HELIA, **14**, Nr. 14, p.p. 55-62 (1991)

LEAF EXPANSION AND PHOTOSYNTHESIS DURING GROWTH AND DEVELOPMENT OF NS SUNFLOWER HYBRIDS AND INBRED LINES

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SUMMARY

Two NS-sunflower (*Helianthus annuus* L.) hybrids, differently resistant to *Diaporthe/Phomopsis helianthi*, and their parental lines were examined on the effect of ageing and position on leaf growth parameters and photosynthetic potential of leaves. It was found that both hybrids, NS-H-26 and NS-H-43, had higher rates of leaf appearance, leaf expansion and leaf area duration than their parental lines. Heterotic effect was especially noticeable in leaf area formation, in both hybrids. Most of the examined parameters point to the similarity between the hybrid NS-H-26 and its female parent and between the hybrid NS-H-43 and its male parent. The hybrid NS-H-43 followed a pattern of the male parent RHA-SNRF in photosynthetic potential of the examined leaves too.

INTRODUCTION

The pattern of leaf expansion, leaf area duration and photosynthesis during the development of leaves is essential to define photosynthetic capacity of plants. Photosynthetic capacity is an important feature in evaluation of new sunflower hybrids (Škorić, 1980).

It was shown earlier that the rate of photosynthesis per unit leaf area is similar in different cultivars of sunflower (English *et al.*, 1979; Rawson & Constable, 1980; Rawson *et al.*, 1980). The patterns of leaf area expansion tend to differ among sunflower cultivars (Rawson et al., 1980) and also, they change with the environment in which a leaf develops (Bunce, 1983).

The aim of this work was to measure th effect of ageing and position on leaf growth and maximum rates of photosynthesis in order to determine photosynthetic capacity of leaves. Two NS sunflower hybrids, differently resistant to *Diaporthe/Phomopsis helianthi* (Škorić, 1985), and their parental lines were examined.

MATERIALS AND METHODS

Six sunflower (*Helianthus annuus* L.) genotypes: RHA-SNRF, OCMS-22 and their hybrid NS-H-43, RHA-58, CMS-Ha-V-9831-3-4 and their hybrid NS-H-26-RM were grown in the field. The hybrid NS-H-26-RM and its parental lines are susceptible to *Diaporthe/Phomopsis helianthi* while a high degree of tolerance (field resistance) was

detected in the line RHA-SNRF and its hybrid NS-H-43 (Škorić, 1985). The experiments were conducted under conditions of a low population of pathogens, i.e., our results were not affected by the causative agents of a single spot disease. The experiment al plots were at Rimski Šančevi near Novi Sad. The plant density was 45000 plants per hectare. Meteorogical data for the period of the study are presented in Table 1. Leaf areas of six plants for each genotype were measured once a week with a LI-3100 Area Meter (LI-COR, USA). The plants of the line RHA-58 are branched, but only the central branch was analysed. Where indicated, leaf areas were estimated from the relationship: A = 0.73 x length x greatest width (Rawson *et al.*, 1980). Duration of leaf expansion (5 - 95% Amax) and average growth rate of leaves during this interval were determined according to Constable and Rawson (1980). All data were examined by analysis of variance using MSTAT statistical programme.

Table 1. Meteorological data for the period od the study

Month	Temperature (°C)			Rainfall (mm)	Short-wave radiation (MJ m^{-2} day^{-1})
	Mean	Max.	Min.		
May	18.6	24.4	12.2	50.8	19.4
June	19.1	24.5	13.0	50.4	19.3
July	19.7	25.3	13.9	77.1	17.2
Aug.	22.0	29.1	15.2	40.0	17.9
Sept.	17.1	24.3	10.2	4.3	15.5

Polarographic measurements of photosynthetic oxygen evolution were done on a leaf disc (10 cm^2) in a closed chamber (LD2, Hansatech, U.K.) at 25°C and 5% CO_2 (Delieu & Walker, 1981). The leaf chamber was illuminated from the top. The Bjorkman

