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EFFECT OF DROUGHT ON YIELD REDUCTION IN DIFFERENT SUNFLOWER HYBRIDS

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SUMMARY

A set of experimental hybrids obtained following the "Nested" mating design (Hallower and Miranda, 1981) was used to analyze genetic variability, in the source population, for drought resistance, calculated as the relative yield reduction under drought with respect to the irrigated control and drought susceptibility index "S" (Fisher and MAurer, 1978). The results indicate that the major part of genetic variability for this character was accounted for by the additive variance with a high heritability expressed in narrow sense. Of great interest is the inbred line HA8 whose two hybrids (7 and 8) have reduced their yield under drought by only 14 and 9% in relation to the average field reduction of 42%. The escape effect of this result is insignificant and for this reason physiological studies are planned to detect the responsible resistance mechanisms. Selection for high seed yield and drought resistance seems to be possible for the environment of Central Italy because the correlation between yield potential and the "S" index is non–significant, but in very arid areas this possibility might not be valid.

Key words: Sunflower, genetic variability, drought resistance

INTRODUCTION

Until today, progress in plant breeding for drought resistance in sunflower has been very limited, due to a lack of synthesis of all available data regarding the many aspects of drought stress (Jones and Turner, 1980; Merrien and Blanchet, 1984; Gimenez et al., 1986; Gimenez and Fereres, 1986; Gimenez and Fereres, 1987; Cox and Jolliff, 1987; Whitfield et al., 1989; Hall et al., 1989) which would build up an easy selection index useful to breeders. This aim to find an easy index is connected with the discovery of specific drought resistance mechanisms in sunflower which are very difficult to detect because the interactions contributing to drought resistance in the crop and the responsible mechanisms assume a different degree of importance according to the environment in which the water stress is considered.

When a breeding programme involves the selection of inbred lines for high quantitativé yield, the main process has to be the evaluation of genetic variability for seed yield and its stability under dry conditions.

Drought resistance in sunflower is nowadays objective of several scientific projects and the aim of this paper is the evaluation of genetic variability for drought resistance in a set of experimental sunflower hybrids obtained from inbred lines selected for high

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genetic combining ability, with the aim to eliminate in the final evaluation, the effect of the escape mechanism and the yield potential which cannot be considered as resistance mechanisms (Fisher and Maurer, 1978) but which, sometimes and in some environments, can influence the yield variability under dry conditions.

MATERIALS AND METHODS

In 1989 four cytoplasmic male sterile lines, 207A, HA8, C224 and ARG1, were crossed, each one with four different restorer lines following the "Nested" design (Hallower and Miranda, 1981). All lines were randomly chosen from the collection of the Agronomy Department of Pisa University. The 16 hybrids obtained were sowned on 5 June 1990 at Baslini experiment station, located at Migliarino village (PI), following an experimental split–plot design (AxB) with three replications. The A treatment (main plot) considered the water availability with the controls with weekly sprinkler irrigation until physiological maturity and the stress conditions, where irrigation was interrupted at the visible flower bud stage. The B treatment (sub–plot) concerned the different hybrid combinations. The experimental units were plots of 4 rows, 5 m long and 0.5 m apart. A sandy soil was chosen with a very poor retention capability and at sowing time 100 kg/ha of N and 80 kg/ha of P_2O_5 was applied. Weeds were mechanically controlled. The temperature was on average for the last twenty years, while only two rainfalls on 30 June (10 mm) and 7 August (25 mm) occurred before the physiological maturity of the plants.

The two central rows were harvested at maturity: all achenes were oven–dried at 70°C and the yield presented on q/ha basis.

The evaluation of the dry condition effects was determined by the yield reduction under drought stress condition (Yd) in respect to the controls (Yp), for each genotype evaluated. Moreover, a drought susceptibility index S was calculated (Fischer and Maurer, 1978) to separate the effects of yield potential and drought susceptibility from yield under drought.

$S = \frac{1 - rd/rp}{D}$, where D is the yield reduction under drought averaged for all hybrids. The lowest values of "S" correspond to higher drought resistant genotypes.

The ANOVA model, corresponding to the "Nested" design, was used to analyze the genetic variability of the reduction yield character and to calculate, according to Fehr (1987), the variance components and the heritability in the narrow sense.

