RESULTS AND TRENDS IN BREEDING AND CULTIVATION OF SUNFLOWER (*HELIANTHUS ANNUUS* L.) IN WEST GERMANY

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The first report on sunflower appeared in Germany more than 260 years ago (Franke, 1725), and the interest in this plant continued to increase in the subsequent centuries until the beginning of the 20th century, when sunflower was considered to be a potential crop plant. Nevertheless, sunflower was not cultivated in field at those times. Only during and after World War I sunflower became important in Germany due to the lack in oils.

In spite of extensive experiments and the breeding progress made in our institute (Schuster, 1977), cultivation of sunflower as a green material remained limited in West Germany. In rare cases it was as a stake-crop (seed rate 5—8 kg/ha) in mixtures with legumes or oilradish. Only recently, sunflower cultivation has extended, and has become increasingly cultivated after winter barley. Due to the possibility of earlier sowing and because of its nematode resistance, sunflower was grown either as a forage stubble-crop (for silage mixed with corn) or as a green manure. The breeding activities at our institute led to two new semi-late, tall and vigorous forage hybrids, bred on the basis of cms-system : Hyfu (Semundo, Hamburg) and Fuso (DSV, Lippstadt)

In West Germany, like in other countries, sunflower cultivation for oil production has been intensified after World War II (Hackbarth, 1949). Breeding work based on materials from Romania and Ukraine was mainly carried out in the Max-Planck-Institute of Plant Breeding at Scharnhorst (later at Köln-Vogelsang) and in our institute. A variety named Hesa (later renamed as Bel 50), bred by von Boguslawski, was registered in 1951 and the variety Von Boguslawski's Frühe was registered in 1954 ; Olea, another early type, was bred by Rudorf at Köln-Vogelsang. The variety Spanner's Allzweck from Bavaria was registered as a crop for oil — and green matter-production in 1955.

First scientific publications were dealing with questions of flowering biology (Schuster, 1951) and with the phenomenon of inbreeding depression and heterosis (Rudorf, 1950, Boguslawski and Schuster, 1955). A review on flower biology has published in the Handbook of Flowering (Schuster, 1985 a). Sunflower breeding in the Max-Planck-Institute of Plant Breeding was finally finished in the 60's ; the results gathered in this institute have been summarized in the second edition of the Handbook of Plant Breeding (Rudorf, 1961 ; Hertzsch, 1970. Contrary to that institute, breeding of oil sunflower continued in our institute at Giessen. The basis for a practical cultivation of sunflower as an oil crop (Schuster, 1986) was provided by investigations on sowing date (Schuster, 1956 a), sowing density (Pospelowa, 1959), nutrition requirements and fertilization (Assadi, 1971), as well as differential interactions of varieties with seeding times and locations (Schuster and Boye, 1971 a). It could be demonstrated in experiments with varying temperatures and daylengths that sunflower exhibits a large variability with regard to physiology of development and growth. Therefore, this crop can be suitable for various areas of cultivation as well as for different kinds of use. In an experiment on development under controlled climatic conditions, no one genotype responded to long photoperiods ; VNIIMK 8931 showed photoperiod-insensitivity (Schuster and Boye, 1971 b).

Experiments on the consequences of inbreeding and hybridation had been started in 1948. First results were published seven years later (Boguslawski and Schuster, 1955), and continued experiments (Schuster, 1964, 1965, 1970 a, 1970 b) led to a detailed evaluation of generations S_0 to S_{25} (Schuster, 1980), which revealed valuable results (*Fig. 1*). Several reports have been given on heterosis for various characters (Schuster, 1964, 1984, 1985 b), which are summarized in *Table 1*.

The obvious presence of inbreeding depression and heterosis in sunflower stimulated the utilization of heterotic effects in applied bree-

