Technological aspects of confectionary sunflower cultivation in arid conditions of the Crimean peninsula

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Abstract. The reaction of large-fruited confectionary sunflower of the LFS variety to different plant density was studied in 2017-2019 in southern slightly humic chernozem in the arid conditions of the steppe zone of Crimea. It was established that the minimum plant stand within the limits of optimal density, which is not more than 30 thousand plants/ha in the climatic conditions during the years of study, allowed obtaining yield within the limits of 1.17–2.38 t/ha with seed oil content of 39.0–46.3 %. With the overcrowding of crops from 30 to 40 thousand pcs/ha, there was a tendency to decrease the indicators of structural elements of crops and the productivity of crops in general. In order to obtain large seeds (102.1–114.0 g), the optimal plant density shall be 20 thousand/ha. The maximum yield of seeds is achieved in crops with plant density of 30 thousand/ha, but the thousand-seed weight under this technology is reduced to 92.4–103.2 g.

1. Introduction

In recent years, sunflower production has steadily increased in the world and in the Russian Federation. If in 2019 this culture occupied 26,270 thousand hectares in the world structure of cultivated lands, in the Russian Federation – 8,578 thousand hectares, then by 2025 it is planned to increase the area up to 9,400 thousand hectares in our country, of which at least 10 % – large-fruited varieties of confectionery purposes. It should be noted that the selection of this type of sunflower is also developing at an intensive rate. At present it is considered promising since the large-fruited sunflower seeds are valuable raw materials in the world market. The seeds include vitamins, microelements, unsaturated fatty acids, which are important for human health. High protein content and low oil content allow using confectionery type of culture not only in food industry, but also as food for birds and animals [1].

The markets of certain countries – consumers of raw materials of large-fruited sunflower for confectionery purposes have their preferences. Thus, some place certain requirements to the content of protein and oil, others – to the fineness of seeds, the third – to their size, shell color, etc. The manufacturers prefer to cultivate varieties with an oblong form of seeds, which are not prone to sprinkling, resistant to diseases and pests, as well as to lodging. These demands make the selection processes somewhat more complex and expensive [2]. In general, the cores should be large, the thousand-seed weight – 100 g and more, huskiness – about 30 %, oil content in seeds – 43–45 % [3].

To date, 92 sunflower varieties have been registered in the State Register of Selection Achievements, of which 40 are selection varieties of V.S. Pustovoit All-Russian Research Institute of Oil Crops, 5 of
which are large-fruited sunflower varieties [4]. The work with confectionary type breeders of the Institute began during the period when nut raw materials became a deficit for food industry, and sunflower raw materials did not meet its requirements [5]. Thus, as a result of hybridization of the Bulgarian Stadium variety and the selection variety of the Institute Yubileiny 60 the first “large-fruited sunflower class” – LFS – was created through selection. Modern varieties of this direction should be characterized by optimal morphometric and economically useful features. The model of this variety began to be developed in 2015 at the Serbian Academy of Sciences and Arts by scientists Dragan Shkorić and Gerald J. Seiler, as a result of which a monograph was written [6]. Domestic scientists are also selecting to improve the main economic benefits. The optimal parameters of the large-fruited confectionary sunflower variety include quantity and weight of seeds in a flower head, thousand-seed weight, natural weight, huskiness, oil content, potential yield, linear size of seeds, hulling, attractiveness, as well as the plant stand for harvesting [7]. At the same time, some characteristics are dependent on others. Thus, yield, thousand-seed weight, oil content, natural weight, etc. depend on the plant stand [8, 9]. The area of nutrition and its shape affect the productivity of not only individual sunflower plants, but also the sowing of the culture as a whole. In the technology of large-fruited sunflower cultivation, the formation of optimal plant stand is an important aspect for obtaining high yield of large fractions of seeds and their qualitative indices [5, 10].

2. Problem statement
In order to grow many zoned high-oleic sunflower varieties and hybrids in different soil-climatic conditions, the optimal plant stand has already been established [11–18]. As for the study to optimize this element of cultivation technology for large-fruited forms, then there is not enough data on their results [5, 19, 20]. So, today the study of the reaction of confectionary sunflower varieties to various elements of cultivation technology, including to the density of plant stand, is particularly relevant. In Crimea, similar to other regions of the planet, there is a change in climatic conditions, which is exacerbated by an increase in temperature and low moisture content due to lack of natural rainfall and artificial irrigation. In the framework of the program on import substitution of domestic breeding, drought-resistant and cost-effective crops are in demand for cultivation on the peninsula. In this regard, a field scientific experiment was conducted in the arid conditions of the central steppe of Crimea, which purpose was to study the impact of the plant stand on harvest and quality of large-fruited sunflower seeds of domestic selection.

