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## RESULTS AND PROSPECTS OF SUNFLOWER BREEDING FOR GROUP IMMUNITY BY INTERSPECIFIC HYBRIDIZATION

Breeding interspecific hybrids was started for resistance to downy mildew (*Plasmopara helianthi* f. *helianthi* Novot) considered to be the main character of the hybrids. At present following many years of breeding the initial hybrid stock is developed which is characterized by almost complete (98-100%) resistance to downy mildew under severe artificial inoculation and by high productivity level equal to or exceeding that of the check variety. First hybrids have been developed, 99% resistant to downy mildew and overyielding the check variety by 5-9% oil per hectare. Two of them, Progress and Novinka, have been submitted to State Varietal Trials.

Wild species *Helianthus* of hexaploid range ( $2n = 102$ ) have a high racial and specific field resistance to rust (*Puccinia helianthi* Schw.). This character is also common to interspecific hybrids obtained by crossing sunflower with *H. tuberosus*. A large breeding stock of hybrids has been developed possessing complete racial specific resistance to rust. These hybrids are also 98-100% resistant to downy mildew and are highly productive yielding high oil output per hectare (Table 1).

Studies of sunflower immunity to white rot (*Sclerotinia sclerotiorum* Lib.) reveal that the world stock of cultivated sunflower is 100% susceptible to this pathogen. Only wild species of *Helianthus* of hexaploid range ( $2n = 102$ ) proved to be resistant to the head form of *Sclerotinia*. Resistance to white rot in wild species and in interspecific hybrids is characterized by plant age and is manifested beginning from the rosette

Table 1

Best Interspecific Hybrids Possessing Immunity to Rust and Downy Mildew

VNIIMK, 1975

Elite and check entries	Vegetation period, days	Fat content in absolutely dry seeds, %	Seed yield		Oil yield	
			c/ha	% of check	c/ha	% of check
49314	92	55.47	36.73	116.4	18.67	125.6
K-8931	91	52.38	31.55	-	14.87	-
49326	91	53.74	35.88	114.0	17.35	120.1
K-8931	90	50.99	31.48	-	14.45	-
49318	91	56.20	37.81	106.7	19.12	113.7
K-8931	90	52.67	35.45	-	16.81	-
49313	91	54.08	35.14	111.4	17.10	115.0
K-8931	91	52.38	31.55	-	14.87	-

phase (inflorescence bud) until full maturity. Until this phase the plants are 100% susceptible to white rot.

When breeding for resistance to sclerotinia we encountered some difficulties as previously resistant hybrids almost completely lost their resistance.

At present we continue improving resistance and oil content in hybrids which have lost resistance to a considerable extent owing to their cross pollination with sunflower. At present breeding hybrids for resistance to white rot is effected only under isolated flowering (inbreeding and pair crosses using oil-paper bags). For the past three years we have obtained lines almost 90% resistant to the head form of sclerotinia.

Development of hybrids resistant only to sclerotinia localized on the head of the plant cannot completely solve the problem, but this form of the disease is the most widespread and this type of resistance will have a positive effect.

All wild species except the tetraploid species *H. tomentosus* are 100% susceptible to verticillium wilt (*Verticillium dahliae* Kleb.) under field epidemics and artificial inoculation.

Resistance to verticillium wilt in interspecific hybrids is inherited from cultivated sunflower varieties bred in VNIIMK. At present populations of interspecific hybrids influenced by selections have almost the same resistance to verticillium wilt as the Peredovik variety. Infection under field conditions is only 1-3%. Under artificial inoculation some families have 92-93% genetic resistance.

All sunflower varieties commercialized in USSR are susceptible to charcoal rot (*Sclerotium bataticola* Taub.), which reduces the seed yield to 40% and oil content by 2-4%. However, perennial wild species proved to be completely resistant to this disease, and annual species were completely susceptible. In 1970 we have

found sources of immunity to charcoal rot among interspecific hybrids (*H. tuberosus* x VNIIMK 8931). Breeding for resistance to this pathogen is complicated by the absence of early symptoms of the disease in sunflower and screening has to be effected in the female parent only after mature cross-pollinated plants have been harvested. However, selections are rather effective in common field infected conditions with a high rate of fungus parasitism. Last year we have developed 60 families, 50 plants each, which proved to be completely resistant to the pathogen in three different geographical localities.

In breeding nurseries of the 1st and 2nd years of studies we have identified over 80 entries highly resistant to charcoal rot (Table 2). These hybrids are 20-30% higher than the check in oil yield per hectares.

