The study of *Helianthus annuus* L. of domestic breeding in arid Crimea

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**Abstract.** An increase in the temperature regime on the planet leads to changes in climatic conditions, as a result of which the aridity of many regions is increasing, which adversely affects, among other things, the productivity of agricultural crops. This issue is also urgent for the Republic of Crimea. The peninsula is characterized by a deficit of precipitation, droughts during the growing season of plants, and an elevated temperature during the period of crop formation. In addition, the situation was aggravated by the cessation of the functioning of the North Crimean Canal, which provided irrigation systems in the region with water. Steep reorientation of the farming system to rainfed conditions implies the introduction of drought-resistant crops into the structure of the cropping land, for which, first of all, it is necessary to identify adaptive varieties and hybrids, as well as to develop a cultivation technology. By order of the President of the Russian Federation No. Pr-1127 as of June 12, 2017, it is necessary to ensure that agricultural producers use, as a priority, competitive domestic seeding and planting material. Since *Helianthus annuus* L., due to its biological characteristics, is a drought-resistant culture, and the demand for its processed products increases every year, the purpose of our research was to identify the adaptive features of domestic hybrids and the study of plant density in arid conditions of the peninsula. As a result of studies conducted in 2017-2018 in the Research Institute of Agriculture of the Crimea, it was found that the highest yield of seeds of *Helianthus annuus* L. in agro-climatic conditions of 2017 was demonstrated by hybrids Garant (1.58 t/ha), Signal (1.68 t/ha) and Sprint (1.70 t/ha); in 2018, by Prestige (0.78 t/ha), Signal and Gorstar hybrids (0.59 t/ha). The highest yield of sunflower was observed after sowing with a plant density of 40K ha⁻¹ and amounted to 1.70 t/ha in conditions of 2017 and 0.64 t/ha in 2018.

**1. Introduction**

Today, the challenge of possible global warming is one of the pressing scientific, social and economic problems facing humanity. Changes in climatic conditions due to an increase in temperature, in addition to increasing the aridity of many regions, can create various abiotic stresses [1, 2], such as increased or decreased temperature, changes in light intensity, lack or excess of moisture, soil salinity, pollution of the environment, nutritional deficiencies [3-7], and also have a negative impact, including that on the productivity of many crops. However, some researchers have a different opinion. For example,
according to V.S. Arutyunov [8], it was experimentally proved that doubling the concentration of CO$_2$ in atmospheric air can increase the yield of some crops by 30%.

It is known that plants are protected from the negative influence of environmental conditions by their internal metabolic capabilities [9]. In the course of evolution, in order to survive in unfavorable ecological situations [10], plants acquired various protective mechanisms causing metabolic reprogramming in cells [11-15].

Therefor, frost-resistant, winter-hardy, drought-resistant, heat-resistant, salt-resistant crops and varieties were cultivated. These abilities of plants determine their adaptability to current environmental changes, which makes it possible to cultivate crops in various agroclimatic zones, ensuring food security in the region. However, it is necessary to clearly understand the agrotechnical basis of the productivity of agricultural crops, including those under stressful conditions.

*Helianthus annuus* L. is a drought-resistant culture of the Asteraceae genus, the raw material of which is the basis of the food, paint and varnish, perfume and cosmetic, pharmacological industry, and is also used in the production of environmentally friendly renewable fuels. In addition, as a crop, it has great agronomic and environmental value: it increases the biodiversity of agrophytocenoses and reduces the pesticidal load; it is a precursor for cereals and used as feed (as green mass, preservative in silage, oil cake) or a good honey plant [16].

Among the biological features of the culture that determine its cultivation technology, it should be noted that the root system penetrates to a depth of 200–300 cm, due to the rapid growth rates of which, the sunflower absorbs moisture from a layer of 100–150 cm and lower and is characterized as a drought-resistant culture [17]. Moisture consumption from seedling to bud formation is only 19.1% of the total amount, 42.6% from bud formation to flowering and 38.3% from flowering to ripening. At the same time, for the formation of 1 ton of product, it is necessary to have 1400–1800 tons of water; therefore, when growing, it is necessary to take into account the moisture supply of the soil and apply moisture-saving technologies.

