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Photosynthesis of different plant organs in short stem rye

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Introduction.

In the process of short-stem rye breeding, the stem has lost 40% of its height and morphology of other ograns has also changed, for instance, the number of spikelets in the ear increased and leaf parameters changed (Kobylyanskii, 1975).

The results of research aimed at revealing the individual organs' contribution to the overall photosynthesis of short-stem winter rye have been published recently (Kobylyansky, 2003). The present work offers the results of studies of assimilate outflow from the top leaves of a plant, which are the main suppliers of assimilate to caryopses during the period of grain formation.

Materials and methods.

The research concentrated on the long-stem winter rye cultivars Kamalinskaya 4, Kazanskaya and Vyatka 2 and their short stem analogs bred by us, namely cvs. Kamalinskaya 4Hl, Kazanskaya Hl and Rossiyanka.

Assimilate partitioning was studied in two upper leaf layers during the caryopsis formation period and at the milky ripeness stage.

To study assimilate outflow from leaves, the method recommended by A. P. Ivanova (1974) was applied. According to this method, radiocarbon (^{14}C) is incorporated in the form of sodium carbonate. For this purpose, a ~1 cm long leaf tip (of the main shoot) is cut off and a narrow, 2-3 cm long polyethylene pouch with 0.1 ml (5-8 μCi) labeled bicarbonate solution, is put on the leaf.

Results and discussion.

The rye straw shortening has caused shifts in importance of different plant organs for the grain yield formation. In the short-stem plants, the role of leaves at all layers, as well as of the ear throughout the vegetative period, has increased. In the long-stem plants, the major contribution to the overall photosynthesis is made by the stem and leaf sheaths, while the share of photosynthetic contribution made by leaves predominates only during the vegetative growth period (Kobylyansky, 2003).

A study of assimilate movement from the two top leaves during the caryopsis formation period has shown that the main amount of assimilate from the flag leaf and from the 2nd leaf from the top in the short-stem analogs is imported by the ear. Accumulation of ^{14}C in the part of the stem above the leaves serving as sources of ^{14}C indicates the direction of assimilate movement towards the ear. In the long-stem cultivars, the apparent outflow of assimilate to the ear has been recorded for the flag leaf only, while from the 2nd leaf from the top the assimilate movement is directed into the stem, mainly to its lower part (Tab.1).

It should be specially noted that in the short-stem analogs the ear uptakes (within a day) 2 times more, and caryopses almost 3 times more assimilate from the flag leaf, if compared with the initial cultivars. The greater part of assimilate was found also in caryopses in the case of outflow from the 2nd leaf from the top, and this marks the fundamental difference from the initial-long stem cultivars. Thus, in the short-stem rye these are the flag leaf and the 2nd leaf from the top that actively participate in grain formation from the very beginning, while in the long-stem cultivars grain formation during this period is supported by the flag leaf only.

Assimilate outflow from the top leaves during grain formation occurs in a similar way in plants with different morphotypes. For instance, at the milky ripeness stage, assimilate from both top leaves move mainly into the ear in all forms of rye.

Table 1. Assimilate partitioning in a winter rye plant at the beginning of the caryopsis formation period (as % of the total ^{14}C content in the shoot)

Plant organ	Long stem			Short stem		
	1	2	3	4	5	6
^{14}C incorporated into the flag leaf						
Flag leaf	44.5	43.0	39.1	43.9	44.3	31.9
Other leaves	1.7	2.0	0.9	2.6	1.4	3.5
Stem	35.6	32.8	31.7	7.9	2.3	5.4
above the flag leaf	20.0	24.4	17.3	5.8	1.9	3.3
below the flag leaf	15.6	8.4	14.4	2.1	0.4	2.1
Ear	18.2	22.2	28.3	45.6	52.0	59.2
glumes	10.4	9.2	7.5	9.8	4.7	6.8
grain	7.8	13.0	20.8	35.8	47.3	52.4
^{14}C incorporated into the 2nd leaf from the top						
Second leaf	51.5	55.0	47.1	50.9	47.2	44.1
Other leaves	1.4	2.8	2.5	4.0	6.1	2.8
Stem	46.4	41.8	48.4	8.0	7.5	10.2
above the 2nd leaf	17.2	7.8	8.3	5.8	6.1	8.6
below the 2nd leaf	29.2	34.0	40.1	2.2	1.4	1.6
Ear	0.7	0.4	2.0	37.1	39.2	42.9
glumes	0.3	0.3	1.6	4.4	4.7	4.8
grain	0.4	0.1	0.4	32.7	34.5	38.1

1– Kamalinskaya 4; 2 – Kazanskaya; 3 –Vyatka 2; 4 – Kamalinskaya 4HL; 5 – Kazanskaya HL;6 – Rossiyanka

Table 2. Assimilate partitioning in a winter rye plant during the milky ripeness period (as % of the total ^{14}C content in the shoot).

