Photosynthesis, translocation and accumulation of assimilates in cereals during grain development

I. Investigations on spring barley and wheat by application of shading and defoliation technique

H. BIRECKA, J. SKUPIŃSKA, U. WOJCIESKA, E. ZINKIEWICZ

The contribution of particular green parts of the plant to the accumulation of organic compounds in the grain of cereals has been the subject of many investigations. In barley and wheat the dry weight increase of shoots after ear emergence till full maturity may account for 30—40 per cent of their final weight. This great increment occurs in a relatively short period as compared to the whole time of plant growth. According to a number authors (Archbold, Mukerjee 1942; Archbold 1942; Asana, Mani 1955; Boonstra 1936; Porter 1950; Watson and others 1958) the weight of the vegetative parts during this period does not decrease significantly. Hence the conclusion is drawn, that the assimilates accumulated before ear emergence do not play any marked role in grain development of the aforementioned species. On the other hand the products of current assimilation in the later period are considered to be of decisive importance.

Many experiments and observations (Asana, Saini 1958; Boonstra 1936; Krawcowa 1957; Niczporowicz 1961; Pietinow, Pawłow 1957; Porter 1950; Starzycki 1959; Thorne 1959) show, that the assimilating area, especially of leaf laminae, decreases considerably after ear emergence; moreover the ageing process of leaves still green brings about a decrease in their photosynthetic capacity. The influence of nitrogen on the assimilating area of leaves is well known. According to Thorne and Watson (1955) the increase in grain yield as a result of higher N doses applied occurs only when the increased green leaf area is maintained after ear emergence.

The aforementioned facts drew the attention of various authors mainly to the contribution of the upper leaves, stem and sheaths and of the ear to the accumulation of organic compounds in the grain. The investigations in most cases were carried out by the use of shading or defoliation technique. Sometimes tillers were also removed. This technique has been applied after ear emergence for the whole subsequent period of development or at two-week intervals.

The results of many investigations concerning the role of laminae of older leaves — except for the flag leaf only or two upper leaves — are in general in agreement. It is assumed that the contribution of their assimilates to the grain yield of barley as well as of wheat is small and does not exceed 10—15 per cent (Archbold, Mukerjee 1942; Archbold 1942; Boonstra 1936; Pietinow, Pawłow 1957; Porter 1950).

The amount of assimilates from the flag leaf lamina — according to Archbold (1942) — accounts in barley for about 18 per cent of the grain weight. The contribution of this leaf including its sheath and the peduncle is estimated by Porter (1950) at 30, and by Watson and others (1958) at 59 per cent. It should be stressed that some of the aforementioned authors attribute great importance to sheaths, which in barley at ear emergence, account — according to Thorne (1959) — for half of the total assimilating area of the plant, and the rate of their true photosynthesis does not differ greatly from the rate of this process in leaf laminae. However the contribution to the barley grain yield of assimilates formed in the stem (including sheaths) below the flag leaf is estimated at 10—15 per cent only (Archbold, Datta 1944; Watson and others 1958).

In field experiments with wheat carried out for several years by Boonstra (1936) the assimilates from the flag leaf lamina accounted for about 12 per cent of the grain yield (all other leaves together gave the same amount). However the results obtained by Asana and Mani (1950, 1955) show that the contribution of all leaf laminae (including the flag leaf) may account for 32—50 per cent depending on the variety and conditions of growth. Boonstra estimates the amount of photosynthetic products from stems (with sheaths) of wheat at about 45 per cent (from which 10 per cent should give the peduncle) of the grain weight. In experiments of Asana and Mani the value varied between 28 and 53 per cent.

There is a wide range of estimates concerning the role of photosynthesis in the ear itself. In the early investigations of Watson and Norman (1939) on two-rowed barley the contribution of ear assimilates to the grain yield accounted for 25—35 per cent. Very similar values were obtained by Archbold and others (1942, 1944), Thorne (1962a, b), Watson and others (1958) and also by Porter (1950), who — in contrast to other authors — determined the net assimilation in the ear of a two-rowed barley variety by direct measurement of carbon dioxide uptake. The latter, as well as Thorne (1961), found that the greatest rate of photosynthesis in the ear occurs during the first two weeks after emergence.

Buttrose and May (1959) on the other hand estimate the real role of ear assimilates at about 50 per cent of the grain yield, and

Frey-Wissling and Buttrose (1959) — even at 75% (experiments with 2-rowed barley). According to Buttrose and May as well as other authors (Thorne 1961; Vervelde 1953) the degree of contribution of photosynthesis in the ear depends on its assimilating area. This area will depend in turn on the number and length of awns as well as on the number of rows. The removal of awns brings about a marked decrease in the grain yield (Harlan 1920). According to Watson and others (1958) the contribution of photosynthesis in awns accounts for about 10 per cent of the yield. Thorne (1961) estimates the amount of ear assimilates in a six-rowed barley variety at about 43 per cent of the grain weight, whereas in the two-rowed varieties at about 30 per cent.

The estimates for ear assimilates in wheat, recorded by different authors, vary between 14 per cent (Thorne 1962; Pietinow, Pawłow 1957) to 30 per cent (Boonstra 1936) of the grain yield. In experiments of Asana and Mani (1950, 1955) the contribution of the ear was about 11 per cent in an awnless variety and 21—26 per cent in awned varieties. According to Asana and Saini (1958a, b) the differences between wheat varieties in grain yield depend mainly on the assimilating area of the ear and on the rate of its yellowing.

All data reported above are based as already mentioned — except for experiments by H. Porter — on the differences obtained as a result of shading or removal of particular plant organs. This technique has met with some criticism from certain authors even from those who have applied it. Archbold (1944), Boonstra (1936), Watson and Norman (1939) have analysed the influence of trauma, of differences in temperature, in ageing, or of compensation processes, caused by shading or defoliation. Others (Buttrose, May 1959; Frey-Wissling, Buttrose 1959) point out the possibility of a more intense translocation of assimilates from vegetative organs to the kernels when the ear is shaded. Nevertheless according to these authors the observed "artefacts" are not so great that the results obtained must be considered as uncertain*. Not long ago Watson and others (1958) and Thorne (1961) have reported that ear shading did not bring about any significant differences in the weight of vegetative parts of barley as compared to the control.