RESULTS AND DISCUSSION

The analysis of variance reported in Table 1, showed a significant genetic variability among females and males whitin females. In the population the major part of genetic variability is accounted for by the additive component of gene action as it results from the ratio of dominance component equal to 0.18 (Table 1). The heritability of 0.54 is considered very high and of great interest for breeding programmes. Figure 1 shows the hybrids' behaviour considering their productivity potential under irrigation (Yp) and under drought (Yd/Yp). The axes forming the four quadrants are the average values for Yp and Yd/Yp data. Area II of the figure, where the hybrids with higher yield potential and drought resistence could be found, shows three hybrids (14, 6 and 11) but their relative yield under drought is similar to the field average. While in area III, which includes genotypes with high drought resistance but relatively low yield potential, the hybrids 7 and 8 show the greatest differences in respect to the other genotypes with the lowest yield reduction under drought. Moreover it is very interesting to notice that the line HA8 is the same female parent.

Table 1. Analysis of variance, estimates of additive variance (ρ^2A),dominance deviation (ρ^2D),degree of dominance and heritability (h^2) for yield reduction in 1990 at Pisa University

Source of variation	d.f.	Mean squares	Expected mean squares	ρ^2A	ρ^2D	$\sqrt{\sigma^2 D/\sigma^2 A}$ A	h^2
Blocks	2						
Female	3	227.5*	$\rho^2+r\rho^2m/f+rm\rho^2f$	54.4	1.88	0.18	0.54
Male/Female	12	66.2*	$\rho^2+r\rho^2m/f$				
Error	16	22.0	ρ^2				

*, ** significant for 5 and 1% respectively
r,m,f number of blocks, males and females, respectively

The similar flowering period of the tested hybrids (Table 2) prevented rain from interasting with the genotypes, maybe except for the 9, 10 and 11 hybrids which matured slightly earlier than the others. The same Table 2, where the S values are reported, showed the lowest values are found in correspondence with 7 and 8 hybrids. This means that the character examined (yield reduction under drought) is not influenced, in this trial, by the yield potential variability.

Table 2. List,flowering date and S values of the examined hybrids in 1990 at Pisa University

Hybrid	Mean flowering date (in days from 1st January)	S index
1) 207A x PH8	209	1.15
2) " x R4	209	1.29
3) " x R12	209	1.21
4) " x R Rotta	208	1.27
5) HA8 x GM	208	1.09
6) " x FR5	210	1.00
7) " x R5ro	211	0.21
8) " x R7	210	0.32
9) C224 x R1054	206	1.12
10) " x R41064	204	1.34
11) " x R Torre	205	0.98
12) " x CH22	207	1.08
13) ARG1 x R1	209	1.09
14) " x R2	211	1.00
15) " x R4	212	0.76
16) " x R6	212	1.05
l.S.D. for P 0.05	3.8	0.41

Table 2 showed the absence of correlation between the yield potential and the drought susceptibility index (S), in accordance with Fereres et al. (1986). This result does

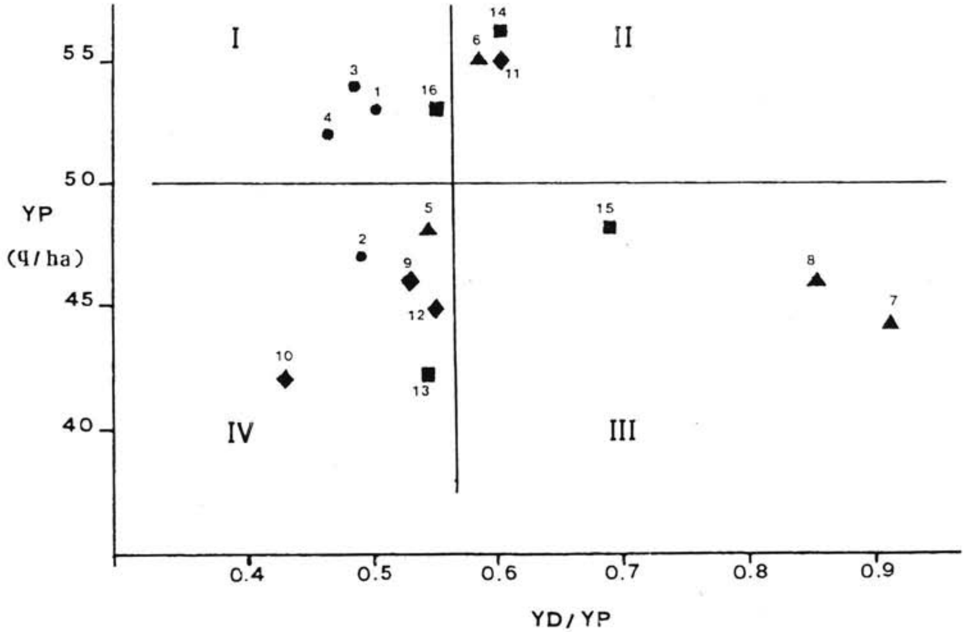

Figure 1 – Relationship between yield under irrigated conditions (Yp) and the ratio between dryland yield and irrigated yield (Yd/Yp). The four areas of the figure are obtained considering as new axes the avarage values of Yp and Yd/Yp data of the examined hybrids. Numbers represent genotypes listed in table 2.

