

## RESULTS AND PROSPECTS IN SUNFLOWER BREEDING FOR GROUP IMMUNITY BY USING THE INTERSPECIFIC HYBRIDIZATION METHOD

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As in the past, the main concern in sunflower breeding in the Soviet Union consists at present in the development of highly productive varieties with high oil content and resistant to the main pathogens and pests of this crop.

In their sunflower breeding programmes, all VNIIMK experiment stations and other scientific institutions, not included in this system, use the method of reserves elaborated by V. S. Pustovoit.

The method of reserves represents one of the variant of the recurrent selection, with individual estimation of the progenies and subsequent intercrossing of the best families. The method provides a gradual change of the population, maintaining however simultaneously the genetic variability necessary for selection. The accumulation of the positive characters provides a continuous improvement of the population and allows to obtain more productive genotypes. This method proved particularly efficient for increasing the oil content of the population which was raised annually by 0.5 to 1%.

The efficiency of the examined method is determined by the existence of the elements for heterosis breeding which allows to identify the best heterosis combinations as a result of the general combining ability of different biotypes with the common tester, the initial variety. The efficiency of this method is corroborated by the brilliant practical achievements obtained in sunflower breeding in the U.S.S.R. In 1973 the varieties developed by this method were planted on 4,600,000 ha (98% of the whole area under sunflower), the varieties of the VNIIMK selection holding 94% of this area.

The average sunflower seed yield obtained last year was 15.4 q/ha. In the Krasnodar region and in the Moldavian Socialist Republic the average yield on more than 600,000 ha was 20.6 q/ha and 20.4 q/ha respectively.

In the frontranking kolkhozes of the quoted regions, sunflower seed yield reached 32—35 q/ha. Mean oil content in absolutely dry seeds for the whole U.S.S.R. was 50.8%, in the Moldavian Socialist Republic and Krasnodar region 52.4 and 51.8% respectively, while in Donetz region it was 56%.

Although the oil content of the Soviet varieties is very high, and their potential performances approach the biological limits, the method of reserves has not lost its efficiency in sunflower breeding.

In the last 3 years better varieties belonging to different maturity groups were developed in the VNIIMK system, using this method. Thus, for instance the following varieties were released in the group of early varieties exceeding the existing ones by their productivity: Luch, Donskoy 47, Armavirski 14, Moldavski 41 and Moldavski 3 as well as Saliut, Rannii 2, Zenit and Zarea which have a shorter growing period.

Sunflower initial material resistant to the new broom-rape race which appeared within the complex of „B“ races was created and high productive forms were identified. The new varieties-populations of different vegetation periods serve as a basis for the development of inbred lines with the purpose of breeding for heterosis, using the methods of intervarietal crossing, top-cross or interline hybridization.

Special importance is attributed to sunflower breeding for immunity against the main pathogens of this crop.

In the Soviet Union, sunflower breeding for immunity forms one of the main concerns for this crop. Up to now people relied on naturally occurred mutations and on the existent gene pool within the populations of cropped varieties.

Sunflower breeding for immunity in the U.S.S.R. resulted in the development of varieties resistant to the most dangerous parasite of this crop — the broom-rape, as well as to *Verticillium* wilt and sunflower moth. The most valuable immunity traits of the Soviet sunflower varieties combine with high productivity, oil content and oil yield per hectare.

Starting from 1955—1956, sunflower breeding for immunity was performed at VNIIMK by interspecific crossing of sunflower varieties released by VNIIMK and cultivated in the Soviet Union, with the *Helianthus* wild species originating from North America, in which sources of immunity against the main sunflower pathogens were discovered. Studies of the wild species of *Helianthus* revealed that they held group immunity against downy mildew, rust, white rot, gray rot, sunflower black spotting, broom-rape and against *Homoeosoma nebulella* and *Brachycandus helichrysi* pests. Except *H. tomentosus*, all the other wild species are attacked by *Verticillium* wilt. The above mentioned characters of immunity, except the resistance to broom-rape, are genotypical and are inherited by the interspecific hybrids. Of a special interest for selection is the group of auto-hexaploid species ( $2n=102$ ) such as *H. tuberosus*, *H. rigidus*, *H. subcanescens* and *H. macrophyllus*.

