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# RESULTS OF RESEARCH WORK IN SUNFLOWER IN THE USSR

As is known, sunflower originated in North America. Seeds of this crop were brought to Europe in the 16th century. In Russia, which became the motherland of cultivated sunflower, writers on the subject opted for sunflower seed cultivation for oil already in the late 1760s.

This idea found its practical realization. In 1829 D.S. Bokarev, a peasant from a large village of Alekseevka, Biryuchinsky district, Voronezh gubernia (now Belgorod region first extracted sunflower oil with the help of manual home-made pressing machine.

The development of oil-mill industry raised the demand for sunflower seeds, which led to a considerable growth of areas under this crop. Between 1948 and 1974 world sunflower seed production grew almost three-told; sunflower yields doubled sunflower acreage increased 50% (Table 1). This is explained by increased demands on sunflower oil and, most importently by increased productivity of this plant in the process of breeding. Soviet high oil sunflower varieties bred by Academician Vassily S. Pustovoit brought about a radical change in views of this crop, focussed attention on it in many countries of the world.

In this country, is major research centers carry out sunflower breeding work in the following three directions:

(1) creation of highly productive, high oil varieties-populations resistant to main diseases and pests and adapted to definite ecological conditions;

(2) creation of single and many-way hybrids on the basis of nuclear and cytoplasmic male sterility, marked by high seed yield, resistance to certain pathogenes and pests and adapted to definite zones of cultivation;

Growth of World Sunflower Production in 1948-1976
(according to FAO)

| | Seeded areas 1000 ha | | Seed yield c/ha | | Gross seed harvest, 000 tons | |
|---|---|---|---|---|---|---|
| | 1948-1952 | 1972-1976 | 1948-1952 | 1972-1976 | 1948-1952 | 1972-1976 |
| World total | 6294 | 9059 | 6.1 | 11.6 | 3864 | 10540 |
| of which in the USSR | 3590 | 4522 | 5.3 | 13.3 | 1906 | 6015 |
| Europe | 1001 | 1585 | 7.4 | 13.3 | 738 | 2105 |
| America | 1418 | 1775 | 7.3 | 7.7 | 1029 | 1376 |
| Asia | 119 | 604 | 11.0 | 11.1 | 131 | 673 |
| Africa | 164 | 329 | 3.5 | 7.9 | 58 | 259 |
| Australia | 2 | 244 | 10.0 | 4.6 | 2 | 112 |

(3) creation of interspecific hybrids having complex immunity and representing a most valuable genofund for breeding varieties and hybrids resistant to different diseases and pests

An All-Union Research Institute of Oil Crops (VNIIMK) was organized on the basis of the breeding station "Kruglik" in Krasnodar, in 1931. It had a network of experimental stations in the main zones of sunflower cultivation in the country, the method of multiple individual selection with estimation of the best families in progenies, developed by Academician Pustovoit is the main and most effective in this country for breeding high-oil varieties-populations. During the last 40 years all production sunflower areas have been sown under varieties-populations which occupy more than 5 mln ha in the Soviet Union and more than 1 mln ha in other countries.

The method of reserves is a variant of periodical selection with individual estimation of progenies and subsequent cross-pollination of best families.

The VIIMK conducts sunflower breeding for 24 characters a basic one being the duration of the vegetation period. According to this character, we have varieties-populations of four biological groups: middle ripening, early-ripening, fast-ripening and ultra fast-ripening. The middle-ripening group is mots widespread and productive in the Soviet Union. It accounts for 73% of all crops and includes Peredovik, Armavirsky 3497, Smena and VNIIMK 6540 varieties (Table 2).

According to the data of competetive variety testing, in 1970-1975 these varieties had 51-54% of oil content, gave 30-36 centners of seeds per hectare and 1400-1800 kg of oil per hectare.

Wide-scale introduction of high-oil varieties and the system of annual variety renovation allowed to raise oil content of commercial varieties from 28.6% to 46.99% or by 18.39% on average between 1940 and 1975 and increase the oil yield at oil mills from 25.4% to 45.67% or by 80% over the same period (Table 3).

