HELIA, 13, Nr. 13, p.p. 63-71 (1990)

EFECT OF ARTIFICAL DEFOLIATION ON SUNFLOWER (*Helianthus annuus L.*)[1]

Paola Belloni, Diletta Piccotino, Gian Paolo Vannozzi [2]

SUMMARY

The authors present results of a study concering the artificial defoliation of two self-pollinated sunflower lines. Defolation treatments of increasing intensities on leaves in different positions were carried out at two different times of plant growth (before and during flowering). The results stress the importance of upper and intermediate leaves for yield which decreased with the increase in artificial defoliation percentage.

INTRODUCTION

This work was carried out in order to gain further knowledge on the relation ship between leaf apparatus, plant development and yield in sunflower. Artificial defoliation was chosen as an experimental means since plant behaviour following a reduction in leaf area - which may occur in the field as a consequence of pathogens or atmospheric conditions - can be properly assessed. It also makes it possible to evaluate the effect of such a reduction at different phenological stages and the portions of leaf apparatus that contribute greatly to the yield.

Defoliation has already been experimented with on a wide number of species. In soybean (*Glycine max* (L.) Merril), for example, it was shown to reduce the yield particulary if it occurs during the final stages of development (Malone and Caviness, 1985; Goli and Weave, 1986) and when the pod begins to develop (R5) (Fehr et all., 1971, 1977, 1981).

After defoliation, a decrease in grain yield of maize (*Zea mais* L.), was observed (Hanway, 1969; Hicks et al., 1977; Conti and Landi, 1981; Vasilas and Seif, 1985) as well as a drop in dry weight (Conti and Landi, 1981).

Total defoliation before flowing in sunflower causes about 93% reduction in yield (Johnson, 1972); defoliation during flowering may either block achene production altogether (Gonzalez de Schelotto, 1978) or enormously reduce achene size and oil content. A progressive increase in the percentage of defoliation corresponds to a progressive decrease in yield (Gonzalez de Schelotto, 1978; Tuberosa and Conti, 1978; Danuso et al., 1983).

The dimension of the effect of artificial defoliation in sunflower depends on the phenological stage at which it is carried out and the part of leaf apparatus eliminated. With regard to the phenological stage, defoliation has its most marked effects on yield just before flowering (Tuberosaa and Conti, 1978) and during flowering (Sackston, 1959;

1 The research was supported in part by the Italian Ministry of Agriculture

2 Graduate assistents and associated professor, respectively, Institute of Agronomy, Pisa University, Italia.

Gonzalez de Schelotto, 1978), but effects are far less notable when carried out during later stages of development (Rodrigeus Pereira, 1978). As far as the portion of plant defoliated is concerned, it can be said that the more apical it is, the greater is its effect on yield, although the yield increases if among the remaining leaves there is a high percentage of young ones (Rodrigues Pereira, 1978; Tuberosa and Conti, 1978). This may be due to their greater capacity to transport assimilates to the flowers (Mc William et al., 1974).

MATERIALS AND METHODS

Trials were carried out during 1987 at the "Duccio Ducci" Experimental Station of Pisa University, Institute of Agronomy, Torretta, Pisa.

A split-plot arrangement was made with three treatments of three replications each. Each plot was planted with four rows, 6.5 m in lenght and 0.8 m apart. The seeding was done on 12 May 1987.

The main treatment was made up of two selfed sunflower lines (S10), chosen by this Institute and countersigned by the letters IAP 72 and IAP 48. They were chosen for suitability of leaf characteristics (number and total area; see Tables 1 and 2).

