TOLERANCE OF SUNFLOWER HYBRIDS TO COMPETITION AMONG PLANTS

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Sunflower plant population, as a technological element that regulates the equilibrium between environment and genetic characters, was widely investigated as early as the beginning of the cultivation of this species (V r â n c e a n u et al., 1974 ; C a r t e r et al., 1978). The relationship "plant population-production" proved to be a very complex functional character, relying upon a multitude of genetic, soil-climatic and cultural factors.

The increase of seed yield by means of high plant populations, maintaining a high photosynthetic activity, requires the creation of "tolerant" forms which would intensify not the competition among plants, but the activity of building up as high as possible yields (D u n c a n, 1969). This implies essential morphologic and metabolic changes of sunflower plant. An efficient solution seems to be that proposed to other species, namely the erect position of the upper leaves which would permit a better luminosity at the lower leaf levels (P e n d e l t o n, 1973).

The present paper represents a complex study of the response of various hybrids to the variation of the nutrition space, aiming at knowing more exactly the main morpho-physiological modifications and the establishment of some orientations of the breeding process, in order to develop sunflower genotypes with a favourable reaction to high plant populations.

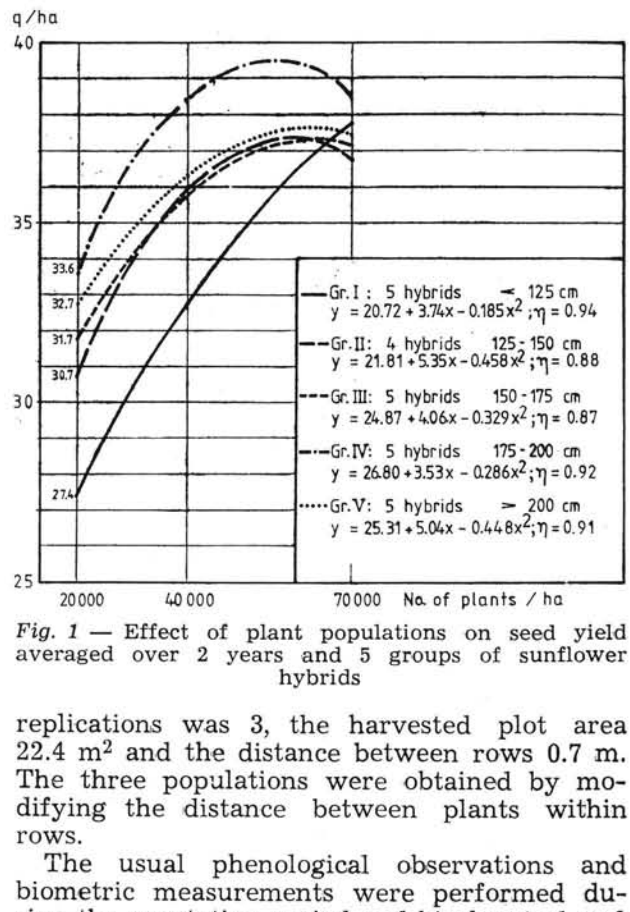

Fig. 1 — Effect of plant populations on seed yield averaged over 2 years and 5 groups of sunflower hybrids

MATERIALS AND METHODS

The study included 18 single and 6 three-way hybrids obtained at Fundulea Research Institute for Cereals and Industrial Crops using cms and restorer Romanian inbred lines. They were grouped into five height categories determined at the standard plant population of 40,000 plant/ha (Fig. 1). The hybrid seed was obtained either under bag or in crossing fields isolated from other sunflower crops at a minimum distance of 1,500 m.

The experiment was conducted at Fundulea in 1979 and 1980, using the split block design, the factor "hybrid" having 24 graduations and the factor "population" — 3 graduations: 20,000, 40,000 and 70,000 plants/ha. The number of replications was 3, the harvested plot area 22.4 m^2 and the distance between rows 0.7 m. The three populations were obtained by modifying the distance between plants within rows.

The usual phenological observations and biometric measurements were performed during the vegetation period and biochemical and physical seed characteristics analysed in laboratory.

The leaf area index representing the ratio between the whole leaf area and the area of the land attributed to the respective plant, was determined at the end of flowering. By leaf area efficiency one understands the mass of dry matter (mg) from one cm^2 of leaf. Only data from 1979 regarding the resistance to the attack of *Sclerotinia sclerotiorum* and those from 1980 concerning the resistance to *Phoma* sp. were taken into consideration, because significant differences in the response of sunflower hybrids to the attack of the two pathogens were recorded in those years.

RESULTS AND DISCUSSION

The seed yield per unit of area does not increase proportionally to plant population, especially due to the drastic decrease of seed quantity per head (Table 1). This diminution is caused not only by the significant reduction of both head and seed size, but also by the number of the unfilled seeds on the head, as a result of the increase of the central zone with blank seeds to most of the genotypes.

