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Grain yield of winter rye and winter wheat in relation to leaf number and leaf age

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Summary

To obtain more detailed information concerning the influence of defoliation, and to study possible differences between winter rye and winter wheat in relation to leaf number and leaf age after heading, defoliation experiments were carried out in 1966 and 1967.

Removing the top leaves gave a lower yield (grain and stem) than removal of the lower leaves, because of the better assimilation ability of the top leaves. The production was influenced by the number of leaves after flowering and besides this, strongly affected by the age of the (remaining) leaves.

Striking differences were found in the distribution of dry matter between rye and wheat with respect to the same defoliation treatment on the one side and in the influence of top and lower leaves on the distribution pattern on the other side.

Introduction

Based on defoliation experiments (e.g. of Schlumberger, 1913; Boonstra, 1929; Shevehenko, 1933; Miller et al., 1948), followed by growth analyses and photosynthesis research (e.g. by Watson et al., 1958; Buttrose and May, 1959; Frey-Wyssling and Buttrose, 1962 and Stoy, 1965) and studies on translocation with ^{14}C (e.g. by Quinlan and Sagar, 1962; Quinlan, 1963; Birecka and Dakic-Wlodkowska, 1963, 1964 and Lupton, 1968), it may be assumed in general that the greatest contribution in the grain yield of cereals is provided by the top leaves, in addition to the assimilation ability of the topmost leaf sheath, the ear stalk and the ear itself.

In the papers on defoliation experiments much emphasis was put on the importance of the two topmost leaves in ear-filling, whereas less attention was paid to the true causes of this aspect, on the one side, and to possible differences in dry-matter distribution at differences in leaf age, on the other side.

To collect more data on this aspect and to supplement the data in the literature, comparative defoliation experiments with 'Petkuser' winter rye and 'Felix' winter wheat were conducted in 1966 and 1967.

Experimental design

The plants were grown in 6-litre pots filled with sandy soil and supplied with the required nutrients, e.g. an application of 700 mg N per pot of 10 plants at optimum water supply.