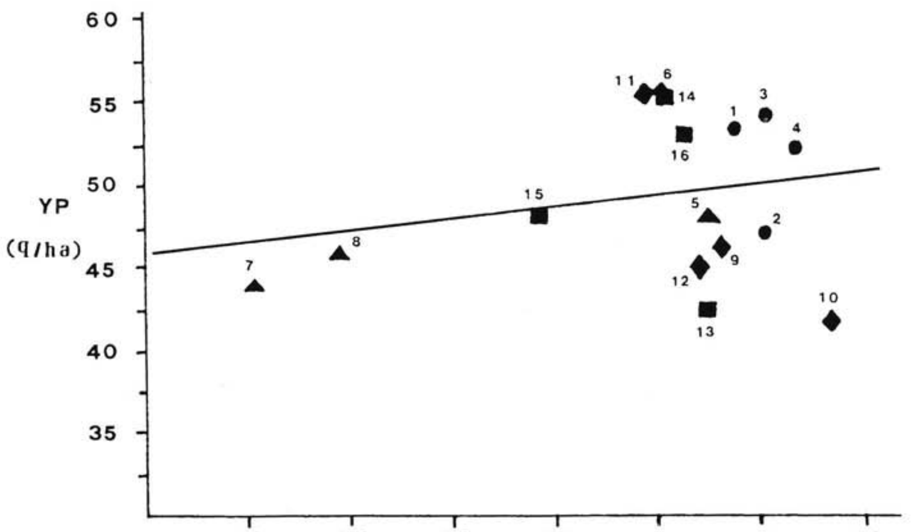

Figure 2 – Relationship between yield potential and the drought susceptibility index "S" for the tested hybrids. Numbers represent genotypes listed in Table 2. The linear regression is: y = 45.99 + 3.22x (r = 0.04 N.S.).

not seem to exclude that the desirable traits, under drought and under non–limiting water conditions, could be found in the same genotype and it expresses the possibility to select sunflower for drought resistence and high productivity potential.

CONCLUSIONS

The relative seed yield under drought has showed a significant genetic variability and a great part is accounted for by the additive variance component; this variability must be referred to the real resistance mechanisms because very few differences were found in the flowering date and yield potential among the genotypes analyzed.

This means that, in the environment of Central Italy, the character examined could be considered as a selection index for drought resistance and a breeding programme could be planed to exploit the variability of such character eventually present in all inbred lines selected for high productivity potential.

Among the female parents, the line HA8 has in fact given two hybrids, 7 and 8, which have reduced their yield under drought by only 14 and 9%, respectively, against the average yield reduction of 42%. These hybrids have not showed a high yield potential, but in environments where water availability (rain and soil) is very limited, they could be of great interest.

The possibility of obtaining drought resistance and high yield in the same sunflower genotype is given by the absence of correlation between "S" and yield potential. This means that the selection for high yield potential genotypes in favourable areas should be an efficient selection criterion to identify higher yielding material for stress conditions. But this assumption, for sunflower, is valid only for some environmental conditions, while in very arid areas where the expression of yield potential may be strongly affected by other limiting factors related to drought (temperature, radiation, air moisture, nutrition,...), thus a positive correlation may exist between yield potential and "S", as found in wheat, where the selection for drought resistance is detrimental to high seed yield (Fischer and Wood, 1978; Ceccarelli et al., 1987).

REFERENCES

Ceccarelli S., Nachit M.M., Ferrara G.O., Mekni M.S., Tahir M., Van Leur J. and Srivastava J.P. (1987) – Drought tolerance in winter cereals. Edited by Svrivastava j.P., Porceddu E., Acevedo E. and Varma S., Publishsed by John Wiley and Sons Ldt.

Cox W.J. and Jolliff G.D. (1987) – Crop–water relations of sunflower and soybean under irrigated and dryland conditions. Crop Sci., 27, 553–557.

Fehr W.R. (1987) – Principles of cultivar development. Ed. By Macmillan Publishing company. Vol.1. New York.

Fereres E., Gimenez C., Berengena J., Fernandez–Martinez J and Dominguez J. (1983) – Genetic variability of sunflower cultivars in response to drought. Helia, 6, 17–21.