VNIIMK has at present obtained a large pool of interspecific hybrids (15 combinations) resulted from crossing 12 wild species of *Helianthus* to sunflowers. The hybrids range from first to seventeenth generation and possess a group immunity against 4 to 6 pathogens. The main breeding work is performed with the F<sub>14</sub>—F<sub>17</sub> combinations (*H. tuberosus* x *H. annuus* no. 8931).

Simultaneously with the interspecific hybrid improvement for immunity, an intensive work is carried on for improving the productivity of the hybrid progenies (seed yield, oil content increase, husk percentage and increase of oil yield per hectare).

The breeding of the interspecific hybrids for immunity is achieved by hybridization followed by continuous individual selection within the hybrid population without backcrossing to sunflowers beginning with the third generation. When applied to early hybrid generations, the backcross leads to the loss of immunity against the whole range of pathogens.

Individual selection is accompanied by progenies estimation for immunity and productivity, carried out on heavily infected soils and by artificial inoculations applied in greenhouse and in the field. Best progenies are increased under space isolation conditions. The nursery in which the initial material for selection is developed, is organized in the same manner as the nursery for the controlled interpollination of the best biotypes, previously selected after having been multilaterally examined.

Interspecific hybrid breeding is mainly performed for vertical resistance, conditioned by the dominant oligogenes which control the specific racial resistance. Intense investigation are made to identify biotypes in which specific racial resistance should combine with field (horizontal) resistance. Each immunity trait of the interspecific hybrids is inherited separately and not by gene blocks, compelling us to do special breeding work for each character. At present a large breeding material resistant to downy mildew, rust, white rot, gray rot, Verticillium wilt, black spotting and broom-rape has been developed. The hybrids are completely resistant to sunflower moth and some of them to *Brachycandus helichrysi*.

BREEDING FOR RESISTANCE TO DOWNY MILDEW (PLASMOPARA HELIANTHI F. HELIANTHI NOVOT.) OF THE INTERSPECIFIC HYBRID INITIAL MATERIAL

Breeding for resistance to downy mildew of sunflower interspecific hybrids began at VNIIMK as a main feature. At present an initial material characterized by complete resistance to the pathogen both in infected fields and under artificial inoculations has been developed. In these hybrids the resistance to downy mildew is combined with high productivity and oil content. Interspecific hybrid varieties with high resistance to downy mildew and with oil yield per hectare equal or

exceeding that of the check variety have been already developed. These varieties (F<sub>13</sub>—F<sub>14</sub>) will be released next year to the state network for variety trials.

BREEDING FOR RESISTANCE TO RUST (PUCCINIA HELIANTHI SCHW.) OF THE INTERSPECIFIC HYBRID INITIAL MATERIAL

The interspecific hybrids obtained by crossing the Peredovik and VNIIMK 8931 varieties, susceptible to rust, with the perennial wild *Helianthus* species, completely immune to rust, are characterized by a high field resistance to this pathogen. By repeated selection under field infection conditions and under artificial inoculation in greenhouses a large group of hybrids resistant to rust was developed. In this group of hybrids, the resistance to rust, Verticillium wilt, downy mildew and sunflower moth is combined with high productivity.

INTERSPECIFIC HYBRID BREEDING FOR RESISTANCE TO WHITE ROT (SCLEROTINIA LIBERTIANA FUCK)

The study of immunity against white rot within the *Helianthus* genus revealed that the cultivated sunflower world collection was 100% attacked by *Sclerotinia* under artificial inoculations. Only the wild *Helianthus* species of the hexaploid series and their hybrids with sunflower proved resistant to *Sclerotinia*.

In hybrids, the resistance is exhibited from bud formation stage and up to their total ripening. In other words, the hybrids are resistant only to the rot form that attacks the heads. A deeper study of the reciprocal relationships between *Sclerotinia* and the resistant hybrids showed that *Sclerotinia* is represented by different geographic races that differ by their pathogenicity. During hybrid breeding for resistance to *Sclerotinia* we underwent many difficulties and failures, but after seven years of selection under artificial inoculation we succeeded in creating a population with a high resistance ranging from 70 to 90% against nine different geographic races of *Sclerotinia* (table 1). These hybrids have not been yet investigated with respect to their economic useful characters.

