

Hybrid Sunflower Breeding in VNIIMK (Russia)

Sergey Gontcharov¹

¹ All-Russia Research Institute of Oil Crops (VNIIMK), Filatova, 17, Krasnodar, 350038, Russia,
serggontchar@hotmail.com

ABSTRACT

- All-Russia Research Institute of Oil Crops (VNIIMK) was set up 100 years ago, in 1912. From the very beginning till now sunflower breeding is the most important aim of its work. The aim of this report is to show new achievements and current situation with hybrid sunflower breeding in VNIIMK.
- Experiments were conducted at the Central Station (Krasnodar) of All-Russia Research Institute of Oil Crops (VNIIMK). Released, prospective and experimental sunflower hybrids and inbred lines of VNIIMK breeding were used as a material. Randomized block design was used to test the obtained hybrids. Plant density was 50 000 plants per ha. Plots were 25.2 m² in size and had four rows; two central rows were harvested to evaluate seed yield, oil and husk content, 1000-seed weight. To test resistance to broomrape, Fusarium and downy mildew artificial infection was used. Field resistance to all other pathogens was registered under the natural conditions.
- The aim of our breeding efforts was to develop sunflower hybrids for three main directions: high oleic, resistant to major diseases and suitable for double-using – as a confectionery and oil-type hybrid. No such commercial hybrids were available at this time in Russia. Such hybrids should perform high seed yield, rather high oil content and high 1000-seeds weight. Results show that the best hybrid (VK-905 A × VK-944) have significantly higher seed yield in comparison with the check. Seed yield level was rather high in the trial. Check OP variety Oreshek gave 3.23 t/ha. Oil content in the absolutely dry seeds was 454 g/kg for the check variety, and varied from 431 to 480 g/kg in the seeds of studied hybrid combinations. As a result tested hybrids could be used in two different ways (for oil production and for confectionery use) along with released confectionery OP varieties (Oreshek, SPK and Lakomka). Significantly less oil content is typical for the confectionery sunflower produced outside the Russia. To evaluate general combining ability (GCA) of our new confectionery lines we crossed two CMS-lines with four restorer lines. As a conclusion line with the best GCA value for the seed yield was VK-944 (0.40) and VK-905 A was the best line among the testers. Combination of two the most important traits (seed yield and seed size) allowed us to define the most prominent hybrids and lines. Among the high oleic material hybrid Hermes were identified and released in 2009. Now we have a set of high oleic lines and prominent new hybrids. Unfortunately high oleic sunflower have no demand from the market in Russia. The most important pathogens for sunflower in our region are broomrape (including new races), downy mildew and Fusarium. For all of them we have new resistant or highly tolerant lines. New hybrids are under the evaluation process.
- It was proved that to develop sunflower hybrids suitable for double-using – as a confectionery and oil-type hybrid – is quite possible. Such hybrids should perform high seed yield, rather high oil content and high 1000-seeds weight. Three-year trial allows us to define the most prominent hybrid combination (VK-905 A × VK-944). High-oleic hybrid Hermes was released in 2009. New prospective inbred sunflower lines with resistance to broomrape races E and F were developed. Evaluation of laboratory method of Fusarium resistance test developed by VNIIMK Immunology laboratory (seedlings infection) shown its effectiveness.
- Results of VNIIMK hybrid sunflower breeding program are presented, new achievements and methods of breeding are described.

Key words: Hybrid – sunflower – high oleic – confectionary – broomrape resistance

INTRODUCTION

All-Russia Research Institute of Oil Crops (VNIIMK) was set up 100 years ago, in 1912. From the very beginning till now sunflower breeding is the most important aim of its work. The aim of this report is to show new achievements and current situation with hybrid sunflower breeding in VNIIMK.

The aim of our breeding efforts was to develop sunflower hybrids for three main directions: high oleic, resistant to major diseases and suitable for double-using – as a confectionery and oil-type hybrid. No such commercial hybrids were available at this time in Russia. Such hybrids should perform high seed yield, rather high oil content and high 1000-seeds weight.