Table 2

Seeded Areas under Sunflower Varieties of VNIIMK Breeding in the USSR, 1973-1975

| Varieties | Areas, 000 ha | % of total area |
|---|---|---|
| Peredovik | 1168.8 | 25.2 |
| Armavirsky 3497 | 1163.6 | 25.1 |
| VNIIMK 8883 | 545.7 | 11.8 |
| VNIIMK 6540 | 519.7 | 11.2 |
| VNIIMK 1646 | 203.6 | 4.4 |
| Other varieties: Salyut, Smena, Mayak, Armavirets, Zelenka 368, Voskhod, VNIIMK 8931 | 704.1 | 15.2 |
| Total | 4305.6 | 92.9 |
| Total seeded areas under sunflower varieties in the USSR | 4630.1 | 100.0 |

Table 3

Oil Content of Commercial Seeds and Oil Yield at Oil Mills in the USSR (% of seed weight at factual moisture and impurity)

| Republics | Oil content of commercial seeds | | | Yield of oil at oil mills % | | |
|---|---|---|---|---|---|---|
| | 1940 | 1960 | 1975 | 1940 | 1960 | 1975 |
| USSR | 28.6 | 39.8 | 46.99 | 25.4 | 37.9 | 45.67 |
| RSFSR | 28.5 | 39.4 | 46.48 | 25.3 | 37.7 | 45.14 |
| Ukraine | 28.7 | 40.7 | 47.56 | 35.6 | 38.8 | 46.11 |
| Moldavia | | 39.9 | 47.97 | | 37.6 | 47.12 |
| Kazakhstan | 26.5 | 32.4 | 44.34 | 23.5 | 29.6 | 44.34 |

New productive varieties-populations with a still higher oil content in seeds were created by the method of population breeding. The Voskhod variety with 53.0-53.5% of seed oil content has been zoned, and Vostok with 54-54.5% of oil content has been transferred to the State Variety Testing. The start variety, marked by high performance and resistance to new broomrape races (Orobanche cumana Wallr). has been developed.

Work on early ripening varieties, such as Salyut, helped surmount the correlation between duration of vegetation period and the performance level the correlation earlier considered to be negative. Another fast ripening variety, Ranny 2 exceeding the check variety in seed yield and oil content, was also transferred to the State Variety Testing.

In 1975 Peredovik showed high seed oil content and oil yield at oil mills (Table 4).

When the oil content further upgrades to reach 55-58% per seed, creation of new varieties of this type becomes difficult. It is therefore advisable to create varieties with new original characters, such as immunity, fast ripeness, high grain unit, and qualitative composition of oil.

Proper production of seeds of varieties-populations is an important condition of high sunflower performance. The method of improving seed production and the system of regular variety renovation has made it possible to improve all genetic characters concerned, by repeated selections. For example, in the oil yield per hectare, VNIIMK 6540 has been improved by 15.5%, VNIIMK 8931 by 10.7%, VNIIMK 8883 by 21.2%, and Peredovik by 15.4%, which resulted in oil yield increase from 7.6 to 14.80 ha for VNIIMK 1646 and from 12.7 to 15.0 c/ha for Peredovik, etc. (Table 5).

Work on new self-pollinated lines is on. These lines are set on the basis of the best home-bred varieties and foreign cultivars. Intensive work is being done to study the general combining ability. Chemical castration by gibbe-

Table 4

Seed Oil Content and Oil Yield at Oil Mills
(1975)

| Oil mills | Seed oil content, % | | Yield of oil, % |
|---|---|---|---|
| | at actual moisture and impurity | of absolute dry basis | |
| Krasnodarsky | 48.4 | 53.1 | 47.6 |
| Labinsky | 49.2 | 53.5 | 48.5 |
| Millerovsky | 50.6 | 54.4 | 49.9 |
| Slavyansky | 50.1 | 54.1 | 48.4 |
| Zaporozhsky | 49.1 | 53.5 | 48.3 |

Table 5

Improvement of Sunflower Varieties in the Process of Seed Growing

| Varieties | Year of zoning | Sown area (000 ha) in 1970 and 1975 | Years of study | Seed yield, c/ha | Seed oil content of absolutely dry seeds, % | Oil yield, c/ha |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| VNIIMK 1646 | 1938 | 231.8 | 1948-1950 | 19.9 | 40.4 | 7.6 |
| | | 205.2 | 1966-1968 | 28.3 | 51.0 | 12.7 |
| | | 205.2 | 1972-1974 | 31.8 | 51.6 | 14.8 |
| VNIIMK 6540 | 1950 | 423.3 | 1945-1948 | 23.3 | 41.2 | 8.8 |
| | | 524.3 | 1966-1968 | 28.7 | 51.1 | 12.9 |
| | | 524.4 | 1973-1975 | 31.4 | 52.7 | 14.9 |
| VNIIMK 8883 | 1955 | 504.9 | 1949-1952 | 22.2 | 42.5 | 8.6 |
| | | 575.7 | 1966-1968 | 26.9 | 49.5 | 11.8 |
| | | 575.7 | 1973-1975 | 31.4 | 50.6 | 14.3 |

