an immediate rate of photosynthesis reduced also its extremely high concentration – 4 N, similarly like in the content of chlorophylls when the measured values of photosynthesis intensity ranged within the values from 2.122 μmol.m^{-2}.s^{-1} (phase 14.DC) to 9.049 μmol.m^{-2}.s^{-1} (phase 30.DC). These values obtained reach 93.77% of the values of photosynthesis intensity of the control variant (1 N).

It can be said that intensity of photosynthesis was not only influenced by the course of ontogenesis and nitrogen concentration in medium, but also the amount of photosynthetically active pigments. This our conclusion was also confirmed by calculated correlation coefficient which amounted to 0.90.

It can be said in conclusion that in view of the content of photosynthetically active pigments and intensity of photosynthesis it appears in laboratory conditions as an optimum concentration of nitrogen in nutrient solution from 0.5 N to 2 N at the given intensity of light (490 μmol.m^{-2}.s^{-1}). Extremely low as well as high concentrations of nitrogen had a negative impact on the content of photosynthetically active pigments, but also on the rate of photosynthesis. Relatively low values of immediate intensity of photosynthesis were above all caused by relatively low content of chlorophyll in leaves which were not yet photosynthetically mature.

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HNILIČKA, F. – NOVÁK, V. (Česká zemědělská univerzita, Agronomická fakulta, Praha, Česká republika):

Rychlost fotosyntézy a obsah fotosyntetických pigmentů mladých rostlin pšenice při různé koncentraci dusíku v živném roztoku.

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V laboratorních podmínkách byl opakovaně zakládán pokus na zjištění vlivu pěti rozdílných koncentrací dusíku v živném roztoku Hoagland č. 3 (varianta kontrolní – 1 N, varianta s výrazným deficitem dusíku – 0,1 N, varianta se sníženým obsahem dusíku – 0,5 N, varianty se zvýšeným obsahem dusíku v roztoku – 2 N a 4 N) na obsah chlorofylů a rychlost fotosyntézy u mladých rostlin pšenice ozimé, odrůdy Samanta.

Ve vybraných fázích ontogeneze (14.DC, 19.DC, 21.DC, 22.DC, 23.DC, 25.DC, 26.DC, 28.DC a 30.DC) jsme stanovili obsah chlorofylů v pěti horních listech a okamžitou rychlost fotosyntézy třetího horního listu pšenice pomocí přístroje LCA-4 ve třech opakováních u každé varianty pokusu.

Ze získaných výsledků je patrné, že obsah chlorofylů v průběhu ontogeneze vykazoval průkaznou tendenci k růstu, neboť nejnižší obsah byl zjištěn ve fázi objevení čtvrtého listu (od 140 do 230 mg.m^{-2}) a do začátku sloupkování narostl až na hodnoty mezi 350 až 620 mg.m^{-2}. Z obr. 1 je patrné, že např. ve fázi 14.DC byl obsah chlorofylů v rozmezí hodnot od 140 mg.m^{-2} u varianty 0,1 N do 230 mg.m^{-2} u variant 1 N a 2 N a na počátku sloupkování bylo nejnižší množství chlorofylů zjištěno u varianty s výrazným deficitem dusíku – 0,1 N, u níž byl naměřen obsah chlorofylů ve výši 350 mg.m^{-2}. Naopak nejvyšší obsah chlorofylů v mg na 1 m^2 byl u varianty s poloviční koncentrací dusíku – 0,5 N (620 mg.m^{-2}). Dále je patrné, že nedostatečná koncentrace dusíku v médiu způsobila statisticky průkazné snížení obsahu chlorofylů v listech pšenice (tab. II). U této varianty (0,1 N) došlo k celkovému snížení obsahu pigmentů o 35 % v porovnání s variantou kontrolní (1 N). Rovněž u varianty s extrémně vysokou koncentrací dusíku v roztoku (4 N) bylo zaznamenáno snížení celkového obsahu chlorofylů o 30 % ve srovnání s variantou kontrolní.

Nejvyšší nárůst obsahu fotosynteticky aktivních pigmentů byl zaznamenán u varianty 0,5 N, u níž se množství chlorofylů zvýšilo z 200 na 620 mg.m^{-2}. Na straně druhé byl nejnižší nárůst v množství pigmentů v 1 m^2 listové plochy zjištěn u varianty s deficitem dusíku v živném roztoku (0,1 N) – obsah pigmentů se zvýšil z hodnoty 140 mg.m^{-2} na 350 mg.m^{-2}.

Při hodnocení vlivu koncentrace dusíku v roztoku na obsah chlorofylů v listu pšenice je možné konstatovat, že nejnižší obsah byl zaznamenán u varianty s výrazným nedostatkem dusíku v roztoku (0,1 N).

