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THE RESEARCH TRENDS IN THE FIELD OF SUNFLOWER BREEDING FOR HETEROSIS — AT THE ALL-UNION RESEARCH INSTITUTE FOR OIL CROPS (VNIIMK)

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Increasing the yield of the cultivated plants by using the heterosis effect, has become today one of the most important problems of the national economy. The replacement of the traditional varieties by heterosis hybrids enabled the achievement of a significant yield increase in corn, sorghum, tomatoes and other crops. The development of certain inbred lines and, on this basis, of hybrids and hybrid populations, comprises an increasing number of agricultural crops while for certain plants such as corn, for example, it constitutes an unique breeding method.

The possibility to increase the sunflower yield by using hybrid seed called for the attention of the plant-breeders for quite a long time. At VNIIMK there were obtained the inbred lines I_9—I_{10} in the nineteen-twenties, characterised by a relatively high, for those times, oil-content and a low hull percentage. The interline hybrids obtained on the basis of such lines, showed a heterosis effect with respect to plant height, head diameter, seed and oil yield per hectare. The hybrids 71 and 45 surpassed the standard variety by 62—65% in seed yield. Even by that time, the academician V. S. Pustovoit pointed out the necessity of elaborating a method for the creation of lines with high combining ability, as one of the main trends of breeding for heterosis.

Nowadays, the main research directions in the field of sunflower breeding for heterosis, at VNIIMK, are the following :

1. The elaboration of breeding methods for the development of lines with high general combining ability, high oil content, low hull percentage and resistant to broom-rape (*Orobanche cumana* Wallr.), a dangerous sunflower parasite.

2. The development of cytoplasmic male sterile lines and, on this ground, of high yielding F_1 hybrids.

3. The utilisation of the initial material, obtained by interspecific hybridization, for selecting inbred lines, resistant to different pathogens.

4. The study and the utilization of the mutagenesis method in order to estabilish a collection of inbred lines with new characteristics and the development on this ground of high yielding hybrids and hybrid populations having an improved fatty acid composition of the oil.

5. The evaluation of the possibility to use the chemical emasculation and the self-incompatibility in order to obtain hybrid seeds.

6. The elaboration of the methodology for creating hybrid populations and synthetic varieties characterized by precocity and high productivity.

The main feature of the parental forms, mainly of the inbred lines, which determines the yielding capacity of the hybrid progeny is the range ot their combining ability.

It was found that the combining ability has a marked hereditary expression. It is also known that the quality of the inbred lines which could be selected from these varieties can be evaluated after the results of the hybridization between varieties. The evaluation of the combining ability has been determined to various agricultural crops.

In our country, the research work in the field of sunflower combining ability has been carried out by A. I. Gundaev (1963—1964), V. G. Volf (1969), A. V. Anaschenko (1965), A. E. Kovarski (1966), T. K. Grebiniuk (1964) a.o. These authors have estabilished the superiority of certain sunflower varieties (Tcherneanka 66, Armavirski 3497 a.o.) from the combining ability point of view. Nevertheless, these papers couldn't cover the whole range of sunflower varietis ; after all, this is just the begining, in this particular field.

In our days, at VNIIMK, this research work is being carried out on a larger scale. Thus, in the years 1969—1971, M. M. Klimov studied the combining ability of 30 local varieties, belonging to different biological groups. It was also studied the possibility to use the topcross and policross methods, without the emasculation of the respective sunflower varieties.

After a three-year period of research it was determined that the varieties significantly differ in their combining ability. Thus, the following 7 varieties had a *good* general combining ability (G.C.A.), Voronejski 143, Voshod, Voronejski 151, Donskoi 4, Tcheakinski 269, Tcherneanka 66 and Enisey, the following 16 varieties had a *medium* general combining ability : Armavirski 3497, Armaviretz, Avangard, VNIIMK 6540, VNIIMK 1641, Voronejski 154, Voronejski 109, Volgar, Donskoi 5, Zelenka 368, Mayak, Okteabr 50, Peredovik, Rassvet, Zarea and Krasnodaretz, while the following 7 varieties had a *low* combining ability : VNIIMK 8883, VNIIMK 8931, Vostok, Smena, Luchy and Kubanetz.