The problem of the contribution of particular plant organs of cereals in the accumulation of organic compounds in the grain has not only a purely physiological but also a practical aspect, of considerable impor-

* Frey-Wissling and Buttrose assume, that by differentiating the kernel number in barley ears immediately after emergence it is possible — with the help of some additional technique — to eliminate the error caused by the differences in carbon translocation to ears.

tance for plant breeding as well as for plant cultivation. Starting investigations on cereal varieties cultivated in Poland it seemed expedient to test to what extent reliable results can be obtained by the technique of shading and defoliation. We were led to this by the wide range of experimental estimates for a particular plant organ, especially for the ear and also by the critical remarks mentioned above. Therefore in the investigations presented here the results obtained for particular organs in each experiment by the use of different treatments, previously applied by various authors, are compared.

METHODS AND OBSERVATIONS

Experiment 1960

A. Pot experiments were carried out in the greenhouse (of the Warsaw College of Agriculture) on a mixture of Vistula sand and soil (1 : 1), pH of which was about 6.5. Mineral nutrients before sowing (mg per pot): N ($\text{NH}_4\text{NO}_3 + \text{KNO}_3$) — 500, K_2O ($\text{KNO}_3 + \text{K}_2\text{SO}_4$) — 500, P_2O_5 ($\text{NaH}_2\text{PO}_4 + \text{NaHPO}_4$) — 300, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ — 615. In addition 5 g of CaCO_3 and microelements (B, Mn) were applied.

Barley, var. "PZHR Browarny" (in all experiments described below the same variety was investigated) was sown on April 27, wheat, an awnless var. "Bajka" — two days later. Full sprouting was noted 6—7 days after sowing. The plants were thinned down gradually to 12 per pot (the last thinning treatment — immediately before the first harvest). At the time of tillering the plants were dressed with N — 300, K_2O — 200, P_2O_5 — 200 mg. per pot. The soil humidity was maintained at 60 per cent of its water capacity.

After five weeks of growth the tillers were removed (2—3 small tillers per barley and 1—2 per wheat plant). The beginning of ear emergence was observed in barley on June 14, in wheat — on June 21. The first harvest of barley was completed on June 21, and of wheat — on June 27 after having removed all lower leaves which were dead (4—3 leaves per plant respectively). Three green leaves (including the flag leaf) were left on each plant.

On the day of the first harvest the plants of each species were divided - according to the treatments applied — into the following series: 1) control, 2) flag leaf * removed, 3) two lower leaves * removed, 4) all leaves removed, 5) ear shaded, 6) all vegetative parts shaded, 7) all leaves removed, stem shaded, 8) lower leaves and stem shaded, 9) lower leaves removed, stem shaded, 10) ear removed. The appro-

* Strictly speaking — leaf lamina, the word leaf will be used subsequently with this meaning.

priate aerial parts were cut off or shaded by a double sheet of white and black (on the inside) paper. The plants of each treatment were harvested twice (harvest II and III): barley on July 6 and 21, wheat — on July 12 and on August 4. At the last harvest the plants were at full maturity. The number of replicates was 18 (2 plants each).

On the harvest II in barley the lowest leaf and two lower internodes of the control were completely yellow (the beginning of flag leaf yellowing was noted on July 14). In the treatments, in which particular organs were shaded or cut off, parts exposed to light were greener and for a longer time than in the control. This was especially remarkable in the flag leaf and was observed also in the awns. Plants deprived of ears after 9—10 days formed new tillers. The ears matured a little earlier when they were shaded.

Wheat plants — on the harvest II — had two upper leaves fully green, the third one was partially yellow. The reaction of plants to the treatments applied was similar to the reaction observed in barley.

B. Field experiment: at the experimental farm at Puławy barley and wheat (var. "Bajka") were sown in strips of two rows (the distance between rows — 7, between strips — 30 cm). In the sixth week of growth tillers were removed. On the fifth day after ear emergence (i.e. on July 17 — in barley) the treatments 1, 2, 3, 4, 5, 7 and 9 were applied after having removed all dead leaves (the plants had only three green leaves at that time). Barley was harvested at full maturity (40 replicates, 2 plants each). Unfortunately wheat plants could not be harvested because of a flood.

Experiments 1961

This year only pot experiments were carried out (in the greenhouse at Puławy). In these experiments — besides barley — a greater number of spring wheat varieties was investigated, i.e. awnless varieties „Bajka”, „Fortunata”, „Opolska” and an awned one — „Ostka Chłopicka”. A mixture of soil and sand (7 + 2 kg.) of pH —7 was used. The basal dressing was analogous as in 1960 (without CaCO_3). Barley was sown on April 19, wheat on April 21. Full sprouting was noted 5 days after sowing. At the time of tillering the plants were dressed as in 1960. A second top dressing was applied at the stage of shooting (N — 200, P_2O_5 — 200 and K_2O — 300 mg. per pot). Full ear emergence in barley was noted on June 12. Each plant had formed two ears (the main shoot and one tiller), which emerged simultaneously. Only a few plants had at that time a second very small tiller. The beginning of ear emergence in wheat was observed: var. „Opolska” — on June 11, „Ostka Chłopicka” — two, „Fortunata” — three, „Bajka” — five days later. Flowering was noted 5—6 days after ears began to emerge. In all investi-

Table 1

The state of control plants during the period from ear emergence to maturity

On the day of harvest	The state of plants *
I	Barley: the lowest leaf partially yellow, other plant organs - green; wheat: var. "Bajka" - all three leaves green, "Fortunata" - half of the lowest /third/ leaf yellow, "Opolska" - all four leaves green, "Chłopicka" - the lowest /fourth/ leaf, 1/5 only green.
II	Barley: the lowest leaf completely yellow; the lower part of stems also yellow; wheat: var. "Bajka" half of the lowest leaf dead, the lower part of the stem without chlorophyll; "Fortunata" - the lowest leaf and 1/2 of the second one dead, "Opolska" - the lowest leaf dead, the third one, 1/3 green, "Ostka Chłopicka" - the lowest leaf dead, the third and the second one only half green.
III	Barley: only flag leaf green, the upper half of the stem /with sheathes/ green, awns and glumes still green; wheat: var. "Bajka" - flag leaf green, the second one, only 1/3 green; "Fortunata" - flag leaf beginning to turn yellow, the second one - almost completely yellow. Only two internodes green, "Opolska" - only flag leaf green, "Ostka Chłopicka" - flag leaf green, the second one only partially green.
IV	Barley: - 1/4 of the flag leaf green, ears beginning to turn yellow, only the peduncle green; wheat: all varieties - flag leaf almost completely dead, ears turning yellow.
V	Plants at full maturity.

* The state of the barley tiller at various times of observation was similar to the state of the main shoot.

gated varieties only main shoots formed ears. The tillers (1—2 per plant) were very small.