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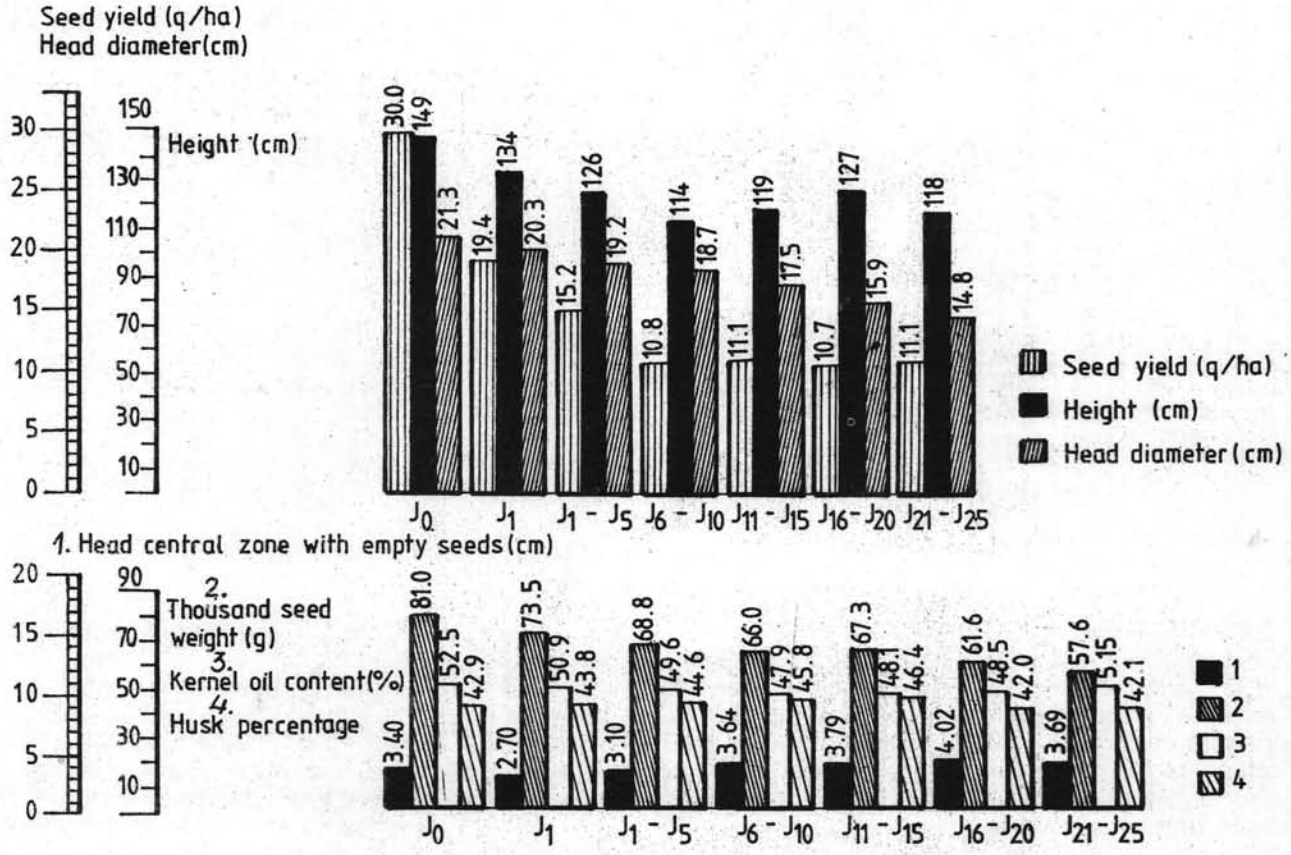

Fig. 1. — Effects of inbreeding on various traits of sunflower from I_0 through I_{25} generations, 1948—1975 (Schuster, 1980)

ding. In a first step, it was tried to use parasterility (i.e. increased fertility after open-pollination) for the production of topcross hybrids (Schuster, 1964), as also suggested by Schulze (1960). Before, male sterility and protogyny had been found in our breeding material (Schuster, 1951). This type of male-sterility proved to be nuclear-genetically determined, with segregation into 50% fertile and 50% sterile individuals in F_1. Therefore, breeding of homozygous stable ms-lines proved impossible, just as stable protogynic lines could also not be established. Consequently, it was tried to induce male-sterile mother lines for hybrid breeding

Table 1

Heterosis for various characters in sunflower (old forage genotypes)

	Grain yield		Height		Head* diameter		Sterile head centre		Oil cont. in grain		Husk* content	
	dt/ha	rel.	cm	rel	cm	rel.	cm	rel.	%	rel.	%	rel.
Original material	25.6	100	126	100	19.2	100	3.2	100	53.2	100	43.7	100
F_1 — mean	20.7	81	126	100	20.6	107	3.1	102	51.8	98	44.7	98
F_1 min-max	32—170		52—147		65—160		13—229		79—113		83—125	
Female parent	12.5	49	100	79	16.7	87	3.2	100	49.0	92	45.4	95
Male parent	12.2	48	100	79	16.7	87	3.2	100	48.7	91	45.2	95
Heritability**												
h^2 O	0.48		0.92		0.16		0.55		0.66		0.24	
h^2 O	0.30		0.84		0.16		0.12		0.33		0.31	

* Negative trait
** Calculated as regression of F_1 on parents (offspring-parent regression).