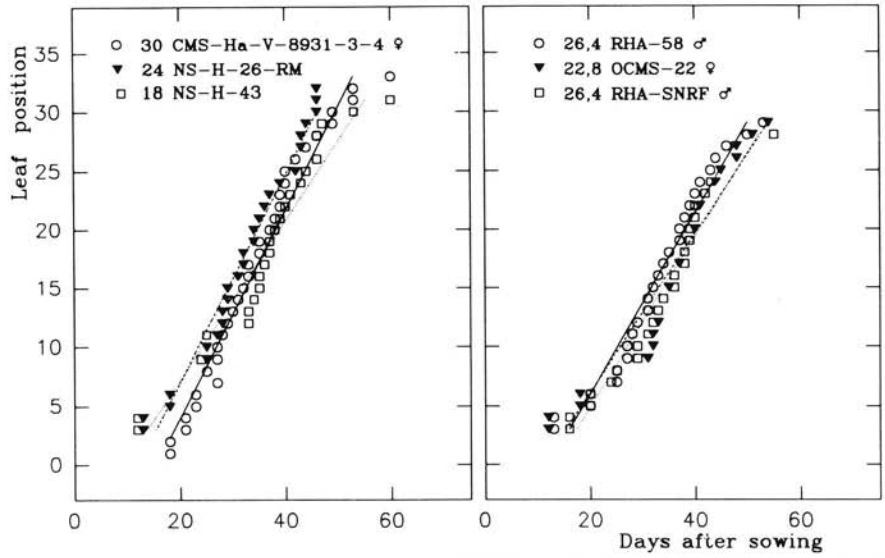

Figure 1. Leaf appearance for six genotypes of sunflower. NS-H-43 , RHA-SNRF, OCMS-22 , NS-H-26-RM , CMS-Ha-V-8931-3-4 and RHA-58