Table 1. Defoliated lines' characteristics

	line IAP 72	line IAP 48
Plant height (cm)	113	129
Head diameter (cm)	11	15
Number of leaves	11	20
Medium leaf area (cm^2)	356.2	289.1
Total leaf area(cm^2)	3918.53	5781.4
Flowering time	July 22	July 26

Table 2. Defoliated lines' characteristics at the time of first defoliation (10 July 1987)

	line IAP 72	line IAP 48
Plant hight (cm)	94.2	95.7
Head diameter (cm)	5.9	5.7
Number of leaves	12	21
Medium leaf area (cm^2)	207.1	179.5
Total leaf area(cm^2)	2484.7	3768.9

The leaf apparatus was divided into tree sectors (A,B and C) according to the total number of leaves present (Fig. 1) and the defoliation was as follows:

N1 - untreated control;
N2 - removal of leaves in sector A (33,3% of total leaves present);
N3 - removal of leaves in sector B (33,3% of total leaves present);
N4 - removal of leaves from sector B and C (66,6% of total leaves present);
N5 - removal of leaves from sector A and C (66,6% of total leaves present);
N6 - removal of one leaf in five (20% of total leaves present);

N7 - removal of every other leaf (50% of total leaves present);

N8 - total removal of leaves (100% of total leaves present).

Leaf removal was carried out at two different stages, i. e., on 10 July 1987 (12 days previous to flowering for line IAP 72 and 16 days previous to flowering for IAP 48), on 22 July 1987 and 26 July 1987, the dates on which IAP 72 and IAP 48, respectively, flowered.

Leaf area was measured by an automatic area meter (AAM – 7) and the following characters were investigated: achene yield (g at 0 moisture) and dry weight of plants, including root apparatus but excluding seeds, at maturity (g) and that of the entire plant (g).

Stomatal conductance (cm/s) was determinated on 27 July, together with transpiration (mg H_2O per cm^2/ sec E -03), photosynthesis (mg CO_2 per dm^2 /hour); light (PAR = photosyntheticaly active radiation) and VPD (vapor pressure deficit) (KILOPASCAL) were also measured several times during the day on plants from line IAP 48 deprived of leaves in sectors A and C during flowering (treatment N5, 66.6% leaves removed), using an infrared gas analyzer, to determine whether the removal of leaves caused changes in photosynthesis.

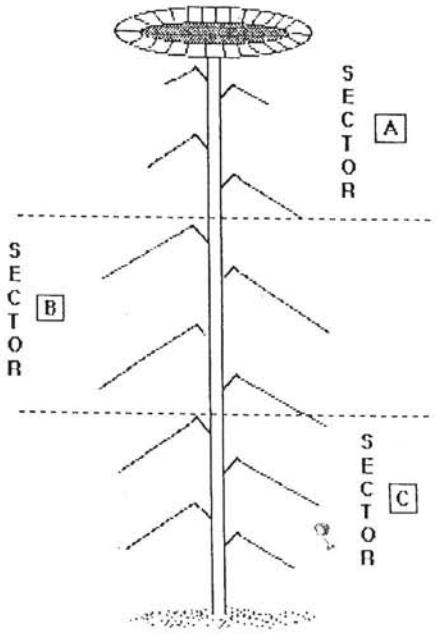

Fig. 1 Subdivision of leaf apparatus in the defoliation trial

RESULTS AND DISCUSSION

Table 3 reports mean values in variance analysis of the considered characters.

No statistically significant differences were found in yield between leaf removal at 33.3, 66.6 and 50% of all leaves present (treatments from N2 to N5 with N7), whereas with leaf removal **in toto** (N8) the difference was evident - as was to be expected. It should be noted that the plants in both 66.6 (N4 and N5) and 33.3% (N2 and N3) defoliation treatments showed a 40% lower yield than the control. This suggests that to the yield the removal of apical (N2) or medium (N3) sectors is more damaging than their complemental (N4 or N5).

The removal of 50% leaves distributed over the whole plant gave the same results as 66.6% removal as specified above. With the exception of N6 (20% reduction of leaves), all treatments gave achene yields different from that of the control. Values for N6 were not statistically different, showing that the loss of one leaf in five does not seem to jeopardize yield to any extent.

Statistical differences in plant dry weight excluding achenes among treatment N2 to N5 with N7 followed a pattern similar to that for yield, while N4 (which left leaves in sector A with 66.6% removal) and N6 (removal of one leaf out of five, 20% removal), N1 (control) and N6 were not significantly different.