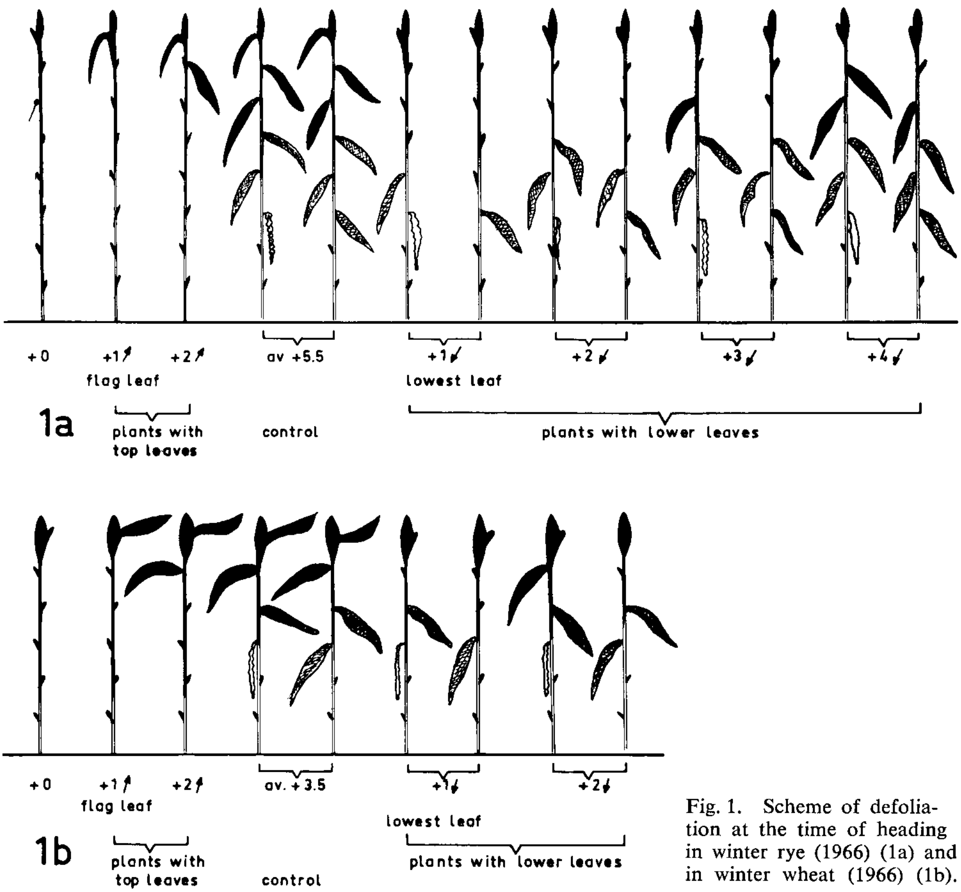

Fig. 1. Scheme of defoliation at the time of heading in winter rye (1966) (1a) and in winter wheat (1966) (1b).

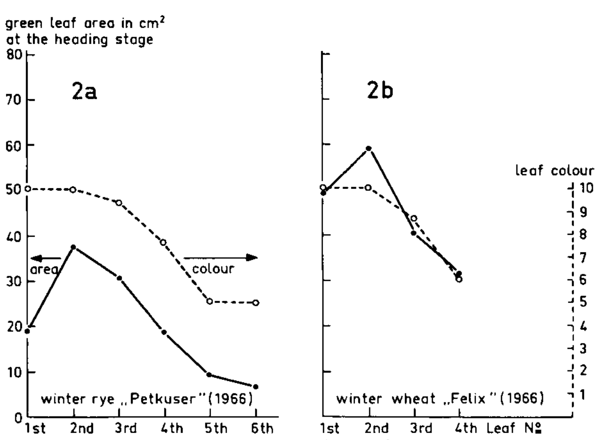

Fig. 2. Relation between the order of leaves and leaf area on the one side and between the order of leaves and leaf colour on the other side in winter rye (2a) and in winter wheat (2b).
Leaf colour: 0 = brown; 1—2 = yellow; 3—4 = yellow-green; 5—6 = pale green; 7—8 = green; 9—10 = dark green.
o------o green leaf area;
•———• leaf colour.

The experiments were conducted in an 'open greenhouse' of which the sides are closed with wire netting and the top with glass under otherwise normal outside conditions with respect to temperature and a light intensity of about 75% compared to natural radiation.

In the 1966 experiment a sample was taken of each crop at the time of heading in order that, next to the ultimate weight, the dry-matter increase of the above-ground parts after flowering could be determined. Moreover, at this moment (heading stage) the leaf area of the present leaves was measured and the green colouring estimated (Fig. 2a and 2b), at the same time various defoliations were applied, as indicated in Fig. 1a and 1b.

In 1967 only a differing number of lower leaves were removed, the green leaf area estimated and the yield determined at the end when the crops had ripened.

Results

Fig. 4 shows that the winter rye controls with complete foliage (+5.5 leaves in 1966 and +4 leaves in 1967) and the winter wheat controls (+3.5 leaves in 1966 and +3 leaves in 1967) produce the highest grain + stem yields.

Each leaf less with respect to the control gives a yield depression. The lowest yield is produced by the completely defoliated plants (+0 leaves).

In spite of no leaves remaining on the plants of the 0 treatment after heading, the grain yield of the winter rye averaged over the two years, was still 56% compared to the control, and in the winter wheat 57%.

When removing the top leaves (treatments +1 through +4 ↓, right in Fig. 1a for rye and treatments +1 and +2 ↓, right in Fig. 1b for wheat), the yields are at a much lower level than when the lower leaves are removed (treatments +1 and +2 ↑, left in Fig. 1a for rye and in Fig. 1b for wheat).

Fig. 4 shows that the yield with respect to the 0 treatment increases with an increasing number of leaves. However the proportional contribution of each lower situated leaf with respect to the flag leaf (+1 ↑) is continually smaller.