Vedle stanovení množství chlorofylů v listech byla v laboratorních podmínkách měřena i okamžitá intenzita fotosyntézy – u mladých rostlin pšenice byl patrný její nárůst v průběhu ontogeneze. Nejnižší intenzita fotosyntézy byla zjištěna ve fázi čtvrtého listu (1,642 až 3,025 µmol.m^{-2}.s^{-1}) a naopak nejvyšší ve fázi 30.DC (9,049 až 10,767 µmol.m^{-2}.s^{-1}). V rámci dané vývojové fáze byla intenzita fotosyntézy u jednotlivých variant pokusu poměrně stabilní, jak dokládá obr. 2. Limitujícím faktorem intenzity fotosyntézy byla fotosyntetická nedospělost listů, resp. nízký obsah chlorofylů v juvenilních fázích růstu (obr. 1), neboť se obecně v literatuře uvádí, že při hodnotách mezi 100 až 250 mg.m^{-2} nastává chlorofylový kompenzační bod. U plně fotosynteticky dospělých listů se obvykle vyskytuje 400 až 600 mg chlorofylů na 1 m^2 listové plochy. Uvedená podmínka byla splněna téměř u všech variant, s výjimkou varianty 0,1 N, tj. na počátku sloupkování.

Z obr. 2 je patrný postupný nárůst intenzity fotosyntézy v průběhu ontogeneze (do fáze 30.DC), který je možné zaznamenat u všech koncentrací dusíku v živném roztoku. Jak je patrné z obr. 2, intenzita fotosyntézy se měnila v závislosti na koncentraci dusíku v roztoku. Nejvyšší nárůst hodnot intenzity fotosyntézy je možné nalézt u varianty 0,5 N, kdy se zvýšila okamžitá rychlost fotosyntézy z 1,877 µmol.m^{-2}.s^{-1} ve fázi 4. listu až na hodnotu 10,767 µmol.m^{-2}.s^{-1} na počátku sloupkování. Nárůst intenzity fotosyntézy v průběhu ontogeneze rostlin pšenice byl také zaznamenán u varianty s výrazným nedostatkem dusíku v živném roztoku (0,1 N). Naměřené hodnoty okamžité intenzity fotosyntézy byly u varianty 0,1 N v porovnání s ostatními variantami nejnižší, neboť na počátku vegetace, tedy ve fázi 14.DC, byla rychlost fotosyntézy 1,642 µmol.m^{-2}.s^{-1} a na počátku sloupkování ve výši 7,799 µmol.m^{-2}.s^{-1}.

Průkazné snížení intenzity fotosyntézy u varianty s nedostatkem dusíku (0,1 N) o 17,19 % při porovnání s variantou 1 N (tab. II) bylo způsobeno tím, že rostliny nevytvořily dostatečné množství chlorofylů. Vedle výrazného nedostatku dusíku v živném roztoku snížila průkazně okamžitou rychlost fotosyntézy i jeho extrémně vysoká koncentrace – 4 N, obdobně jako u obsahu chlorofylů, kdy se naměřené hodnoty intenzity fotosyntézy pohybovaly od 2,122 µmol.m^{-2}.s^{-1}(fáze 14.DC) do

9,049 μmol.m^{-2}.s^{-1} (fáze 30.DC). Tyto získané hodnoty dosahují 93,77 % hodnot intenzity fotosyntézy kontrolní varianty (1 N).

Je možné konstatovat, že intenzita fotosyntézy byla ovlivněna nejen průběhem ontogeneze a koncentrací dusíku v médiu, ale také množstvím fotosynteticky aktivních pigmentů. Tento náš závěr potvrdila i vypočítaná hodnota korelačního koeficientu 0,90.

Závěrem je možné konstatovat, že z hlediska obsahu fotosynteticky aktivních pigmentů a intenzity fotosyntézy se v laboratorních podmínkách ukazuje jako optimální koncentrace dusíku v živném roztoku od 0,5 N do 2 N, při dané intenzitě osvětlení (490 μmol.m^{-2}.s^{-1}). Extrémně nízké i vysoké koncentrace dusíku působily nejen na obsah fotosynteticky aktivních pigmentů, ale i na rychlost fotosyntézy negativně. Relativně nízké hodnoty okamžité intenzity fotosyntézy byly především způsobeny relativně nízkým obsahem chlorofylů v listech, které ještě nebyly fotosynteticky dospělé.

pšenice; koncentrace dusíku; chlorofyl; fotosyntéza

Contact Address:

Ing. František Hnilička, Ph.D., Česká zemědělská univerzita, Agronomická fakulta, Kamýcká 129, 165 21 Praha 6-Suchdol, Česká republika, tel.: 02/24 38 25 19, fax: 02/20 92 03 12, e-mail: hnilicka@af.czu.cz