Interspecific hybrids developed from crossing *H. tuberosus* immune to broomrape with the resistant variety VNIIMK 8931, were severely affected by broomrape (*Orobanche cumana* Wallr.). Resistance to broomrape in hybrids is inherited on the pattern of intermediary inheritance. When breeding for resistance to broomrape infected fields are utilized as well as artificial inoculation in the greenhouse. During winter about 12,000-14,000 elite plants are evaluated in the greenhouse.

Breeding for resistance to broomrape was started in 1965, using hybridization followed by individual selection in infected plots against the background of a complex broomrape population reflecting its racial diversity in USSR. At present hybrids highly resistant to broomrape and downy mildew with the oil content of 48% to 56% are rapidly multiplied and tested at all links of the breeding scheme.

Trials of hybrids resistant to broomrape and downy mildew in the nurseries of the 1st and 2nd years of studies have shown that the best families yielded over 40 c/ha of seeds (Table 3).

Table 2

Best Entries of Interspecific Sunflower Hybrids (H. tuberosus x 8931) in Terms of Resistance to Ashen Rot

Elite and check entries	Vegetation period, days	Fat content in absolutely dry seeds, %	Seed yield, c/ha	Oil yield, c/ha	Degree of affection, %
45599	98	54.4	36.4	17.8	1.9
K-8931	95	50.9	32.2	14.8	62.7
45953	98	53.9	36.7	17.8	3.9
K-8931	96	52.3	33.3	15.7	58.8
45840	97	56.7	34.7	17.7	1.9
K-8931	97	52.0	33.6	15.7	60.0

Table 3

Best Entries of Interspecific Hybrids in Tems of  
Resistance to Broomrape and Downy  
Mildew

Elite and check en- tries	Vegeta- tion pe- riod, days	Fat con- tent in absolu- tely dry seeds, %	Seed yield		Oil yield		Affection	
			c/ha	addi- tion to check, %	c/ha	addi- tion to check, %	downy mildew, %	number of broomrapes in flores- cences per 100 plants in green- field house
49297	90	50.46	42.67	140.8	19.38	141.9	0	0
K-8931	89	49.73	30.31	-	13.66	-	100	0
49276	89	50.73	34.57	121.8	16.02	123.0	0	1
K-8931	90	50.50	28.37	-	13.02	-	100	0
49275	89	49.74	34.80	122.7	15.87	121.9	0	3
K-8931	90	50.50	28.37	-	13.02	-	100	0
49181	90	50.08	49.26	123.0	20.85	121.3	0	4.5
K-8931	90	50.05	37.61	-	17.19	-	100	4

They overyielded the check by 40% in oil output per hectare and displayed high resistance to two major pathogens.

All wild species of *Helianthus*, except annuals, are resistant to *Phoma oleraceae* Sacc. under field epidemics, and under artificial inoculation 6 species are completely resistant to the pathogen.

All commercialized varieties are completely susceptible to *Phoma* sp. under field epidemics. Breeding for resistance to *Phoma* sp. has been started in 1973 in interspecific hybrids of sunflower. Populations that have been bred are considerably less affected by this pathogen.

It is difficult to breed interspecific sunflower hybrids for group immunity because the traits of resistance are separately inherited by hybrids from wild species of *Helianthus* rather than in blocks of genes controlling several traits. It is necessary for the breeder to combine traits of resistance to different pathogens in one plant or a variety and to combine them with important traits of high economic value.

A special breeding method was developed for the purpose. Breeding for high productivity was based on the principles of sunflower selection developed by Academician V.S. Pustovoit. Sunflower varieties commercialized in the USSR contain 49-55% oil in the seeds and under favourable conditions they are able to accumulate up to 57% oil in the seeds in large commercial lots.

Interspecific hybrids in F<sub>7</sub> had 27% mean oil content and 39.8% huskness. We were therefore faced with a difficult task of developing resistant counterparts of the best commercial varieties of the Peredovik type.

In 1975, after 10 years of breeding work the oil content of breeding elite of interspecific hybrids was within the range of 49-63.5% in absolutely dry seeds, that is 73-76% in absolutely dry kernel of 6000 selected elite heads 70% contained 54-63.5% oil in absolutely dry seeds.

