PHOTORESPIRATION OF C-3 PLANTS IN RELATION TO SOIL HUMIDITY AND PRODUCTIVITY LEVEL

FOTORESPIRAȚIA C-3 A PLANTELOR ÎN RELAȚIE CU UMIDITATEA SOLULUI ŞI NIVELUL PRODUCTIVITĂȚII

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Abstract. *In this work new results are presented on relationship between photorespiration, level of productivity and plant resistance (species, varieties, cultivars with C_3 - metabolism) to hydric stress. It has been established that the plants of more productive genotypes are assisted by a lower level of photorespiration (CO_2 elimination and glycolate oxidase activity). The resistant genotypes to edaphic drought are characterized by a higher level of photorespiration compared to unresistant genotypes. The action of hydric stress on plants of unresistant genotypes to edaphic drought is manifested by a substantial deceasing of the both dry organic matter accumulation process and photorespiration. It is shown that the influence of steroidical biological active substance (BAS) - "Ecostim" on plants of unresistant genotypes to edaphic drought is manifested in modification of consequences, induced by edaphic drought and it is characterized by an increased dry organic matter accumulation process and much more reduced photorespiration level.*

Rezumat. *În lucrarea dată se aduc rezultate noi privind legătura dintre fotorespirație, nivelul de productivitate şi rezistența plantelor (specii, varietăți, soiuri cu C_3 - metabolism) la stresul hidric. Se demonstrează că genotipurile cu un nivel mai ridicat al productivității plantelor sunt asistate de un nivel mai scăzut al fotorespirației (eliminarea de CO_2 şi activitatea glicolatoxidazei). Genotipurile mai rezistente la secetă se caracterizează printr-un nivel mai înalt al fotorespirației față de genotipurile mai puțin rezistente. Acțiunea stresului hidric asupra plantelor genotipurilor nerezistente la seceta edafică se manifestă prin diminuarea substanțială a procesului de acumulare a substanței organice şi a nivelului de fotorespirație. S-a evidențiat că influența SBA de natură steroidică "Ecostim" asupra genotipurilor nerezistente la seceta edafică, se manifestă prin modificarea consecințelor, induse de seceta edafică şi se caracterizează prin sporirea procesului de acumulare a substanței organice uscate şi reducerea şi mai aprofundată a nivelului de fotorespirație.*

Gas exchanges (CO_2, O_2) at the plant level determines the intensity of productivity process and it is concomitantly developed in framework of three processes as photosynthesis, respiration and photorespiration.

The role of photorespiration is not elucidated definitivly yet. But it is well known that during photorespiration up to 50% of photosynthesis products are consumed. Photorespiration is not accompanied by oxidative phosphorilation of ADP and the reduction force of $NADPH_2$ accumulated in photosynthesis is used for the reduction of molecular oxygen and through this the energetic function of

photorespiration becomes zero and lead to the energy loss. In this context it was supposed that the productivity of C_3 plants could be doubled if the energetic losses and photosynthesis products might be decreased. The attempts in this direction (2) have been done for 30 years to find out plants with lower photorespiration level by application of some specific photorespiration inhibitors, by obtaining of mutant forms and more detail investigations on biochemistry of photorespiration process have shown that this problem (the increasing of plant productivity by reducing of photorespiration level) has not a positive resolve. But during these studies it was established that photorespiration represents a component of production process. Analysis of these data permitted us to state that there are not so many investigations on photorespiration level and its role in formation of plant productivity in relation to the level of plant productivity and resistance

The aim of this study consisted in elucidation of photorespiration level for different C_3 plant genotypes differing in their productivity level and resistance to edaphic drought.

MATERIALS AND METHODS

To elucidate the photorespiration level and glycolate oxidase (GO) activity in relation to plant productivity level the following C_3 - crop plants were used: Soybean cultivars (centner/ha) – *Timpurie* (18.5), *Belisztkaia* 82 (22,5), *Bucuria* (23,8), *Aura* (30,7). Pea cultivars (centner/ha) – *Moldavskii usatii* (19,2), *Renata* (26,4), *Vomo* (28,5), *Gloria* (32,2). Sugar beet cultivars (centner/ha) – *Vilia* (300), *Victoria* (400).

