T1974PHY10

EFFECTS OF ARTIFICIAL DEFOLIATION ON COMPONENTS OF YIELD IN SUNFLOWER

A. S. RODRIGUES PEREIRA
(The Netherlands)

The interest in the relationship between leaves and aspects of yield is twofold. On the one side there is the fact that the leaves are the principal source of the organic substances that we are harvesting with the seed or in other parts of the crop plant. It is a task both for pure and applied research to study this phisiological relationship. On the other hand we have the practical datum at hand that in the course of the life cycle of the plant the leaves are losing in capacity not only by the natural process of senescence but also by all kinds of adverse influences like drought, hail, pests, diseases, etc., and here it is of practical importance for us to collect information concerning the amount of damage sunflower plants can stand without too heavy losses in yield. As most of the pertinent work to be found in the literature this study which has been carried out in a country that does not take part in the commercial culture of sunflower (1) has been initiated with both these motives in mind.

Although measurements of the rate of photosynthesis or of net assimilation rate would probably render more exact data, in this first stage we have chosen the device of artificial defoliation. As you know this method implies that leaves are being removed according to a certain scheme and the eventual effects of the treatment on yield components are assessed. The method, however, often suffers from two weak points. Firstly exact measurements of the areas of the leaves concerned are mostly lacking. Examples of defoliation experiments where leaf area measurements have been included are those of maize by Allison and Watson (2) and of sorghum by Stickler and Pauli (3). Secondly in many experiments (4) the leaves are removed all at the same time, mostly at flowering or a couple of days before. This is done on the strength of the argument that the photosynthetic activity of the vegetative period should contribute little to seed production, which may be true. This consideration, however, negates the fact that any reduction of the leaf area at an earlier stage of the vegetative development not only influences the eventual size and form of the plant but at the same time also its resources for seed production and, therefore, indirectly, also the yield. Some removed the leaves shortly after their emergence as has also been done by V r e b a l o v (5).

MATERIAL AND METHODS

Material. INRA 4701 sunflower seed was planted in April 1972 in rows 75 cm apart running east-west. Approximately 3 weeks after planting stands were thinned to one plant per meter of row. For weed control 4 litres of Aalipur per hectare were applied just before sowing. Fertilizers were applied in the following ratio : 500 kg superphosphate (19.5% P_2O_5) per hectare, and 500 kg potassium (40% K_2O) per hectare. Before fertilizer application soil structure was bad, afterwards it was normal. There were 12 different treatments arranged in three groups of 4 plots. Each plot consisted of two rows of eight plants with untreated border rows, and border plants respectively.

Defoliation scheme. The number of leaves of the INRA 4701 hybrid ranged from 20—25, with 23 as a good average. Leaves were 7—8 cm in length when they were removed. The defoliation procedure was as follows (see Fig. 1) :

A. *First group of treatments.* In treatment A1 all the leaves younger than leaf nr. 5 were removed. For the other treatments of this group — A2, A3 and A4 — each time a new leaf had attained a length of about 7 cm the one 5 positions lower on the stem was removed. This procedure was continued until the emergence of the 11th leaf respectively of the 16th or 21st one when all the newly emerging leaves were removed. In this way groups of 5 leaves came to be situated at different heights along the stem.

B. *Second group of treatments.* From the moment that the plants had produced a certain number of leaves every time a new one had attained the crucial lenght of 7—8 cm then the lowest leaf was removed. In this way leaf numbers were kept constant at 5, 10, 15 or 20 but the individual leaves present changed all the time until the plant became generative and stopped producing new ones. In all the treatments of this series the uppermost leaf present is at the same time the last leaf that has been formed by the vegetation point.

See treatments B 1 — B 4.

C. *The third group of treatments.* From a certain moment in the development, that is to say starting from the 11th, 16th or 21st leaf respectively every newly emerging leaf was removed. By consequence the plant continued its development using the leaf material it had at that particular moment. See treatment C2—C4 ; C5 was the undefoliated check.

In this figure the situation at the end of the vegetative period is summarized. The number 23 simply stands for the top leaf, but this does not mean that every individual plant had exactly 23 leaves.