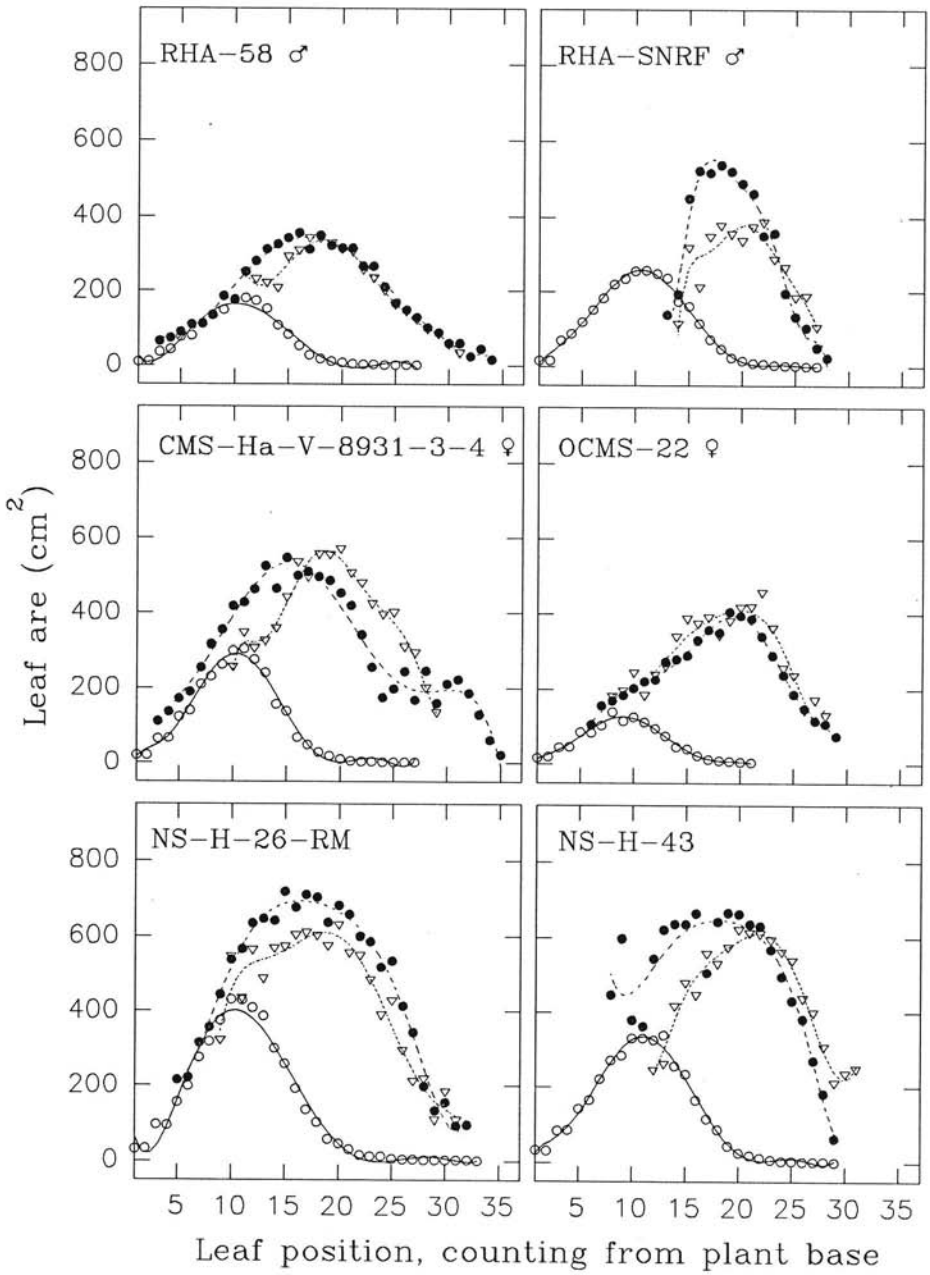

Figure 2. Area for each leaf position (leaf area profile) of sunflower plants at the stages of flower bud ○, anthesis ● and seed-filling ▽. Results are the mean values of the measurements on six plants

lamp which was used as a source of light intensities, accommodates neutral density filters, thereby providing a range of light intensities. Oxygen evolution rates were measured at increasing photon flux densities, the plot of the rates against incident light and maximum rates of photosynthesis in saturating irradiance and CO_2 were obtained with the help of the computer programme LEAF DISC (Walker, 1987).

RESULTS AND DISCUSSION

The pattern of leaf appearance in the NS-sunflower hybrids and their parental lines is presented in Figure 1. The rate of appearance was on average 0.61 leaves per day, the slowest rate was 0.56 (RHA-58 and CMS-Ha-8931-3-4), the fastest 0.71 leaves per day (NS-H-43), considering leaves 10 to 25. Final number of leaves was 29 for the lines RHA-58, OCMS-22 and RHA-SNRF, but it was over 30 for both hybrids and for the line CMS-Ha-8931-3-4. The rates of leaf expansion, from 5 to 95% Amax, increased with leaf position, reaching the maximum at positions 11 - 20, and therefrom declining for all genotypes (Table 2).

Table 2. The rates of leaf expansion ($cm^2\ day^{-1}$) for indicated leaves on plants of the 6 sunflower genotypes. Values used for each leaf position are the means of 6 plant replicates.