Breeding for resistance (or at least tolerance) to pathogens always considered to be the most important aim in sunflower breeding. The most important pathogens for sunflower in our region are broomrape (including new races), downy mildew and *Fusarium*. Broomrape (*Orobanche cumana* Wallr. syn. *O. cernua* Loefl.) is a parasitic plant, feeding on sunflower roots. The main method to control broomrape is development of resistant hybrids. During the more than 100 years of co-evolution sunflower and broomrape in Russia biotype A was subsequently changed by B and then E. Biotype E is the predominant one on the Russia territory now. Majority of released Russian hybrids and OP varieties are resistant to that biotype, but broomrape continue to produce new races. Last years the new, more aggressive races, started to spread in many regions of Russia. The aim of our work was to find donors of resistance to this biotype, studying heredity of this trait and development new sunflower inbred lines combining broomrape resistance with other valuable traits. *Fusarium* is one of the most important pathogen for many crops. But for sunflower it was earlier considered to be of less importance or minor pathogen (Tikhonov, 1992; Gulya et al., 1997). During last years *Fusarium* became a serious problem for sunflower crop in Russia. First report was made in the 90s years when five species of *Fusarium* were found in the sunflower fields of Voronezh and Belgorod regions of Russia (Yakutkin, 1995). In Krasnodar region of Russia 12 different species and varieties of *Fusarium* were found during the phytopathology surveys in 1999-2001 (Antonova et al. 2002). It's pathogenity for sunflower plant was also demonstrated. Among them *F. oxysporum* var. *orthoceras* was the most widely spread, and *F. sporotrichiella* var. *sporotrichioides* was the most aggressive one. During the last decade *Fusarium* is regularly registered in the breeding nurseries of All-Russia Research Institute of Oil Crops (Krasnodar). For example, in 2006 at sunflower hybrid trial field we found 19-28% damaged plants in average. Some hybrid plots had up to 80 % of damaged plants. Special breeding program for resistance to *Fusarium* started here in 2001 year using the laboratory test developed in VNIIMK. Field experiments demonstrated high level of resistance newly bred lines to this pathogen.

Development of a new cultivar, combining short vegetation period with high productivity, is a rather challenging problem. Many researchers report correlations between yield and duration of the vegetation period for different crops, including sunflower (Putt (1943), Kovacic and Skaloud (1972), Stoenescu (1985), Merrien (1992)). At the same time the possibility of successful combination such traits in one hybrid is not completely denied (Pustovoit, 1939). The aim of our work was to develop new ultra-early inbred lines and hybrids and also to find out relationships between duration of the vegetation period as a whole and its separate parts and seed yield, oil content and oil yield in sunflower hybrids.

Sustainable market demand for confectionery sunflower seeds made VNIIMK initiate a special breeding program with the aim to develop modern confectionery open-pollinated varieties. Dr. S. Borodin with his colleagues released four OP varieties – SPK, Lakomka, Borodinskiy and Oreshkek (Borodin, 2003; Mamonov, 2004). Their seeds are close to the oil-type one by structure but larger in size and 1000-seed weight, has bigger husk content and less oil content (450-490 g/kg). Husk is black or black with grey stripes in color. This type of seeds has special Russian name “mezheumok” and means intermediate. People in Russia and Ukraine prefer such types of sunflower seeds for the direct consumption. Such seeds also could be easily dehulled by the machinery for confectionery use. Now these three OP varieties covered about 500 thousands hectares in Russia. Commercial success of confectionery OP varieties encouraged us to start confectionery hybrid breeding program also. This program started in 1999. Russian market demands for sunflower with 1000-seed weight 80 g or more, oil content on the level 450-490 g/kg and seeds should be easily dehulled (Borodin, 2003; Mamonov, 2004). As a new initial breeding material we used non-oil samples of sunflower from Iran and Syria, Russian modern confectionery OP varieties and high-oil inbred lines of our breeding with relatively big seed size. As a result of crossing this material and self-pollination it we developed a number of inbred lines for confectionery hybrid breeding. Lines were crossed with CMS-lines to test their ability to restore pollen fertility. So we found some restorer lines and some maintainer lines. Several of such lines were converted to CMS-lines by back-crossing. The aim was to develop and evaluate new confectionery inbred lines and hybrids.

