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The Influence of Suddenly Changing Quantity of Produced Photosynthetic Products on its Export from Donor-Leave

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Abstract: In order to sharply change the amount of photo-assimilates formed in the leaf, flag leaves of spring wheat plants, grown under ambient CO_2 and light, were exposed to increased CO_2 or decreased irradiance at the moment of $^{14}CO_2$ fixation only. Lowered irradiance accelerated assimilate influx to the wheat ear while increased CO_2 reduced the rate of photo-synthate translocation.

Key words: $^{14}CO_2$ · Photo-assimilates · Photosynthesis · Transport · Wheat

INTRODUCTION

Plants exist in the constantly changing environment, which changes the intensity of synthesis of photosynthetic products, photo-assimilates. Although the influence of changes in CO_2 concentration and irradiance on photosynthesis and productivity has been thoroughly studied [1-5], early reactions of photo-assimilate transport system to changing environmental conditions remain unclear. Clarification of this issue was the aim of the present study.

MATERIALS AND METHODS

To investigate assimilate export from the leaf under sudden alteration in amount of photosynthetic products the experiments were conducted in wheat plants, in which the export and distribution of labeled products of photosynthesis along the plant within the next 1 hour after 1 min CO_2 assimilation in the light were traced.

Spring wheat plants (*Triticum aestivum L.*, cv. Moscovskaya-35) were grown in field conditions, 15 plants per pot (9 kg of gray forest loamy soil) under high concentration of mineral nutrition (1 g of N, P and K each per pot), optimum humidity (70% of total moisture capacity) and natural irradiance. Plants were used in the reproductive stage of development when the export function of leaves increased (flowering completed; kernel watery ripe, 10.5.4 according to Feekes scale [6]). In this phase, wheat plants have completely grown source leaves and intensive demand of assimilates by the ear. After beginning of caryopsides formation the flow of assimilates to roots and uptake of elements of mineral nutrition decrease [7]. The rate of formation of photosynthetic products was assessed using $^{14}CO_2$. The flag leaf was placed to thermostated leaf-chamber (2.0×2.5) and $^{14}CO_2$ (0.03%) was delivered from a gas-holder, as described [8]. After 1 minute exposure to $^{14}CO_2$, the leaf was cut off and after 30 s was fixed by boiling 80% ethanol. One group of leaves, exposed to $^{14}CO_2$, was kept on their plants for 1 hour before fixation with the purpose of obtaining information about ^{14}C distribution among individual organs of the aboveground plant part. The ambient light intensity measured with a luxmeter was 440 W/m^2, day temperature + 25°C. In some plants, experimental leaves were fed with $^{14}CO_2$ under conditions of low light (110 W/m^2- 4 times lower than ambient) or increased CO_2 concentration (0.3%). To create CO_2 (0.3%) NaH $^{14}CO_3$ was added into the gas-holder together with NaH $^{12}CO_3$, so that the final CO_2 concentration achieved 0.3%, but $^{14}CO_2$ specific radioactivity was 3 times lower than in control. Samples were ground in 60% ethanol and their radioactivity was determined using scintillation counter "Delta-300" (Tracor Analytic, USA). Five plants were used for each treatment and the means and calculated standard errors are reported.

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RESULTS AND DISCUSSION

Given the 3 times lower specific radioactivity in the photosynthetic chamber in the experiments with increased CO_2, we should multiply all the values measured (presented in the table) by three in order to compare them with control ones. Thus, the higher CO_2 concentration only at the moment of CO_2 assimilation significantly increased CO_2 assimilation (Table 1). Decrease in irradiance lowered CO_2 fixation compared to control (Table 1). Thus, different amount of photosynthetic products were formed under these two treatments. There is functional connection between outflow of assimilates from source leaf and the intensity of the assimilation of CO_2 (r= - 0.93) [9]. Decrease or increase in amount of assimilates with lowering of illumination or rising of CO_2 concentration, respectively, should change also their subsequent post-photosynthetic fate. The changes of illumination and CO_2 concentration only on 1 minute significantly changed the export of labeled products of photosynthesis from the leaf. Less formation of assimilates in low light was accompanied by their intensive export in the next 60 minutes. On the contrary, elevated CO_2 concentration that increased the mass of products of photosynthesis being formed relatively inhibited their transport from the leaf.