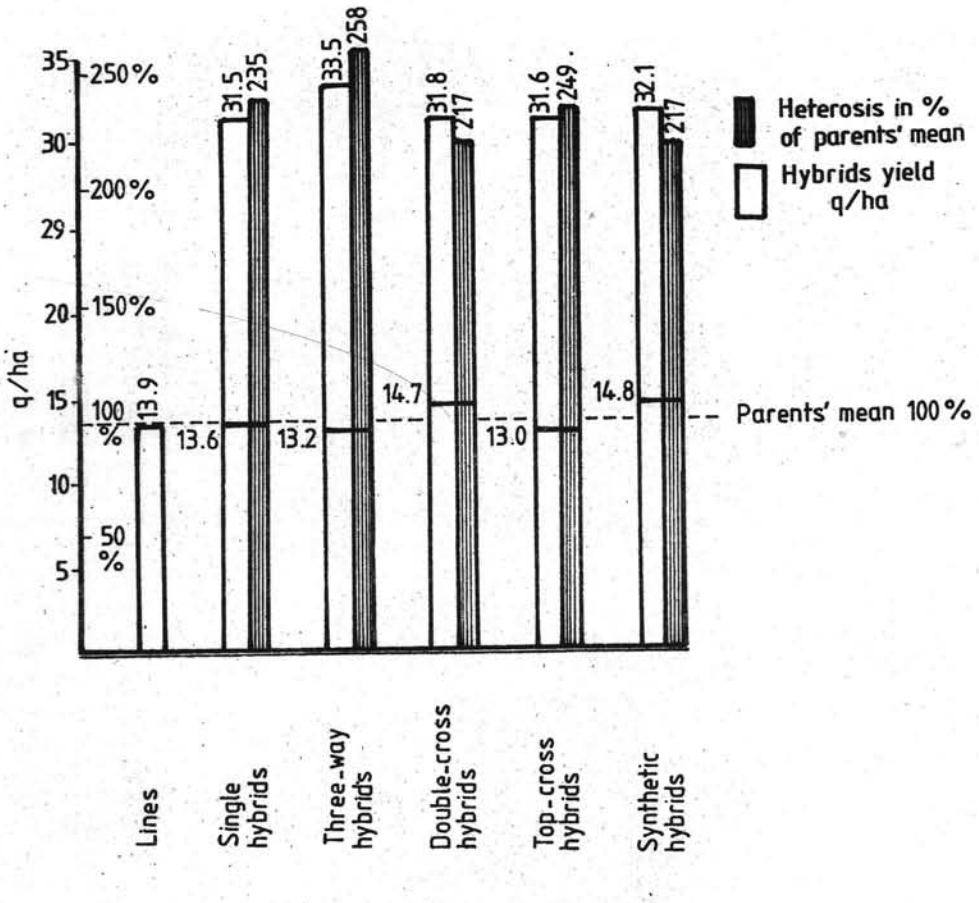

Fig. 2. — Grain yield (q/ha) and heterosis (% of mid-parent) of different hybrid types of sunflower (means of 2 years and 4 locations)

programmes by applying gametocides (Schuster, 1956 b, 1961, 1963, 1969, 1979; Mirasimsadeh, 1973; Liu, 1981; Schuster and Liu, 1983). The first experiments led to two hybrids, Sobrid (registered in 1970) and Sorex (registered in 1975). They were produced via male-sterility, induced by treating mother plants in the early flower-bud stage with 0.5 mg gibberellic acid per plant (in 3 ml of weak aqueous alcohol solution). This procedure became unnecessary after cytoplasmic genetically controlled male sterility could be established in our breeding material. The latter system is to be preferred because of environmentally modified (and therefore unpredictable) effect of gibberellic acid; furthermore, gibberellic acid treatments seem to increase susceptibility of flower-buds to Botrytis.

In a recent cooperation with the Vetömag Institute at Nyiregyhaza (Hungary), the performance and yield stability of single and three-way hybrids have been studied at 4 locations in 2 years (Schuster et al., 1984; Schuster and Stamm, 1984, 1985; Stamm, 1987). These trials revealed slightly higher yield (*Fig. 2*) and yield stability (*Table 2*) of three-way crosses as compared to singles. Nevertheless, a single-cross hybrid, Semira, was developed in our institute on the basis of cms-system and released in France in 1985.