Table 3. Mean values for different defoliation treatments in the considered characters

effect	yield (gr)			dry weight excluding seeds (gr)			total dry weight (gr)		
1	2			3			4		
lines									
IAP 72	26.95	b	B	64.41	b	B	90.42	b	B
IAP 48	62.96	a	A	138.54	a	A	201.51	a	A
defoliation treatments									
N1	73.35	a	A	139.99	a	A	213.00	a	A
N2	43.45	c	B	87.86	d	C	131.56	c	C
N3	44.44	c	B	98.07	cd	C	142.52	c	C
N4	41.69	c	B	103.12	c	BC	144.82	c	C
N5	41.15	c	B	98.89	cd	C	140.05	c	C
N6	63.48	b	A	121.08	b	AB	184.57	b	B
N7	43.06	c	B	101.31	cd	C	144.38	c	C
N8	5.01	d	C	61.46	e	D	66.47	d	D
defoliation times									
preflowering	44.31	a	A	96.88	b	B	141.20	b	B
flowering	44.60	a	A	106.06	a	A	150.73	a	A
lines – defoliation treatments									
IAP 72–N1	59.77	b	B	89.58	e	EF	149.36	d	CD
IAP 72–N2	20.65	d	DE	60.59	fh	GH	81.74	f	EF
IAP 72–N3	22.99	d	D	55.14	gh	GH	78.14	f	EF
IAP 72–N4	20.44	d	DE	76.66	ef	FG	97.11	ef	E
IAP 72–N5	18.92	d	DE	61.24	fh	GH	80.16	f	EF
IAP 72–N6	40.98	c	C	73.00	eg	FG	113.98	e	DE
IAP 72–N7	21.11	d	DE	53.93	gh	GH	75.04	fg	EF
IAP 72–N8	2.74	e	F	45.10	h	H	47.84	g	F
IAP 48–N1	86.94	a	A	190.40	a	A	277.34	a	A
IAP 48–N2	66.26	b	B	115.13	d	DE	181.39	c	BC
IAP 48–N3	65.89	b	B	141.01	c	CD	206.90	bc	B
IAP 48–N4	62.95	b	B	129.57	cd	CD	192.52	bc	B
IAP 48–N5	63.40	b	B	136.55	c	CD	199.94	bc	B
IAP 48–N6	85.99	a	A	169.16	b	AB	255.16	a	A
IAP 48–N7	65.01	b	B	148.70	c	BC	213.71	b	B
IAP 48–N8	7.29	e	EF	77.81	ef	FG	85.10	ef	EF
lines – defoliation times									
IAP 72–prefl.	26.50	b	B	61.84	c	C	88.34	c	C
IAP 72–flow.	25.39	b	B	66.98	c	C	92.50	c	C
IAP 48–prefl.	62.12	a	A	131.93	b	B	194.05	b	B
IAP 48–flow.	63.81	a	A	145.15	a	A	208.97	a	A

Table 3. Mean values for different defoliation treatments in the considered characters (continued)