According to literature data, alteration of CO_2 and irradiation impacts primarily the synthesis of the main transport products - sucrose. Increasing CO_2 concentration immediately enhances the synthesis of sucrose, the formation of alanine, malate and aspartate and reduces the flow of carbon into glycolate pathway [7]. On the contrary, lowering of the illumination reduces the intensity of CO_2 assimilation; among labeled products of photosynthesis the fraction of sucrose phosphates and the products of glycolate pathway decreases, whereas those of sucrose, alanine and malate relatively increase [7]. Thus, although both factors similarly influence the relative amount of labeled sucrose, they diversely affect its absolute content.

The changes in the leaf influenced the distribution of labeled photo-assimilates between plant organs (Fig. 1). Temporary abundance or deficiency of assimilates in the leaf oppositely affected assimilate influx to wheat ear. Lower light increased the inflow of new-assimilates to the ear, while increased CO_2 concentration stimulated synthesis of photosynthetic products in the leaf, but decreased their import into the ear.

So, the obtained data shows that the balance of production and export of photoassimilates from leaves to sink organs of plant has a certain stability and corrects transport processes after short-term changes in quantity of products of photosynthesis to support their export at the level which existed before the advent of the disturbing factor.

Work over the past ten years shows that doubling of carbon dioxide concentration stimulates photosynthesis on average by 20-30%, but the final yield increase is only 10% [10, 11], which indicates that a "narrow neck" limiting additional carbon fixation is outflow of photo-assimilates [12]. It was found [13] that in wheat plants at increased CO_2 concentration sink limitation is induced by ear photosynthesis. In our experiments, sink limitation by the ear was not so severe because the ear was kept at ambient CO_2 and the reason of diminished photosynthates export under high CO_2 was associated with some processes occurring in the leaf transport system.

It follows that, in the plant a suddenly appeared pool of newly formed assimilates have to perform (at least, at the first) the existing export program which is determined by previous conditions.

Table 1: The influence of lowered irradiance and increased CO_2 concentration on changes in radioactivity of the above-ground part of wheat plants. Under high CO_2 conditions $^{14}CO_2$ specific radioactivity in the photosynthetic chamber was 3 times lower than in control

Radioactivity	Control 100 000 lux, 0.03% CO_2	Lowered irradiance 25 000 lux, 0.03% CO_2	Increased CO_2 100 000 lux, 0.3% v/v* CO_2
Fixed after 1 min assimilation of $^{14}CO_2$ by source leaf [kBq]	1450±48	1072±40	764±32
In the whole plant in 1 h after assimilation of $^{14}CO_2$ [kBq]	1044±45	932±48	648±52
In the ^{14}C-source leaf [kBq]	864±84	684±64	576±48
Exported from the leaf [kBq]	180±20	248±25	72±6
Exported from the leaf [% from fixed $^{14}CO_2$]	12.4	23.1	9.4
Exported from the leaf [% from radioactivity in 1h]	17.2	26.6	11.1
Losses of ^{14}C from the plant [kBq/plant]	406±28	140±22	116±15
Losses from the plant [% from the fixed ^{14}C]	28	13.1	15.2