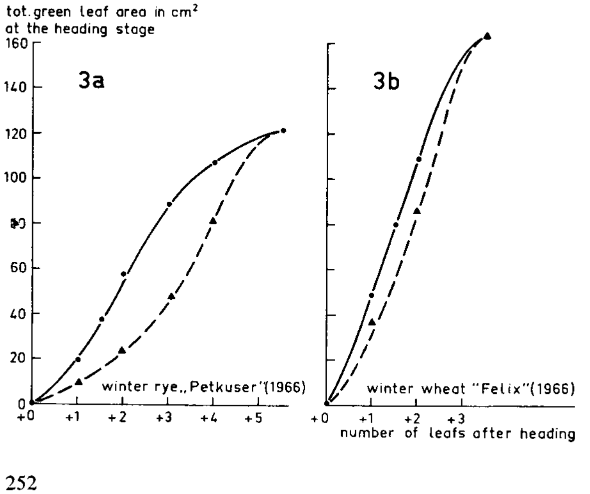

Fig. 3. Relation between the total green leaf area at the time of heading and the number of leaves in winter rye (3a) and in winter wheat (3b).
•——• plants with top leaves;
▲- - - -▲ plants with lower leaves.

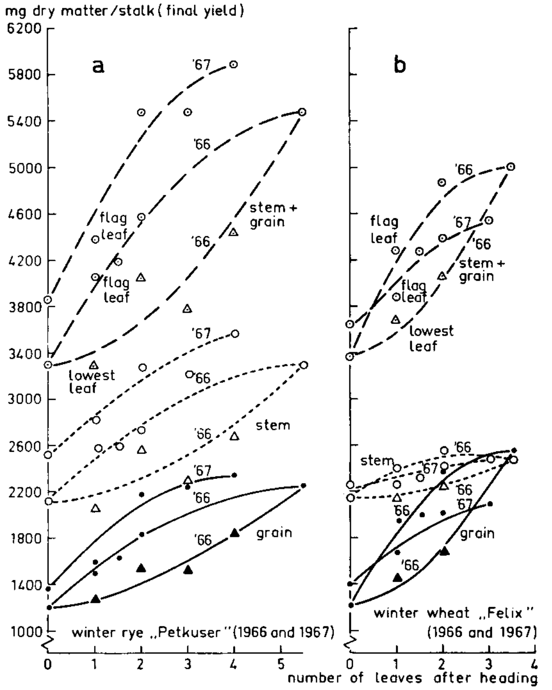

Fig. 4. Relation between the final yield of dry matter and the number of leaves after heading in winter rye (a) and in winter wheat (b). Circles: plants with top leaves; triangles: plants with lower leaves.

Plants of which the top leaves have been removed (1966) also show an increasing yield with an increasing number of leaves, but here the proportional contribution of each higher situated leaf grows larger with respect to the one situated below.

A striking difference between rye and wheat is – at least in these two varieties – that the proportional increase in stem weight after flowering compared to the ear weight in the same treatments, is appreciably larger for rye than for wheat (Fig. 5).

Discussion

In studying the relation between the grain yields of the various treatments and the number of leaves after heading, three factors may be involved. The first factor is the size of the green leaf area, the second is the quality of the assimilating area, dependent on the physiological age of the leaves, which is determined by the place (order) of the leaves on the stem and the third factor is the light intensity as influenced by mutual shading.

In Fig. 3a and 3b the total green leaf area is plotted of the plant groups, of which the leaves were removed from the bottom or from the top. The graphs show that there is a clear difference in leaf area between both groups for each number of leaves between 0 and 5.5 in rye and between 0 and 3.5 in wheat. This difference is appreciably larger in rye than in wheat. Besides the difference in green leaf area between plants with leaves on the top part of the stem and on the bottom part of the stem, in both