Due to the low requirements for environmental conditions, sunflower is widely distributed, and the countries leading in its production are Russia, Ukraine, the United States, Argentina and China. In the Russian Federation, along with the demand for the processed products of a given crop, an increase in acreage and gross yield over the years has been traced. For comparison, according to the Ministry of Agriculture of the Russian Federation, since 2001, acreage has increased by 108%, and gross yield by 310%. The seed yield for this period varied from 1.4 to 1.5 t/ha.

Today it is extremely important that the needs of the Russians in seed material were met through domestic production. According to the Rosselkhoz Center, the share of domestic hybrids in the structure of varietal crops in 2017 was only 29.6%, while that of foreign hybrids was 59.4% [18].

The order of the President of the Russian Federation No. Pr-1127 as of June 12, 2017, reads: it is necessary to ensure that agricultural producers use, as a priority, competitive domestic seeding and planting material. It is obvious that in order to achieve food security in the country, a transition to the cultivation of domestic varieties and hybrids of agricultural crops is necessary, including *Helianthus annuus* L.

This issue is also urgent for the Republic of Crimea. In addition, due to the cessation of the operation of the North-Crimean Canal, which provides irrigation systems of the region with water, agricultural production should be stabilized by minimizing tillage and the use of fallow grounds, the cultivation of the most drought-resistant crops, the introduction of moisture-saving technologies, and such agrotechnological methods as a time shift planting and optimization of plant density for productive use of moisture reserves. In the system of measures aimed at increasing crop production, the optimal varietal composition of crops plays an important role, effectively using the agroclimatic possibilities and climatic resources of a certain soil-climatic zone.

The purpose of this study was to identify the adaptive characteristics of varieties and hybrids of *Helianthus annuus* L. of domestic breeding with high genetic potential and to study the density of standing plants in the arid conditions of the peninsula.
2. Materials and Methods

The investigation was carried out in 2017-2018 on the experimental field of the field crops department of the Research Institute of Agriculture of the Crimea located in the central steppe zone of the republic (Figure 1).

![Figure 1. Place of research (2017-2018).](image)

The soils are represented by southern weakly humus chernozems on yellow-brown loess-like light clays. In the arable layer of soil contains 5.6 mg/100 g of mobile phosphorus (according to the method of Machigin B.P.), 35 mg/100 g of potassium (according to the method of Machigin B.P.), and 2.29% of humus (according to the method of Tyurin I.V.). The components of the biopotential for growing sunflower on the peninsula are presented in Table 1.

| Factor                                      | Indicator                          |
|---------------------------------------------|------------------------------------|
| Frost free period                           | 171–238 days a year                |
| The sum of effective temperatures (over 10 °C)| 3100–3600 °C                      |
| Duration of sunshine                        | 2180–2470 hours per year           |
| Inflow of photosynthetically active radiation (PAR) | 2179–2383 MJ/m²                   |

In triplicate, 5 variants of plant standing density were studied: 30, 40, 50, 60, 70 thousand plants per hectare. The total area of the plot was 28 m², the record plot was 14 m². Sowing was carried out manually, three seeds in a seedbed, followed by 2–3 pairs of true leaves in the phase and leaving 1 plant in the seedbed. The object of research is the domestic hybrid Avangard. The sowing period was the 1st decade of April, in the period when the soil temperature at a depth of 8–10 cm for 3–5 days was 6–9 °C.

The following domestic hybrids were tested in quadruplicate in ecological variety testing: Garant, Komandor, Signal, Paritet, Prestizh, Sprint, Sprint 2, Gorstar. The total area of the plot was 56 m², the record plot was 28 m². Standing density was 40 thousand plants per hectare. Sowing was carried out
with a SUPN-8 seeder, the harvesting was done by a Sampo-130 combine. The hybrids under study were entered into the State Register of Breeding Achievements of the Russian Federation for the period 1998–2018: Garant in 1998, Komandor in 2017, Signal in 1998, Parity in 2014, Prestizh in 2002, Sprint in 2015, Gorstar in 2018, Kometa in 2018 [19]. Prestizh hybrid was used as the reference. Harvest was reduced to 100% purity and 10% seed moisture. The field experiments carried out in accordance with the guidelines B.A. Dospekhov [20] and methods of field and agrotechnical experiments with oilseeds [21]. The oil content in the seeds was determined according to GOST 8.596-2010.

Weather conditions for the period 2017-2018, in general, were unfavorable for the growth and development of plants. Precipitation from September 2016 to March 2017 exceeded the average multiyear average by 21.7 mm or 9.5%; in 2018 for the same period it was only 25.7% of the multiyear average (170.2 mm), which indicates a low level moisture security when sowing sunflower (Table 2).

