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SIMULATION OF LEAF DAMAGE BY ARTIFICIAL DEFOLIATION AND ITS EFFECT ON SUNFLOWER (*Helianthus annuus* L.) PERFORMANCE

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SUMMARY

Sunflower (*Helianthus annuus* L.) hybrid NK-212 was planted at National Agricultural Research Center, Islamabad, during 1992 and 1993 to assess the impact of various levels of simulated leaf damage, commonly caused by insects, hail or foliar diseases, on source and sink relationship. Insect attack, hail and foliar diseases often partially defoliate sunflowers and may become important factors limiting the production. Reduction in leaf area may also occur in the field as a consequence of pathogens or atmospheric conditions. Artificial defoliation was chosen as an experimental means to assess its effect on seed yield and plant behavior. It had also made possible to evaluate the effect of such a reduction at different phenological stages and to identify the leaves that contribute greatly to the seed yield. The leaves were clipped in various proportions from different parts of the plant, *i.e.*, lower, middle and upper. The removal of upper 2/3 and 1/2 leaves caused a yield reduction of 29 and 55.8%, in 1992 and 37 and 44.8%, in 1993, respectively. In 1992, about 1% yield decline was recorded when the lower 1/3 leaves were removed and 6% yield decline with the removal of the lower 1/2 leaves. In 1993, the yield reduction was 26.7 and 39.2% due to removal of lower 1/3 and 1/2 leaves, respectively. This indicated that the upper leaves (source) contribute more towards seed yield (sink) than the lower ones. Correspondingly, the results indicated that insects and pests feeding on the upper portion of the sunflower plant can cause larger reduction in seed yield than those feeding on the lower leaves.

Key words: **sunflower (*Helianthus annuus* L.), artificial defoliation, leaf damage, simulation, performance, seed yield, source and sink relationship, Pakistan**

INTRODUCTION

Insect attack often partially defoliate sunflower (*Helianthus annuus* L.) and may become an important limiting factor in production. Reduction in leaf area may

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also occur in the field as a consequence of pathogens or atmospheric conditions. Artificial defoliation was chosen as an experimental means to assess its effect on seed yield and plant behavior. It had also made possible to evaluate the effect of such a reduction at different phenological stages and to identify the leaves that contribute greatly to the yield. Defoliation has been tried in a wide number of crop species. In soybean (*Glycine max* L.), for example, it was shown to reduce the yield considerably, particularly if it occurs during the final stages of development (Malone and Calviness, 1985; Goli and Weaver, 1986) and when the pods begins to develop (Fehr *et al.*, 1971; 1977; 1981). After defoliation, a decrease in grain yield as well as a drop in dry weight was observed in maize (*Zea mays* L.) (Hanway, 1969; Vasilas and Seif, 1985).

Total defoliation before flowering in sunflower caused about 93% reduction in seed yield (Johnson, 1972). Defoliation during flowering may either block achene production altogether or enormously reduce achene size and oil content. A progressive increase in the percentage of defoliation corresponds to a progressive decrease in yield. The dimension of the effect of artificial defoliation in sunflower depends on the phenological stage at which leaves are removed. With regard to the phenological stage, defoliation has its most marked effects on seed yield when performed just before flowering or during flowering (Sackston, 1959). The effects are far less notable when carried out during later stages of development (Rodrigues, 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. Yield continues to increase if among the remaining leaves there is a high percentage of young ones (Rodrigues, 1978). This may be due to their greater capacity to transport assimilates to the flowers (Mc William *et al.*, 1974). Stickler and Pauli (1961) reported that grain sorghum (*Sorghum bicolor* L.) yields were reduced more by removing approximately one half of the upper portion of the plants than by the removal of an equal proportion of leaves from the lower portion. The present study was conducted to evaluate the impact of various levels of simulated leaf damage, corresponding to that caused by insects, hail or foliar diseases, and to assess the source and sink relations in sunflower.

MATERIALS AND METHODS

Sunflower hybrid NK-212 was planted on 2^{nd} March 1992 and 7^{th} February 1993 at National Agricultural Research Center (NARC), Islamabad, Pakistan, to assess the impact of various levels of simulated leaf damage on the source and sink relationship. A randomized complete block design (RCBD) with four replicates was used. A plot size having four rows of 5 m length, spaced 75 cm apart, was used. Plant to plant distance of 25 cm within rows was maintained in each plot.