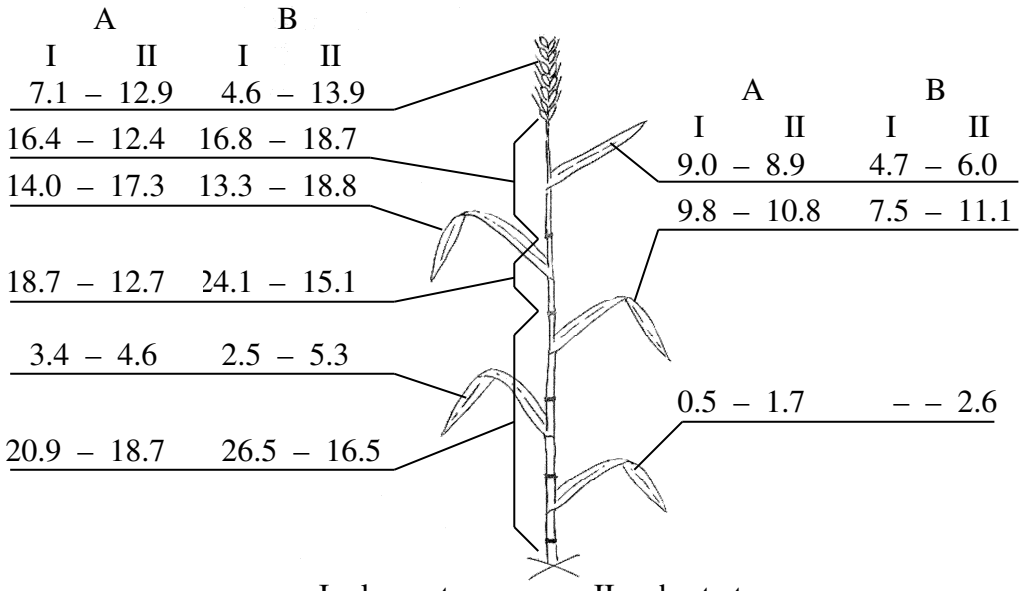
Plant organ	Long stem			Short stem		
	1	2	3	4	5	6
^{14}C incorporated into the flag leaf						
Flag leaf	35.8	44.2	50.7	50.0	55.4	46.6
Other leaves	0.5	1.4	0.7	1.8	1.7	1.5
Stem	16.6	6.5	14.4	9.4	10.1	8.1
above the flag leaf	16.2	6.5	14.0	9.4	10.1	8.1
below the flag leaf	0.4	+	0.4	+	+	+
Ear	47.1	47.9	34.2	38.8	32.8	43.8
glumes	3.9	2.6	3.8	4.7	4.3	3.4
grain	43.2	45.3	30.4	34.1	28.5	40.4
^{14}C incorporated into the 2nd leaf from the top						
Second leaf	47.3	55.7	60.0	59.6	58.6	51.4
Other leaves	0.1	1.0	0.6	2.2	0.5	1.8
Stem	24.5	33.7	15.9	6.2	9.4	11.9
above the 2nd leaf	11.9	12.3	12.8	4.1	7.8	11.2
below the 2nd leaf	12.7	21.4	3.1	2.1	1.6	0.7
Ear	28.1	9.6	23.5	32.0	31.5	34.9
glumes	1.7	0.7	1.2	4.7	3.6	2.1
grain	26.4	8.9	22.3	27.3	27.9	32.8

1– Kamalinskaya 4; 2 – Kazanskaya; 3 –Vyatka 2; 4 – Kamalinskaya 4HL; 5 – Kazanskaya HL; 6 – Rossiyanka.

A the same time, a comparison with the previous stage shows that in the short-stem analogs the outflow of assimilate from the top leaves somewhat slows down. The import of assimilate into the ear from the flag leaf decreases on the average from 52% at the stage of caryopsis formation down to 38% at the milky ripeness stage, and that from the 2nd leaf drops from 40 down to 34%, respectively (Tab. 2).

The contribution of different organs to the overall photosynthesis has been changing in all forms of rye throughout their vegetation. Before ear emergence, the largest contribution was made by leaves: 55% in the short-stem and 50% in the long-stem plants. In the short-stem analogs, the contribution made by leaves (40%) stayed high throughout the vegetation, while in the long-stem cultivars it decreased in the end of flowering stage, and by the end of caryopsis formation amounted to just 1/3 of the overall photosynthesis. The role of stem in photosynthesis during the milky ripeness stage was over 67% in the long-stem cultivars and equalled 42% in the short-stem ones.

The ear and upper part of the short-stem plants were making a greater contribution to the overall photosynthesis throughout vegetation than the same parts of the long stem cultivars [2]. At the later stages of grain formation in the long-stem cultivars, the inflow of assimilate into the ear from the flag leaf increased from 23% at the caryopsis formation stage up to 43% at the milky ripeness stage, and the inflow from the 2nd leaf – from 1 to 20%, respectively. Nevertheless, a comparison with the short-stem analogs showed that the amount of assimilate transported to the stem from the flag leaf within a day was 1.3 times higher and that from the 2nd leaf – almost 2 times higher (Tab. 2).



I – long-stem II – short-stem

A – beginning of grain formation B – milky ripeness

	I	II		I	II
EAR:	7.1	12.9	EAR:	5.8	13.5
LEAVES:	36.9	43.3	LEAVES:	32.5	43.5
STEM:	56.0	43.8	STEM:	61.7	43.0

	A		B	
	I	II	I	II
Ear + upper internode + flag leaf:	32.5	34.2	26.1	30.6
Upper part of the plant + 2nd leaf from the top:	46.7	51.5	39.4	49.4

Fig. 1. Contribution of different plant organs to the overall photosynthesis (%).

In the short-stem rye, assimilate from the top leaves is supplied directly to caryopses throughout the grain formation period, it being a positive factor lacked by the initial long-stem cultivars of winter rye. This is an evidence that the 'stem model' of photosynthesis of the long-stem rye has transformed into the 'leaf model' of wheat. As the result, the total assimilate supplied to the ear from the two top leaves of the short-stem rye during the grain formation period sufficiently exceeds this amount in the long-stem cultivars (Fig. 1.).

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