Genotype	L e a f						
	5	7	9	11	15	20	25
RHA-58	4.0	6.9	7.4	10.8	12.4	11.7	7.6
CMS-Ha-V-8931-3-4	6.2	8.4	12.5	16.2	15.0	16.5	7.6
NS-H-26-RM	6.9	10.5	14.5	16.1	15.8	12.9	10.9
RHA-SNRF	7.8	11.0	14.2	15.1	16.9	13.8	4.6
OCMS-22	4.8	5.6	6.9	10.3	10.8	9.0	5.0
NS-H-43	9.1	10.8	15.6	15.9	19.8	15.7	14.3

The hybrid NS-H-43 and its parental line RHA-SNRF exhibited the fastest rates of leaf expansion, while OCMS-22 and RHA-58 showed the slowest rates of leaf expansion. The areas of individual leaves were analysed as a function of leaf position (leaf area profile), stage of plant development and genotype (Figure 2). At the stage of flower bud, the maximum leaf area was at the position 11 for all genotypes except for OCMS-22, which had the maximum area at the position 10. Leaf area profile was significantly changed at anthesis, with the maximum at the leaf position 16 (NS-H-26 and its parental lines) and 18 (NS-H-43 and its parental lines). The maximum shifted towards the leaf position 18 (NS-H-26) and 20 (NS-H-43) at the seed filling stage. The maximum of leaf area profile was here, as in other cases, allocated to the central position among the living leaves (Rawson *et al.*, 1980). When comparing leaf area profiles and other characteristics, the similarity between the hybrid NS-H-26 and its female parent and between the hybrid NS-H-43 and its male parent RHA-SNRF becomes apparent. Differences in leaf area profiles among genotypes were caused partly by the differences in leaf area duration (Table 3). Lower leaf positions (up to the leaf 11) of NS-H-43 and RHA-SNRF had shorter LAD compared with NS-H-26 and RHA-58. On the other hand, the leaves in the upper half (15 - 25) of the hybrid NS-H-43 and both parental lines had significantly longer LAD than NS-H-26 and its parental lines. The effect of heterosis was noticeable all along

the leaf area formation in both hybrids. It is probably most apparent when maximum areas of individual leaves for the hybrid and its parental lines are compared (Figure 3).

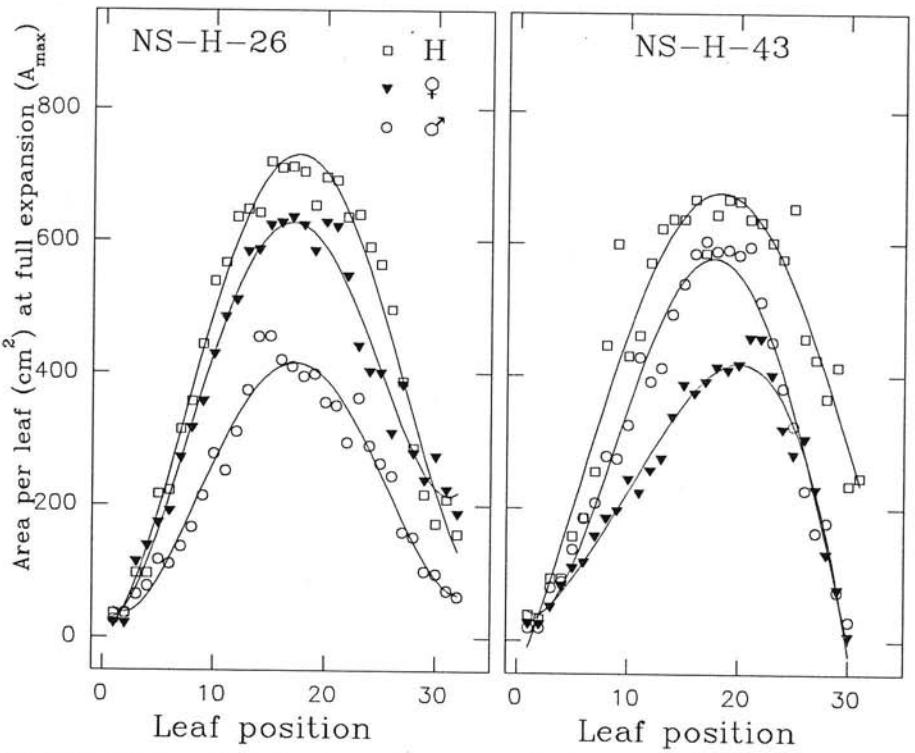

Figure 3. Final area for each leaf of sunflower plants measured in the course of development. Result are the mean values of the measurements on six plants.