A uniform fertilizer dose of 60 N and 60 P_2O_5 (kg/ha) was applied to each treatment at the time of sowing, in both experiments, while 60 N (kg/ha) was given at the time of first irrigation, when the plants attained 35-45 cm height. Planting was done by dibbler, putting three seeds per hill at a depth of 3-5 cm. After germination, hills were thinned to one seedling per hill. The crop was thinned to one plant per hill at 2-4 leaf stage. Two hoeings were done to eradicate weeds. Hilling was done manually after the second irrigation to prevent the crop from lodging. The following ten defoliation treatments were applied at the time of flower initiation.

Treatment	Defoliation level and parts of the plant
T1	All leaves intact (control)
T2	Lower 1/3 leaves
T3	Lower 1/2 leaves
T4	Lower 2/3 leaves
T5	Middle 1/3 leaves
T6	Middle 2/3 leaves
T7	Upper 1/3 leaves
T8	Upper 1/2 leaves
T9	Upper 2/3 leaves
T10	All leaves removed (control)

Leaves were clipped (removed) from their point of attachment to the petiole in all four rows of each plot but the data were recorded only for the two central rows. Plant height (PH), head diameter (DH), seed yield (SY), 100-achene weight (100-AW) and oil content (OC) were recorded. Plant height was measured from ground level to the receptacle of the flower as an average of 10 plants selected randomly from the two central rows of each plot at physiological maturity stage. Head diameter was measured from the same randomly selected 10 plants. The central two rows from each plot were harvested for recording seed yield, oil content and 100-AW. After recording the seed yield, seed samples of 120 to 150 g were collected in kraft paper bags for determining the moisture content of seed at harvest using the following formula:

$$MC\ (\%) = \frac{\text{Fresh wt.(g) at harvest - dry wt.(g) of the seed taken after drying in oven at 70°C for 120 hours}}{\text{Fresh wt. (g) at harvest}} \times 100$$

Hundred-seed weight was taken as an average of three samples from each plot. Oil content was determined by nuclear magnetic resonance (NMR), Model Oxford 4000. The data collected were subjected to analysis of variance (Steel and Torrie, 1980), using Mstat-C software of microcomputers. Duncan's multiple rang test (Duncan, 1955) was used for separating the treatment means.

RESULTS AND DISCUSSION

The defoliation treatments affected seed yield, plant height, head diameter and oil content highly significantly in both years. Treatment x year interaction was also highly significant. In 1992, the treatment with intact leaves brought the maximum yield of 3511 kg/ha, followed by T2 (removal of lower 1/3 leaves) and T3 (removal of lower 1/2 leaves) with 3483 and 3287 kg/ha yields, respectively. Seed yields of T2 and T3 were not significantly different from T1 (Table 1).

Table 1: Simulation of leaf damage by artificial defoliation and its effect on sunflower performance in 1992

Defoliation treatment	PH (cm)	HD (cm)	Yield (kg/ha)	100-AW (g)	OC (%)
None	166	17.9	3511	7.7	48.6
Lower 1/3	168	18.2	3483	7.4	49.1
Lower 1/2	169	17.2	3287	7.0	49.3
Lower 2/3	170	16.4	2649	6.3	50.0
Middle 1/3	167	17.2	2758	6.8	50.0
Middle 2/3	170	15.5	2006	5.4	49.8
Upper 1/3	163	17.4	2492	7.1	46.4
Upper 1/2	163	16.2	1553	5.2	45.4
Upper 2/3	161	12.4	685	3.8	38.4
All	152	08.3	90	2.2	25.6
CV (%)	2.4	6.5	7.3	6.8	3.3
LSD (0.05)	5.7	1.5	238	0.6	2.2

These results indicated that the removal of lower 1/3 or 1/2 leaves did not reduce yield significantly. Contrarily, maximum yield reductions were observed when upper 2/3, 1/2 and 1/3 leaves were removed, giving 685, 1533 and 2492 kg/ha seed yields, respectively. Seed yield was also significantly reduced when middle 1/3 (2758 kg/ha) and 2/3 leaves (2006 kg/ha) were removed. The lowest yield of 90 kg/ha was obtained when all the leaves were removed, which was significantly lower than any other defoliation treatment. In T10, the plants failed to attain higher seed filling because leaves were removed before they reached physiological maturity stage. These results are in agreement with those obtained by Stear *et al.* (1988), Schneiter *et al.* (1987), Butignol (1983), Fleck *et al.* (1983) and Beer (1983).