The first harvest of barley was completed on June 14, and of wheat: var. „Opolska” on June 19, „Ostka Chłopicka” — on June 21, „Fortunata” — on June 22, „Bajka” — on June 24, at the same time removing small tillers and lower leaves, which were completely yellow (their total weight was in barley about — 0,39 g., in wheat — 0,19 — 0,31 g. per plant). The number of green leaves left on the plant accounted in barley for three (per shoot), in wheat var. „Bajka” and „Fortunata” for three, var. „Opolska” and „Ostka Chłopicka” — for four.

Taking into account the reaction to treatments applied after ear emergence in 1960, in the reported experiments plants were divided into

several groups and the appropriate treatments were applied for a relatively short period, i.e. for 8—10 days. The first group was treated on the day of the first harvest *. At the end of each period the investigated plants were harvested and analogous treatments were applied to the subsequent group of plants, which up till then were treated like controls.

In the experiment with barley the following plant series were investigated: 1) control, 2) tiller removed, 3) awns from both ears removed, 4) ears shaded, 5) all vegetative parts shaded, 6) all leaves removed, stems shaded; in the experiment with wheat: 1) control, 2) flag leaf

Fig. 1

Fig. 2

Fig. 1, 2. Dry weight of barley — g.d.m. per plant. Experiment 1961.

A — total, main shoot; A₁ — total, tiller; B — grain of the main shoot; B₁ — grain of the tiller; C — stem of the main shoot; C₁ — stem of the tiller; D — leaves of the main shoot; D₁ — leaves of the tiller; E — chaff, main shoot; E₁ — chaff, tiller.

* On the same day some plants of each wheat variety were top dressed with 400 mg. N per pot. As they formed new tillers, the results obtained in this treatment are not reported below.

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 3—8. Dry weight of wheat — g.d.m. per plant. Experiment 1961.
A — total; B — grain; C — stem; D — glumes; E — lower leaves; F — flag leaf.

var. „Ostka Chłopicka”

LSD.

Fig. 9

Fig. 10

Fig. 9, 10. Dry weight of wheat var. „Ostka Chłopicka” 9 g.d.m. per plant. Experiment 1961.

A — total; B — grain; C — stem; D — glumes and awns; E — lower leaves; F — flag leaf.

removed, 3) lower leaves removed 4) stem shaded, 5) ear shaded, 6) ear removed. In the var. „Ostka Chłopicka” treatment 4 was omitted since there were not enough plants.

In Table 1 the state of control plants at particular harvests is reported. The reaction of barley to the treatments applied was hardly noticeable at any time during the investigations. In wheat on the other hand the reaction at the end of each period was clearly manifest and was of the same character as in the experiment 1960. However it should be added, that no plants deprived of ears — except for var. „Fortunata” — formed new tillers after 8—10 days (the stems of these plants were greener than in the control).

All plants immediately after being harvested were killed at 100° and dried at 60°C.

RESULTS

Barley

Table 2 presents the dry weight increase of barley investigated in 1960. The results from plants deprived of ears are not reported on account of their having formed new tillers*. The total increment in the

* For the same reason the results of this treatment in wheat — in 1960 — will also be omitted.

Table 2

Dry weight increment of barley during the last month of growth - mg d.m.
per plant.

Pot experiment 1960.

No.	Treatment	Date of harvest	Flag leaf	Lower leaves	Stem*	Chaff	Grain**	Total
	Control	20.VI	54	299	1024	147	144	1.667
I	Control	changes in dry weight						
		6.VII	0	-103	+19	+10	+696	+622
		21.VII	-10	-38	-115	+11	+313	+161
		20.VI-21.VII	-10	-141	-96	+21	+1009	+783
II	Flag leaf removed	6.VII	-	-127	+15	+30	+638	+556
		21.VII	-	-21	-89	+5	+236	+131
		20.VI-21.VII	-	-148	-74	+35	+874	+687
III	Lower leaves removed	6.VII	+5	-	-58	+4	+615	+566
		21.VII	-17	-	-56	0	+242	+169
		20.VI-21.VII	-12	-	-114	+4	+857	+735
IV	All leaves removed	6.VII	-	-	-123	+4	+625	+506
		21.VII	-	-	+3	-3	+167	+167
		20.VI-21.VII	-	-	-120	+1	+792	+673
V	Ear shaded	6.VII	+10	-141	+57	-9	+554	+471
		21.VII	-6	-2	-128	+7	+215	+86
		20.VI-21.VII	+4	-143	-71	-2	+769	+557
VI	All leaves and Stem shaded	6.VII	-16	-158	-123	+24	+412	+139
		21.VII	+2	0	-10	-13	+77	+56
		20.VI-21.VII	-14	-158	-133	-11	+489	+195
VII	All leaves removed, stem shaded	6.VII	-	-	-120	+17	+363	+260
		21.VII	-	-	+11	+8	+108	+127
		20.VI-21.VII	-	-	-109	+25	+471	+387
VIII	Lower leaves and stem shaded	6.VII	+7	-166	-81	+38	+638	+436
		21.VII	-17	+7	-13	-19	+243	+201
		20.VI-21.VII	-10	-159	-94	+19	+881	+637
IX	Lower leaves removed, stem shaded	6.VII	+10	-	-83	+28	+575	+530
		21.VII	-19	-	-2	-10	+276	+245
		20.VI-21.VII	-9	-	-85	+18	+851	+775
	L.S.D. /p-0,05/		9	20	48	10	48	106

* Including the rachis.

** The number of grains per ear in all treatments accounted for 26-27.

control within the last month of growth was relatively high — about 50 per cent of the weight noted after ear emergence (this increase occurred mainly during the first two weeks). However the grain increment was greater.

When the plants were deprived of the flag leaf or lower leaves or of all leaves, their total increment after 16 days was smaller than in the control. However the difference — max. 19 per cent — is statistically proved only for the latter treatment (the increments in the later period did not differ from those of the control). In all these cases the grain weight was also less, but only by about 9—12 per cent. However, as changes in other plant parts indicate, it is hard to assume, that the real contribution of current photosynthesis in leaves to the accumulation of organic compounds in the grain was so small during the investigated period. For the results obtained show that: 1) the removal of the flag leaf caused during the subsequent 16 days: a) an increased transfer of earlier accumulated assimilates from the lower leaves, b) an increment of the glumes and awns, which could bring about a more intense CO_2 fixation in the ear itself; 2) the removal of lower leaves, especially together with the flag leaf caused a marked decrease in the stem weight. It must be remembered that the stems (with sheaths) in these treatments were greener than in the control. It can be seen from the comparisons of treat. VI and VIII, and treat. VII and IX, to what extent the observed "artefacts" could have influenced the results. These treatments, as I and II, are also supposed to supply information about the role of the flag leaf. The difference between I and II would show, that the contribution of flag leaf assimilates to the total and grain increment during the last month of growth accounts for 12—13 per cent. According to VI and VIII this contribution would be about 56 per cent of the total and 40 per cent of the grain increment. The difference between VII and IX

T a b l e 3

Contribution of photosynthesis in the ear to the plant increment calculated from differences in total and grain weights after various treatments - per cent of the weight increase in the control.