effect	yield (gr)			dry weight excluding seeds (gr)			total dry weight (gr)		
1	2			3			4		
defoliation treatments–defoliation times									
N1–prefl.	73.53	a	A	144.43	a	A	217.95	a	A
N1–flow.	73.18	a	A	135.55	ab	A	208.74	ab	A
N2–prefl.	44.22	cd	C	84.58	g	GH	128.81	gh	F
N2–flow.	42.68	cd	C	91.13	fg	EH	134.32	fh	EF
N3–prefl.	43.86	cd	C	102.14	df	CG	146.00	dg	DF
N3–flow.	45.02	cd	C	94.01	eg	DH	139.03	eh	DF
N4–prefl.	43.74	cd	C	95.50	eg	CH	139.24	eh	DF
N4–flow.	39.66	d	C	110.74	d	BE	150.40	df	CF
N5–prefl.	38.79	d	C	89.06	fg	FH	127.86	h	F
N5–flow.	43.52	cd	C	108.72	de	BF	152.24	de	CE
N6–prefl.	48.69	a	A	127.05	bc	AB	195.75	b	AB
N6–flow.	52.28	b	B	115.11	cd	BC	173.39	c	BC
N7–prefl.	38.88	d	C	90.79	fg	EH	129.67	gh	EF
N7–flow.	47.24	c	C	111.84	d	BD	159.08	cd	CD
N8–prefl.	2.79	e	D	41.50	h	I	44.29	l	H
N8–flow.	7.24	e	D	81.41	g	H	88.65	i	G
lines–defoliation treatments–defoliation times									
IAP 72–N1–prefl.	60.62	eg	DE	96.41	im	G	157.03	hi	EF
IAP 72–N1–flow.	58.93	fg	E	82.76	ln	HL	141.68	i	FG
IAP 72–N2–prefl.	22.13	i	G	55.12	qr	LO	77.25	mp	LN
IAP 72–N2–flow.	19.16	il	G	66.07	nr	LN	86.23	mo	HN
IAP 72–N3–prefl.	22.82	i	G	60.90	or	LN	83.72	mo	HN
IAP 72–N3–flow.	23.17	i	G	49.38	rs	NO	72.56	np	LN
IAP 72–N4–prefl.	20.30	il	G	74.39	nq	HN	94.69	ln	HM
IAP 72–N4–flow.	20.58	il	G	78.95	mo	HM	99.53	lm	HL
IAP 72–N5–prefl.	20.17	il	G	58.32	or	LO	78.49	mp	LN
IAP 72–N5–flow.	17.67	il	G	64.16	nr	LN	81.82	mo	IN
IAP 72–N6–prefl.	43.93	h	F	68.18	nr	IN	112.11	l	GI
IAP 72–N6–flow.	38.03	h	F	76.82	mp	HN	115.00	l	GH
IAP 72–N7–prefl.	20.01	il	G	51.26	rs	MO	71.28	np	LN
IAP 72–N7–flow.	22.20	i	G	56.61	pr	LO	78.81	mp	LN
IAP 72–N8–prefl.	2.07	m	H	30.12	s	O	32.19	p	O
IAP 72–N8–flow.	3.41	m	H	60.09	or	LN	63.50	op	MO
IAP 48–N1–prefl.	86.44	ab	AB	192.44	a	A	278.88	a	A
IAP 48–N1–flow.	87.44	ab	AB	188.35	ab	A	275.80	a	A
IAP 48–N2–prefl.	66.32	dg	CE	114.06	gi	EG	180.38	gh	DE
IAP 48–N2–flow.	66.20	dg	CE	116.21	gi	DG	182.41	fg	DE
IAP 48–N3–prefl.	64.91	dg	DE	143.37	de	BD	208.28	ce	BD
IAP 48–N3–flow.	66.87	dg	CE	138.64	df	BE	205.51	df	CD
IAP 48–N4–prefl.	67.18	df	CE	116.61	gi	DG	183.78	eg	DE
IAP 48–N4–flow.	58.73	fg	E	142.53	de	BE	201.26	dg	CD
IAP 48–N5–prefl.	57.42	g	E	119.81	gh	DG	177.22	gh	DE
IAP 48–N5–flow.	69.38	ce	CE	153.29	cd	BC	222.67	bd	BC
IAP 48–N6–prefl.	93.46	a	A	185.92	ab	A	279.39	a	A
IAP 48–N6–flow.	78.53	bc	B	152.41	cd	BC	230.93	bc	BC
IAP 48–N7–prefl.	57.75	fg	E	130.32	eg	CF	188.07	eg	DE
IAP 48–N7–flow.	72.28	cd	CD	167.07	dc	AB	239.35	b	B
IAP 48–N8–prefl.	3.51	m	H	52.89	r	MO	56.40	pq	NO
IAP 48–N8–flow.	11.07	lm	GH	102.73	hl	FH	113.80	l	GI

Means in a row followed by the same letter are not significantly different according to a pairwise t test ($p = 0.05$ and 0.01)

Analogous patterns were followed by whole plant dry weight, with the exception of N4 and N6, the latter of which, in fact, proved to diverge from all the others.