By removing upper leaves in treatments T7, T8 and T9, the yield reductions were 29.0, 55.8 and 80.0%, respectively. The removal of lower leaves in treatments T2, T3 and T4 caused yield reductions of 0.8, 6.4 and 24.6%, respectively. These results are in agreement with those obtained by Johnson (1972), Mitchell (1984), Belloni *et al.* (1990) and Silva *et al.* (1984). In 1993, the trend in yield reduction due to defoliation treatment was almost identical to that observed in the previous year although the magnitude was slightly different (Figure 1). The main difference in the results was that, in 1993, the removal of lower 1/3 and 1/2 leaves also reduced the seed yield significantly (Table 2). Similarly, the removal of middle 1/3 and 2/3 leaves caused severe reductions (36.3 and 72.7%, respectively) in seed yield in

1993, while yield reductions in 1992 were somewhat lower, ranging from 21.4 to 42.9% for the removal of middle 1/3 and 2/3 leaves.

Table 2: Simulation of leaf damage by artificial defoliation and its effect on sunflower performance in 1993

Defoliation	PH (cm)	HD (cm)	Yield (kg/ha)	100-AW (g)	OC (%)
None	178	17.6	2426	6.3	39.8
Lower 1/3	185	19.7	1778	6.1	37.8
Lower 1/2	183	16.8	1474	5.4	38.5
Lower 2/3	182	16.5	1247	5.4	37.5
Middle 1/3	184	17.8	1545	5.8	37.8
Middle 2/3	186	14.4	663	4.9	37.3
Upper 1/3	181	17.4	1512	5.5	36.1
Upper 1/2	180	17.2	1339	4.8	35.0
Upper 2/3	181	13.5	606	3.8	33.4
All	175	10.0	308	3.6	21.9
CV (%)	3.4	15.0	16.5	7.2	4.7
LSD (0.05)	8.9	3.5	308	0.6	2.5

However, in both years, the effect of the removal of upper leaves on seed yield, seed development and oil content was more drastic than the effect of the removal of middle and lower leaves (Sharma and Sharma, 1986; Banerjee and Haque, 1984). It was probably because the upper leaves are young, they intercept the sunlight the most, and therefore, have high photosynthetic activity (Silva *et al.*, 1984). Moreover, lower leaves are shaded by the upper ones and therefore cannot contribute to the production of photosynthates as effectively as upper leaves can. Correspondingly, the results showed that damages caused by insect pests, hail or foliar diseases on upper leaves of the plants cause more reduction in seed yield as compared with middle and lower leaves of sunflower (Beer, 1983).

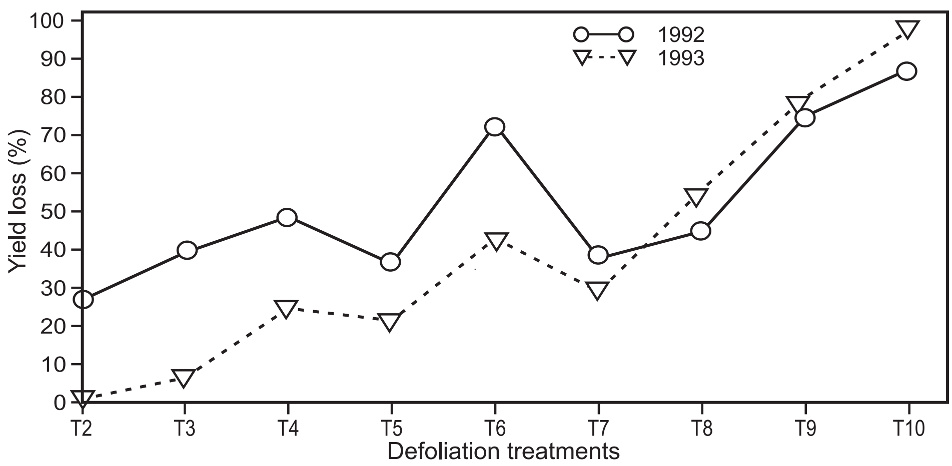

Figure 1: Yield loss in sunflower due to various artificial defoliation treatments compared with the control treatment having all leaves intact

The results also indicated that the upper leaves contributed more towards sink compared with the lower ones. In addition, reduction in leaf area reduced proportionally the contribution of photosynthates to sink (Figures 2 and 3), which was conspicuous in all parts of the plant, *i.e.*, lower, middle and upper leaves. In 1992, the maximum oil content (50.1%) was obtained in T5 in which the middle 1/3 leaves were removed. Other treatments, which gave higher oil percents, were T2, T3, T4 and T6. They were not statistically different from each other and from T1 (all leaves intact). The removal of upper leaves in the case of T7, T8, and T9 reduced the oil content significantly. The treatment having plants without leaves had only 25.6% oil in seed. Similar results were obtained in 1993. The results indicated that the contribution to oil content was not proportionally linked to defoliation of lower and middle leaves, however, reduction in oil content was conspicuous on removal of upper leaves. It indicates that the upper leaves contribute most to oil synthesis.