Date of harvest	Treatments					
	ear shaded		all leaves and stem shaded		leaves removed, stem shaded	
	total	grain only	total	grain only	total	grain only
6. VII	24	20	22	59	42	52
21. VII	47	33	35	24	79	34
20.VI - 21.VII	29	23	25	48	49	47

gives 50 and 38 per cent respectively. Confining the comparison just to the first period of investigation shows a similar divergence of results.

The role of current photosynthesis in the stem (including sheaths) could be estimated from treat. IV and VII and treat. III and IX. In the first case its contribution would amount to 36 per cent of the total and 32 per cent of the grain increment, in the second case its contribution would be nil. Clearly, this divergence results from the different reaction of the flag leaf, stem and ear to the various treatments applied.

The role of photosynthesis in the ear itself could be estimated comparing treatments V, VI and VII with the control. The values obtained (Table 3) are also divergent. It should be noted, that 1) ear shading brought about a clear reaction of the flag leaf; the weight decrease in lower leaves was greater in the first period — although at the end of the experiment it was the same as in the control; 2) shading all vegetative parts (VI) caused a marked reaction of awns and glumes; moreover in this case a greater weight decrease in all these parts is manifest. If assumed that their respiration rate was similar to that of the control, then in this treatment the contribution of assimilates accumulated earlier to the grain increment can be considered greater, particularly during the first 16 days.

It is precisely these facts, so it seems, that caused great differences in the results concerning the role of photosynthesis of the ear in the total as well as in the grain increment of barley. These results may be either too low or too high depending on the character of the treatment applied.

In the field experiment (Table 4) the grain increment in the control during the last month of vegetation was about 50 per cent higher than the total increment (there are appreciable differences — as compared to the pot experiment — in the growth rate before and after ear emergence).

Removal of the flag leaf had no significant influence either on the total or grain yield. On the other hand in the plants deprived of lower leaves the total increment was about 50 per cent less. The difference however in their grain increment did not exceed 10 per cent. This is — in all probability — the result of a higher supply to the ear of assimilates accumulated earlier in the plants.

The contribution of photosynthesis in the stem to the total plant increment would be nil — if the results of treat. III and VII were taken into account, and would be very high — about 50 per cent (and 40 per cent of the grain increase) — if the treat. IV and VI are considered.

The data obtained for the net photosynthesis in the ear are also divergent. According to treat. V (ear shaded) the contribution of ear assimilates would be at least (the value of the L.S.D. is high) 35 per cent of the total and about 20—30 per cent of the grain increment. According to VI (all leaves removed, stem shaded) it would be nil. An analogous

T a b l e 4

Dry weight increment of barley during the last month of growth

g d.m. per plant

Field experiment 1960

No.	Treatment	Flag leaf	Lower leaves	Stem*	Chaff	Grain**	Total
	Control after ear emergence-17.VI	0.06	0.34	1.86	0.18	0.22	2.66
		changes in dry weight at full maturity					
I	Control	-0.12	-0.38	-0.01	+1.10	+0.59	
II	Flag leaf removed	-	-0.14	-0.49	+0.01	+1.14	+0.52
III	Lower leaves removed	-0.03	-	-0.61	-0.08	+1.00	+0.28
IV	All leaves removed	-	-	-0.61	-0.06	+0.97	+0.30
V	Ear shaded	-0.14	-0.49	-0.05	+0.88	+0.20	
VI	All leaves removed; stem shaded	-	-	-0.58	-0.06	+0.64	0
VII	Lower leaves removed; stem shaded	-0.04	-	-0.52	-0.04	+0.88	+0.24
	L.S.D. /p-0.05/	0.033	0.101	0.020	0.071	0.172	

* Including the rachis.

** The number of grains per ear in all treatments accounted for 27,3-28.4

treatment in the pot experiment gave the highest value for the ear contribution.

In the pot experiment 1961 the grain increment — in the main shoot as well as in the tiller — was similar to their total weight increase (Fig. 1, 2. p. 441). An increment of the stems during the first days of investigation — amounting to 25 per cent of the total — is worthwhile noting. This accumulation of organic compounds in the stems was transient, because after the subsequent week their weight was the same as at the beginning of the experiment.

The plant increments having been relatively very small in the period following the second harvest, all differences between treatments at that time could not be statistically proved. Therefore in Table 5 the results of the first period only, i.e. between June 14 and 22 are presented. In this experiment the attention was paid mainly to the role of photosynthesis in the ears. The contribution of assimilates from awns in the

T a b l e 5

Changes in the weight of barley after various treatments during the period
from the first to the second harvest.
Pot Experiment 1961.

No.	Treatment	Main shoot					Tiller				
		leaves	stem	chaff*	Grain**	total***	leaves	stem	chaff**	Grain***	total
I	Control	-14	+128	+42	+355	+511	+8	+149	+39	+241	+437
II	Tiller removed	-3	+138	+51	+328	+514	-	-	-	-	-
III	Awns removed	-7	+23	+15	+315	+346	+5	+36	+10	+214	+265
IV	Ears shaded	-11	+45	+12	+184	+230	+7	+41	+23	+125	+196
V	Leaves and stems shaded	-30	-46	+45	+169	+134	-22	-54	+23	+121	+68
VI	Leaves removed; stems shaded	-	-85	+26	+165	+106	-	-29	+23	+119	+113
	L.S.D. /p=0.05/	53			51	98		54			70

* At the first harvest the dry weight of awns was 71, and of glumes - 20 mg per ear, at the harvest second /control/ - 98 and 35 mg respectively.