Different removal times, whether before or during flowering, did not seem to affect yield results. Removal during flowering did, however, give rise to greater dry weight.

Analysis of the interaction between these two lines and the treatments reveals that there were no statistically significant yield differences among treatments N2 to N5 with N7 for IAP 48 and N1 for IAP 72 (untreated control), or among N2, N4, N5 with N7 for IAP 72 and N8 for IAP 48. This means that even at high leaf loss rates IAP 48 gives a yield comparable to that of IAP 72 even at maximum intensities of damage. When 3rd order interaction is analysed, however, this is seen to occur only in the case of total removal during flowering, probably because the plants had at this stage already stored enough reserves in the flower head. IAP 48 which proved to give better yields than IAP 72 and percentagewise, suffered the consequences of defoliation less than the latter (Table 4); this may be due to IAP 48 having a greater number of leaves (about 7) than IAP 72, which enabled it to maintain sufficient leaf area to guarantee a certain yield level.

Plant dry weight excluding achenes did not reveal results significantly divergent from the fully leaved IAP 72 control or N2 and N8 for IAP 48, or among treatments N2-N7 for IAP 72 and N8 for IAP 48 (total removel of leaves).

Total dry weight of the plant followed a different pattern from the above in treatments N1 for IAP 72 and N2 for IAP 48; these were statistically diffent from N8 for IAP 48.

The two lines did not show differences in yield according to the time of leaf removal, whether before or during flowering, although plant dry weight was in all cases greater in IAP 48 defoliated at flowering.

Inspection of interaction between the lines and leaf removal time did not reveal a significant difference in values of dry weight excluding achenes, apart from N7 and N8, which gave greater values for removal during flowering. Total dry weight was greater for leaf loss during flowering for N5 too.

Table 4. Yield reductions (%) in IAP 72 and IAP 48 for the different defoliation treatments

Treatment	line IAP 72	line IAP 48
N1 control	–	–
N2	65.46	26.33
N3	61.54	24.22
N4	65.81	27.60
N5	68.35	27.08
N6	31.44	1.10
N7	64.69	25.33
N8	95.42	91.62

Concerning line/ defolation treatment/removal time interaction, significant values for yield could be observed only for N6 and N7 treatments carried out on IAP 48 before or during flowering, while dry weight for this line was different in all cases, including N5 and N8.

Measurements made with the IRGA the day following leaf removal did not reveal (Figures 2, 3 and 4) significant differences in net photosynthesis, stomatal conductance or transpiration in plants with 66.6% defoliation (treatment N5) as compared with the control. Differences in yield and dry weight between defoliated plants and controls

cannot, therefore, be attributed to an increase in photosynthesis rates in the remaining leaves. It could be supposed, however, that the defoliated plants at a later stage in plant development are in a more favourable situation than the control, regarding water supply, and with their smaller leaf area are better able than the control to adapt to water stress developing in the soil. It seems to be confirmed from this: with no higher photosynthesis rate and lower leaf area (-66.6%) the defoliated plants (line IAP 48, treatment N5) had only 27.1% lower yield than the control.

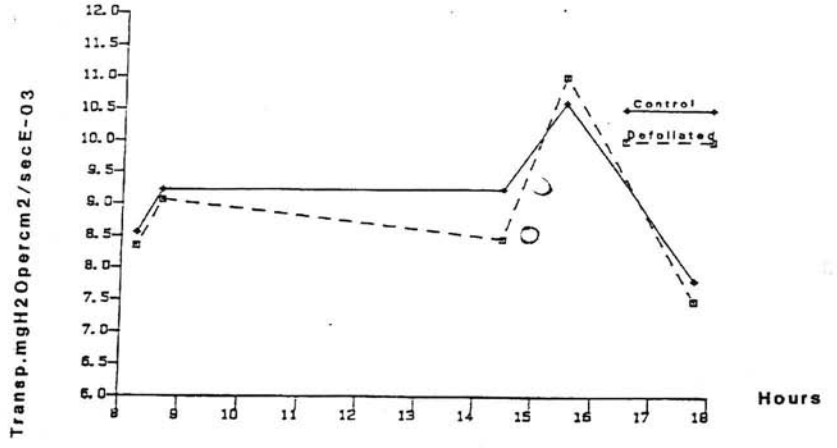

Fig. 2 Trend of net photosynthesis in defoliated plants and untreated control on the day following leaf removal (27 July 1987)