Table 3. Leaf area duration (day) for the indicated leaves on plants of 6 sunflower genotypes. Values used for each leaf position are the means of 6 plant replicates.

Genotype	Leaf						
	5	7	9	11	15	20	25
RHA-58	53	52	58	62	66	63	58
CMS-Ha-V-8931-3-4	50	60	63	66	73	68	64
NS-H-26-RM	46	45	49	54	73	74	67
RHA-SNRF	41	37	40	47	79	82	79
OCMS-22	43	63	66	68	74	78	73
NS-H-43	41	42	45	48	66	85	86

The effect of ageing and position on the photosynthetic potential of most active leaves of the hybrid NS-H-43 and and its parental lines is presented in Figure 4.

In all cases the maximum rate of photosynthesis was reached before full leaf expansion and then declined as the leaf aged (Saftić & Plesničar, 1990). Among the examined leaf positions leaf 15 had the lowest maximum rate of photosynthesis which lasted longer, while leaf 25 had the highest maximum rate which started to decline long

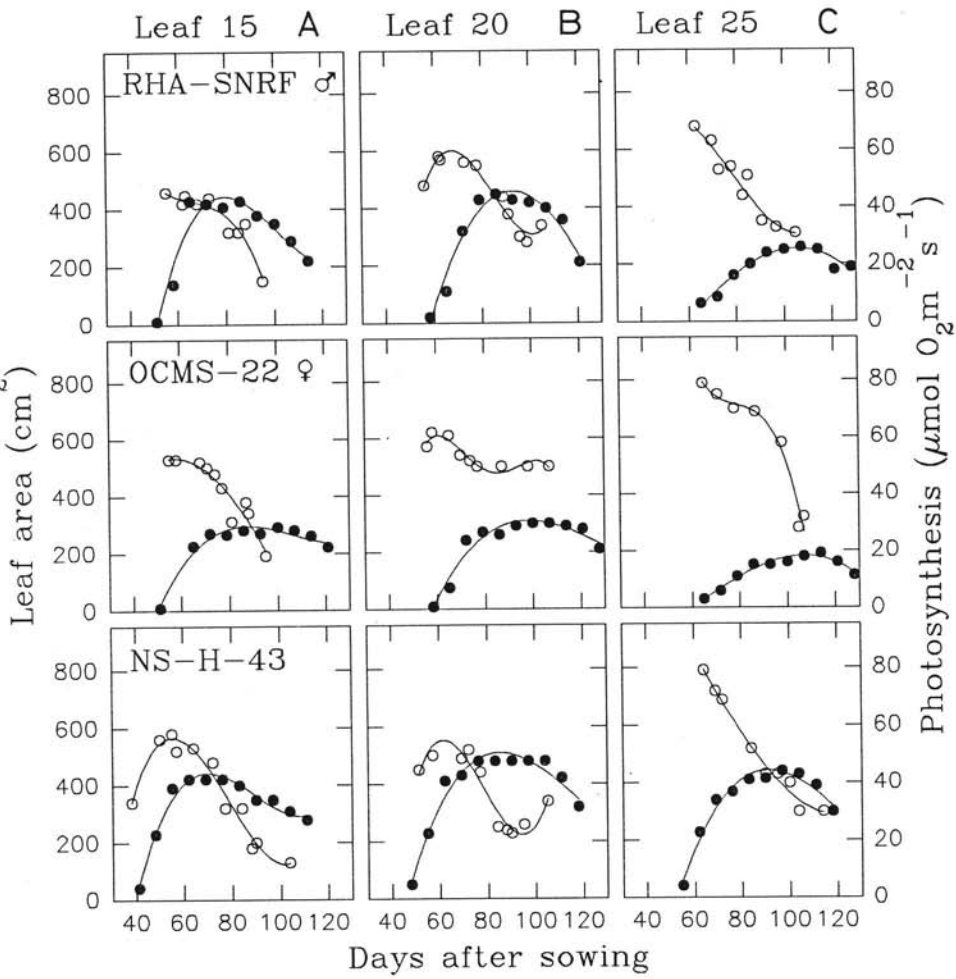

Figure 4. Leaf area growth and photosynthesis during plant development. Growth curves of the hybrid NS-H-43 and its parental lines are presented for 3 leaf positions: leaf 15 (A), leaf 20 (B), leaf 25 (C).

before the leaf reached its maximum area. Leaves 20 and 25 maintained high photosynthetic rates over the life of the leaf, which indicates their role in supplying assimilates during seed-filling stage of plant development. Our data support the finding (El-Sharkawy & Hesketh, 1964; McWilliam *et al.*, 1974; English *et al.*, 1979; CETIOM, 1983; Djakov, 1985; Ćupina & Plesničar, 1985) that the bulk of assimilates produced during the period of seed development is derived from photosynthesis in the leaves in the upper third of the plant. When comparing the parental lines, leaves 20 and 25 of OCMS-22 showed higher photosynthetic potential throughout their life-span. The hybrid NS-H-43 followed the pattern of the parental line RHA-SNRF in both photosynthetic potential of examined leaves and leaf area duration. Due to the heterotic effect, leaf areas of the hybrid were larger than those of the parental lines and therefore, photosynthetic capacity (product of the potential rate of photosynthesis and leaf area) was also higher.

CONCLUSIONS