** First harvest: awns - 50; glumes - 12 mg, harvest second - 74 and 27 respectively.

*** The number of grains per ear in all treatments accounted in the main shoot for 20.7-21.3, in the tiller 17.0-17.9.

T a b l e 6

Dry weight increment of barley after ear emergence g d.m. per plant
Field experiment 1962

Date of harvest*	Main shoot - dry weight						Tillers with ears - dry weight						Remaining tillers		
	flag leaf	lower leaves**	stem	chaff	grain	total	mean number	flag leaf	lower leaves**	stem	chaff	grain	total	mean number	total dry weight
26.VI	0.02	0.18	1.17	0.14	0.08	1.59	1.62	0.03	0.22	1.22	0.15	0.07	1.69	3.9	0.25
							1 tiller	0.02	0.14	0.75	0.10	0.04	1.05		
4.VII	0.04	0.23	1.61	0.22	0.20	2.30	4.29	0.13	0.78	4.70	0.77	0.35	6.73	3.1	0.38
							1 tiller	0.03	0.18	1.10	0.18	0.08	1.57		
31.VII	0.02	0.16	1.13	0.14	1.04	2.49	4.40	0.08	0.60	4.24	0.51	4.12	9.55	3.8	0.58
							1 tiller	0.02	0.14	0.96	0.12	0.94	2.18		

* On the day of the third harvest /10.VII/ main shoot: lower leaves -0.20, stem - 1.45 g ; tiller:
lower leaves - 0.15, stem - 1.02 g.

** Five leaves per shoot; on the day of the first harvest only 2 - 3 leaves on each shoot were green
/besides the flag leaf/.

total weight increase of the main shoot would account for 30 and of the tiller — for 40 per cent (L.S.D. = 15 per cent). However the grain weight did not decrease significantly after removal of the awns. This was caused, it seems, by a more intense supply of assimilates from the stems.

The role of photosynthesis in the whole ear can be estimated from three treatments. The results obtained after ear shading would show, that the contribution of its assimilates accounts for about 50 per cent of the main shoot and tiller increment. According to two other treatments (ears only exposed to light) this contribution would be 20—25 per cent only. In all the three treatments the grain increment was the same and amounted to 50 per cent only of its increment in the control. The behaviour of plants with ears shaded (a relatively small increase in the grain as well as in the stem weight) permits the assumption, that during the period under investigation the treatment applied brought a diminishing in the photosynthesis rate in the vegetative organs.

It is worth noting that tiller removal had no influence on the main shoot growth.

In order to test whether changes in the weight of plant organs, observed in the described experiment during the last month of vegetation, occur also under normal growth conditions, 10 plants were harvested in 1962 every 6—8 days from a field (at Puławy) with barley var. "PZHR Browarny" and their dry weight was determined. Table 6 presents the results of the first two harvests and the last one (at full maturity). These plants differ from barley in pots in a greater number of tillers. However, the changes in the weight of stems after ear emergence are of the same character as under greenhouse conditions. It may be added, that the weight of vegetative parts of the main shoot at full maturity was the same as immediately after ear emergence, and the average weight of a tiller was even higher.

Wheat

The plant increment in 1960 after ear emergence was relatively high, about 60 per cent of this weight increase fell within the first 15 days of the experiment (Table 7). The difference between the grain yield and the total plant increase is statistically insignificant. However at the end of the first period the grain weight was only about 38 per cent of its final yield. At that time a relatively high accumulation of assimilates in the stem and a decrease in the weight of the lower leaves could be observed. In the following period — when the accumulation of organic compounds in the grain was intense — the stem weight decreased to the same degree as it had increased during the first 15 days.

The contribution of the flag leaf assimilates can be estimated from

Table 7

Dry weight increment of wheat var. "Bajka" during the last month of growth - mg d.m. per plant.

Experiment 1960.

No.	Treatment	Date of harvest	Flag leaf	Lower leaves	Stem*	Husks	Grain**	Total
	Control	27.VI	148	333	1500	326	0	2307
I	Control	changes in dry weight						
		11.VII	-4	-105	+354	-62	+513	+696
		4.VIII	-24	+15	-359	+29	+836	+497
		27.VI-4.VIII	-28	-90	-5	-33	+1349	+1193
II	Flag leaf removed	11.VII	-	-111	+233	-76	+331	+377
		4.VIII	-	0	-361	-8	+629	+260
		27.VI-4.VIII	-	-111	-128	-84	+960	+637
III	Lower leaves removed	11.VII	-2	-	+289	-59	+489	+716
		4.VIII	-31	-	-288	+12	+640	+333
		27.VI-4.VIII	-33	-	+1	-47	+1129	+1049
IV	All leaves removed	11.VII	-	-	+96	-65	+284	+315
		4.VIII	-	-	-242	-18	+487	+227
		27.VI-4.VIII	-	-	-146	-83	+771	+542
V	Ear shaded	11.VII	+13	-119	+292	-93	+353	+446
		4.VIII	-48	+17	-307	+1	+678	+341
		27.VI-4.VIII	-35	-102	-15	-92	+1031	+787
VI	All leaves and stem shaded	11.VII	-35	-137	-97	-76	+185	-160
		4.VIII	-3	+3	-107	-30	+88	-49
		27.VI-4.VIII	-38	-134	-204	-106	+273	-209
VII	All leaves removed stem shaded	11.VII	-	-	-164	-105	+171	-98
		4.VIII	-	-	-70	-13	+51	-32
		27.VI-4.VIII	-	-	-234	-118	+222	-130
VIII	Lower leaves and stem shaded	11.VII	+16	-150	+103	-60	+351	+260
		4.VIII	-49	-10	-327	-23	+362	-47
		27.VI-4.VIII	-33	-160	-224	-83	+713	+213
IX	Lower leaves removed, stem shaded	11.VII	+17	-	-45	-81	+310	+201
		4.VIII	-42	-	-167	-12	+330	+109
		27.VI-4.VIII	-25	-	-212	-93	+640	+310
	L.S.D./p-0,05/		15	30	98	20	81	158

* Including the rachis.

** The number of grains per ear in all treatments except VI and VII accounted for 29-31; in treatm.VI and VII: 25-26.

T a b l e 8

Contribution of photosynthesis in the flag leaf of wheat var. "Bajka" to the plant increment calculated from differences in total and grain weights after various treatments - per cent of the weight increase in the control

Date of harvest	Treatments* compared							
	I-II		III-IV		VIII-VI		IX-VII	
	total	grain only	total	grain only	total	grain only	total	grain only
12.VII	46	35	57	40	60	32	43	27
4.VIII	48	25	21	18	0	33	28	33
27.VI-4.VIII	47	29	42	27	35	33	37	31

* See tab. 7.

the treatments I—II, III—IV, VIII—VI and IX—VII. As the calculations show (Table 8) this contribution to the total plant increment in the last month of growth would amount to 37—47 per cent, and to the grain yield 27—33 per cent. The value of the L.S.D. being about 13 per cent for the total and 6 per cent for the grain weight, it can be assumed that all treatments yielded analogous results. However they supplied different data for particular periods of investigations. As the changes in the stem weight indicate (Table 7) two facts might have been responsible for this: 1) a part of assimilates derived from the flag leaf is accumulating in the stem during the first 15 days and only later is translocated to the grain (control plants), 2) the amount of assimilates, accumulated in the stem before ear emergence and translocated to the kernels during the last period of their development, was greater in plants deprived of the flag leaf than in the control. In spite of the accordance of results obtained for the whole investigated period, it must be borne in mind, that the flag leaf reacted to the shading or removal of other organs, as can be also seen from its weight changes.