MATERIALS AND METHODS

Experiments were conducted at the Central Station (Krasnodar) of All-Russia Research Institute of Oil Crops (VNIIMK). Krasnodar region is situated in the Southern part of Russia near the Black Sea. Climatic conditions are very favorable here for sunflower production. Sunflower usually covers about 0.5 million ha in this region.

Released, prospective and experimental sunflower hybrids of VNIIMK breeding were used as a material. Above the hybrids two OP-varieties (SUR and Enisey) were used as checks, because VNIIMK had not such ultra-early hybrids before. To produce confectionery hybrids we used one line of our own breeding (VK-905 A) and line VD-354 A released by Donskaya Experimental Station of VNIIMK (Rostov region of Russia). Restorer lines were developed from crosses of our elite lines with dolichocarpous sunflower. The most interesting sample was bought in the local Iranian market. It was very specific dolichocarpous sunflower *Helianthus annuus* var. *armeniacus* Wenzl. & Anaschcz (Anaschenko, 1971; 1974; 1977). This botanical variety of cultivated sunflower considered to be the most genetically distant from usually used sunflower cultivars (Anaschenko, 1979). Main traits for individual selection were early flowering time (Iranian sample was very late in our conditions), short stem (initial material population was very tall – up to 3 m and more), bigger seed and kernel size, resistance to diseases.

Shneiter and Miller's method (1981) was used for phenological observations. Among the agronomy characteristics only the most important ones were used: seed yield per hectare, oil content in the absolutely dry seed and oil yield per hectare. Experimental design was randomized blocks with three replications. Each replication had four rows and two central rows were analyzed only to exclude the border effect. Oil content was evaluated by NMR-analyzer.

Broomrape seed (*Orobanche cumana* Wallr. syn. *O. cernua* Loefl.) were collected in different regions of Russia. We used two different samples of *Fusarium*: *F. oxysporum* var. *orthoceras* as the most widely spread *Fusarium* pathogen on sunflower plants in the Krasnodar region, and *F. sporotrichiella* var. *sporotrichioides* as the most aggressive one.

For the testing we used a method, developed at the Immunology laboratory of VNIIMK (Saukova, 2001). Two-days-old sunflower plantlets were placed for 6 hours on the perforated covers of Petri dishes with 15-days old *Fusarium* culture. Two days after it they were incubated in the moisture chamber. After it plantlets were visually evaluated, the best plants were placed in the soil and cultivated in the greenhouse till maturity. Seeds after self-pollination were collected and used for field resistance test and breeding purposes. During next years only healthy sunflower plants were selected and self-pollinated. Mass selection method was used on the final stage of breeding.

RESULTS AND DISCUSSION

For effective breeding for earliness we conducted correlation analysis (only high-yielded hybrids were taken in each groups of earliness). The number of studied hybrid combinations was 20 during the all period. Results showed tight correlations between studied traits (table 1).

Table 1. Correlations between duration of the main parts of vegetation period and yields characters in high-yielded sunflower hybrids of different groups of earliness (Gontcharov and Zaharova, 2008)

Character	Year	Durations of the parts of the vegetation period				
		V-E – R 1	V-E – R 5.1	R 5.1 – R 8	R1 – R 5.1	V-E – R 8
Seed yield, t/ha	2004	0,21	0,59**	0,64**	0,37	0,88**
	2005	0,56*	0,66**	0,27	0,35	0,77**
	2006	0,50*	0,59**	0,27	0,54*	0,69**
Oil content, %	2004	0,14	-0,31	0,27	-0,51*	-0,01
	2005	-0,16	-0,36	0,42	-0,34	-0,04
	2006	-0,36	-0,60**	0,19	-0,67**	-0,48*
Oil yield, t/ha	2004	0,27	0,41	0,75**	0,11	0,83**
	2005	0,44*	0,37	0,48*	0,08	0,65**
	2006	0,33	0,29	0,41	0,20	0,49*

** P = 0,01

* P = 0,05

It was concluded that seed yield is mainly determined by duration of the period from emergence to flowering (VE-R5.1), and oil content – by the period from beginning of flowering to maturity (R5.1-R8). Being integrated trait oil yield is determined by the all vegetation period (VE-R8).