Table 1

Resistance of sunflower interspecific hybrids (*H. tuberosus* x VNIIMK 8931) to *Sclerotinia libertiana* under artificial inoculations (1973)

Entry number	No of. the infected plants	No. of nonattacked plants	Percentage of resistant plants
22444	144	144	100
22443	141	140	99.3
22450	140	139	99.3
22452	144	143	99.3
22442	144	140	97.2

BREEDING FOR RESISTANCE TO VERTICILLIUM DAHLIAE KLEB. OF THE INTERSPECIFIC HYBRID INITIAL MATERIAL

The initial wild *Helianthus* species are 100% infected by *Verticillium* wilt, while the sunflower varieties of the VNIIMK selection are extremely resistant to this disease. The hybrid population holds at present a high resistance to *Verticillium* wilt, at the same level with the cultivated varieties of the VNIIMK selection, from which they inherited their immunity. This result was obtained by discarding each year the diseased plants, before the anthesis phase at all breeding stages.

THE CREATION OF THE INTERSPECIFIC HYBRID INITIAL MATERIAL RESISTANT TO GRAY ROT (*SCLEROTIUM BATATICOLA*, TAUB.)

All sunflower varieties released in the Soviet Union are susceptible to gray rot. The most attacked are the early varieties, causing a yield decrease that may go up to 40%. In 1970, immunity sources against this pathogen were discovered among the interspecific hybrids of higher generations. Up to 1970 this character had not been checked. Sunflower breeding for resistance to *S. bataticola* is rendered more difficult by the absence of any symptoms at an early stage. But in a short period of time (3 years), as a result of selection, 62 families completely resistant to the pathogen were identified and a large hybrid source was constituted having a high degree of resistance (80—96%), when sunflower was infected up to 75%. In this hybrids the resistance to *S. bataticola* is combined with a high yielding capacity (tables 2 and 3).

Table 2

Interspecific sunflower hybrids (*H. tuberosus* x VNIIMK 8931) immune to *S. bataticola*

Entry number	VNIIMK		OSH „Berezanskoe“		% diseased plants (VNIIMK)	% diseased plants OSH „Berezanskoe“)
	Total no. of plants	Of which diseased	Total no. of plants	Of which diseased		
43009	13	0	14	0	0	0
43035	17	0	19	0	0	0
43043	20	0	19	0	0	0
43125	16	0	13	0	0	0
43137	13	0	19	0	0	0
43217	16	0	18	0	0	0
43289	20	0	15	0	0	0
43298	20	0	18	0	0	0
43335	18	0	15	0	0	0
K-8921	14	11	17	8	78.6	47.1

Table 3

Best sunflower interspecific hybrids (*H. tuberosus* x *H. annuus* 8931) with respect to *S. bataticola* resistance in the first year selection nursery

Entry number	Total plants in the trial	Of which diseased	Percentage of diseased plants
43241	47	0	0
K-8931	51	32	62.7
43340	50	0	0
K-8931	47	28	59.6
43405	47	1	2.1
K-8931	46	22	47.8
43537	42	1	2.4
K-8931	44	20	45.5
43595	47	1	2.1
K-8931	49	23	46.9
43706	47	1	2.1
K-8931	45	34	75.6

BREEDING FOR RESISTANCE TO BROOM-RAPE (*OROBANCHE CUMANA* WALLR.) (COMPLEX OF „B“ RACES) OF THE INTERSPECIFIC HYBRID INITIAL MATERIAL

The interspecific hybrids, obtained by crossing *H. tuberosus* to sunflower, were severely attacked by broom-rape although the mother form (the wild species) is completely immune to the parasite, and the sunflower VNIIMK 8931 was formerly very resistant to broom-rape but now is attacked by the new races that appeared in the last ten years.