Earlier, grain yield as well as grain quality (Sietz, 1966) of open pollinated and hybrid varieties had been tested in a world-wide series of experiments (Schuster and Seibel, 1977; Seibel, 1978; Schuster and Skoric, 1978). Valuable results were obtained in this series with regard to interactions of varieties and locations (*Table 3*). Besides grain yield, oil and protein content as well as other components of grain quality are strongly affected by environment, e.g. vitamin E (tocopherol, cf. Fig. 3) and show striking interactions between genotype and environment (Schuster et al., 1972; Marquard et al., 1977; Schuster and Seibel, 1977; Marquard, 1980). It was particulary important in these trials to estabilish that the content of tocopherol, just like the fatty acid composition, is determined by the embryo and therefore directly influenced by alien hybridation (Marquard et al., 1977).

Investigations on sunflower grain quality including genotypic, environmental and interaction effects have been particularly intensified in our institute in recent years (Schuster; 1967, 1973, 1975; Schuster and Kübler, 1981 a, 1981 b, 1983; Schuster and Tugay, 1977; Schuster et al., 1972, 1980). For example, it was possible by mutagenic treatment

Table 2

Parameters of stability of oil yield, based on trials in 8 environments

	Oil yield	Stability					
		arithmetic			logarithmic		
	dt/ha	W_i	b_i	S_d2	W_i	b_i	S_d2
Inbred lines (n=12)	5.15	13.90	0.62	8.93	0.107	1.37	0.090
Single crosses (n=10)	13.33	31.12	1.33	26.07	0.035	1.02	0.032
Three-way crosses (n=6)	13.87	25.66	1.41	10.93	0.021	1.00	0.015
Double crosses (n=10)	12.90	12.73	1.10	9.11	0.018	0.82	0.013
Topcross hybrids (n=5)	13.11	18.29	1.02	14.27	0.029	0.74	0.024
Synthetics (n=6)	12.72	13.97	1.01	13.68	0.026	0.74	0.022

W_i = Ecological stability ("Ökovalenz") . b_i = Coefficient of regression of genotypes on environments ;
S_d2 = Variance of genotypic/environment regression.

Table 3

Grain yield (dt/ha) of various sunflower cultivars at widely differing locations (means of 2 years) indicating pronounced interactions of genotypes with environments

Location / Cultivar	Morden (Canada)	Gross-Gerau (F.R.G.)	Novi Sad (Yugosl.)	Bornova (Turkey)	Karadj (India)	Lincoln (New Zeal.)	Average
VNIIMK 8931	21.30	31.95	42.03	17.57	33.15	24.77	28.46
Peredovik	26.11	32.17	40.73	17.95	32.01	30.76	29.95
Cms HA 89 × RHA 266	37.58	30.98	35.08	8.47	30.44	29.54	28.68
Valley	28.01	37.24	34.84	18.69	31.82	27.29	29.65
Romsun HS 52	36.71	33.39	35.49	17.39	34.05	29.99	31.17
INRA 4701	18.89	24.32	32.23	9.20	32.93	26.75	24.05
INRA 6501	19.47	29.24	36.36	9.05	32.74	29.41	26.05
Sobrid	28.87	36.24	33.82	16.87	31.30	28.72	29.30
Sorex	36.27	38.37	31.60	20.18	31.71	33.76	31.98
Mittel	28.13	32.66	36.80	15.04	32.24	29.00	28.81

and repeated selfing to increase the content of either oleic acid or linoleic acid (Schuster and Kübler, 1983; Kübler, 1984). These experiments are presently continued with emphasis on environmental stability of the positively selected lines as well as their genetics and usefulness in hybrid breeding programmes (Schmidt, 1987).

Further, more emphasis is given to problems of disease resistance, e.g. to *Sclerotinia sclerotiorum*. The latter pathogen is the major causal agent of diseases under moderate climatic conditions in Europe, besides *Botrytis* (Acimovic, 1984). Previous experiments have indicated some degree of tolerance to *Sclerotinia* rot in our materials (Grauert, 1979; Grauert et al., 1980; (*Fig. 4*). However a major problem of testing for tolerance or resistance under field conditions is the pronounced environmental variation of *Sclerotinia* field reaction. Therefore, screening for resistance has to be carried out under controlled environmental conditions, e.g. in growth cabinets. It would be necessary to establish a reliable screening system in early development plant stages.

After sunflower cultivation has been extended in France year by year, new activities were started in 1980 for oil-sunflower cultivation in the south and south-west of West Germany. First trials in comparatively small plots (<5 ha) were however strongly affected by bird damage, so that kernel yield could not compete with that of winter wheat at that time. Recently, promising results have been obtained in Alsace (France) and southwestern areas of West Germany. Therefore, several thousand hectares of sunflower were grown in southern Baden, Palatinate and Rhinehessen in 1986. For 1987, it is planned to grow several tenthousand of hectares in these areas.