The difference in the total plant increment after removal of lower leaves is not statistically proved. However this treatment caused a diminishing in the grain yield of about 17 per cent. The removal of all leaves brought about a decrease of 43 per cent.

As calculated from treatments IV—VII and III—IX the contribution of photosynthesis in the stem (including the sheaths) to the total increm-

ent would be 56 and 62 per cent respectively, and 41 and 36 per cent — to the grain yield. In both cases shading of the stem caused a marked decrease in its weight as well as in the weight of the husks.

The results which might indicate the role of net assimilation in the ear are very divergent. According to differences in the plant yield between treat. I and V the contribution of ear assimilates to the total increment would account for 34 and to the grain weight 24 per cent. However when the results of treat. VI and VII are considered, the amount of these compounds would have been so small, that it could not have covered the quantity of assimilates utilized in respiration and eventually translocated to the root. Clearly in the latter treatments it is difficult to estimate what organic compounds constituted the grain yield, amounting to 17—20 per cent of the yield in the control, and to what degree (products of CO_2 fixation in the ear or assimilates accumulated before ear emergence).

In the experiment 1961 the final yields of four wheat varieties (Fig. 3—10 pp. 442—443) did not differ appreciably, except for "Fortunata". The increases in grain weight were — also except for the latter variety — similar to the total plant increments (the mean number of kernels for all varieties was 31 per plant varying between 29—33).

In all plants the weight of the flag leaf as well as of the lower leaves was gradually decreasing with ageing. A marked accumulation of organic compounds in the stem during the first two weeks is worth noting also in this experiment. In this period the glumes and in „Ostka Chłopicka” also the awns* were increasing their weight.

Total plant increments having been very small in three varieties after the third and in "Fortunata" after even the second harvest, the differences between treatments at that time were not statistically proved. Therefore results for the first (Table 9) and the second period (Table 10) only are reported; in most cases the treatments, which did not cause any significant differences either in the total or in the grain yield are also omitted.

During the first 8—9 days after anthesis the removal of neither the flag leaf nor of lower leaves had any appreciable influence on the total and grain increment in three varieties, with the exception of "Fortunata". In all these cases the treatments applied brought about a more intense growth of leaves remaining on the plant, which is revealed by their weight. On the other hand in var. "Fortunata" the removal of the flag leaf or of lower leaves caused a strong diminishing of the total plant increment — at least about 50 per cent as compared to the control — but did not influence the grain weight.

* From 80 to 125 mg. per. ear.

T a b l e 9

Changes in the weight of wheat plants after various treatments during
 "the period from the first to the second harvest - mg d.m. per plant.
 Experiment 1961.

Treatment*	Flag leaf	Lower leaves	Stem	Husks	Grain	Total
var. "Bajka" **						
Control	-6	+18	+250	+44	+180	+450
Stem shaded	-22	-27	+98	+2	+166	+217
Ear shaded	+10	+12	+241	+3	+169	+431
Ear removed	+12	-11	+661	-	-	+662
L.S.D. /p=0,05/			93		41	112
var. "Fortunata"						
Control	-2	-24	+313	+66	+171	+524
Flag leaf removed	-	-31	+21	+2	+132	+124
Lower leaves removed	-4	-	-9	-13	+145	+119
Stem shaded	+3	-17	+133	+32	+161	+312
Ear shaded	0	-23	+336	+59	+158	+533
Ear removed ***	+3	-13	+294	-	-	+284
L.S.D. /p=0,05/			101		51	109
var. "Opolska" **						
Control	+9	+7	+156	+44	+224	+440
Stem shaded	+10	+5	+125	+38	+157	+335
Ear shaded	+19	-4	+87	+20	+107	+229
Ear removed	+45	+10	+332	-	-	+387
L.S.D. /p=0,05/			62		41	97

* The differences between treatments applied in var. "Ostka Chłopska" - in spite of the greatest weight increment in the period investigated - were insignificant /L.S.D. of the total increment - 18%/.

The same increment of the plants deprived ears as in the control was due to a greater increase of the stem weight.

** The results of some treatments in var. "Bajka" and "Opolska" are not here reported the differences /10-15%/ being insignificant as compared to the control.

*** Plants of this variety only formed new tillers after ear removal.

The stem shading caused a smaller weight increment in all varieties listed in Table 9. In var. "Bajka" this increment accounted for 50, in others for 60—77 per cent of the total weight increase in the control. However this treatment influenced the grain weight only in "Opolska".

Table 10

Changes in the weight of wheat plants after various treatments during the period from the second to the third harvest - mg d.m. per plant.

Experiment 1961.

Treatment*	Flag leaf	Lower leaved	Stem	Husks**	Grain	Total
var. "Bajka"						
Control	+10	-4	+144	-3	+415	+562
Flag leaf removed	-	-6	-4	-31	+291	+250
Lower leaves removed	-14	-	+151	-8	+381	+510
Stem shaded	-21	+15	+105	-20	+293	+372
Ear shaded	-21	-4	+32	-22	+303	+288
Ear removed	+12	+9	+433	-	-	+454
L.S.D. /p=0,05/			88		64	125
var. "Opolska"						
Control	+28	-23	-22	+19	+346	+342
Stem shaded	+7	-22	-97	-16	+310	+182
Ear shaded	+25	-24	-100	-31	+261	+130
Ear removed	+32	+1	+294	-	-	+327
L.S.D. /p=0,05/			68		51	102
var. "Ostka Chłopicka"						
Control	-21	-33	+116	+33	+360	+455
Ear shaded	-7	-21	-111	-31	+265	+95
Ear removed	+5	-16	+319	-	-	+308
L.S.D. /p=0,05/			87		52	111

* The results obtained in the var. "Fortunata" and in some treatments of var. "Opolska" and "Ostka Chłopicka" are not reported here because of the insignificant differences as compared to the control.