A seven year hybridization and selection on infected fields as well as the selection performed under artificial infection in greenhouses

Table 4

Best interspecific  $F_{16}$  hybrids (*H. tuberosus* x VNIIMK 8931) resistant to broom-rape as estimated twice on a severely infected soil and under greenhouse conditions

Plot number and checks	Estimation in the field				Estimation in the greenhouse			
	No. of plants per plot	No. of broom-rape plants per plot	Broom-rape attack %	Degree of the attack %	No. of plants in trial	No. of broom-rape plants	Broom-rape attack %	Degree of the attack %
198	19	0	0	0	8	0	0	0
300	19	0	0	0	10	0	0	0
314	16	0	0	0	10	0	0	0
322	13	0	0	0	10	0	0	0
326	14	0	0	0	10	0	0	0
350	14	0	0	0	10	0	0	0
353	12	0	0	0	9	0	0	0
371	16	0	0	0	10	0	0	0
Peredovik	15	91	80	7.6	24	408	91.7	18.5
A-41	14	318	100	22.7	25	571	96.0	23.8

allowed the obtention of over 5000 elite heads from hybrids that maintained their resistance for three years. The selection is performed in special fields infected with a complex population of broom-rape, collected from different regions of the Soviet Union and representing the whole diversity of "B" races of broom-rape. In 1974 the resistant hybrids were introduced in the breeding field for getting new varieties (table 4).

DEVELOPMENT OF HYBRID INITIAL MATERIAL WITH COMPLEX IMMUNITY AGAINST THE MAIN PATHOGENS OF SUNFLOWERS

The complexity of sunflower interspecific hybrid breeding consists in the fact that the resistance characters are separately inherited by the hybrids from the *Helianthus* wild species and not in gene blocks controlling the complex characters.

The breeder should keep in view the complex processes that simultaneously occur in the populations of the different organisms. Practically it is necessary to put together the characters of resistance to different pathogens in one single variety and combine them with the economic useful characters. In order to achieve this task, a recurrent breeding method was elaborated, founded on the breeding principles worked out by V. S. Pustovoit for sunflower. At present we have at our disposal a vast hybrid breeding material that comprises 4 to 6 characters of resistance to different pathogens. The first varieties that will be released this year to the State network for variety testing hold a high resistance to downy mildew, to Verticillium wilt, to rust and to gray rot. All these hybrids possess a complete phytomelan layer in the seed coat that induces resistance to sunflower moth (*Homoeosoma nebulella*) (table 5).

Table 5

Testing results obtained in the first year selection nursery with interspecific  $F_{17}$  hybrids (*H. tuberosus* x VNIIMK 8931) resistant to gray rot and downy mildew (VNIIMK, 1973)

Entry number	1000 seed weight (g)	Phytomelan layer (%)	Test weight (g/l)	% husk	Oil content in completely dry seed (%)	Seed yield (q/ha)	Oil yield (q/ha)	Degree of infection	
								gray rot (%)	downy mildew (%)
43132	52.2	100	461.2	21.1	53.9	33.5	16.2	1.9	0
K-8931	63.4	100	421.2	16.6	52.0	25.3	11.9	51.0	99
43219	56.1	100	426.0	21.1	52.0	38.7	18.1	3.9	1
K-8931	59.9	100	402.8	21.1	50.1	28.7	13.0	58.3	100
43311	64.1	100	409.2	21.3	50.7	34.1	15.6	3.9	0
K-8931	69.9	100	416.0	20.2	51.8	29.0	13.5	55.3	100
43340	73.1	100	424.4	21.2	53.8	34.6	16.8	0	0
K-8931	76.6	100	397.6	21.0	50.7	26.2	12.0	59.6	99

BEREDING OF SUNFLOWER INTERSPECIFIC HYBRIDS OF HIGH TY HOLUCTIVIODPRDING  
GROUP IMMUNITY AGAINST THE MAIN PATHOGENS

Sunflower varieties presently grown in the Soviet Union contain from 49 to 54% oil, and they can accumulate in commercial seeds up to 57% oil. These varieties supply high seed and oil yields per hectare. The interspecific hybrid population of the seventh generation within which only crosses between hybrids were made starting from the third generation without applying the backcross, held a mean oil content of 32% and husk proportion of the seeds of 39.8%. Therefore, a heavy task was set to us: to combine in the future varieties the group immunity with a high productivity, equal and superior to that of the cultivated varieties. The high variability of interspecific hybrids, superior to sunflower variability, allowed in a term much shorter than necessary for sunflower the change of the half wild hybrids into sunflower varieties with high oil content and high productivity which do not differ from the best released varieties.