Table 5 (cont.)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Armavirsky 3497 | 1953 | 1256.4 | 1949-1951 | 24.3 | 45.2 | 9.8 |
| | | 1167.2 | 1966-1968 | 27.0 | 50.0 | 12.7 |
| | | 1167.2 | 1973-1975 | 30.4 | 51.1 | 14.0 |
| Peredovik | 1960 | 1388.1 | 1957-1959 | 24.4 | 48.8 | 10.4 |
| | | 1147.3 | 1966-1968 | 28.5 | 51.8 | 13.0 |
| | | 1147.3 | 1973-1975 | 31.4 | 53.2 | 15.0 |

rellin is widely used to obtain test hybrids.

In recent years work has developed apace on the creation of simple and many-cross hybrids on the basis of nuclear and cytoplasmic male sterility.

At present, in line with the comprehensive research programme a number of institutes concentrate on the creation of highly-productive sunflower hybrids, methods of accelerated obtaining of sterile analogues, fertility restorers, evaluation of lines' general and specific combining ability, methods of use of the selfincompatibility phenomenon and chemical induction of male sterility for getting hybrid seeds, creation of high-yielding interline and varietal-line hybrids resistant to diseases and pests, and also hybrids with different fatty acid composition.

New interline and varietal-line hybrids the best of them exceeding the seed yield of zoned varieties by 10-30%, are being tested.

Effort are made to create new selfpollinated lines. The best home-bred varieties foreign cultivars are used for their setting (Tables 6, 7). General combining ability is studied intensively. Chemical constration with gibberellin is widely used for obtaining test hybrids.

Gene "marked" male sterility is studied and used on a wide scale. VNIIMK now disposes of a large collection of lines with gene male sterility. Many of them are practically suitable for use in hybrid seed production Much use is made of cytoplasmic male sterility. Work on the development of sterile and fertile analogues of the best lines and the first hybrids on the CMS basis is nearing completion.

Much is being alone on heterosis breeding at the All-Union Research Institute of Plant Growing, All-Union Research Institute of Plant Breeding and Genetics and Ukrainian Research Institute of Plant Growing, Breeding and Genetics. A fund of different foreign bred lines from the USA, Canada, Bulgaria, Romania, Argentina

Table 6

Results of Testing Romanian Sunflower Hybrids
1972-1974

| Names of variety testing station standard variety | Name of hybrid | Seed yield, c/ha | | Seed oil content, % | | Oil yield, kg/ha | |
|---|---|---|---|---|---|---|---|
| | | hybrid | deviation ± | hybrid | deviation ± | hybrid | deviation ± |
| **Testing Station of Krasnodar Territory** | | | | | | | |
| Ust-Labinsky, | GS-2 | 30.9 | -1.2 | 43.8 | -3.7 | 1207 | -130 |
| Smena improved | GS-3 | 32.0 | -0.1 | 45.2 | -2.3 | 1279 | - 68 |
| **Kavkazsky Testing Station of Krasnodar Territory** | | | | | | | |
| Peredovik improved | GS-2 | 26.6 | -0.8 | 42.8 | -4.0 | 1010 | -122 |
| | GS-3 | 27.2 | -0.2 | 42.1 | -4.7 | 1026 | -104 |
| **Orlovsky Testing Station of Rostov Region** | | | | | | | |
| Armavirsky 3497 | GS-2 | 20.6 | -0.2 | 42.2 | -3.2 | 803 | - 65 |
| | GS-3 | 21.4 | +0.6 | 43.2 | -2.2 | 846 | - 22 |

Table 6

Results of Testing Romanian Sunflower Hybrids
1972-1974

| Names of variety testing station standard variety | Name of hybrid | Seed yield, c/ha | | Seed oil content, % | | Oil yield, kg/ha | |
|---|---|---|---|---|---|---|---|
| | | hybrid | deviation ± | hybrid | deviation ± | hybrid | deviation ± |
| **Testing Station of Krasnodar Territory** | | | | | | | |
| Ust-Labinsky, | GS-2 | 30.9 | -1.2 | 43.8 | -3.7 | 1207 | -130 |
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| Armavirsky 3497 | GS-2 | 20.6 | -0.2 | 42.2 | -3.2 | 803 | - 65 |
| | GS-3 | 21.4 | +0.6 | 43.2 | -2.2 | 846 | - 22 |