In studies on photorespiration level in relation to resistance level of plants to edaphic drought the following soybean cultivars (*Bucuria* – resistant to edaphic drought; *Ghiza* – unresistant to drought) and been cultivars (*Fetanisia* – resistant and *Aluna* – unresistant to edaphic drought) were used. The experiments were effectuated in a greenhouse under controlled environmental conditions especially with respect to soil moisture. Two levels of soil moisture was used in experiments; 60% - optimal conditions and 25-30% of water content in the soil from total water soil capacity, which provided the edaphic drought conditions. Photorespiration was determined on the base of CO_2 eliminated in the assimilation chamber of the Installation for studying of respiration, photorespiration and photosynthesis (1) after switching off the light for the first 10 minutes.Glycolate oxidase activity was determined according to the method (3).

RESULTS AND DISCUSSIONS

The balance of CO_2 exchange in leaves under the light action consists of two processes – photosynthesis and photorespiration. The both processes have the beginning in the chloroplasts, but photorespiration continues in peroxisomes, then in mitochondria, where CO_2 is eliminated. In peroxisomes the oxidation of glycolate takes place in the reaction catalyzed by glycolate oxidase (GO) with glyoxilate formation, followed by the series reactions that lead to CO_2 elimination. It means that the elimination level of CO_2 in peroxisomes depends on the GO activity. The obtained results on determination of GO activity show that investigated crop species differ by the enzyme activity level in leaves (Fig.1). The highest GO activity is observed in sugar beet leaves, followed by decreasing enzyme activity in soybean and pea cultivars (fig.1 a, b, c)

The comparative analyze of GO activity in relation to productivity level demonstrates that there is a tendency of correlation between these two indices for eacg species. An increased GO activity is demonstrated in cultivars with lower level of productivity and inverse in cultivars with the highest level of productivity the GO activity is decreased (fig.1 a, b, c). So, the GO activity correlates with productivity level. This correlation is confirmed by the elimination level of CO_2 in photorespiration process of the same cultivar plants.

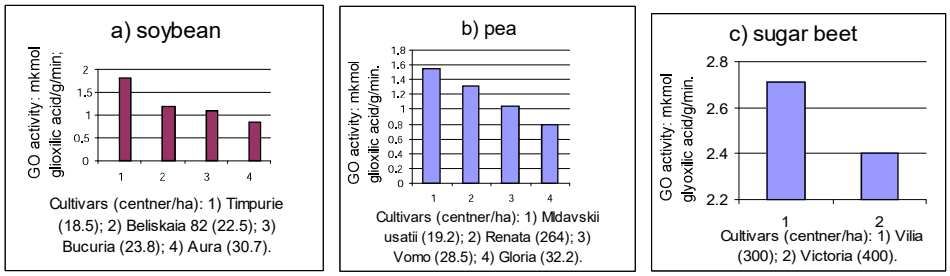

Fig.1. - Glycolate oxidase (GO) activity in crop leaves differing in productivity level.

Soybean cultivar with a lower productivity level (*Timpurie* – 18,5 centner/ha) has the highest respiration level – 3,27 µmoli CO_2 /sec/m^2, while the cultivar plants with the highest productivity level demonstrates the less level of photorespiration – 1,19 µmoli CO_2 /sec/m^2. The soybean cultivars *Beliztkaia* 82 and *Bucuria* which have approximately the same productivity level (22,5 and 23,8 centner/ha corresponding) showed approximately the same photorespiration level –2,29 and 2,68 µmoli CO_2 /sec/m^2 correspondingly. So, obtained results demonstrate that the increasing of productivity level for different plant species and cultivars is accompanied by the decreasing of plant photorespiration level. In such away a question appear: what are the processes, that provide the protective mechanisms of respiration – through the decreasing of photorespiration level or its amplification? In table 1 the data is presented on studying of photorespiration level for various species and cultivars differing in plant resistant level.