Table 4

Highest Oil Breeding Elite of Interspecific Sunflower  
Hybrids F<sub>18</sub> (H. tuberosus x 8931)

VNIIMK, 1975

Elite entries	Husk, %	Oil content of absolutely dry seeds, %	Oil content of absolutely dry kernel, %
37636	14.0	62.85	73.08
37822	16.3	62.79	75.00
37505	17.7	62.62	76.10
37144	18.7	62.02	76.30



In the nursery of the 1st year of study 500 families out of 900 showed 54-60.4% oil in the progeny. This is the upper limit of the oil content in sunflower and it is registered in the progeny for the first time. As is known, sunflower is next to the last in the range of oil plants, while castor bean is the first one. Our interspecific hybrids which half wild plants in the not too distant past have at present surpassed castor bean in the oil content in the seeds. Such oil content is a biological upper limit of oil in sunflower, and it is impossible to further raise it, but it is quite possible to breed for higher oil yields per hectare than modern commercialized varieties can show. Thus, during a period which is just a moment in the long evolution of sunflower, initial stock has been created for breeding purposes. The stock is resistant to seven fungal diseases and two predators, and has a phenotype and productivity level equal to the best Soviet commercialized varieties and the highest oil content.

In 1975 fifty interspecific hybrids were minutely studied in competitive and preliminary varietal trials. Most of them, cultivated in crop rotation fields, reached the productivity level of the Peredovik variety, and some even overyielded it by 2-9% (Table 5). The hybrids possess high resistance to downy mildew (98-99%), field resistance to verticillium wilt (97-98%), field resistance to charcoal rot (60-80%) and complete resistance to sunflower moth (100%).

Trials of the first two varieties of this type, Progress and Novinka, under conditions of artificial inoculation gave the following results. Varieties were practically not affected by downy mildew. Infection rate was only 0.07-0.32% while in the case of Peredovik infection rate was 99.3%. Seed yield was 34.1-33.8 c/ha, respectively, with 1.2 c/ha of the check. Oil yield amounted to 17.02 and 17.00 c/ha in the varieties and 0.40 c/ha in the check. Advanced material of the above type was tested in the first year nur-

Table 5

Results of Competitive and Preliminary Trials of  
Interspecific Hybrids

VNIIMK, 1975

Variety	Vegetation period, days	Oil content of absolutely dry seeds, %	Seed yield		Oil yield		Degree of affection by downy mildew, %
			c/ha	% of check	c/ha	% of check	
MVG No. 88	98	53.9	31.9	103.6	15.5	105.3	0.5
MVG No. 91	96	52.7	32.6	105.8	15.5	105.2	0.2
MVG No. 93	96	52.1	32.9	106.8	15.4	105.0	0.4
MVG No. 117	97	52.7	33.2	107.8	15.8	107.1	0.4
K-8931	95	53.0	30.8	100.0	14.7	100.0	100
		m %	171				
		HCP	0.95				1.1

Table 6

Best Entries of Interspecific Hybrids Resistant to Downy  
Mildew and Other Diseases

VNIIMK, 1975

Elite and check en- tries	Vegeta- tion pe- riod, days	Oil con- tent of absolute- ly dry seeds, %	Yield		Oil yield	
			c/ha	% of check	c/ha	% of check
49013	92	53.71	46.30	157.6	22.38	166.0
K-8931	91	51.02	29.37	-	13.49	-
49028	92	57.06	43.08	145.0	22.12	160.4
K-8931	92	51.53	29.73	-	13.79	-
48328	90	60.44	37.78	130.0	20.55	147.3
K-8931	90	53.29	29.09	-	13.95	-
48445	91	57.63	40.64	128.3	21.10	144.5
K-8931	91	51.90	31.63	-	14.60	-
48284	92	57.63	39.39	124.9	20.43	141.5
K-8931	92	50.90	31.53	-	14.44	-

sery. Certain families were screened showing the upper oil content (57-60%) in the seeds, seed yield of about 40 c/ha and complete resistance to downy mildew. Best families were 30-66% - higher than the check in oil yield per hectare. (Table 6). These hybrids are most prospective for developing varieties representing the middle ripening group. Of special interest for the Soviet Union are hybrids containing resistance to broomrape in their complex of resistance.

Along with the traditional breeding methods we accumulate stock for heterosis breeding by the line-hybridization method.

Over 1000 lines possessing group immunity were selected and transferred to CMS. In populations of interspecific hybrids we found excellent MS maintainers and fertility restorers. Trials of test-hybrids in 1974 showed the possibility of obtaining a high heterosis of about 35-68%. Thus, interspecific hybridization in the genus *Helianthus* has broadened the horizons of the sunflower breeding and allowed to create unique breeding material utilizing which can be used to solve the urgent problem of breeding highly productive sunflower varieties with group immunity to the major pathogens of this crop.