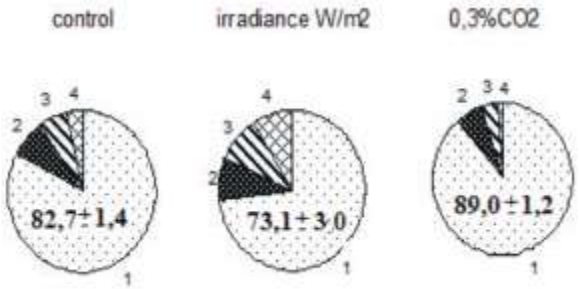

Fig. 1: Effect of changes in irradiance and CO_2 concentration (at the time of fixation of $^{14}CO_2$) on the distribution of labeled assimilates among different organs of wheat in 1 h after 1 min $^{14}CO_2$ fixation. Irradiance and CO_2 concentration of each treatment were 100 000 lux and 0.03% for control, 25 000 lux and 0.03% for lowered irradiance, 100 000 lux and 0.3% for increased CO_2 treatment. Under high CO_2 conditions $^{14}CO_2$ specific radioactivity in the photosynthetic chamber was 3 times lower than in control 1-^{14}C-source leaf, 2- sheath of ^{14}C-source leaf, 3- stem, 4- ear

REFERENCES

1. Stitt, M., W. Wirtz and H.W. Heldt, 1983. Regulation of sucrose synthesis by cytoplasmic fructosebisphosphatase and sucrose phosphatesynthase during photosynthesis in varying light and carbon dioxide. Plant Physiol., 72: 767-774.
2. Habash, D.Z., M.J. Paul, M.A.J. Parry, A.J. Keys and D.W. Lawlor, 1995. Increased capacity for photosynthesis in wheat grown at elevated CO_2: the relationship between electron transport and carbon metabolism. Planta, 197: 482-489.
3. Ludewig, F., U. Sonnewald, F. Kauder, D. Heineke, M. Geiger, M. Stitt, B.T. Muller-Rober, B. Gillissen, C. Kuhn and W.B. Frommer, 1998. The role of transient starch in acclimation to elevated atmospheric CO_2. FEBS Letters, 429: 147-151.
4. Long, S.P., E.A. Ainsworth, A. Rogers and D.R. Ort, 2004. Rising atmospheric carbon dioxide: Plants Face the future. Annual Reviews in Plant Biol., 55: 591-628.
5. Zhang, D.Y., G.Y. Chen, J. Chen, Z.H. Yong, L.G. Zhu and D.Q. Xu, 2009. Photosynthetic acclimation to CO_2 enrichment related to ribuloze-1,5-bisphosphate carboxylation limitation in wheat. Photosynthetica 47: 152-154.
6. Miller, T.D., 1992. Growth stages of wheat. Better crops with plant food. Potash and Phosphate Institute, 76: 12-17.
7. Chikov, V.I., 1987. Fotosintez i Transport Assimilyatov. [Photosynthesis and Assimilate Transport] - Nauka, Moskva [In Russian].
8. Chikov, V.I., M.E. Bulka and V.G. Yargunov, 1985. Effect of removal of fruits on photosynthetic metabolism of ^{14}C in leaves of cotton. Fiziologia Rasteniy, 32: 1055-1063 [In Russian].
9. Ximin, X.M., X.M. Deng, R.J. Joly and D.T. Hahn, 1990. The influence of plant water deficit on photosynthesis and translocation of ^{14}C-labelled assimilates in cacao seedlings. Physiology of Plants, 78: 623-627.
10. Ainsworth, E.A. and S.P. Long, 2005. What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy properties and plant production to rising CO_2. New Phytologist, 165: 351-372.
11. Rogers, A. and E.A. Ainsworth, 2006. The response of foliar carbohydrates to elevated [CO_2]. - In: Managed Ecosystems and CO_2 Case Studies, Processes and Perspectives (eds J. Nosberger, S.E. Long, R.J. Norby, M. Stitt, G. Hendrey and H. Blum), pp: 293-310. Springer-Verlag, Berlin Heidelberg.
12. Stitt, M., Y. Gibon, J.E. Lunn and M. Piques, 2007. Multilevel genomics analysis of carbon signalling during low carbon availability: coordinating the supply and utilization of carbon in a fluctuating environment. Functional Plant Biol., 34: 526-549.
13. Zhu, C.W., J.G. Zhu, G. Liu, Q. Zeng, Z.B. Xie, J. Pang, Z.Z. Feng, H.Y. Tang and L. Wang, 2008. Elevated CO_2 concentration enhances the role of the ear to the flag leaf in determining grain yield of wheat. Photosynthetica, 46: 318-320.