Table 7

Results of Testing Sunflower Hybrid INRA-6501 from France

| Names of strain testing station, standard variety and hybrid | Years of study | Seed yield, c/ha | Seed oil content | | Oil yield, kg/ha | |
|---|---|---|---|---|---|---|
| | | | % | deviation ± | kg | ± |
| **Labinsky Testing Station of Krasnodar Territory** | | | | | | |
| Peredovik improved | 1973-1975 | 30.0 | 45.3 | | 1359 | |
| INRA-6501 | " | 29.3 | 37.8 | -7.5 | 1107 | -252 |
| **Sinelnekovsky Testing Station of Dniepropetrovsk Region** | | | | | | |
| VNIIMK 6540 improved | 1975 | 19.7 | 45.4 | | 894 | |
| INRA-6501 | " | 21.0 | 34.7 | -10.7 | 729 | -165 |
| **Gremyachinsky Testing Station of Voronezh Region** | | | | | | |
| Peredovik improved | 1975 | 27.7 | 42.4 | | 1174 | |
| INRA-6501 | " | 28.1 | 33.0 | -9.4 | 924 | - |
| | Average | | | | | |
| Check variety | 6 test years | 26.5 | 45.0 | - | 1190 | - |
| INRA-6501 | " | 26.8 | 39.0 | -6.0 | 1054 | -136 |

and other countries is collected. Some of them have male nuclear marked and cytoplasmic male sterility, and separate lines are good restorers.

A number of fast ripening hybrids, which are valuable for arid and northern zones of sunflower cultivation are created and being tested. Work is apace at other institutions and experiment stations of the country. A principally new variety Pervenets, notable for the ratio of fatty acids in oil was created at the Institute of Oil Crops by the method of chemical mutagenesis. It contains up to 80% of oleic acid in oil. This oil is similar to olive oil.

Work on interspecific hybridization with a view to making sunflower resistant to the most important diseases assumes ever greater importance. Sunflower is being affected in the Soviet Union by more than 28 pathogens. The highest pathogenecity have white (Sclerotinia libertiana Fuck.), grey (Botritis cinerea Pers.), dry (Rhizopus nodosus Namysl.), and charcoal (Sclerotium bataticola Taub.) rots and downy mildew (Plasmopara helianthi Novot.). For the first time in the world crossing cultural sunflower (Helianthus annuus) with wild species of Helianthus has produce hybrids equal to varieties; these have valuable properties for profuction and inherited wide immunity to the most important pathogens. For the first time in the world, quite a new genotype of sunflower plant with a number of valuable characters was created. Excellent fixators of sterility and restorers of fertility were found among interspecific hybrids. This opens wide prospects for creation of hybrid sunflower and wide use of heterosis effect.

Valuable breeding material with group immunity and 58-60% of the maximum seed oil content on the absolute dry basis or 73-76% in kernel is created by the method of interspecific hybridization. In 1975 two first unterspecific sunflower varieties Progress and Novinka were transferred to the State Variety Testing. Their oil yield per hectare is no less than that of the

best variety - Peredovik, and they are highly resistant (98-100%) to downy mildew (Plasmopara helianthi Novot.) sunflower moth (Homoeosoma nebulella Hb.) and by 80% to charcoal rot (Sclerotium bataticola Taub.) and to verticillium wilt (Verticillium dahliae Kleb.). In extremely dry 1975 the Progress variety gave in rainfed conditions at Krasnogvardeysky Testing Station of Krasnodar Territory 41.2 centners of seeds per hectare or 5 cent more than the check Peredovik variety (Table 6). Oil yield per hectare exceeded 2000 kg, which is a record figure both for our country and for abroad.

Soviet breeders have developed varieties and hybrids with potential seed yielding ability of 36-40 c/ha. Further work in this direction will allow to create varieties and hybrids with the yielding-ability of 45 and even 50 cent of seeds per hectare and seed oil content of 52-56% on the absolutely dry basis.

Biochemical investigations in breeding sunflower have shown a wide range of varying sunflower oil fatty acid composition and made it possible to conduct breeding for a definite character. Study of the process of fatty acid biosynthesis in high oleic mutant oil showed that a new type of sunflower plant has been developed which, unlike the existing productive varieties has a definite direction of biochemical processes.

