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Diversity of photosynthetic activity of organs of wheat genotypes and breeding of high-yielding varieties tolerant to water stress

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Introduction

Drought has dramatic effects on plant growth and morphogenesis and is likely to be one of the major environmental factors determining plant productivity and species distribution (Woodward, 1987). Due to its economic importance, the negative impact of water shortage on plant productivity has been studied intensively (Cornic and Massacci, 1996; Aliev et al., 1998). Proceeding from the actuality of this problem and with the purpose of studying and directed forming of mechanisms of plant adaptation to water stress genotypes collected from the regions close in soil-climatic conditions and widely cultivated wheat varieties created by us were tested under the conditions of soil drought.

Materials and methods

Evolutionary formed ancient forms, well known widely cultivated varieties and drought tolerant genotypes were investigated. The samples were chosen from the genotypes numbering ten of thousands, including received from ICARDA, CIMMYT and other regional centers of the world. The plants were grown in the field conditions under normal water supply and strong water deficit (**Fig.1**). The contribution of photosynthesis of an ear and other assimilating organs in protein synthesis of grain was defined by means of blocking photosynthesis of these organs and by exposition of $^{14}CO_2$ in atmosphere of all plants in sowing (Voznesensky, 1977; Cook and Evans, 1978). Water regime indexes were studied according to the procedure described by Boyer J. (Boyer, 1995)

Figure 1. Wheat genotypes under drought

Results and discussion

Summarizing the experiments of numerous genotypes on their tolerance to the water stress and soil drought we relatively divided genotypes on three groups:

1. Non-drought tolerant genotypes which lose on the average up to 65% of grain yield;
2. Moderate drought tolerant genotypes with the grain losing about 50% of grain yield;

3. High drought tolerant genotypes which lose on the average about 25% of grain yield.

Among these groups of genotypes there are some ones with grain losses less than 20% and more than 70%. Under the water stress conditions active photosynthetic function of different assimilating organs, mainly of an ear, together with an optimal architectonics of plants plays a decisive role in yield formation. **Figure 2** presents some characteristic data about the contribution of separate assimilating organs in grain formation of moderate tolerant variety *Shark* and high tolerant variety *Vugar*. In each of these intensive-type genotypes the contribution of organs in the total CO_2 assimilation is almost of a similar value and can be characterized by its average value. Ear photosynthesis plays a decisive role in grain formation and protein synthesis. In drought tolerant intensive variety *Vugar* more than 60% of grain formation and protein synthesis occurs at the expense of ear photosynthesis. Such advantages of drought tolerant intensive-type genotypes such as great assimilating ability of an ear in current photosynthesis and the best acceptor activity in utilization and reutilization of reserve products of photosynthesis are decisive in developing both high-yielding and drought tolerant genotypes. When leaves lose their photosynthetic functions under drought conditions an ear does main contribution in photosynthesis at earring and grain filling period. In drought tolerant genotypes the CO_2 assimilates are transported more vigorously and carbon dioxide assimilation by ears is twice intensive. For this reason in high-yielding intensive type genotypes with high photosynthetic function of an ear a considerable amount of protein is accumulated in grain under extreme water supply condition. Depending on a value of ear photosynthesis and drought tolerance of plants, under strong drought genotypes accumulate 35-70% of protein from their content in plants under normal water supply. On the other hand the process of intensified protein synthesis by ears of high productive genotypes is realized with intensive photosynthetic accumulation of CO_2. In compact sowings of these genotypes with optimum assimilating surface and sufficient donor ability the value of photosynthesis intensity is always high. Together with high photosynthetic activity and attractive force of ear it constitutes the basis of high yield. The activation of attractive forces upon blocking of an ear stimulates an increase of the CO_2 assimilation intensity with marked differences

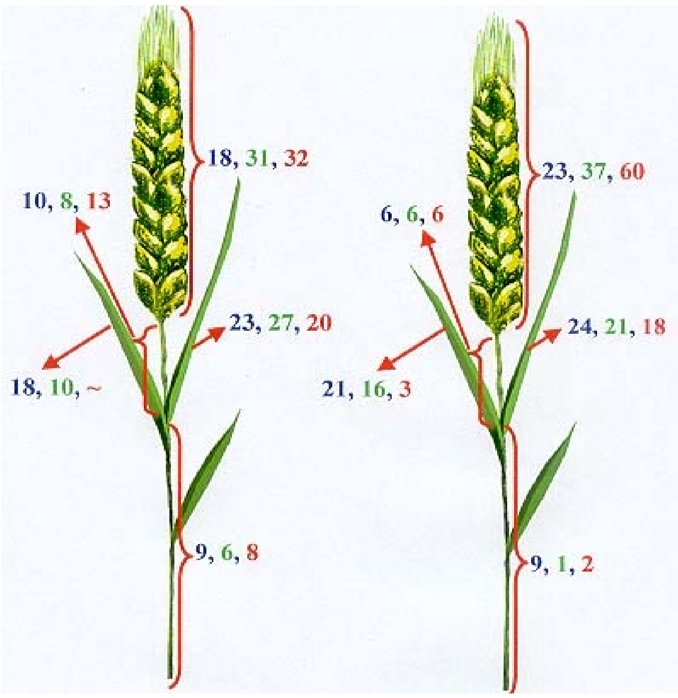

Figure 2. Contribution of separate organs in production process in wheat genotypes with different drought tolerance