Leaf area measurements. Basic for our approach was to work out a method by which to obtain reliable values of the leaf areas. We chose the method by which the length and maximum width of the leaves and their product is multiplied by a previously determined factor. In this way it has been done before in maize and sorghum. These species, however, have the advantage that all the lea-

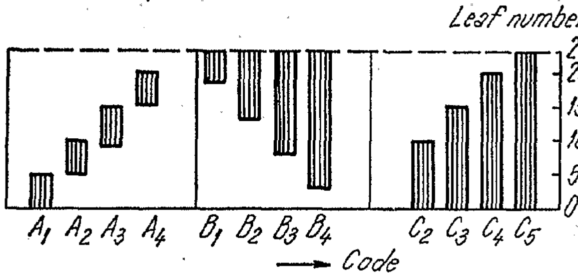

Fig. 1 — Experimental design. Number and pcsition of sunflower leaves at the vegetatative period.

ves have more or less the same shape, so that the multiplication factor may be supposed to be identical for all the leaves. For maize it was found to be 0.73 and for sorghum 0.747. In sunflower, however, both the area of the leaves and their shape are changing in the course of the life cycle which means that the exact value of the factor is depending on the leaf number (Fig. 2).

On the basis of the leaves of 20 plants our statistical department has worked out a formula that does justice to the course of this graph. In this formula the

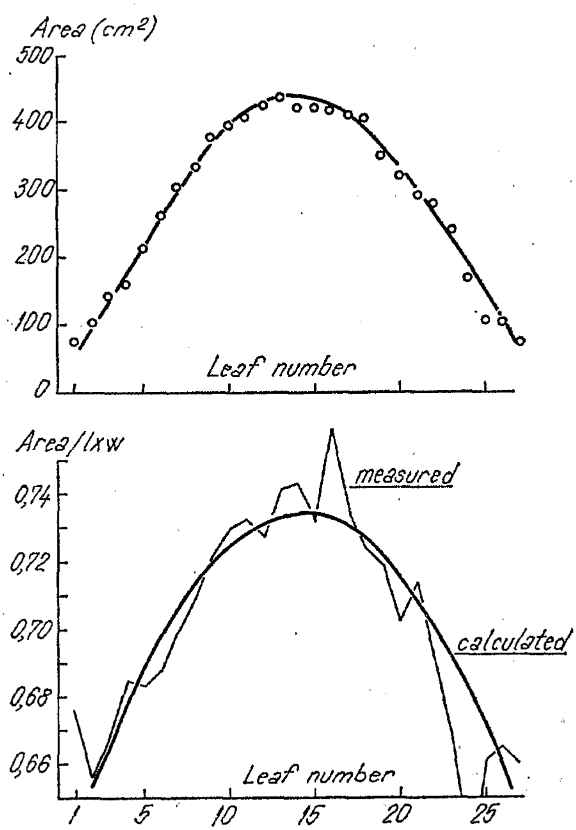

Fig. 2 — Arca and teh ratio area/ length×width of sunflower leaves.

factor by which the product of length x maximum width has to be multiplied has been resolved into a quadratic function of the leaf number:

$$Q = -0.00054535\, P^2 + 0.01545\, P + 0.62447.$$

The regression coefficient is 0.940.

The values for area/1 x as calculated with the help of this formula match the real ratios to a reasonable extent.

It is conceivable that the formula as it is written down here is not independent of plant density and plant variety. We are now trying to extend the formula in this sense by means of a new series of experiments.

Plant height and length and maximum width of the leaves recorded at the beginning of flowering.
Total oil content of the kernels was determined with the help of the so called residue—method. Fatty acid composition of the oil was determined by gasli/uid chromatography.

RESULTS AND DISCUSSION

INFLUENCE OF DEFOLIATION ON THE VEGETATIVE DEVELOPMENT

In figure 3 the average total leaf area and the height of the plants of each treatment are represented as percentages of the undefoliated control. With one small exception (A4) they go parallel in the A and C treatments but not in the B-treatments where top leaves were left untouched.