** In the var. "Ostka Chłopicka" - glumes and awns.

It must be added, that the stem increment in this variety was the lowest and shading did not cause — in contrast to other varieties — any change in its magnitude.

The var. "Opolska" differs also in its reaction to the ear shading. This treatment had no influence in the period under investigation either on the total or on the grain weight in "Bajka" and "Fortunata", but in "Opolska" it caused a diminishing in the increment of about 50 per cent.

It is worth noting, that the weight increase of plants, which after ear removal did not form new tillers, was analogous to, or even higher than in the control. In all these cases the accumulation of assimilates took place in the stem (including sheaths). During the second period "Bajka" only reacted to the flag leaf removal, by a diminishing in the plant increment of about 50 per cent as compared to the control. In other varieties — similarly to the first period — no significant differences could be stated. The removal of lower leaves did not cause any changes in any varieties either in their total or in their grain increment. Also similarly to the first period the plants of "Bajka" and "Opolska" reacted strongly to stem shading, their total increment diminishing by about 40 per cent in comparison with the control. This treatment had influenced the grain weight to a different degree, which, in all probability, was caused by differences between these varieties in the translocation of assimilates to the stem and from the stem to the ear.

A diminishing of the total increment by ear shading occurred in the period investigated not only in var. "Opolska" but also in "Bajka" and "Ostka Chłopicka". The reaction of the latter variety to the treatment applied was the greatest although it was not at all manifest in the first period. The influence of ear shading on the grain weight was in general less than on the total plant increment.

The behaviour of plants deprived of ears was similar to that in the first period of investigation.

DISCUSSION

As it has already been mentioned, two objectives have been aimed at in the reported experiments: 1) to recognize the role of particular green parts of the investigated cereal plants after ear emergence in the accumulation of organic compounds in the grain, 2) to estimate the magnitude of the error resulting from "artefacts" caused by the applied treatments of shading or defoliation.

In the experiments with barley plants deprived of tillers 2—3 weeks before ear emergence or of small infertile tillers after ear emergence, and intact plants were investigated. The results obtained show that, when the tillers are removed early, the grain yield can be higher than the total plant increment during the last month of growth. In the pot experiment the difference amounted to about 20 per cent, in the field experiment it was much higher. When only infertile shoots were removed (in pots 1961) the grain increment was the same as the total weight increase of barley. A similar fact (per shoot) was observed under field conditions in intact plants. Wheat in the greenhouse formed only one shoot with ear. Independently of the time of tiller removal the

grain yield was equal to the total plant increment (except perhaps for var. "Fortunata").

Disregarding the causes of the various behaviour of barley plants (among other things the diverse influence of roots as acceptors of assimilates could have played an important role), it can be assumed that most of the results obtained are in accordance with the results of other authors, quoted in the introduction. Nevertheless the conclusion that, when the total and the grain increment is the same, only assimilates of current photosynthesis after ear emergence take part in the kernel development, does not seem to be fully justified. Because a part of these assimilates may be incorporated into vegetative organs and organic compounds accumulated in plants before ear emergence or fertilization may be transported to the grain later. The fact of elongation of the upper part of the stem after ear emergence and the decrease in its weight as well as in the weight of leaf laminae in some investigated treatments can support these possibilities. The technique applied in the reported experiments does not permit estimation of the contribution of assimilates accumulated before ear emergence or flowering to the grain yield.

The transient increase of the stem weight in barley as well as in wheat after ear emergence, is worth noting. This phenomenon was also observed in other experiments (Archbold 1942; Asana, Saini 1958a, b; Czebano $\dot{w}$ a, Makarewicz 1951); a great accumulation of sugars in stems was found. As the sheaths were not separated from the stem, it is difficult to estimate, to what degree each of these plant parts had participated in the observed increment in our experiments. It is also difficult to determine the source of organic compounds, which caused this weight increase, because it resulted from at least three processes (disregarding respiration and translocation to the root), i.e. 1) CO $_2$ assimilation *in situ*, 2) supply of assimilates from leaves, 3) translocation of organic compounds to the ear. An estimation, which could have been made indirectly from several treatments (ear removal, stem shading etc) would be charged with a very great error. However it is worth noting that ear removal in the investigated plants and in the investigated stage of their development had no significant influence on the translocation of assimilates to the stem, though this treatment could have caused a "rejuvenation" of plants (it is possible, that the rate of photosynthesis in the stem itself was higher also).

The accumulation of organic compounds in the stem lasted for a shorter time in barley than in wheat. This difference seems to be related to the differences in the rate of grain development between the investigated species. The results obtained would indicate the one of the main causes of the weight decrease of the stem in the later period is the translocation of accumulated assimilates to the grain. There are two

opinions on this subject. According to Archbold and Datta this decrease is related mainly to the ageing process and utilization of assimilates in respiration. According to several other authors, e.g. Czebajnowa and Makarewicz — the stem of cereals after ear emergence can be regarded as a transient "storage" organ for assimilates.

It is very difficult — on the basis of the experiments carried out — to make a reliable estimation of the role of assimilates, formed in particular plant organs after ear emergence, in the accumulation of organic compounds in the grain. Without doubt, at any rate in the investigated varieties, the applied treatments of shading or removing particular parts lead to substantial changes in the plants*. These changes do not comprise only an increased supply of organic compounds to the ear, a different rate of maturation etc, but also a physiological compensation for the shaded or removed organs. This compensation is revealed in the growth and perhaps in the rate of photosynthesis in organs exposed to light. This phenomenon could be observed not only in the vegetative parts but also in the ear. Kursanow (1934) noted a similar fact in pods of peas after shading the leaves. It seems, that this process of compensation is a source of serious errors which may occur in experiments involving shading or defoliation technique for a longer period of plant growth. The character and the degree of the observed changes depended in our investigations on the treatment applied and also on the varietal traits of plants as well as on their stage of development. A detailed analysis of these changes has been presented above. It would seem, that ear shading — so often applied by various workers — is relatively the mildest treatment as regards the influence on the photosynthesis rate in other organs. However the plant reaction also in this respect was appreciable and not always of the same character, as the experiments with barley would indicate. In order to lessen the influence of "artefacts" on the results, in the investigations 1961 various treatments were applied for shorter periods. However, as it came out, also under these conditions, it could not be prevented especially in wheat. Moreover, the value of the L.S.D. as compared to the value of the total increment, mainly in the later stages of grain development was so high, that the differences looked for could not be statistically proved.