Table 1

Photorespiration for soybean and been plants under optimal conditions of growth

Specie cultivars	Year of experiments	Plant resistance	Soil humidity, % from total soil water capacity	Photorespiration, µmoli CO_2 /sec/m^2
Soybean				
Bucuria	2004	resistant	60	2.82 ± 0.4
Ghiza	2004	unresistant	60	1.83 ± 0.3
Bucuria	2005	resistant	60	1.46 ± 0.14
Ghiza	2005	unresistant	60	1.17 ± 0.01
bean				
Fetanisa	2002	resistant	60	0.44 ± 0.02
Aluna	2002	unresistant	60	0.34 ± 0.03
Fetanisa	2005	resistant	60	1.08 ± 0.16
Aluna	2005	unresistant	60	0.84 ± 0.01

The results demonstrate that plants of more resistant genotypes (soybean cultivar - *Bucuria* and bean –cultivar *Fetanisa*) have a higher photorespiration level

than plants of unresistant genotypes (soybean cultivar- *Ghiza* and bean cultivar – *Aluna*). These differences were observed for the period of two years (table 1) and also at different time intervals during the period of 27 days of plant growth under optimal conditions of soil humidity (60%) (table 2). The accumulation process of plant dry organic matter as total plant productivity characterizes the intensity of production process. The evidence of changes in this process under stress conditions comparative to changes in photorespiration process could more or less demonstrate the role of photorespiration in plant resistance to abiotic unfavorable factors. Analysis of the data presented in table 3 demonstrates that the action of water deficit in soil (30%) diminishes the accumulation process of plant dry organic matter approximately by 18% after one week of edaphic drought, by 29% after 2 weeks of edaphic drought and by 55% in 27 days of plant growth under permanent conditions of edaphic drought (30%).

The utilization of steroidal biological active substance "Ecostim" not only diminished essentially the consequence of edaphic drought action on the accumulation process of dry organic matter, but also led to the amplification of this process under the conditions of soil humidity insufficiency (table 3).

In the same experiments, which lasted for three years, the photorespiration level was studied and in relation to climate conditions of respective years. It was found out that the photorespiration level varied for the same cultivars (table 4) under optimal conditions of plant development.

But it is clearly observed the "phenomena" of considerably photorespiration diminishing in both soybean and bean cultivars grown under the edaphic conditions (table 4). This "phenomena" is much more evident in soybean and bean plants grown from seeds treated by BAS "Ecostim" water solutions before sowing.

The comparative analyzes of 2004 year data on concomitantly studies of accumulation dry matter process (table 3) for soybean plants (*Ghiza* cultivar – unresistant to drought) and photorespiration level (table 4) demonstrates an decreasing for 30 % in accumulation dry matter process of plants grown and subjected to edapfic drought conditions (soil humidity - 30 %) for two weeks comparing to plants of optimal conditions (soil humidity - 60%). In plants grown in the same conditions, but the seeds of which were treated with BAS "Ecostim" water solutions before sowing the intensity of accumulation dry matter process was diminished only by 15%. The photorespiration level in these plants decreased approximately by 38 %, while in plants of optimal conditions (soil humidity - 60%) and subjected only to drought action (without "Ecostim" application) photorespiration level decreased only by 7 %.

So, phenomenological the photorespiration level of C_3 – plants demonstrates a genotypic character. This character of photorespiration is changed under the action of exogenous factors (insufficient of soil humidity, biological active substance "Ecostim"). Both edaphic drought and BAS "Ecostim" induce processes that decrease considerably the level of plant photorespiration.