The following sunflower varieties have recently been listed in the Federal Republic of Germany (Bundessortenamt, 1985) : Giganta, Spanner's Allzeck and Mirasol. Just the last of these cultivars can be recommended for grain production, whereas the former are exclusively

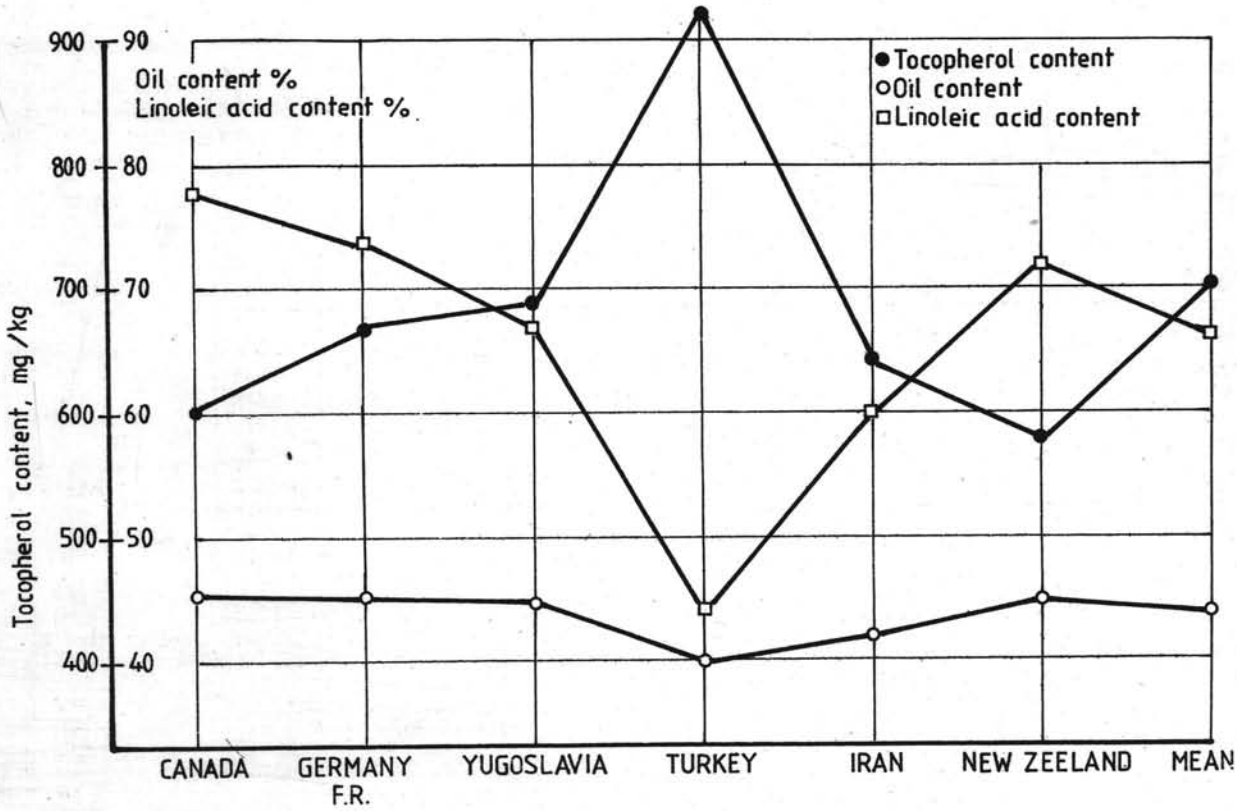

Fig. 3. — Environmental effects on oil — linoleic acid — and tocopherole-content in sunflower oil (means of varieties in the year 1974)

Fig. 4. — Different reaction to infection by *Botrytis* and/or *Sclerotinia* of different sunflower lines (left : "resistant" or tolerant ; right : susceptible)

suited for use as a green matter. i.e. forage or manure. New, improved hybrids are going to be released in the near future.

Further intensified breeding activities will be necessary to improve earliness, disease resistance, grain yield and quality of sunflower. Experiments have been initiated to try to speed up breeding progress by the application of tissue and cell-culture techniques. Altogether, combined breeding activities will hopefully lead to improved adaptation of sunflower to the growing conditions in some favourable areas of West Germany (see above) so that it there may become a major crop like in other countries.

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