Fereres E., Gimenez C. and Fernandez J.M. (1986) – Genetic variability in sunflower cultivars under drought. I. Yield relationships. Aust. J. Gric. Res., 37, 573–582.

Fischer R.A. and Maurer R. (1978) – Drought resistance in spring wheat cultivars. I. Grain yield responses. Aust. J. Agric. Res., 29, 897–912.

Fischer R.A. and Wood J.T. (1978) – Drought resistance in spring wheat cultivars. III. Yield associations with morpho–physiological traits. Austr. J. Agric.Res., 30, 1001–1020.

Gimenez C. and Fereres E. (1986) – Genetic variability in sunflower cultivar under drought. II. Growth and water relations. Aust. J. Agric. Res., 37, 583–597.

Gimenez C. and Fereres E. (1987) – Resistencia a le sequia de cultivares de girasol bajo conditiones de campo. Inv.Agrar.: Prod. Prot. veg., 2, (1), 67–87.

Hall A.J., Connor D.J. and Whitfield D.M. (1989) – Contribution of pre–anthesis assimilates to grain filling in irrigated and water–stressed sunflower crops. I. Estimates using labelled carbon. Field Crops Research, 20, 95–112.

Hallauer A.R. and Miranda J.B. (1981) – Quantitative genetics in maize breeding. Iowa State University Press, Ames.

Jones M.M. and Turner N.C. (1980) – Osmotic adjustment in expanding and fully expanded leaves of sunflower in response to water deficits. Aust. J. Plant Physiol., 7, 181–192.

Merrien A. and Blanchet R. (1984) – Aspects agronomiques de la resistence à la sécheresse chez le Turnesol (*Helianthus annus* L.). Actual. bot., 1, 45–50.

Whitfield D.M., Connor D.J. and Hall A.J. (1988) – Carbon dioxide balance of sunflower (*Helianthus annus*) subjected to water stress during grain–filling. Field Crops Research, 20, 65–80.

EFECTOS DE LA SEQUIA SOBRE LA REDUCCION DEL RENDIMIENTO EN HIBRIDOS DIFERENTES DE GIRASOL

RESUMEN

Un grupo de híbridos experimentales obtenidos siguiendo el diseño experimental anidado (Hallower y Miranda, 1981) fué utilizado para analizar la variabilidad genética, en una población inicial formada para resistencia a sequía, calculada como la reducción del rendimiento bajo secano respecto al control regado y como el índice de susceptibilidad 8 (Fisher y Maurer, 1978). Los resultados indican que la mayor parte de la variabilidad para este caracter fué explicada por la varianza aditiva con una alta heredabilidad en sentido estrioto. De gran interés fué el resultado de la línea pura HA 8 que ha producido dos híbridos (7 y 8) los cuales han reducido su rendimiento bajo sequía por 14 y 9% solamente respecto a una media de reducción en campo del 42%. El efecto del escape en este resultado es insignificante y por esta razón estudios fisiológicos se están planeando para detectar los mecanismos responsables de la resistencia. La selección para alto rendimiento de semilla y resistencia a sequía parecen ser posibles para el ambiente de Italia Central debido a que la correlación entre el rendimiento potencial y el índice S no resultó significativa pero en áreas muy áridas esta posibilidad podría no ser válida.

EFFETS DE LA SÉCHERESSE SUR LA RÉDUCTION DU RENDEMENT CHEZ DIFFÉRENTS HYBRIDES DE TOURNESOL.

RÉSUMÉ:

Un lot d'hybrides expérimentaux obtenu d'aprés le plan de croisement "Nested" (Hallower et Miranda, 1981) a été utilisé afin d'analyser la variabilité génétique dans une population source pour la résistance à la sécheresse. La résistance à la sécheresse est estimée grâce au rapport :réduction relative du rendement en sec à un control irrigué et par un index S, index de sensibilité à la sécheresse (Fisher et Maurer, 1978). Les résultats indiquent que la majeur partie de la variabilité génétique pour ce caractére est prise en compte par la variance additive avec une forte héritabilité au sens stricte.La ligné HA8 s'est révélée particulièrement intéressante en produisant deux hybrides (hybrides 7 et 8) qui ont réduit leur rendement de seulement 14 et 9% alors qu'en moyenne la réduction du rendement au champ était de 42%. La sélection pour un haut rendement en grain et une résistance à la sécheresse semble être possible dans un environement identique à celui du centre de l'Italie en raison du coefficient de corrélation non significatif existant entre le rendement et l'index S, mais en conditions trés arides cette possibilité pourrait ne plus être valide.