Table 1

Mean values of seed yield and morpho-physiological traits for 24 single and three-way sunflower hybrids tested in three plant populations (Fundulea, 1979—1980)

Traits	Plant populations		
	20,000	40,000	70,000
Seed yield (kg/ha)	2,980	3,560**	3,710
Amount of seeds per head (g)	148	92**	54**
Per cent unfilled seeds	3.1	11.6*	23.5*
1,000 seed weight (g)	74	62**	53**
Volumetric weight (kg/hl)	36	36	37
Oil content in dry seed (%)	50.6	52.6*	53.1
No. days sowing-flowering 75%	81	83	82
No. days sowing-physiol. mat. 75%	128	127	125
Plant height (cm)	163	172*	187*
Stem thickness (cm) at 1 m from ground	3.3	2.8*	2.0*
Head diameter (cm)	30	24*	16**
Percent plants attacked by *Sclerotinia sclerotiorum* (1979)	2.6	3.9	8.1*
Phoma sp. attack, notes (0=very resistant, 9=very susceptible)	4.0	4.6	5.6*
Lodging and breaking resistance, notes (0=very resistant, 9=very susceptible)	1.4	2.1	4.3**
Leaf area index at the end of flowering	2.0	2.7*	2.9
Leaf area efficiency (mg·d·m·/cm²)	1.5	1.3	1.2

*, ** Indicates a significant difference between one value and the left-side value, at P = 0.05 and 0.01 respectively.

The rise of the number of plants per unit of area exerts a less influence on seed oil content and influences unsignificantly the volumetric weight and the growth period until flowering and physiological maturity.

The increase of plant population determines the elongation of the stem and the reduction of its thickness, probably due to the keen competition for light. These modifications, together with the higher susceptibility to stem diseases, result in a lower resistance to lodging and breaking, especially to the population of 70,000 plants per hectare.

Leaf area formation as well as dry matter accumulation are two elements less known in sunflower. Data show that the leaf area increases simultaneously with plant population, but not proportionally, because the majority of the genotypes tested at 70,000 plants/ha presented many dry or half-dry basal leaves at the moment of determinations. The average efficiency of leaf area does'nt appear to be significantly influenced by plant population.

Seed yield within the three populations is the most closely correlated with the quantity of seed per head, growth period, plant height, head diameter and leaf area index, and non-correlated with the seed size and oil content in the seed (Table 2).

Table 2

Correlation coefficients between the main morpho-physiological traits and seed yield over 24 sunflower single and three-way hybrids and three plant populations (Fundulea, 1979—1980; the effect of years excluded)

Traits	Plant populations		
	20,000	40,000	70,000
Amount of seeds per head (g)	+0.68**	+0.71**	+0.93**
1,000 seed weight (g)	—0.07	—0.12	+0.22
Volumetric weight (kg/hl)	+0.01	+0.13	+0.44*
Oil content in dry seed (%)	—0.12	+0.08	+0.10
No. days sowing-flowering 75%	+0.50*	+0.45*	+0.27*
No. days sowing-physiol. mat. 75%	+0.69**	+0.52**	+0.43*
Plant height (cm)	+0.62**	+0.57**	+0.25
Stem thickness (cm) at 1 m from ground	+0.28	+0.16	+0.44**
Head diameter (cm)	+0.43*	+0.48*	+0.83**
Percent plants attacked by *Sclerotinia sclerotiorum* (1979)	+0.12	—0.03	—0.49*
Phoma sp. attack (notes)	—0.42*	—0.56**	—0.68**
Lodging and breaking resistance (notes)	—0.18	+0.31	+0.42*
Leaf area index at the end of flowering [1]	+0.44*	+0.46*	+0.56**
Leaf area efficiency (mg d.m./cm²) [1]	+0.09	—0.06	+0.31

[1]) Determinations performed to 5 hybrids with different morpho-physiological traits.

*, ** The correlation coefficients are significantly different from 0, with P = 0.05 and 0.01 respectively.

The correlation coefficients between the main morpho-physiological traits and seed yield, calculated at the population of 70,000 plants/ha, show that in the process of creating sunflower hybrids with favourable response to high populations, selection should be directed primarily toward the ability to produce a large amount of filled seeds and correspondingly a low percent of blank seeds, especially in the centre of the head. The phenomenon of diameter reduction should also be as attenuated as possible, the lower leaves should maintain their photosynthetic capacity as long as possible and the stem should preserve a high resistance to lodging and breaking. The last trait is closely related to the stem thickness and the resistance to stem diseases. At high populations, very important appear to be the volumetric weight, which expresses the degree of seed filling and the efficiency of the leaf area.