Table 2

Photorespiration of soybean plants under optimal conditions of growth at different time intervals

Soybean cultivars	Year of experiments	Plant resistance	Soil humidity, % from total soil water capacity	Photorespiration, μmoli CO_2 /sec/m^2				
				06.07	13.07	19.07	26.07	12.08
Bucuria	2004	resistant	60	3.13 ± 0.19	3.10 ± 0.002	2.82 ± 0.11	3.17± 0.3	1.83 ±0.03
Ghiza	2004	unresistant	60	1.76 ± 0.04	1.69 ±0.03	1.83 ±0.3	1.62 ±0.15	1.27 ±0.12

Table 3

The influence of humidity deficit in soil on the process of dry matter accumulation

Specie cultivars, BAS treatment	Soil humidity, % from total soil water capacity	The dynamics of dry matter accumulation (g/plant)				
		06.07.2004	13.07.2004	19.07.2004	26.07.2004	02.08.2004
Ghiza	60	1.31 ± 0.17	3.03 ± 0.25	4.61 ± 0.71	8.95 ± 1.58	13.09 ± 0.88
Ghiza	30	1.31 ± 0.17	2.54 ± 0.30	3.30 ± 0.13	4.50 ± 0.78	5.90 ± 0.13
Ghiza +Ecostim*	30	1.71 ± 0.13	3.31 ± 0.15	4.02 ± 0.06	5.00 ± 0.31	7.32 ± 0.79

* biological active substance (BAS).

Table 4

The influence of edaphic drought and biological active substance "Ecostim" on the soybean and bean photorespiration level

Specie cultivars, BAS treatment	Year of experiments	Plant resistance	Photorespiration, μmoli CO_2 /sec/m^2 Soil humidity, % from total soil water capacity	
			60 %	30 %
Aluna (bean)	2002	unresistant	0.34 ± 0.02	0.34 ± 0.03
Aluna (bean) + Ecostim	2002	unresistant	0.34 ± 0.03	0.10 ± 0.02
Ghiza (soybean)	2004	unresistant	1.83 ± 0.03	1.69 ± 0.01
Ghiza (soybean) + Ecostim	2004	unresistant	1.83 ± 0.01	1.13 ± 0.01
Ghiza (soybean)	2005	unresistant	1.28 ± 0.01	0.30 ± 0.01
Ghiza (soybean) + Ecostim	2005	unresistant	0.89 ± 0.01	0.23 ± 0.04
Aluna (bean)	2005	unresistant	0.84 ± 0.01	0.37 ± 0.04
Aluna (bean) + Ecostim	2005	unresistant	0.70 ± 0.01	0.0 ± 0.0

For the bean plants (*Aluna* cultivar) in the hydric stress conditions, application of BAS "Ecostim" reduced photorespiration up to zero. It means that the plants with C_3 – metabolism, which are characterized by the presence of photorespiration, become like plants with C_4 – photosynthesis type, in which the photorespiration is not evidenced and the elimination of CO_2 takes no place. Our results permit to conclude that the decreasing level of photorespiration level under the action of edaphic drought and BAS "Ecostim" is axed on different vectors of plant growth and development. In the case of edaphic drought action the decreasing of photorespiration level takes place concomitantly with the diminishing of plant dry matter accumulation process. These data represent an indicator of disturbances of plant metabolism. While at the application of BAS "Ecostim" the diminishing level of photorespiration is accompanied by an intensification of dry organic matter accumulation process. These data and results mentioned above, which demonstrate that the highest productivity level is assisted by a lower level of photorespiration conduct to a suggestion that the literature conclusions (2) on increasing plant productivity by the reduction of photorespiration level could not have perspective, at least they are contradictory.

CONCLUSIONS

1. The plants of more productive genotypes are assisted by a lower level of photorespiration (CO_2 elimination and glycolate oxidase activity).

2. More resistant genotypes to edaphic drought are characterized by a higher level of photorespiration compared to less resistant genotypes.

3. The action of hydric stress conditions on plants of unresistant genotypes to edaphic drought is manifested by a substantial decreasing of the both dry matter accumulation process and photorespiration level.

4. The influence of steroidal BAS "Ecostim" on plants of unresistant genotypes to edaphic drought grown up under hydric stress conditions is manifested by modification of consequences, induced by edaphic drought and is characterized by an increasing accumulation process of dry organic matter and much more reduced photorespiration level.

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