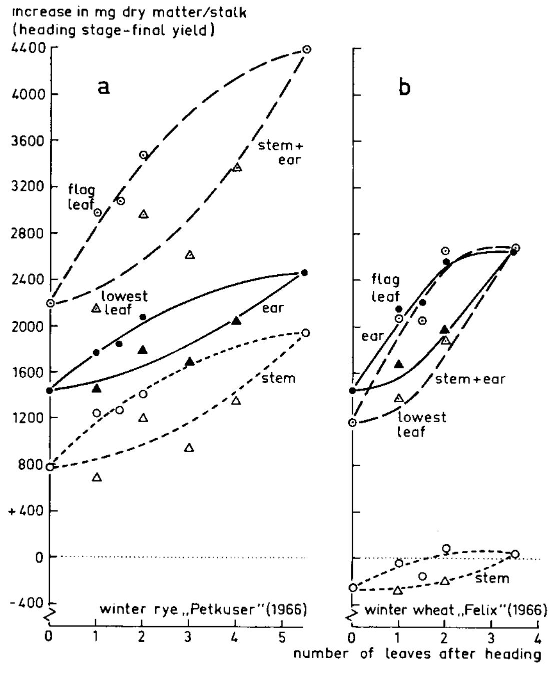

Fig. 5. Relation between the increase of dry matter in the post-floral period and the number of leaves after heading in winter rye (a) and in winter wheat (b). Circles: plants with top leaves; triangles: plants with lower leaves.

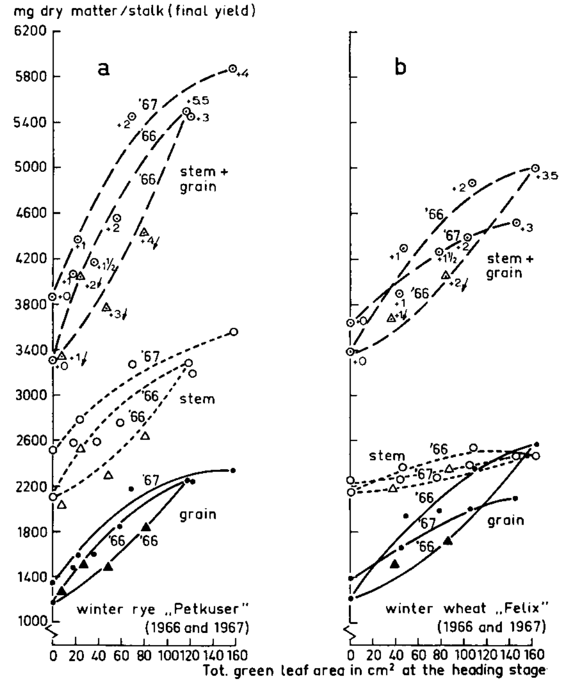

Fig. 6. Relation between the final yield of dry matter and the total leaf area at the time of heading in winter rye (a) and in winter wheat (b). Circles: plants with top leaves; triangles: plants with lower leaves.

cereal species the shade of green colouring (leaf colour varying from dark green to yellowish green) decreases with the order of the leaves (Fig. 2a and 2b).

The differences in final yield (Fig. 4) are not only caused by differences in assimilating area, as shown by Fig. 6: here the yields have not been plotted against the number of leaves, but against the green leaf area. Although to a less extent, the characteristic form of the curve remains intact, which means that the assimilating ability of the green leaf area of the lower leaves (older) is reduced compared to that of the top leaves.

Since shading, in any case of the plants with one leaf, is negligible, the difference in yield between both groups can be considered to be mainly due to differences in photosynthesis per unit of green leaf area between the lower and the upper leaves, due to aging.

This also explains the phenomenon that with an increasing number of leaves below the flag leaf (+1 ↓), the proportional contribution of each subsequent leaf with respect to the preceding one decreases, whereas the proportional contribution of each subsequent leaf with respect to the lowest leaf (+1 ↓), is greater.

Corresponding results were obtained in recent photosynthesis studies by Puckridge (1969) in a field crop of wheat.

The harvest of the rye in 1966 was somewhat less than in 1967, due to the lower total global radiation after flowering, viz 17.1×10^3 cal cm^{-2} in 1966 against 19.3×10^3 cal cm^{-2} in 1967. For wheat these values were 14.6×10^3 cal cm^{-2} and 12.1×10^3 cal cm^{-2}, respectively.

Concerning the above-ground dry-matter distribution, it may be inferred from Fig. 5 that in wheat this is much more favourable than in rye. Fig. 5 also shows that particularly in wheat with the lower leaves the distribution seems to be more favourable than in wheat with the top leaves. The decrease in stem weight is also highest in the plants with lower leaves and therefore the value of the total grain + stem weight is decreased as well. One of the causes of this might be that the decreased photosynthesis efficiency of the lower leaves cannot sufficiently compensate for the dissimilation. In the first instance, the stem weight will show a greater decrease and the ear weight will increase to a less extent than in the plants with the top leaves. (After flowering the plants with lower leaves had a stem weight decrease of 10.7% and an ear weight increase of 413% against a stem decrease of 3.3% and an ear weight increase of 538% in the plants with top leaves.)