Now we may ask whether the leaves remaining after partial defoliation are representative for those at the same positions in the undefoliated control. As can be seen from Table 1 the total leaf areas of the

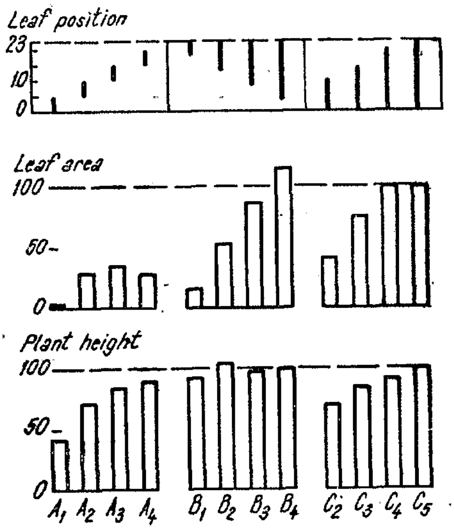

Fig. 3 — Effect of leaf removal on leaf area and plant height (C 5 = control).

Table 1

Treatment and control area

Leaf number	Code	Treatment area (cm²)	Control area (cm²)
6—10	A2	2539	2100
10—15	A3	2836	2601
16—20	A4	2444	2222
1—10	C2	3394	2913
1—15	C3	6429	5515
1—20	C4	8285	7837

plants in the A and C treatments are always larger than the areas of the corresponding leaves of the control plants. For these 6 cases the mean difference is about 10%. The same is true for the third group which is not represented here. It is obvious that leaves remaining after partial defoliation grow larger than they would have done in their normal situation. Whether this also implies an increase in yield we will see later on.

ASPECTS OF YIELD

The general aspects of yield are represented in Fig. 4. There seems to be a good correlation between total yield, the number of full seeds and the leaf area. The seed weight shows less effect of defoliation except for those treatments where only 5 or 10 leaves were left. The share of the upper and particularly of the upper middle leaves in seed yield is much bigger than their share in the total leaf area, viz. approx. 43% for the yield as against 16 and 29% resp. for the areas of the nr. 10—23 and 14—19. Another point is that in the B-treatments (leaves on the upper part of the stem) the full seeds are perhaps heavier and bigger than those in the control and the number of seeds per head is about 25% lower. We pass over such details as percentage of husks and deaf seeds which were not too much influenced by various treatments. One exception, however, will be discussed here.

The head diameters in the bar graph given in Fig. 5 show almost the same picture as the stem lengths. It is, however, the area of the

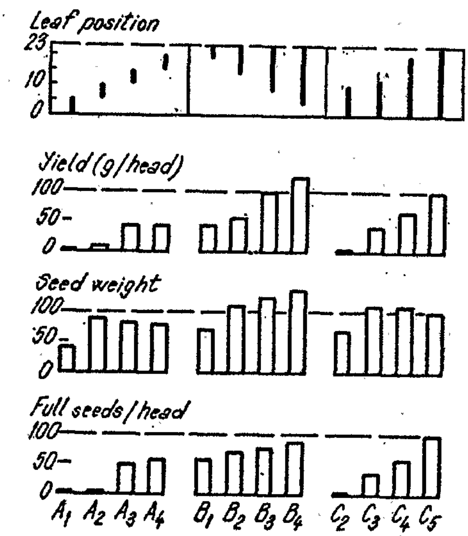

Fig. 4 — Effect of leaf removal on seed yield and on weight and number per head of full seed (C5 = control).

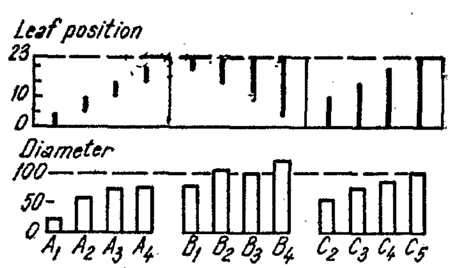

Fig. 5 — Effect of leaf removal on head diameter (C5 = control).

central part where the seed did not set and the ratio of this area to that of the whole head which most strikingly shows the influence of the various defoliation treatments. Faultly seed setting in the center of the capitulum is often reported to be a big problem.