Table 2. The distribution of precipitation in years of research, mm

| Year          | Total precipitation for the period September-March | Month | Total precipitation for the period April-March |
|---------------|---------------------------------------------------|-------|-----------------------------------------------|
|               |                                                   | April | May   | June  | July | August | September |                                    |
| Average       | 229                                               | 32    | 35    | 62    | 45   | 45      | 30        | 249                                   |
| perennial     | 250.7                                             | 39.9  | 23.6  | 20.5  | 12.6 | 53.2    | 1.1       | 150.9                                  |
| 2017          | 170.2                                             | 3.1   | 15.6  | 46.3  | 136.8| 4.3     | 88.8      | 294.9                                  |

During the vegetation period, from April to September 2017, the distribution of precipitation by month was uneven. Indeed, from May to June (the period “budding - flowering”), there was a shortage of them; and in August, they fell in the maximum amount of 53.2 mm (8.2 mm more than the average multiyear norm), which at an elevated temperature could have a negative impact on the yield of sunflower seeds. In general, their number was 150.9 mm (60.6% of the average multiyear norm), which is 144 mm less than the amount of precipitation for 2018. Thus, under the conditions of 2017, the yield of sunflower was formed, mostly due to fall-winter moisture reserves.

In 2018, precipitation during the growing season of sunflower fell in the amount of 294.9 mm (118.4% of the average multiyear norm). However, low moisture provision during sowing of seeds (25.7% of the average multiyear average) and a lack of precipitation at the beginning of the growing season had a significant negative impact on the productivity of plants. As a result, strong dry winds in the daytime leaves were loosing turgor by almost 30%. As a result, an emergency situation was declared in most areas of the republic due to soil and atmospheric drought. The intensity of dry winds was reduced only in the third decade of June: precipitation fell in the amount of 225% of the norm. At the end of July, the amount of precipitation was 101 mm or 360% of the average multiyear average. In the same period, 9 days were noted with an air temperature of 30 °C and higher (4 days more than the average annual data), which caused the manifestation of diseases on the plants of *Helianthus annuus* L.

In general, the average daily air temperature during the years of research in the “flowering” phase of sunflower was above the multiyear average, and in August 2018 exceeded the average multiyear level by almost 3 °C (Figure 2).
Figure 2. Average daily air temperature for the period 2017-2018, °C (Klepinino meteorological station, Research Institute of Agriculture of the Crimea).

Thus, the climatic conditions in the studied years were assessed as dry. Hydrothermal index in 2017 amounted to 0.5 and to 0.7 in 2018. However, 2017 was more favorable for the growth and development of sunflower plants. This is due to the fact that the July precipitation in 2018, which amounted to 136.8 mm in total (91.8 mm more than the average annual data), turned out to be less productive than the fall-winter moisture reserves (250.7 mm) along with precipitation at the beginning of the growing season (84 mm) in 2017.

3. Results
In 2018, as a result of the action of stressful abiotic factors, the vegetation period for sunflower plants was 5–7 days shorter than in 2017 and amounted to 95–96 days. The length of the vegetation period in the years of research did not depend on the density of standing plants.

However, plant density has had a negative impact on the biometric indicators of sunflower plants (Figure 3). During the years of research with the thickening of crops, there was a tendency to decrease in the indicators of the bud diameter, the diameter of the blind seed center of the bud and, accordingly, its productive area. So, the diameter of the bud in 2017 with an increase in plant density decreased from 18 to 12.2 cm, in 2018 from 11 to 9 cm. In 2017, the diameter of the blind seed center of the bud increased from 1.8 to 4.6 cm, in 2018, from 2 to 2.5 cm, while the productive area of the bud over the years of research decreased by almost 2 times. In general, in 2017, all biometric indicators, except for the diameter of the blind-seed center of the bud, had the highest values than in 2018.