Thus, for instance, the oil content in the absolutely dry seeds of the selected elites ranged in 1971—1974 from 49% to 60% and 76 of these hybrids had 50% oil content or even more (table 6). The oil content of the hybrid population reached the oil level of the cultivated varieties, certain biotypes having the limiting oil content of 60% in the whole seed or 69—72 in the kernel.

Table 6

The best selected elites of the interspecific hybrids (*H. tuberosus* x *H. annuus* — 8931), with respect to the oil content (VNIIMK, 1972)

Entry number	1000 seed weight (g)	Husk proportion (%)	Seed weight per head (g)	Downy mildew attack under artificial infection (%)	Oil content in completely dry kernels (%)
334	78	22.0	174	0	59.4
3979	57	16.4	153	0	58.7
4081	61	17.0	142	0	58.2
4319	65	19.6	141	0	58.2
4548	70	19.2	213	0	58.2
4684	58	22.0	183	0	58.7
5184	65	22.6	130	0	60.1
5619	80	21.0	133	0	60.1

The experimentation of 18 hybrid varieties with group immunity in preliminary trials in 1973 showed that 11 varieties representing  $F_{13}$  and  $F_{14}$  hybrid populations were on the same level as the check variety in what regards seed and oil yield per hectare, while varieties no. 3 and no. 35 exceeded the check by 4—6% (table 7).

Investigation of the following generations ( $F_{15}$ — $F_{17}$ ) revealed the existence of a material that by far exceeds the check with regard to productivity (by 10 to 72%) (table 8). This proves that there is a



Table 7

Results of preliminary and competitive trials with interspecific hybrids  
(*H. tuberosus* x *H. annuus* — 8931), in 1973

Variety number and generation	Seed yield		Oil content in comple- tely dry seed (%)	Oil yield		Degree of infection	
	q/ha	%		q/ha	%	downy mildew (%)	gray rot (%)
F <sub>13</sub> No.34	31.0	102	50.2	14.01	101	0.5	34.9
K-8931	30.4	100	50.7	13.90	100	100	51.0
F <sub>13</sub> No.35	31.6	106	50.1	14.33	104	0.8	33.6
K-8931	29.3	100	52.3	13.78	100	100	46.2
F <sub>13</sub> No.40	30.0	102	51.4	13.74	100	1.2	25.7
K-8931	29.4	100	52.4	13.84	100	100	51.1
F <sub>13</sub> No.47	29.5	102	50.8	13.51	100	1.2	40.1
K-8931	28.9	100	51.9	13.50	100	100	53.6
F <sub>13</sub> No.3	29.2	104	50.4	13.24	99	2.0	36.1
K-8931	28.0	100	52.9	13.33	100	100	58.0

Table 8

Best interspecific F<sub>17</sub> hybrids (*H. tuberosus* x *H. annuus*-8931) in the first year  
selection nursery (VNIIMK, 1973)

Entry number	Phyto- melan layer (%)	1000 seed weight (g)	Test weight (g/l)	% husk	Oil content in comple- tely dry seed (%)	Seed yield (q/ha)	Oil yield (q/ha)	Yield gain over the check	
								q/ha	%
43275	100	62.3	410.8	21.0	53.94	38.74	18.81	7.88	172.1
43645	100	66.5	425.8	18.1	56.21	34.50	17.45	7.30	171.9
43136	100	54.4	456.4	19.1	54.13	34.08	16.60	6.33	161.6
43478	100	62.2	420.0	19.0	52.18	36.38	17.08	6.40	160.0
43257	100	60.6	438.4	19.8	54.28	39.74	19.41	6.71	152.8
43342	100	67.9	430.2	18.4	54.76	39.00	19.22	6.44	150.4

possibility to develop interspecific hybrids that exceeds the released varieties with regard to oil production even when there is no pathogen problem. In order to select the interspecific hybrids for heterosis, constant inbred lines were developed possessing group immunity and a high oil content. Cytoplasmic male sterile lines have been developed. Interspecific hybrid varieties with high fixation and restoration capacity were identified.

Thus, the interspecific hybridization within *Helianthus* genus broadened out the horizon of sunflower breeding and allowed to obtain an unique selected material the utilization of which can solve the most urgent problem of the present — the creation of the new sunflower varieties with group immunity against the basic pathogens of this crop. The first varieties of this type will be released next year to the State network trials.