In Fig. 6 we have presented the average diameters of heads and central sterile regions and the ratio of the areas in percentages. They go from less than 1 to almost 60 percent. The lowest parcentage we find, next to the control, in all the B-treatments (Bl is a small exception), the highest one, which is not represented here, is in those plants where only the 5 lowest leaves were left. The intermediate values are in the A4 to A2 and C4 to C2 treatments respectively.

In our experiments it appeared that not only relatively but also in an absolute sense the sterile centre is at its smallest in the biggest capitulum, which is not so strange. More important, therefore, is the upper part of the figure. Here, in the four different B-treatments there are big differences in total leaf area but the area at the centre of the head is very very small in each case, and equal to that of the undefoliated control. The sums of the leaf areas in each of the three A treatments are all about 2500 cm^2, but the part of the capitulum with fault seed setting increases from 2.3% in A4 to 15.2% in A2. A sterile area of 15% of the head we find also in C3 where, however, total leaf area is 6400 cm^2.

From this figure it is clear that at least in our experiments the size of the sterile part had very little to do with total leaf area. But it is the more extended as more leaves from the top downwards are

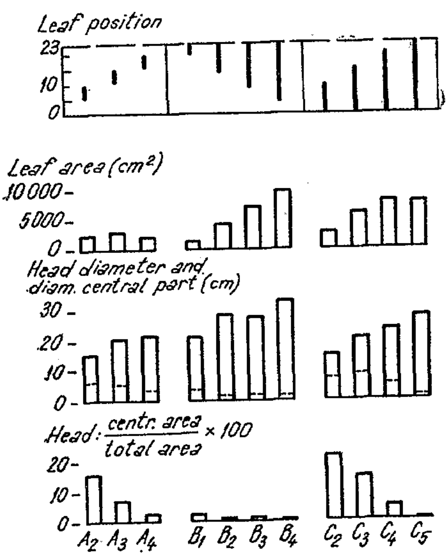

Fig. 6 — Effect of leaf removal on ratio of central to total head area.

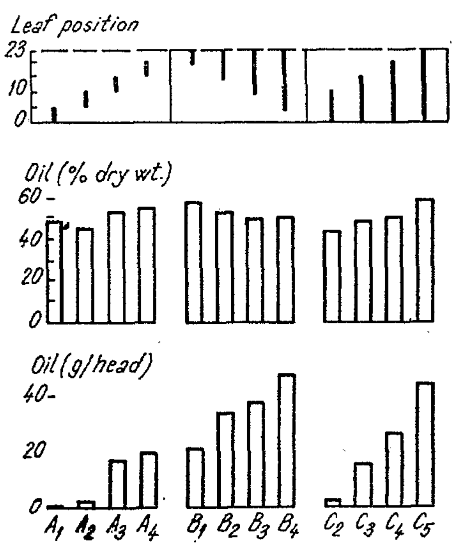

Fig. 7 — Effect of leaf removal on % oil and on g oil per head (C5 = control).

missing. In this respect there is no difference between the ranges A2—A4 and C2—C4. We may therefore also say it in this way : the area increases with the number of leafless internodes from the top downwards.

Since productivity of the leaves decreases from top to bottom, as we shall discuss in a minute, bad seed setting in the centre might thus well be connected with shortness in the amount of nutrients produced. Because flowering proceeds centripetally the centre in particular and not the whole capitulum in an evenly way is suffering from this. It may also be due to a decrease in the rate of transport of the nutrients or to a combination of both factors.

From Fig. 7 it can be seen that the oil content of the kernels varied from 46.65% in the Al treatment to 59.95% in the untreated control. Possibly there is a weak relationship between oil content and leaf position to the effect that the oil content of the seed increases when younger leaves are going to be engaged in the production. That would mean a shift to the production of seed compound with lower caloric value as the leaves are getting older.

The absolute amount of oil per 100 g of seed varied from 21.23 g in A2 to 41.21 g in Bl (see Table 2).