As a part of our study a set of new hybrid combinations was produced and tested. One of them is recommended for release in the nearest future (table 2). Hybrid Aurora (Kubanskiy 86 x VK 789) is a three-way cross, all 3 year of trial it showed better results than all tested OP varieties and hybrids with the similar vegetation period.

Table 2. Characteristics of the new ultra-early sunflower hybrid (Gontcharov and Zaharova, 2008)

Hybrid or OP variety	Period VE-R8, day	Seed yield		Oil content, %	Oil yield	
		t/ha	± to check		t/ha	± to check
Enisey (Check OP variety)	76	3.09	-	42.2	1.17	-
SUR (OP variety)	78	3.19	+0.10	47.8	1.37	+0.20
Aurora	74	3.41	+0.32	45.9	1.41	+0.24
LSD _{0.5}	-	-	0.20	-	-	0.09

Broomrape (*Orobanche cumana* Wallr. syn. *O. cernua* Loefl.) is a parasitic plant, feeding on sunflower roots. The main method to control broomrape is development of resistant hybrids and (or) OP varieties. Race E was the predominant one on the Russia territory till recently. Majority of released Russian hybrids and OP varieties are resistant to race E, but the new, more aggressive races, appeared in many regions of Russia. Trying to find donor of resistance line VK-623 were identified. It was resistant to the race F from Spain and resistance were controlled by two independent recessive genes (Gontcharov et al., 2004). On the base VK-623 new prospective inbred sunflower lines with resistance to both broomrape races – E and F were developed. Later we find dominant resistance to the new races and new elite lines and hybrids are under the evaluation process.

During the last decade different species of *Fusarium* fungi became usual pathogens for sunflower plants. Average number of plants with different symptoms of *Fusarium* damage was 21 % in the nursery of breeding material in 2001 for example, varying from 0 % up to 100 % in different lines. Four segregating populations of sunflower with the best field resistance were used for our work. After treatment by *F. oxysporum* var. *orthoceras* seedlings had different level of damage – from hardly visible necrosis to full destruction. Individual plantlets with minimal visible symptoms of *Fusarium* damage and maximal root growth rate were selected and transplanted in greenhouse. Treatment by *F. sporotrichiella* var. *sporotrichioides* gave more severe results – all seedlings had greatly reduced root length (less than 5 mm) as a result of damage. Plantlets with maximal shoot growth rate with green cotyledons (majority were of brownish color) were selected for transplanting. Field experiment was started in 2001. Spring was unusually cold with high soil humidity followed by hot dry summer. Such weather conditions influenced phytopathologic situation greatly – *Phomopsis helianthi* (the most frequent pathogen previous years) was registered rarely and on the most susceptible specimens only, but *Fusarium* fungi coupled with *Verticillium* were the most frequent pathogens on sunflower plants this year. Average ratio of plants with different symptoms of *Fusarium* damage was 21 % in the nursery of breeding material. But only 11 % of plants were damaged among the offspring of plants selected by laboratory test. From the first set of experiments we made a conclusion that combination of laboratory test developed by VNIIMK Immunology laboratory with individual selection can rapidly improve a segregated population for *Fusarium* resistance (Gontcharov et al., 2006).

By this way we developed a number of lines with high level of field resistance to *Fusarium* fungi. Now they were crossed with tester lines to study their combining ability.

Among the high oleic material hybrid Hermes were developed and released in 2009. Now we have a set of high oleic lines and prominent new hybrids. Unfortunately high oleic sunflower have no demand from the market in Russia.

New hybrid named Legion were developed and put in the State trial as a result of joint breeding program VNIIMK-Maisadour. The hybrid showed excellent results in VNIIMK trial.