A special experiment also pointed out that, when using the topcross and the policross without emasculation, the perentage of the obtained hybrids reached 85%.

Special attention was given to the creation of lines resistant to the new agressive races of broomrape. As we have resistant biotypes among

all the existing varieties and inbred lines the problem has risen to study the whole fund of inbred lines obtained in this field at VNIIMK and to identify those lines carrying genes for resistance against this parasite. Fields infested with broomrape seeds were used for evaluation purposes, as well as a fast greenhouse method developed by the physiologist A. I. Pantchenko. More than 2,000 lines and 8,000 inbred generations were studied with the help of these methods, in the period 1972—1973. The result was the identification of more than 50 lines resistant to the complex of various races of *Orobanche cumana* Wallr.

Particular attention is given in the research carried out at the Institute, to the study of cytoplasmic male sterility, as the most reliable basis for hybrid seed production. In the years 1971—1973, more than 500 sources of male sterility were studied at VNIIMK, out of which 88 of foreign origin obtained from U.S.A., Romania, Bulgaria, Kenya and France. The analysis of the obtained data indicated that the cytoplasmic male sterility source from Kenya had the highest fixation ability (100%). Among the lines with nuclear male sterility, the best results were obtained from the line No. 485 from Bulgaria. This line is characterised by a considerable uniformity, lack of branching and a clear-cut segregation into sterile and fertile plants in a 1 : 1 ratio.

A certain amount of work was also carried out for the identification of the sterility maintainers and pollen fertility restorer lines, among the interspecific hybrids.

By selfing within the hybrids obtained from interspecific crosses of the wild species *H. divaricatus, H. tuberosus, H. petiolaris, H. rubrus* and a spontaneous species allied with the cultivated sunflower, Dr. G. V. Pustovoit obtained a number of lines with male sterility. When studying the offsprings of the sterile plants of the interspecific hybrids she established that, in most of cases, the male sterility was transmitted through nucleus, without depending on the cytoplasm condition.

Besides the nuclear male sterility found in the interspecific hybrids, Dr. G. V. Pustovoit also succeeded in identifying the cytoplasmic male sterility. As source of this cytoplasmic male sterility served the lines obtained from the hybrid populations F_9, *H. tuberosus* x 8931 and *H. rubrus* x 8931. Interesting lines with high percentage of male sterility were also obtained by crossing the tetraploid form *H. divaricatus* with the variety Peredovik. It is very significant the fact that Dr. G. V. Pustovoit succeeded in obtaining fertility restorer lines from interspecific hybrids. These lines proved to be good fertility restorers for the lines obtained from Dr. Kinman.

Initially, experiments were conducted at VNIIMK in order to obtain hybrids under open pollination conditions, based on the selective fertilization. A considerable number of varieties were employed for the mutual cross-pollination. However, this method couldn't find its application in practice. Later on, one switched to the creation of single hybrids. Great attention was paid to the selection of the crossing components. Neverthelless, the intervarietal sunflower hybrids were not able

to get a place in the agricultural production. The main cause was the low hybridization level achieved by crossing the open pollinated varieties.

The following stage in sunflower breeding for heterosis at VNIIMK was the elaboration of the methods for using the heterosis effect at the inter-line level. In connection with this, a number of research works were initiated in 1958 at the sunflower laboratory of VNIIMK, aiming at creating inbred lines with high combining ability and, based on them, hybrids between inbred lines and between lines and varieties, as well as hybrid populations. Even since 1964, the breeder. A. I. Gundaev obtained the first synthetic varieties based on inbred lines. Two synthetic varieties composed of 14 and 8 lines respectively, surpased the check-variety VNIIMK 8931 in what concerns the main trait — the oil yield — by 8—10%. However these varieties didn't show enough adaptability and in some of the years, their productivity decreased.