In spite of these strictures it is worth analysing the results concerning the role of particular organs and confronting them with the data in other literature. Most of the results obtained in our experiments

* The results obtained from several treatments in particular experiments do not indicate that in the case of defoliation a lesser supply of mineral nutrients to the ear would have had any significant influence on these changes.

would indicate, that the role of lower green leaves after ear emergence in barley as well as in wheat was very small. The same is pointed out by several authors, quoted in the introduction.

However it must be borne in mind that the removal of lower leaves more often than not causes a more intense photosynthesis at least in the flag leaf. It is possible, that the strong reaction of the wheat variety "Fortunata" to this treatment was related to its lesser capacity for compensation in comparison with other investigated varieties.

The flag leaf in the wheat varieties was greater than any of the lower leaves and was greener for longer. In barley on the other hand this leaf was smaller. The results after flag leaf removal in 1960 (if assumed that in this treatment the error caused by "artefacts" is the smallest) would indicate that its role in the wheat var. "Bajka" is much greater than in the investigated variety of barley. Big differences between wheat varieties in 1961 in the results concerning the flag leaf contribution would be additional evidence that here also varietal differences in the compensation capacity played an important role. It seems however, that the contribution of the flag leaf lamina, especially in wheat is greater than is indicated by the data of Boonstra (1936). All experiments with barley as well as with wheat show the appreciable role of the stem assimilates. Their contribution to the total plant increment amounted to 50 per cent. The causes mentioned above make it difficult to state, what compounds accumulated in this plant organ are translocated to the grain and what is their contribution. Most of the results concerning the role of ear assimilates in barley vary between 25—35 per cent of the total plant increment. Thus this evaluation is analogous to that made by most authors for two-rowed barley. However, because of the observed changes these data do not seem fully proved. The experiments with wheat gave very divergent results for the contribution of ear assimilates to the total increment, namely from 0 to above 50 per cent.

It seems, that an estimation of the role of particular plant organs of various species in the grain development — disregarding the influence of any applied technique — is very difficult, especially "percentual" estimation. For in such investigations a great role is played by varietal traits (the leaf area, its life length, the size of the ear, the activity of roots etc) as well as by the influence of external factors, which can undergo changes in particular years. However such data are necessary. Taking into account the difficulties, which arose in the reported experiments, in subsequent investigations an attempt was made to diminish them as far as possible. Their results will be the subject of further papers.

SUMMARY

In 1960—1961 experiments with barley var. "PZHR Browarny" and wheat var. "Bajka" were carried out; in 1961 three other wheat varieties were also investigated. In order to determine the role of particular organs after ear emergence in the total as well as the grain increment appropriate plant parts were shaded or removed. In 1960 the treatments were applied several days after ear emergence for the whole subsequent period of growth, in 1961 — for shorter, 8—9 day intervals.

In most experiments the grain yield (or weight increase) was equal to the total plant increment after ear emergence. In the first stage of grain development a transient weight increase in the stem was observed. This increment was maintained for a longer time in wheat than in barley. The translocation of organic compounds to the ear seems to be one of the main causes of the later decrease in the stem weight.

The techniques applied in the reported investigations do not permit estimation of the contribution of assimilates, accumulated in plants before ear emergence, to the grain yield. The results, which could indicate the role of current photosynthesis in particular organs, were divergent. This fact is due to changes caused by the applied technique of shading and defoliation. The observed changes comprise not only an increased supply of assimilates to the ear but also a compensation for the shaded or removed organs, consisting in a greater growth and photosynthesis in the parts exposed to light. The character and the degree of these changes depended on the treatment applied and also on the varietal traits of plants as well as on their stage of development.

The results obtained are compared with the results of other authors.

Plant Physiology Dpt.

Central College of Agriculture, Warsaw.

Plant Physiology Section,

Institut of Soil Science and Plant Cultivation

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STRESZCZENIE

W latach 1960—61 przeprowadzono doświadczenia z jęczmieniem odm. „Browarny PZHR” oraz z pszenicą odm. „Bajka”. W 1961 r. uwzględniono dodatkowo trzy odmiany pszenic, a mianowicie „Opolską”, „Fortunatę” oraz „Ostkę Chłopiczką”. W celu zbadania roli poszczególnych części roślin — po wykłoszeniu do pełnej dojrzałości — w ogólnym przyroście masy organicznej jak też w plonie ziarna, odpowiednie organy usuwano lub też zaciemniano. W 1960 r. wprowadzono następujące kombinacje: 1) kontrola, 2) bez liścia flagowego, 3) bez dolnych liści, 4) bez wszystkich liści, 5) kłos zaciemniony, 6) wszystkie organy wegetatywne zaciemnione, 7) wszystkie liście usunięte, łodyga zaciemniona, 8) dolne liście i łodyga zaciemniona, 9) dolne liście usunięte, łodyga zaciemniona. Wszystkie zabiegi związane z badanymi kombinacjami zastosowano kilka dni po wykłoszeniu roślin. Rośliny sprzątano po upływie dwóch tygodni i w pełnej dojrzałości. W 1961 r. odpowiednie kombinacje wprowadzano na krótsze, przeważnie 8—9-dniowe okresy. W większości doświadczeń plon (względnie przyrost) ziarna był analogiczny do ogólnego przyrostu masy roślin po wykłoszeniu. W pierwszej fazie wypełniania

ziarna obserwowano przejściowy wzrost ciężaru żdźbła (wraz z pochwami). To gromadzenie asymilatów w żdźbale roślin jęczmienia trwało krócej niż u pszenic. Uzyskane wyniki wskazują, iż jedną z głównych przyczyn późniejszego spadku ciężaru tego organu jest odpływ nagromadzonych związków do ziarna.

Wyniki, które pozwoliłyby ocenić rolę asymilatów powstających w poszczególnych organach roślin po wykłoszeniu w akumulacji związków organicznych w ziarnie, okazały się bardzo rozbieżne. Fakt ten jest spowodowany przez zmiany, jakie zastosowane zabiegi wywołały w badanych roślinach. Obserwowane zmiany polegają nie tylko na zwiększeniu odpływu asymilatów do kłosa, ale również na fizjologicznej kompensacji zaciemnionych lub usuniętych organów, przejawiającej się w procesach wzrostu i intensywności fotosyntezy ekspozycyjnych na światło części. Charakter i stopień zmian zależały od zabiegu, jaki zastosowano, a także zarówno od właściwości odmianowych roślin jak i od fazy ich rozwoju.

Uzyskane wyniki są porównywane z wynikami innych autorów.

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