Both hybrids had higher rates of leaf appearance, leaf expansion and leaf area duration for leaves in the upper third of the plant than their parental lines. The areas of individual leaves of the hybrids were larger than corresponding leaf areas of the parental lines.

Most of the examined parameters point to the similarity between the hybrid NS-H-26 and its female parent, and between the hybrid NS-H-43 and its male parent.

The Hybrid NS-H-43 showed the fastest rate of leaf expansion among the examined genotypes and leaf area duration that was longest for the leaves in the upper third of the plant. The above mentioned properties and high potential rates of photosynthesis over the life span of leaves ensure high photosynthetic capacity for production of assimilates in leaves of the hybrid NS-H-43 (Sakač *et al.*, in press) and resistance to pathogenic organisms (Škorić, 1980).

REFERENCES

1. Bunce, J.A., 1983. Photosynthetic characteristics of leaves developed at different irradiances and temepratures: an extension of the current hypothesis, Photosynth. Res., 4, 87-97.
2. CETIOM, 1983. Physiologie de la formation du rendement chez le tournesol, Info. Tech. CETIOM, No. 83, pp 1-72.
3. Constable, G.A., Rawson, H.M., 1980. Carbon production and utilization in cotton: inferences from a carbon budget, Aust. J. Plant Physiol., 7, 539-553.
4. Ćupina, T., Plesničar, M., 1986. Physiological properties of source and sink of assimilates in some NS-sunflower hybrids (in Serbo-Croatian). Proceedings of the XX Meeting of Yugoslav Agronomeists, IFVC, Kupari, pp 445-457.
5. Delieu, T., Walker, D.A., 1981. Polarographic measurement of photosynthetic oxygen evolution by leaf discs, New Phytol, 89, 165-175.
6. Djakov, A.B., 1985. Morfofunkcionaljnie osobenosti listev raznih jarusov rastenij podsolnecnika, Naučno-tehničeskij buleten VNIMK, 3, (90), 3-7.
7. El-Sharkawy, M.A., Hesketh, J.D., 1964. Effects of temperature and water defficit on leaf photosynthetic rates of different species, Crop Sci., 4, 514-518.
8. English, S.D., McWilliam, J.R., Smith, R.C.G., Davidson, J.L., 1979. Photosynthesis and partioning of dry matter in sunflower, Aust. J. Plant Physiol., 6, 149-164.