Single crosses and top-crosses have been subsequently obtained from the lines with nuclear male sterility MS-318, MS-324, MS-358, MS-257, MS-215 a.o., surpassing the check-variety VNIIMK 8931 by 15—17% with respect to oil yield. The single hybrids PR-39 and PR-46 showed a good productivity level. Heterosis in single hybrids was manifest not only in seed yield, but also in oil content. Some combinations of the lines having an oil content of 60—62%, in kernels, produced hybrids with an oil content of 65—68% in kernels. According to the 4-year trial data, the hybrid PR-2 surpassed, from this point of view, the variety VNIIMK 8931 by 1.8%, but in other single hybrids the increase of the oil content in kernel reached 2—3%. In all the research years at VNIIMK, the highest level of the oil content in the seed, i.e. 57%, was reached by the hybrid PR-3. Under the same conditions, the variety Peredovik had 53.5% oil in seeds. The single hybrids obtained at VNIIMK might be well introduced in commercial production if they didn't prove to be susceptible to a number of diseases such as downy mildew, white rot, gray mould a.o. This is one of the reason why they were not widespread in the agricultural practice. Therefore, the task was assigned to create new lines and hybrids with a high resistance to the main pathogen agents of sunflower known in this country.

The fund of interspecific hybrids created by Dr. G. V. Pustovoit — combining a high productivity with a group immunity, was a precious starting material, not only for developing new varieties, but also for the creation of inbred lines carrying genes for resistance to different diseases (downy mildew, rust, gray mould a.o.). She has obtained by now more than 1,000 inbred lines (I_1—I_9), resistant to a number of diseases. This extends the possibilities of using the heterosis effct based on the inter-line crossing.

In the years 1971—1973 a number of 4500 lines (I_1—I_{10}) were studied, out of which 1276 lines with different degrees of resistance to downy mildew, verticillium wilt, broomrape. Some lines were selected for cytoplasmic male sterility in order to obtain commercial hybrids.

Besides the usual, already "classical" methods of employing the heterosis effect by developing new productive hybrids the breeder

K. I. Soldatov from our laboratory has studied the possibility of using the chemical mutagenesis in order to create the necessary genetic variation.

It is well known that the experimental mutagenesis causes a marked increase of the hereditary variability. Mutants with valuable breeding traits were obtained by using this variability and the breeding methods developed by the academician V. S. Pustovoit. Among them, families in which precocity combines with a high oil content and the thinness of the seed hull, dwarf mutants with an increased number of leaves per plant (up to 40); mutants with a high content of fatty acids (oleic and linoleic), as well as plants with male sterility and other interesting forms. A number of breeding works have been started at present for the creation of inbred lines based on the most valuable mutants.

Interesting results have been obtained through the direct utilisation of mutants for crosses, according to the type of heterosis hybrids. The study of this problem was carried out with two very early dwarf mutants: M-845 and M-846. The hybrids were obtained through the artificial pollination of the mutants with the pollen of the VNIIMK 8931 and Saliut varieties and also with the pollen of the mutants obtained from these varieties. The results of the trials performed in 1972 indicated that the hybrids having the same degree of precocity as the Saliut variety were positively different from the latter in what concernes the other indices. As far as the oil yield was concerned, these hybrids proved superior to the check variety Saliut with 17—26%. The results of the experiments performed in 1973, confirmed the superiority of sunflower hybrids, which proved to be much more productive than the check-variety.

The creation on the basis of mutants, of sunflower hybrid populations turned out to be very promising. Thus, a number of sunflower hybrid populations were obtained using the method of the open cross-pollination of the selected mutants, which surpassed the oil yield of the check-variety VNIIMK 8931 by 123—184 kg/ha (table 1).