The two experimental years exerted a significant different influence on seed yield which however did not cover the differences between populations and especially between genotypes (Table 3). Among interactions, the

Table 3

Analysis of variance for seed yield over 24 sunflower hybrids and three plant populations (Fundulea, 1979—1980)

Source of variation	df	Mean squares	F
Blocks (B)	4	407.03	
Year (Y)	1	235.37	71.54**
Populations (P)	2	1,012.51	141.02**
P×Y	2	36.62	5.10*
Error A	8	28.72	
Genotype (G)	23	13,826.41	247.39**
G×Y	23	518.14	9.27**
G×P	46	1,403.86	12.44**
G×P×Y	46	1,056.17	9.45**
Error B	276	690.07	

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

highest value presented the genotype×population interaction, indicating a significant different response of sunflower hybrids to the three plant populations, and therefore the existance of certain hybrids with superior performances at high populations.

The optimum population for sunflower hybrids with the plant height over 125 cm is situated between 55,000 and 60,000 plants/ha (Fig. 1). The seed yield curve of hybrids shorter than 125 cm is ascending at 70,000 plants/ha, reaching or even surpassing the maximum yields of the medium or high stem hybrids. Thus it appears feasible to replace the late or medium-late hybrids with early short stature hybrids, by cultivating them at high plant populations.

Among the investigated hybrids of the height groups II-IV, the single hybrid FELIX recently released at Fundulea, displayed the most favourable response to the increase of plan population per unit of area. As compared to the check hybrid Sorem 82 (Fig. 2), Felix

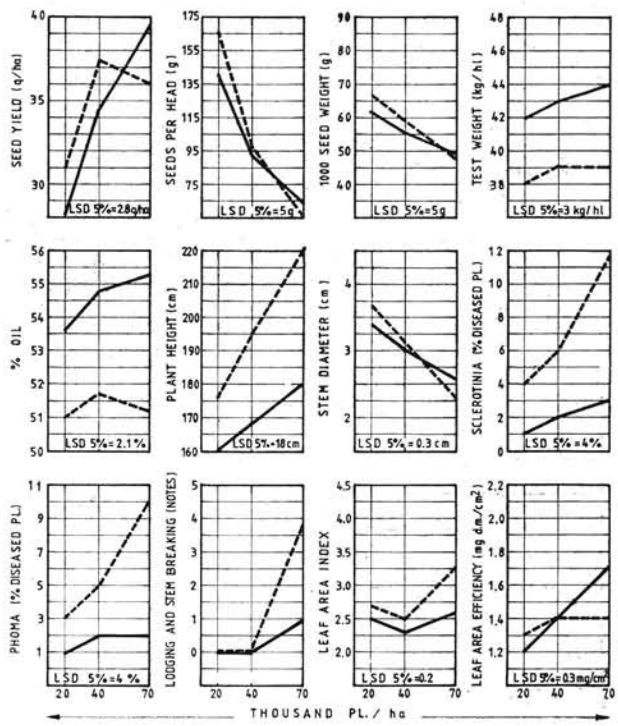

Fig. 2 — Response of sunflower hybrid Felix (—) to three plant populations, in comparison with Sorem 82 (- - -), Fundulea 1979—1980

starts from a significant inferior seed yield level at 20,000 plants/ha but succeeds to exceed the check by 10% at 70,000 plants/ha. A similar reaction is also noticeable in the case of the amount of filled seeds per head, stem thickness, leaf area index and dry matter accumulation. This hybrid also ranks first as concerns the volumetric weight, oil content and resistance to stem diseases in all three plant populations. The last trait, together with a smaller reduction of stem diameter and a less intense increase of plant height, determines a better resistance to lodging and breaking at 70,000 plants/ha.

The single hybrid Felix distinguishes itself by a different foliage architecture. After flowering, the plant presents 30—36 leaves of a medium size, which maintain their green colour until physiological maturity. The leaves from the upper half of the plant have a semierect position, making an angle with the stem less than 60°. However one cannot affirm that all the present sunflower hybrids with erect or semierect position of leaves display a better response to higher populations than the common hybrids, because this objective has not been tackled by now in sunflower breeding works.

CONCLUSIONS

The ability to produce a high amount of filled seed per head is one of the main factors that induces the favourable response of sunflower hybrids to high plant populations. This yield component, associated with a good seed setting in the center of the head and a less accentuated reduction of the head diameter in high populations, could be improved in the process of breeding sunflower inbred lines and hybrids. A new foliage architecture is required, as well as a better resistance to lodging and breaking and to stem diseases.

Althogh there is a certain variation among the present hybrids concerning their tolerance to competition among plants, special morpho-physiological ideotypes capable to produce high seed yields by increasing the number of plants per unit of area should be designed and developed.