9. McWilliam, J.R., English, S.D., McDougall, G.N., 1974. The effect of leaf age and position on photosynthesis and supply of assimilates during grain development in sunflower, Proc. Sixth Int. Sunflower Conf., Bucherest, Romania, pp. 171-179.
10. Rawson, H.M., Constable, G.A., 1980. Carbon production of sunflower cultivars in field and controlled environments. I. Photosynthesis and transpiration of leaves, stams and heads, Aust. J. Plant Physiol., 7, 555-573.
11. Rawson, H.M., Constable, G.A., Howe, G.N., 1980. Carbon production of sunflower cultivars in field and controlled environments. II. Leaf growth, Aust. J. Plant Physiol., 7, 575-586.
12. Saftić, D., Plesničar, M., 1990. Photosynthesis and chlorophyll fluorescence quenching in aging leaves of three sunflower (*H.annuus L.*) genotypes, Current Research in Photosynthesis, M. Baltscheffsky (ed.), vol.4, Kluwer Academic Publishers, Dordrecht, pp. 267-270.
13. Škorić, D., 1980. Desired model of hybrid sunflower and the newly developed NS-hybrids, Helia, 3, 19-24.
14. Škorić, D., 1985. Sunflower breeding for resistance to *Diaporthe/Phomopsis helianthi*, Helia, 8, 21-24.
15. Walker, D.A., 1987. The use of oxygen electrode and fluorescence probes in simple measurements of photosynthesis, Oxygraphics Ltd, Sheffield, pp. 1-53.

CROISSANCE DES FEUILLES ET PHOTOSYNTHÈSE PENDANT L E DÉVELOPPEMENT DES HYBRIDES NS DE TOURNESOL ET DE LEUR LIGNÉES PARENTALES

RÉSUMÉ

Les effets du vieillissement et de la position sur les paramétres de croissances de la feuilles et sur la phgotosynthèse ont été examinés chez deux hybrides NS de tournesol (*Helianthus annuus* L.) présentant une différence de résistance à *Diaporthe (Phomopsis) helianthi* et chez leurs lignées parentales. Concernant l'apparition et le développement des feuilles, la durée de la surface foliaire, les valeurs trouvées aussi bien chez NS-H-26 que chez NS-H-43 étaient supérieures à celles observées chez leurs lignées parentales. L'effet d'hétérosis était particulièrement notable chez les deux hybrides. La plus part des paramétres étudiés souligne la ressemblance de l'hybrides NS-H-26 avec la lignée maternelle et de NS-H-43 avec la lignée paternelle. L'hybride NS-H-43 a suivie le même type de dévelopement et de potentiel photosynthétique que la lignée paternelle RHA-SNRF.

EXPANSION FOLIAR Y FOTOSINTESIS DURANTE EL CRECIMIENTO Y DESARROLLO DF HIBRIDOS Y I NFAS PURAS NS

RESUMEN

Dos híbridos NS de girasol (*Helianthus annuus* L.) con distinta resistencia a *Diaphorthe/phomosis helianthi* y sus líneas parentales fueron examinados para estudiar el efecto de la edad y posición sobre parámetros de crecimiento y potencial de fotosíntesis de las hojas. Se encontró que ambos híbridos, NS-H-26 y NS-H-43, tuvieron tasas mas altas de aparición y expansión de hojas y mayor duración de área foliar que sus líneas parentales. El efecto heterotilo se noto sespecialmente en la formación del área en ambos híbridos. La mayoría de los parámetros examinados apuntan hacia la similaridad entre el híbrido NS-H-26 y su línea materna y entre el híbrido NS-H-43 y su línea paterna. El híbrido NS-H-43 tuvo también el mismo comportamiento que la línea paterna RHA-SNRF en potencial fotosintético.