Table 1

The characteristics of the best sunflower hybrid populations (VNIIMK, Krasnodar)

Population	Growth period (days)	Oil content of the seed %	1972		1973		Average		
			seed yield q/ha	oil yield kg/ha	seed yield q/ha	oil yield kg/ha	seed yield q/ha	oil yield kg/ha	oil yield %
GP-41	95	49.6	33.9	1481	31.5	1400	32.7	1440	113.3
GP-42	97	50.2	33.1	1459	33.0	1490	33.0	1474	116.0
GP-50	96	49.8	32.6	1439	30.7	1351	31.6	1395	109.8
GP-57	97	50.1	32.2	1444	31.4	1468	31.9	1456	115.3
VNIIMK 8931	96	49.1	30.6	1323	27.7	1221	29.2	1272	100.0

We consider that the experimental mutagenesis can be successfully used in sunflower breeding for heterosis. Our laboratory carries on its research work in this field, on the following directions :

— the creation of valuable inbred lines on the basis of mutants ;
— the study of the combining ability of the mutant forms
— the development of a method for creating hybrid populations on the basis of mutants, with high productivity ;
— the investigation of the nature of the male sterility induced by chemical mutants ;
— the investigation of the fertilization electivity and incompatibility phenomena, on the mutagenesis background.

In order to find out new ways and means, simple and safe, for producing hybrid seeds, the effect of gibbereline upon the flower sex in sunflower was studied in 1973. The experiment was performed with the varieties Armavirski 3497 and VNIIMK 8931. The growth tips and the heads were treated with a 0.005% solution of gibberelline in the morning time (10 : 00 h — 11 : 00 h), using 10—15 ml of solution for each plant. The treatment was done in 5 stages, starting with bud formation phase (table 2).

Table 2

The influence of the stage of treatment with gibberelline, upon sunflower chemical emasculation (VNIIMK, Krasnodar)

Stage of treatment	Number of plants in the experiment				
	total number	fertile plants	sterile plants	%	
				fertile	sterile
Head with leaflets	32	21	11	65.6	34.4
Starting of the „rosette" growth	27	12	15	44.4	55.6
Head of 1.5 cm Stipule length 0.3—0.5 cm	25	0	25	0	100
Head of 1.7—2 cm Stipule length 1 cm	24	3	21	12.5	87.5
Head of 2.5—3 cm Stipule leaflets	24	8	16	33.4	66.6

The experiments showed that, in the case of an early treatment with gibberelline, not all the plants become male-sterile ; the delay, too, leads to an incomplete sterility. Better results are obtained when the treatment is performed at the head dimension of 1.5 cm. The recording of the head diameter and filling degree indicated, as a rule, that the sterile plants have smaller heads and the central, non-filled zone, is larger ; however, there was the exception of the late treatment in which there was no such effect. At the treated, fertile plants there were no such great differences, as far as these traits were concerned (table 3).

Table 3

The influence of gibberelline upon the size and filling degree of sunflower heads

The stage where the treatment was performed	Head diameter (cm)			Diameter of the central, non-filled zone (cm)		
	Treated plants		Check-variety (untreated)	Treated plants		Check-variety (untreated)
	fertile	sterile		fertile	sterile	
Beginning of the head formation. Head covered with leaflets	21.5	19.5	22.2	8.0	6.5	5.8
Beginning of rosette formation	24.1	23.8	22.2	7.4	10.0	5.8
Head of 1.5 cm Stipule length: 0.3—0.5 cm	—	18.1	19.2	—	4.6	2.5
Head of 1.7—2 cm Stipules of 1 cm	21.2	16.2	22.2	5.5	5.0	5.8
Head of 2.5—3 cm Stipules — leaflets	18.5	18.7	22.2	5.0	6.9	5.8

We consider necessary the extension of the chemical emasculation in sunflower, as this method might open large perspectives.

If we review the above mentioned data, we can ascertain that, in the last years at VNIIMK an intense activity was developed with positive results.