Thickening of crops to 60–70 thousand/ha contributed to a decrease in the number of seeds in the bud. For instance, in 2017, with a standing density of 30 thousand plants/ha 663 more seed pods formed than at 70 thousand plants/ha; in 2018, the increments was 360 plants. During the study period, the number of seed pods with the thickening of the crops decreased by almost 2 times: in 2017, from 1487 to 744; in 2018, from 968 to 584. Under the conditions of 2017, a larger number of seed pods were formed in the bud, and they were larger, despite the high percentage of set and plumpness of seedlings in 2018, which once again confirms the high importance of moisture reserves for sunflower (Table 3).
Table 3. Elements of the crop structure of *Helianthus annuus* L., depending on plant density

| Plant density, thousand pcs./ha | Total number of seed pods in bud, pcs. | Plumpness of seed pods in bud, pcs. | Set, % | Plumpness [%] | Mass of 1000 seed pods d|
|--------------------------------|----------------------------------------|-------------------------------------|--------|---------------|------------------------|
|                                | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| 30                             | 1746 | 1000 | 1487 | 968  | 85.1 | 96.8  | 87.8 | 94.8  | 42.2 | 32.2  |
| 40                             | 1735 | 920  | 1461 | 880  | 84.2 | 95.7  | 90.9 | 93.3  | 42.4 | 28.0  |
| 50                             | 1421 | 864  | 1179 | 812  | 83.0 | 94.1  | 87.2 | 92.8  | 40.0 | 27.0  |
| 60                             | 1190 | 840  | 984  | 776  | 82.8 | 92.4  | 84.2 | 93.8  | 38.4 | 23.0  |
| 70                             | 1083 | 640  | 744  | 584  | 68.7 | 90.3  | 80.6 | 92.2  | 37.6 | 21.6  |

HCP05  60.1  32.9  61.4  36.5  5.9  4.1  0.8  3.7  1.0  0.8

The highest yield of sunflower was obtained for a plant density of 40K ha⁻¹ and amounted to 1.70 t/ha in conditions of 2017 and 0.64 t/ha in 2018 (Figure 8).

![Figure 4. Yield of seeds of *Helianthus annuus* L., depending on the density of plant standing, t/ha.](image)

Thus, in the years of research, the plant density of 40K per hectare was optimal for the formation of the harvest. With the thickening of crops from 40 to 70 thousand plants per hectare, the seed yield decreased.

As a result of research, it was also found that the highest yield of seeds of *Helianthus annuus* L. hybrids of domestic breeding in arid conditions of the Crimean peninsula on the southern weakly humus black soil under the conditions of 2017 was formed in hybrids Garant (1.58 t/ha), and Sprint (1.70 t/ha) (Figure 5). In 2018, due to climatic conditions unfavorable for plant growth and development, the level of productivity of hybrids was significantly lower: the highest seed yield was formed in Prestige hybrids (0.78 t/ha), Signal and Gorstar (0.59 t/ha each).

The greatest oil content in the years of research was recorded in the Garant hybrid, 43.6-45.0% (Figure 6). In general, in dry conditions in 2018, the level of oil content in the seeds of most of the hybrids of *Helianthus annuus* L. was slightly lower than in 2017.

4. Conclusion
The productivity of *Helianthus annuus* L. in the conditions of the central steppe of the Republic of Crimea depends on the elements of the cultivation technology, in particular on the density of plant growth.
The moisture reserves accumulated during the fall-winter period had a significant impact on the growth and development of plants. In the arid conditions of the central steppe of the Crimean peninsula, due to low moisture supply and low probability of precipitation during the vegetation period, the thickening of the crops has a negative effect on the yield of seeds. The highest yield was obtained for a plant density of 40K ha\(^{-1}\) and amounted to 1.70 t/ha in conditions of 2017 and 0.64 t/ha in 2018. The cultivation of sunflower should provide for the minimum plant stand within the optimum standing density, not more than 40 thousand plants per hectare.

The results of the ecological varietal testing of Helianthus annuus L. hybrids of domestic breeding indicate the potential for crop productivity in the arid conditions of the central steppe zone of the Crimea, subject to the agrotechnology, including the varietal, aimed at improving the yield and seed quality. The highest yield of seeds of Helianthus annuus L. in agro-climatic conditions of 2017 was demonstrated by hybrids Garant (1.58 t/ha), Signal (1.68 t/ha) and Sprint (1.70 t/ha); in 2018, by Prestige (0.78 t/ha), Signal and Gorstar hybrids (0.59 t/ha).

5. Acknowledgments

The study was conducted in the framework of the state assignment number 0834-2015-0011- "To develop techniques for increasing the productivity of oilseeds in order to design highly productive agrophytocenosis with the effective use of the natural resource potential of the Crimea."

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