New breeding program with the aim to develop sunflower hybrids suitable for double-using – as a confectionery and oil-type hybrid – started at VNIIMK in 1999. No such commercial hybrids were available at this time in Russia. Such hybrids should perform high seed yield, rather high oil content and high 1000-seeds weight. Results show that two best hybrids (VD-354 A × K-4 and VK-905 A × K-4)

have significantly higher seed yield in comparison with the check. Seed yield level was rather high in the trial. Check variety Oreshek gave 3.23 t/ha.

Oil content in the absolutely dry seeds was 454 g/kg for the check variety, and varied from 431 to 480 g/kg in the seeds of studied hybrid combinations. As a result tested hybrids could be used in two different ways (for oil production and for confectionery use) along with released confectionery OP varieties (Oreshek, SPK and Lakomka). Oil-type sunflower hybrids usually have higher oil content (480-520 g/kg), but in this case industry had a problem with dehulling procedure. Significantly less oil content is typical for the confectionery sunflower produced outside the Russia. But such material had no commercial success here.

1000-seeds weight of all tested hybrid combinations was higher 80 g, though superiority of check variety was obvious. Comparison of 1000-seeds weight of all tested combinations showed big variation for this trait. 1000-seed weight varied from 79.1 g (VD-354 × K-3) to 109.9 g (VK-905 × K-3).

To evaluate general combining ability (GCA) of our new confectionery lines we crossed two CMS-lines (VD-354 A and VK-905 A) with four restorer lines (K-1, K-3, K-4 and K-5). CMS-lines were used as testers. Obtained hybrids were tested for the seed yield. Analysis of results allowed us to calculate GCA values (Table 3).

Table 3. General combining ability evaluation of confectionery sunflower lines for seed yield (Gontcharov and Beresneva, 2009)

Line	Type	GCA value
K-1	Paternal (pollinator) line	-0.35
K-3	Paternal (pollinator) line	0.13
K-4	Paternal (pollinator) line	0.40
K-5	Paternal (pollinator) line	-0.18
VK-905 A	Mother line (tester)	0.17
VD-354 A	Mother line (tester)	-0.17

As a conclusion line with the best GCA value for the seed yield was K-4 (0.40), average value was demonstrated by K-3 line (0.13). Other two lines showed poor results. VK-905 A was the best line among the testers.

It was proved that to develop sunflower hybrids suitable for double-using – as a confectionery and oil-type hybrid – is quite possible. Such hybrids should perform high seed yield, rather high oil content and high 1000-seeds weight. Three-year trial allows us to define the most prominent hybrid combination Katyusha (VK-905 A × VK-944) (table 4).

Table 4. Trial results of new confectionery sunflower hybrid Katyusha (Krasnodar, 2009-2011)

Hybrid or OP variety	Seed yield		Oil content, %	Oil yield		1000-seed weight, g
	t/ha	± to check		t/ha	± to check	
Oreshek (check)	2.29	-	45.4	0.94	-	117.2
Katyusha	2.66	+0.37	47.7	1.14	+0.20	106.8

The most prominent parental forms (CMS-line VK-905 A and restorer lines K-4, K-3 and K-1) will be used for the future sunflower breeding work.

REFERENCES

- Anaschenko, A.V. 1971. The dolichocarpous sunflower in the Transcaucasia. Bulletin of Applied Botany, Genetics and Plant Breeding. 45 (2): 51-60. (in Russian with English summary).
- Anaschenko, A.V. 1974. To the system of genera *Helianthus* L. Botanical Journal. 59 (10): 1472-1481. (in Russian).