On the other hand, it is neither impossible that because the top leaves are missing, which results in a shortage of direct assimilates, the ear will try to compensate by mobilizing more reserves from the stem.

From data in the literature (e.g. Puckridge, 1968) it is also known that in defoliated plants the leaf sheaths and stems show proportionally greater photosynthesis than in the presence of leaves. Due to this it might be possible that particularly without the top leaves, there will be some compensation by a proportionally greater assimilation efficiency of the leaf sheaths and stems in favour of ear filling.

References

Birecka, H. & L. Dakic-Wlodkowska, 1963. Photosynthesis, translocation and accumulation of assimilates in cereals during grain development. III. Spring wheat photosynthesis and the daily accumulation of photosynthates in the grain. *Acta Soc. Bot. Pol.* 32: 631–650.

Birecka, H. & L. Dakic-Wlodkowska, 1964. Photosynthesis, translocation and accumulation of assimilates in cereals during grain development. IV. Contribution of products of current photosynthesis after heading to the accumulation of organic components in the grain of spring wheat. *Acta Soc. Bot. Pol.* 33: 407–426.

Boonstra, A. E. H. R., 1929. Invloed van de verschillende deelen op de korrelproductie bij Wilhelmina-tarwe. *Meded. LandbHogesch. Wageningen* 33.

Buttrose, M. S., 1962. Physiology of cereal grain. III. Photosynthesis in the wheat ear during grain development. *Aust. J. biol. Sci.* 15: 611–618.

Buttrose, M. S. & L. H. May, 1959. Physiology of cereal grain. I. The source of carbon for the developing barley kernel. *Aust. J. biol. Sci.* 12: 40–52.

Frey-Wyssling, A. & M. S. Buttrose, 1959. Photosynthesis in the ear of barley. *Nature, Lond.* 184, 2031.

Lupton, F. G. H., 1968. The analysis of grain yield of wheat in terms of photosynthetic ability and efficiency of translocation. *Ann. appl. Biol.* 61: 109–119.

Miller, E. C., G. A. Gries, W. A. Lunsford & J. C. Frazier, 1948. The effect of defoliation on the functions of red winter wheat. *Bull. Kansas agric. Exp. Stn* 62: 1–95.

Puckridge, D. W., 1968. Photosynthesis of wheat under field conditions. I. The interaction of photosynthetic organs. *Aust. J. agric. Res.* 19: 711–719.

Puckridge, D. W., 1969. Photosynthesis of wheat under field conditions. II. Effect of defoliation on the carbon dioxide uptake of the community. *Aust. J. agric. Res.* 20: 623–634.

Quinlan, J. D., 1963. Studies of the components of yield of spring wheat. Ph.D. thesis, University College of North Wales, Bangor.

Quinlan, J. D. & G. R. Sagar, 1962. An autoradiographic study of the movement of ^{14}C labelled assimilates in the developing wheat plant. *Weed Res.* 2: 264–273.

Schlumberger, O., 1913. Untersuchungen über den Einfluss von Blattverlust und Blattverletzungen auf die Ausbildung der Ähren und Körner beim Roggen. *Arb. Kais. biol. Anst. Land- u. Forstw.* 8: 515–551.

Shevehenko, V., 1933. An experimental study of the influence of the artificial decrease of the assimilating area of cereal leaves on yields. *Trudy pol. Iashch. Rast., Ser. 3,* 3: 44–60.

Stoy, V., 1965. Photosynthesis, respiration and carbohydrate accumulation in spring wheat in relation to yield. *Physiologia Pl.* Suppl. 9: 1–117.

Thorne, G. N., 1959. Photosynthesis of lamina and sheat of barley leaves. *Ann. Bot., N.S.* 23: 363–370.

Thorne, G. N., 1963. Varietal differences in photosynthesis of ears and leaves of barley. *Ann. Bot., N.S.* 27: 155–174.

Watson, D. J., G. N. Thorne & S. A. W. French, 1958. Physiological causes of differences in grain yield between varieties of barley. *Ann. Bot., N.S.* 22: 321–352.