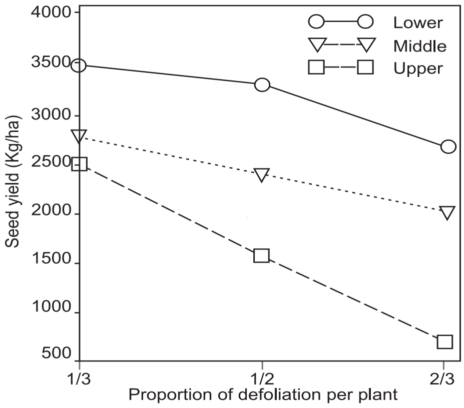

Figure 2: Simulation of leaf damage by artificial defoliation and its effect on sunflower yield during 1992

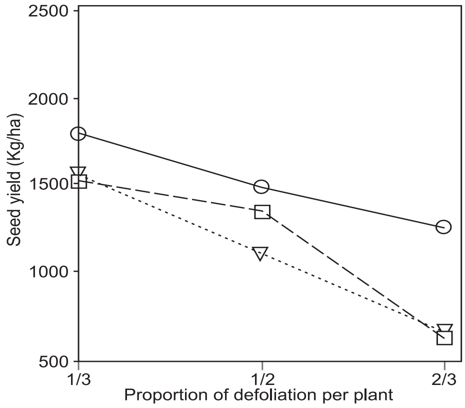

Figure 3: Simulation of leaf damage by artificial defoliation and its effect on sunflower yield during 1993

The largest head diameter was obtained in both years when the lower 1/3 leaves were removed. The treatments which reduced the head diameter significantly were the removal of upper 2/3 and middle 2/3 leaves. These results conform with those obtained by Moscardi and Boas (1983) and Singh and Khan (1981). Plant height was not significantly affected by most of the defoliation treatments in either year, however, the effect of the removal of leaves was more obvious in 1993. Removal of all leaves reduced the plant height significantly (Mariko and Hogetsu, 1987). In both years, plant height increased with all defoliation treatments except T10. In 1992, increase in plant height was more larger when lower leaves were removed than when upper leaves were removed, however, in 1993, the removal of upper leaves in T7, T8, and T9 also reduced plant height. All defoliation treatments, irrespective of leaf position on the plant, reduced the 100-achene weight significantly. In both years, reduction in seed size was significantly higher when upper 2/3, upper 1/2 and middle 2/3 leaves were removed as compared with the removal of leaves from lower 1/2 lower 2/3 and upper 1/3. The removal of lower 1/3 leaves reduced the seed size but the reduction was not statistically significant. These results are in agreement to those obtained by Silva *et al.* (1984).

CONCLUSIONS

The sunflower (*Helianthus annuus* L.) hybrid NK-212 was planted at National Agricultural Research Center, Islamabad in 1992 and 1993 to assess the impact of various levels of simulated leaf damage, comparable to that caused by insects, hail or foliar diseases, on the source and sink relationship. Leaves were clipped in various proportions from different parts of the plant, *i.e.*, lower, middle and upper. The removal of upper 2/3 and 1/2 leaves caused yield reductions of 29 and 55.8%, in 1992, and 37 and 44.8%, in 1993, respectively. These results indicated that the removal of upper 2/3 and 1/2 leaves affected the seed yield the most. It showed that in the sunflower the upper leaves contribute more assimilates towards sink (yield) than lower leaves. It indicates that the upper laves are more actively involved in photosynthesis. It is probably because the upper leaves are younger than the lower ones.

Yield decline was low when lower 1/3 and 1/2 leaves were removed. The results showed that the damage caused by insect pests, hail or foliar diseases, in the upper portion of sunflower plants, can cause maximum yield reduction if the attack is severe. This indicated that the upper leaves (source) contribute more towards seed yield (sink) than the lower ones. Correspondingly, the results indicated that insects and pests feeding on the upper portion of the sunflower plant can cause higher reduction in seed yield than their feeding on the lower leaves.