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LA TOLÉRANCE DES HYBRIDES DE TOURNESOL À LA CONCURRENCE ENTRE PLANTES

Résumé

On a étudié la réponse de 18 hybrides simples et de 6 hybrides à trois-voies à la variation de l'espace de nutrition pour établir quelques orientations dans les travaux de création de génotypes tolérants aux grandes densités de plantes.

Le rendement à l'hectare n'a pas augmenté proportionnellement avec la densité des plantes, surtout à cause de la réduction accentuée des quantités de graines par capitule, produite par la réduction du diamètre des capitules et de la dimension des graines, aussi bien que par l'extension de la zone centrale à graines vides. Aux grandes densités, la taille de la plante s'agrandit, la grosseur de la tige se réduit et s'accroît l'attaque des maladies à la tige, causes qui produisent à la plupart des génotypes une sensibilité agrandie à la verse et à la rompement des tiges, surtout à la densité de 70 000 plantes/ha. Moins affectées par la densité sont : la teneur en huile des graines, la masse volumétrique, la période de végétation et l'efficience de la surface foliaire.

Le rendement en graines a été significativement et positivement corrélé avec la quantité de graines par capitule, la période de végétation, la taille de la plante, le diamètre du capitule et l'index de la surface foliaire, et non-corrélé avec la dimension des graines et la teneur en huile.

Au cours du processus de création d'hybrides tolérants aux grandes densités de plantes, la sélection doit être orientée tout d'abord vers la capacité de produire une quantité plus élevée de graines pleines, surtout au centre du capitule, que les feuilles basales maintiennent leur capacité photosynthetique une période aussi longue que possible et que la tige possède une très bonne résistance à la verse et au rompement. Cette dernière propriété dépend de la grosseur de la tige et de sa résistance à l'attaque des maladies.

Parmi les interactions, la plus grande importance, a présenté l'interaction génotype-densité. La densité optimale de la plupart des hybrides plus hauts que 125 cm a été comprise entre 55 000—60 000 plantes/ha. Les hybrides à la taille plus petite que 125 cm ont maintenu leur courbe de production ascendente même à la densité de 70 000 plantes/ha. Ainsi, il apparaît la possibilité de remplacer les hybrides tardifs ou demi-tardifs avec hybrides de taille moins haute, cultivés à des densités accrues.

L'hybride roumain Felix, récemment introduit en culture, a augmenté son rendement en graines et en huile proportionnellement avec la densité, probablement grâce à une architecture toute spéciale du feuillage.

TOLERANCIA DE LOS HIBRIDOS DE GIRASOL EN LA COMPETICIÓN ENTRE PLANTAS

Resúmen

Está presentado un estudio complejo con respecto a la respuesta de 18 hibridos simples y 6 hibridos trilinearios de girasol a la varionción del espacio de nutrición (20.000, 40.000 y 60.000 plantas/ha) con la meta de establecer unas orientaciones del proceso de mejora para crear genotipos de reacción cuanto más favorable a densidades grandes de plantas.

La producción de semillas por hectárea no aumenta proporcionalmente a la densidad de las plantas. Esto se debe especialmente a la accentuada reducción de la cantidad de semillas an el capitulo provocada a su turno por la reducción del tamaño del capitulo y de las semillas, así como por la extensión de la zona central con semillas secas. A densidades grandes crece la talla de la planta, se reduce la grosura del tallo y se intensifica el ataque de enfermedades en el tallo, lo que determina en la mayoría de los genotipos una resistancia más suave a caida y partimiento. Mucho menos están afectadas el contenido de aceite en la semilla, la masa volumétrica, el período de vegetación y la eficacidad de la superficie foliária.

Los coeficientes de correlación entre la produccion de semillas y los principales rasgos morfo-fisiológicos en el marco de cada densidad muestran que para obtener híbridos con respuesta favorable al incremento de la densidad, hay que mejorar en primer lugar la capacidad de las plantas de producir una cantidad cada vez mayor de semilylas llenas especialmente en el centro del capítulo que las hoja básicas se mantengan su función de fotosintesis más largov perioda de tiempo posible y que el tallo posea resistencia a la caída y al partimiento. El último rasgo está relacionado a la grusura y resistencia del tallo a enfermedades. La interracción genotipo-densidad tuvo el mayor valor. La densidad óptima para los híbridos más altos de 125 cm es de 55 000—60 000 plantas/ha.

Los híbridos más bajos de 125 cm, manteniendo la curva de la productibilidad ascendente también a 70 000 plantas/ha, pueden alcanzar e incluso sobrepasar a densidades superiores, a los híbridos más altos que regularmente son más tardíos. El híbrido rumano Felix, recientemente introducido a la cultura, aumenta su producción de semilla y aceite proporcionalmente a la densidad, al menos hasta 70 000 plantas/ha, probablemente también debido a una arquitectura distinta del foliaje.