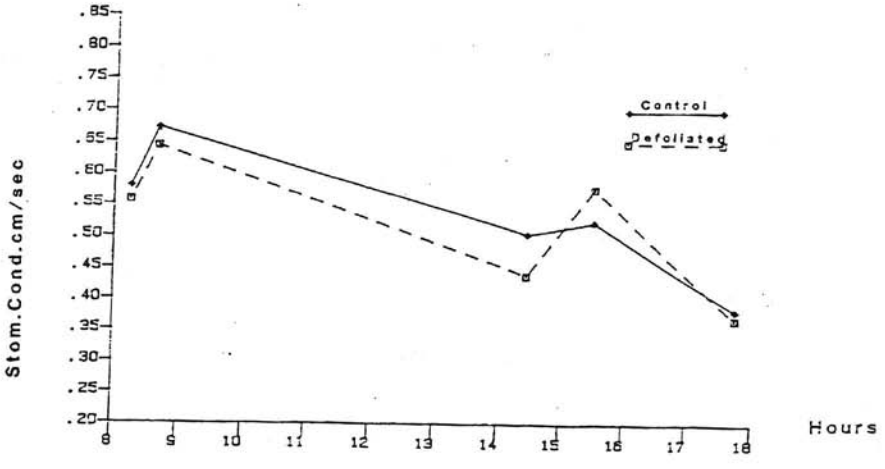

Fig. 3 Trend of stomatal conductance in defoliated plants and untreated control on the day following leaf removal (27 July 1987)

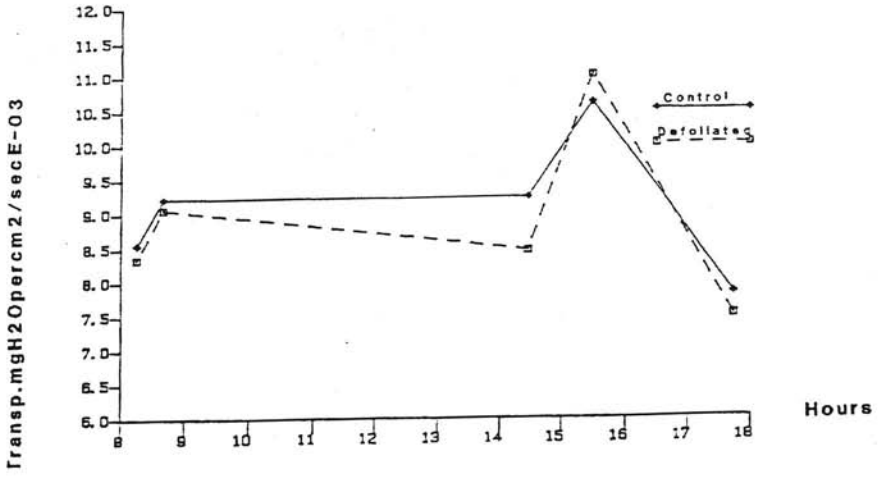

Fig. 4 Trend of transpiration in defoliated plants and untreated control on the day following leaf removal (27 July 1987)

CONCLUSIONS

Results of these trials may be summarized as follows:

- total leaf loss (100%) reduced yield by about 93%;
- an even distribution of leaf removal over the whole plant (50%) reduces yield to the same extent as a greater (66.6%), but localized, destruction;
- the removal of 20% leaves do not give rise to a significant decrease in yield with respect to the control;
- apical and central leaves are definitely the most important for yield, making a fundamental contribution in product of photosynthesis;
- leaf removal times (before or during flowering) does not seem to affect yield;
- the plants with more, although smaller, leaves (line IAP 48), were always less affected by defoliation than those with fewer but larger leaves. This may be due to the former's better phyllotaxic distribution, enabling more efficient capture and utilization of radiation;
- no differences were measured in net photosynthesis, stomatic conductance or transpiration between defoliated plants and the control.