Research conducted at the All-Union Research Institute of Oil Crops and the All-Union Research Institute of Fats has shown that oil of this variety is more stable in storage than the oil of usual sunflower varieties.

Sunflower breeding for high oil content is accompanied by a considerable change in the qualitative composition of the seed protein complex. Comparative study of composition of proteins of high and low oil sunflower varieties has shown that in Peredovik variety seeds the quantity of water soluble fraction, the richest in indispensible aminoacids and especially in lysin, exceeds by 20-30% the low oil variety Kruglik A-41.

The data obtained suggest the conclusion that water soluble proteins play an active role in oil-forming process. Their accumulation level to a certain extent predetermines the oil content of seeds. Quantity of protein in kernels of present varieties of VNIIMK breeding fluctuates within the range of 20-24% and in defatted flour within the range of 56-60%.

The protein of these sunflower varieties has a comparatively high content of all the indispensible aminoacids, including lysin (up to 3.5%), tryptophan (up to 2.2%) and methionine (up to 2.5%). The data obtained show a great nutritional value of sunflower protein and a possibility of using it in the food industry.

Comparative physiological studies of plants of high and low oil content varieties have shown that photosynthesis does not set limits to the fat and protein accumulation in seeds, and hence there is no antogonism between the processes of biosynthesis of these substances. No varietal differences were found in the absolute fat content per an accumulating seed cell. New varieties give higher oil yields only as a result of accelerated outflow of substances from stems and leaves of plants with increased mitotic activity of seed embryos before the beginning of the period of the intensive oil formation.

Research in the field of physiology of immunity revealed the nature of sunflower resistance to new broomrape races and helped develop effective methods of early diagnosis.

An important role in raising sunflower seed yields is played by the proper zoning of seed production. Ecological conditions exert significant influence on the formation of high-quality seeds with good yielding abilities. Sunflower seeds reproduced in favourable soil-climatic conditions of the southern zone of the country raise the seed yield by 2.5-2.8 c/ha, as compared to seed grown in northern zones of sunflower cultivation. Oil content of progenies of these reproductions is 1.0-3.0% higher.

A large volume of work has been done by Soviet scientists in the sphere of farming and chemicalization. In recent years the Pustovoit All-Union Research Institute of Oil Crops and its experimental network have developed methods for the minimum preseeding treatment of soil under sunflower and other oil crops. Scientists of our Institute have developed new progressive technology of sunflower cultivation, using highly effective herbicides of treflan type (nitran, nitrofor). This technology helps reduce the number of mechanical treatments of soil in the spring-summer period from 8-10 to 2-4 operations and considerably (by 2-4 c/ha) to increase sunflower seed yield without hand weeding.

Significant results have been obtained in research on optimizing the system of primary treatment of soil in oil crop rotation and in the development of practices to prevent wind erosion.

Application of mineral fertilizers is instrumental in raising sunflower yields. Fertilizers increase seed yields by 2-4 c/ha. Long-term investigations conducted at Soviet research institutions have shown that nitrogen-phosphorus fertilizers are most effective on chernozem soils. The system of fertilization in oil crop rotation has been developed on the basis of relevant research. It provides for a regular application of fertilizers under all crops, including high rates ($N_{90}P_{120}$) under winter wheat and sugar beet and average rates ($N_{40}P_{60}$) under sunflower. This system assures the most economical use of fertilizers.

Investigations conducted at VNIIMK, Voroshilovgrad Agricultural Institute, Nikolaev Regional Agricultural Experimental Station, Southern Research Institute of Hydrotechnical Engineering and Land Improvement and Gorsky Agricultural Institute have confirmed a high efficiency of sunflower irrigation. Seed yields under irrigation are 2-3 times more than in rainfed conditions. In arid zones of Volga region and south of the Ukraine sunflower yields in rainfed conditions,

as a rule, do not exceed 8-12 c/ha, while with a rational irrigation regime they reach 32-36 c/ha.

Today, the efficiency of farm crop production is greatly influenced by the level of mechanization of production processes, availability of machines for carrying over agronomical practices that can guarantee high yields. New machines and devices for harvesting and postharvest treatment and drying of sunflower seeds have been developed in this country in recent years.

Close cooperation of scientists from different countries is of crucial importance for achieving high results in breeding. Exchange of scientific information and the use of theoretical R and D all low to accelerate the process of breeding and create more productive varieties and hybrids. A further development of collaboration in the field of research into sunflower will make it possible to speed up scientific and technical progress in this sphere and help advance agriculture in many countries of the world.