- Anaschenko, A.V. 1977. Modern problems of Applied Botany, Genetics and Breeding of Sunflower. Bulletin of Applied Botany, Genetics and Plant Breeding. 69 (1977) 47-51 (in Russian).
- Anaschenko, A.V. 1979. Phylogenetic interrelationships in genera *Helianthus* L. Bulletin of Applied Botany, Genetics and Plant Breeding. 64 (2): 146-156. (in Russian).
- Antonova, T.S., N.M. Araslanova and S.L. Saukova. 2002. A harmfulness of sunflower disease caused by *Fusarium* sp. in Krasnodar region. The Reports of Russian Academy Agricultural Science. 3: 6-8. (in Russian).
- Borodin, S.G. 2003. Sunflower OP varieties breeding for specific use. p. 15-25. In: Proc. Internat. Conf. devoted to 90 years of VNIIMK, Krasnodar. (in Russian).
- Gontcharov, S.V. and N.D. Beresneva. 2011. Confectionery hybrid sunflower breeding in Russia. Journal of Agric. Sci. and Technology B 1: 919-924.
- Gontcharov, S.V. and M.V. Zaharova, 2008. Vegetation period and hybrid sunflower productivity in breeding for earliness. p. 531-533. In: Proc. 17th International Sunflower Conference. Cordoba. Spain.
- Gontcharov, S.V., T.S. Antonova, N.M. Araslanova. 2004. Sunflower breeding for resistance to the new broomrape race. *Helia*. 27 (40): 193-198.
- Gontcharov, S.V., T.S. Antonova, S.L. Saukova. 2006. Sunflower breeding for resistance to *Fusarium*. *Helia* 29(45): 49-54.
- Gulya, Rashid and Masirevic. 1997. Sunflower diseases. pp. 263-380, In: A.A. Schneiter (ed.), Sunflower Production and Technology. Agronomy Monograph 35. ASA, CSSA and SSSA, Madison, WI, USA.
- Kovacic A. and V. Skaloud. 1972. The proportion of the variability component caused by the environment and the correlations of economically important properties and characters of the sunflower (*Helianthus annuus* L.). p. 249 – 261. In: Science Agricultural Bohemoslov № 4.
- Mamonov, A.I. 2004. Development of initial breeding material of confectionery and oil-type sunflower with big seed size. p. 39-41. In: NTB VNIIMK, Krasnodar (2004) 39-41. (in Russian).
- Merrien, A. 1992. Some aspect of sunflower crop physiology. p. 481 – 498. In: Proc. 13th Conf., Pisa, Italy, Int. Sunf. Assoc. V. 1.
- Morozov, V.K. 1947. Confectionery sunflower breeding. p. 161-168. In: Sunflower breeding in the USSR. Moscow. (in Russian).
- Pustovoit, V.S. 1939. Sunflower breeding for increased oil content, breeding methods, results and prospects. (PhD thesis). Krasnodar, Russia. (in Russian).
- Putt, E. D. 1943. Association of seed yield and oil content with other characters in the sunflower. Science Agricultural. 23: 377 – 382.
- Putt, E.D. 1997. Early history of sunflower. p. 1-19. In: A.A. Schneiter (ed.), Sunflower Production and Technology. Agronomy Monograph 35. ASA, CSSA and SSSA, Madison, WI, USA.
- Saukova, S.L. 2001. Laboratory test for evaluation of *Fusarium* resistance of sunflower seedlings. p. 113-114. In: Proc. Internat. conference of young researchers. Kharkov, Ukraine. (In Russian).
- Shneiter, A.A. and J.F. Miller. 1981. Description of sunflower growth stages. Crop Science 20: 901-903.
- Stoenescu F., N. Pârvu, M. Iuoraș, M. Terbea, G. Voinescu. 1985. Particularități ale ameliorării florii-soarelui pentru optimizarea perioadei de vegetatie. p. 219 – 240 In: Probleme de genetică teoretică și aplicată. Vol. XVII.
- Tikhonov, O.I. 1992. Sunflower diseases. p. 263-380. In: Sunflower biology, plant breeding and growing technology. Moscow: Agropromizdat. Russia (In Russian).
- Yakutkin, V.I. 1995. Sunflower fusariozis and phytosanitary monitoring problem in Russia. p. 108 In: Plant protection under agroindustrial complex reformation: economy, effectiveness, ecology. Sanct-Petersburg, Russia. (In Russian).