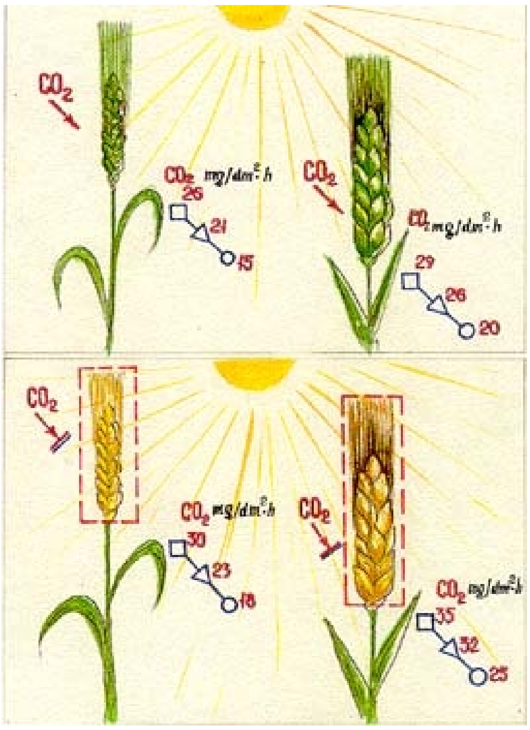

Figure 3. Role of ear photosynthesis in wheat genotypes at different phases of vegetation

Table 1. Role of ear photosynthesis in grain yield

Variety	Version	Amount of nitrogen in grain				Amount of protein at grains an ear	
		Protein nitrogen		Non-protein nitrogen			
		%	*under light*	*%*	*under light*	*mg/ ear*	*% under light*
Gyrmyzy bugda	Non-photosynthesizing	3,05	125	0,94	-	164	71
	Photosynthesizing	2,45	100	0,45	100	232	100
Garagyl-chyg-2	Non-photosynthesizing	2,53	111	0,80	-	166	59
	Photosynthesizing	2,28	100	0,42	100	283	100

among genotypes (Fig.3 and Table 1). Non-photosynthesized acceptor with intensified attractive force creates condition for increase of intensity of CO_2 assimilation by leaves up to 25-35 mg CO_2/dm^2*hour. At the same time if an ear does not photosynthesize, then we observed the changes of carbon photosynthetic metabolism and reduction of quantity of assimilates in an organ. Especially these variations are considerably displayed in high productive forms with high intensity of CO_2 assimilation (Aliev at al, 1996). It is interesting that of non-protein nitrogen increases more than twice in grain as well as in the straw of non-photosynthesized ears with prevalence increase in low productive genotypes. Therefore it is possible to speak about a great amount of nitrogen which is not used for ear synthesis. By other words the low protein percentage is connected not with the lack of nitrogen content but with shortage of carbohydrates necessary for protein synthesis. As a result, upon blocking of an ear the formation of grain completed by protein accumulation in it up to 45%. Other action occurs in intact plants in atmosphere of $^{14}CO_2$ when all organs function normally under natural condition and true potential contribution of an ear and its elements in grain formation and protein synthesis (up to 60%) are revealed.

C_4-cycle enzymes (PEP-carboxylase, NAD- and NADP malate dehydrogenase) play a certain role in adaptation to water stress in C_{-3} plants. High-yielding wheat genotypes tolerant to water stress have high activities of C_4-cycle enzymes in leaves and elements of ear; under the water stress the C_4-cycle are activated. By comparative investigation on photosynthetic carbon metabolism it was established that the values of ratio of true photosynthesis to photorespiration in the leaves and ear elements of genotypes with various rates of CO_2 assimilation are close and equal at average to 3:1 with some increase in intensive genotypes. Thus, it is possible to denote the parallel increase of the intensity of true photosynthesis and photorespiration in ontogenesis of leaves and therefore the attempts to reduce photorespiration with the purpose of increase the producti-vity are inconsistent. The rate of photorespiration in some degree is in inverse correlation with the water supply. By increasing of a tolerance of genotypes to water stress or with increasing of drought, the rate of photorespiration decreased to a large degree in the elements of ear.

As a matter of investigation the series of genotypes with high activities of the primary processes and photosynthetic CO_2 metabolism under water stress, having the appropriate morphophysiological characters were revealed. The use of these genotypes in combination with studying photosynthetic parameters, which connected with activities both of ear and other non-leaf organs and high productivity of a grain protein, served as the basis of creation of high tolerant varieties. Genotypes with evolutionary fixed properties of tolerance to water stress were used for breeding, as an initial material of maternal forms in the creation of high tolerant varieties. As a result of purposeful breeding activities, the new ***T. durum L.*** variety *Barakatli* was obtained - the best one among stated indexes that were examined - non lodging, frost and drought tolerant, with yielding capacity of 7 t/ha and with excellent grain quality.

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