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SIMULACION DEL DAÑO DE HOJA POR LA ELIMINACION ARTIFICIAL DE HOJAS Y SU EFECTO SOBRE LAS PERFORMANCES DEL GIRASOL

RESUMEN

El hibrido del girasol (*Helianthus annuus* L.) NK-212 fue sembrado en el Centro Nacional de investigaciones agricolas en Islamabad durante 1992 y 1993 para constatar el efecto de diversos niveles de simulacion de daño de hojas, es decir, de daños semejantes a esos causados por los insectos, el granizo o las enfermedades de hojas sobre la relacion entre la fuente de asimilado y aceptante de asimilado. El ataque de insectos, granizo y enfermedades de hoja dejan a menudo la planta de girasol parcialmente sin hojas, lo que puede ser un factor limitante significativo en la produccion. La reduccion de la superficie de hojas puede tambien ocurrir bajo las condiciones de campo como consecuencia del ataque de patogenos y condiciones atmosfericias. La eliminacion de hojas artificial fue escogida como un medio experimental para hacer constar el efecto de eliminacion de hojas sobre el rendimiento de semillas y el comportamiento de la planta misma. La eliminacion artificial posibilita tambien de investigar el efecto de eliminacion de hojas en diversas fases fenologicas y constatar cuales hojas tienen un efecto importante sobre el rendimiento de semillas. Las hojas eran eliminadas en diversas relaciones y de diversas partes de la planta, es decir, de las partes interior, media y de cima. La eliminacion de 2/3 y 1/2 superiores de hojas hizo la reduccion del rendimiento en 29 y 55,8% en 1992 y 37 y 44,8% en 1993. En 1992, la reduccion del rendimiento en cerca de 1% ocurrio como consecuencia de eliminacion de 1/3 inferior de hojas, y 6% cuando fue eliminada la mitad inferior de hojas. En 1993, la reduccion del rendimiento era de 26,7 y 39,2% despues de la eliminacion de 1/3 y 1/2 inferiores de hojas. Eso indica que las hojas superiores (fuente de asimilado) contribuyen mas al rendimiento de semillas (aceptante de asimilado) que las hojas inferiores. Conforme a eso, estos resultados indican que los insectos y parasitos que se nutren con hojas de la mitad superior de la planta pueden causar mas grande reduccion del rendimiento que los parasitos que se nutro de la mitad inferior de la planta.

SIMULATION DE DÉTÉRIORIATION DES FEUILLES CAUSÉE PAR DEFOLIATION ARTIFICIELLE ET SON EFFET SUR LE TOURNESOL (*Helianthus annuus* L.)

RÉSUMÉ

Durant les années 1992 et 1993, on a semé l'hybride de tournesol (*Helianthus annuus* L.) NK-212 au Centre de recherche d'agronomie d'Islamabad pour évaluer l'influence de différents niveaux de dommages causés aux feuilles par simulation, dommages semblables à ceux qui sont causés par les insectes,

la grêle ou les maladies des feuilles en rapport avec la source d'assimilation et l'accepteur d'assimilation. Les attaques des insectes, la grêle et les maladies des feuilles privent souvent le tournesol d'une partie de ses feuilles ce qui peut être un facteur limitatif de la production. Dans les champs, la réduction de la surface des feuilles peut aussi être la conséquence de conditions atmosphériques ou pathogènes. La défoliation artificielle a été choisie comme moyen expérimental d'évaluation de l'effet de la destruction des feuilles sur le rendement en graines et sur le comportement même de la plante. Enlever les feuilles de façon artificielle permet aussi l'examen de l'effet de la perte des feuilles pendant différentes phases phénologiques et de constater quelles feuilles ont une influence déterminante sur le rendement en graines. Les feuilles ont été coupées en différentes proportions et sur différentes parties de la plante, c'est-à-dire, les parties inférieures, moyennes et supérieures. L'enlèvement des deux tiers et de la demie des feuilles supérieures a causé une réduction du rendement de 29 et de 55.8% en 1992 et de 37 et 44.8% en 1993. En 1992, on a enregistré un déclin du rendement de 1% quand le tiers des feuilles inférieures avait été enlevé et un déclin de 6% du rendement avec l'enlèvement de la moitié des feuilles inférieures. En 1993, la réduction du rendement a été de 26.7 et de 39.2% avec l'enlèvement du tiers et de la moitié des feuilles inférieures respectivement. Cela indique que les feuilles supérieures (source d'assimilation) contribue de façon plus importante au rendement en graines (accepteur d'assimilation) que les feuilles inférieures. Ainsi ces résultats indiquent-ils que les insectes et les animaux nuisibles qui se nourrissent dans la partie supérieure de la plante sont la cause d'une plus grande réduction de rendement en graines que ceux qui se nourrissent dans sa partie inférieure.