REFERENCES

Conti, S. and P. Landi. 1981. Effetti della defogliazione in realizione al portamento fogliare e alla densità di piante in ibridi di mais. Riv. Agr. 3-4: 151-155.

Danuso, F., F. Miceli and G. Venturi. 1983. Asportazione delle foglie, componenti della produzione e sviluppo delle piante. Inf. Agr. 20: 25931-33.

Fehr, W. R., C. E. Caviness, D. T. Burmod, and J. S. Pennington. 1971. Stage of development descriptions for soybeans, *Glycine max* (L.) Merril. Crop Sci. 11: 929-931.

_____, _____, *and J. J. Vorest*. 1977. Response of indeterminante and determinante soybean cultivars to defoliation and half- plant cut off. Crop Sci. 17: 913-917.

_____, *B. K. Lawrence, and T. A. Thompson*. 1981. Critical stages of development for defoliation of soybean. Crop Sci. 21: 259-262.

Goli, A., and D. B. Weaver. Defoliation responses of determinate and indeterminate late-planted soybeans. Crop Sci. 26: 156-159.

Gonzalez de Schelotto, A. L. 1978. Efectos de la defolacion no natural sobre el rendimento de girasol. Sun. New. 2, nl: 19-22.

Hanway, J. J. 1969. Defoliation effects on different corn hybrids as influenced by plant population and stage of development. Agron. J. 61: 534-539.

Johnson, B. J. 1972. Effect of artificial defoliation on sunflower yields and other characteristics. Agron. J. 64: 688-689.

Malone, S. R., and C. E. Calviness. 1985. Cut-off, break over, and defoliation effect on a determinate soybean cultivar. Agron. J. 77: 585-588.

Mc William, J. R., S. D. English, and C. N. Mc Dougall. 1974. The effect of leaf age and position on photosinthesis and the supply of assimilates during development in sunflower p. 173-179. In 6th Int. Sun. Conference (Bucharest).

Rodrigues Pereira, A. S. 1978. Effect of artificial defoliation on yield components in sunflower. Sun. New. 2, n 3: 7-13.

Sackston, W. E. Effect of artificial defoliation on sunflowers. Can. J. Plant Sci. 39: 108-118.

Tuberosa, R., and S. Conti. 1978. Effetti della defogliazione artificale su giresole. Convegno sugli aspetti genetici ed agronomici del giresole. Pisa.

Vasilas, B. L., and R. D. Seif. 1985. Pre-athesis defoliation effects on six corn inbreds. Agron. J. 77: 831-835.

EFFETS DE LA DEFOLIATION ARTIFICIELLE SUR LE TOURNESOL (*Helianthus Annuus L.*)

Beloni, P., Piccotino, D. Vannozzi, G. P.

Les auteurs présentent les résultats d'une étude concernant l'effet d'une défoliation artificielle sur deux lignées autofecondées. Des défoliations d'intensité croissante à differents étages folliaires ont été pratiquées à deux stades de developpment de la plante (avant et pendant floraison). Les résultats ont souligné l'importance du rôle des feuilles intermediaires et superieures dans le rendement qui décroit d'autant plus que le pourcentage de défolliation artificielle augmente.

EFECTOS DE DESFOLIACION ARTIFICIAL EN GIRASOL (*Helianthus Annuus L.*)

Paola Belloni, Rialete Picitino, Gian Paolo Vanozzi.

Los autores se refieren a resultados de un estudio referente a la desfoliación artificial en dos líneas autofecundadas de girasol. El tratamiento de desfoliación de intensidades crecientes en diferentes posiciones de hojas fueron llevadas a cabo en dos diferentes estados de crecimiento (antes y durante floración). Los resultados han puesto de manifiesto la importancia de las hojas superiores e intermedias en el rendimiento que decreció con el incremento del procentage de desfoliación.