The fatty acid composition of the oil was not influenced by any of the defoliation treatments.

Since we had measured the leaf areas we were also able to calculate efficiencies as yield per unit leaf area. In Fig. 8 the efficiencies obtained in the various treatments are presented as mg seed per cm^2 leaf area. Leaf productivity increases from bottom to top (see A-treatments and Bl treatment). This implies that the efficiency of our experimental plants as a whole increased as more leaves placed higher up on the stem came to take part in the production process (C-treatments) and decreased as more and more leaves downwards on the stem were present.

Of course first of all this is due to increasing age of the leaves and to increasing damage experienced by the older ones. However, in the conditions of our experiment also the effect of

Table 2

Effect of leaf removal on oil yield

Code	Leaf number	g oil per 100 g seed
A1	1—5	35.6
A2	6—10	21.23
A3	11—15	36.12
A4	16—20	39.93
B1	19—23	41.21
B2	14—23	36.77
B3	9—23	31.88
B4	4—23	33.35
C2	1—10	23.44
C3	1—15	32.26
C4	1—20	34.45
C5*)	1—23	38.29

* Undefoliated check.

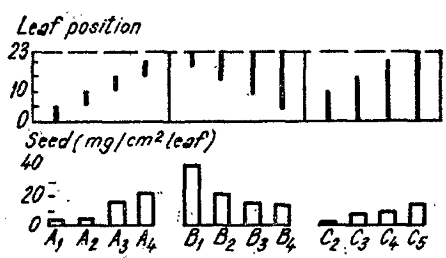

Fig. 8 — Effect of leaf removal on seed weight per cm^2 leaf area (C5 = control).

internal shading may be of more than a little importance, at least in those cases where more than 5 leaves were left on the plants.

We may now ask whether an extra increase in leaf area after partial defoliation as we described earlier has any influence on yield. Now it is not possible to directly compare the yield due to the leaves of partly defoliated plants with the partial yield of the same leaves in the undefoliated control plants. What we can do is to compare yields of the plants of one treatment with the differences between the yield of the control plants and that of the treated plants with the complementary leaves.

In Table 3 we have done this for 6 cases. The 5 bottom leaves are responsible for only about 1% of the total yield and 10 bottom leaves for 5% of the yield. Because of the overlap in the defoliation scheme of the B and the C series, in the column at the right-handside, we took the mean of 2 treatments, which resulted in a difference of $\frac{1}{2}$ leaf with the column at the lefthandside. Now, in the first place it again appears from this table that in a plant missing some of its leaves the remaining ones grow to a bigger area than in the untreated plants. This extra leaf growth, however, only partly corresponds with an increase in seed yield. In fact the average increase in seed yield over the control was something like 10% for the leaf groups shown here, as against 20% for the increase in leaf area. This might mean that the increase in leaf area noted is primarily due to cell enlargement by way of water absoption without the photosyntetic apparatus having grown proportionally.

Table 3

Effect of leaf removal on leaf area and seed yield

Number of leaves	Leaves absent			Leaves present		
	code	Reduction in % of undefoliated control		code	% of undefoliated control	
		leaf area	seed yield		leaf area	seed yield
6—25	C1	95	99	(B4+ B3)/2	102	113
11—23	C2	59	95	(B3+ B2)/2	69	92
16—23	C3	23	57	(B2+ B1)/2	34	63
1—18	B1	85	55	(C4+ C3)/2	88	55
1—13	B1	48	18	(C3+ C2)/2	59	25
1— 8	B3	13	0	(C2+ C1)/2	23	3

REFERENCES

1. Dantuma, G. and Faure, M. F., 1973, Landbouwk. Tijdschr. *85*, 143.
2. Allison, J. C. S. and Watson, D. J., 1966, Ann. Bot. N. S. *30*, 365.
3. Stickler, F. C. and Pauli, A. W., 1961, Agron. J., *53*, 99.
4. Johnson, B. J., 1972, Agron. J. *64*, 688.
5. Vrebalov, Th., 1972, Proc. 5th Intern. Sunflower Conf., p. 57.