3. Materials and methods
In 2017–2019, 5 variants of the plant stand were studied in three replications on the southern slightly humic chernozem formed on yellow-brown loess-like light clays of the experimental site of the Research Institute of Agriculture of Crimea: 20, 25, 30, 35 and 40 thousand plants per hectare. The sowing period – II decade of April. The total plot area is 28 m², accounting area – 14 m². The object of the study – modern, popular and commercially successful mid-season large-fruited sunflower variety of domestic selection – LFS. The period “sprouting – physiological ripeness” takes 91 days. The variety is able to form a seed yield of up to 3.5 t/ha with oil content of 44 % and is an excellent melliferous plant.

Agrochemical indices of the arable soil layer of the experimental site in the years of study: content of labile phosphorus (according to Machigin B.P.) – 5.6 mg/100 g, potassium (according to Machigin B.P.) – 35 mg/100 g, humus (according to Turin I.V.) – 2.29 %.

Field experiments were carried out in accordance with the methodological instructions of B.A. Dospekhov [21] and the method of field and agricultural experiments with oilseeds [22]. Oil content in seeds was determined according to GOST 8.596-2010.

The weather conditions during sunflower vegetation (April-September) throughout the years of study were quite contrasting. The monthly rainfall distribution was uneven (Table 1).
Table 1. Rainfall distribution in the years of study, mm

| Year      | Month | Total rainfall over September-March | April | May | June | July | August | September | Total rainfall over April-September |
|-----------|-------|-------------------------------------|-------|-----|------|------|--------|-----------|------------------------------------|
|           |       | Long-term average annual             |       |     |      |      |        |           |                                    |
|           | Total | 229.0                               | 32.0  | 35.0| 62.0 | 45.0 | 45.0   | 30.0      | 249.0                              |
| 2017      | April | 250.7                               | 39.9  | 23.6| 20.5 | 12.6 | 53.2   | 1.1       | 150.9                              |
| 2018      | May   | 170.2                               | 3.1   | 15.6| 46.3 | 136.8| 4.3    | 88.8      | 294.9                              |
| 2019      | June  | 325.0                               | 27.2  | 23.9| 119.6| 67.5 | 0.6    | 21.1      | 266.9                              |

Weather station in Klepinino village, 2017-2019

Thus, in 2017, May and June were characterized by the lack of rains, which in a complex with high temperature conditions (Figure 1) had a negative impact on crop yield. In 2018, at the beginning of the vegetation, their shortage is obvious, which subsequently, as in most parts of the Republic of Crimea, led to an emergency situation due to soil and atmospheric drought. However, already in the third decade of June the rainfall amounted to 225 % from standard, and at the end of July – 360 %, which, against the background of high air temperature (30°C and higher) caused the manifestation of plant diseases. In 2019, the current weather conditions favored the growing of the culture, as they were characterized by good moisture content, absence of drought and reduced temperature mode. As for the rainfall of the autumn-winter period, in 2017 they exceeded the average summer standard by 9.5 % (21.7 mm), in 2018 – amounted to 25.7 % of the standard (170.2 mm), and in 2019 – 325 mm, which is 96 mm more than the standard. The hydrothermal index of the growing period in 2017 amounted to 0.5, in 2018 – 0.7, in 2019 – 0.8, which, according to Selyaninov, in general corresponds to arid conditions.

Figure 1. Average daily air temperature during sunflower vegetation, weather station in Klepinino village, 2017-2019.

4. Results and discussion
The growing period of confectionery sunflower in 2017 was the shortest and amounted to 106–107 days, which is 9–10 days less than in 2018 and 11 days less than in 2019 (Table 2). The duration of interstage periods also varied slightly across the years. It is known that the duration of the maturation phase of seeds depends on the variety and growing conditions: it is shorter in dry years and longer in wet years. Thus, in 2018 and 2019, due to heavy rainfall in June-July, the duration of this period lasted 14–16 day, which was longer than in 2017. However, in 2017, the phase of “seedling – flowering” lasted 5 days longer than in other years of study, which is caused by the increase of air and soil temperature, as well as the lack of moisture content.

As a result of the field experiment it was found that the plant stand had no effect on the duration of interstage periods and the vegetation period as a whole.

In 2017 and 2018 the seed overcrowding was characterized by the decrease in the height of plants, and in 2019, on the contrary, by the increase (Figure 2).
Table 2. Duration of interstage and vegetation periods of LFS confectionary sunflower depending on plant stand, days

| Plant stand, th.pcs/ha | Interstage period, days | 2017 | 2018 | 2019 |
|------------------------|-------------------------|------|------|------|
|                        | seeding – sprouting     | sprouting – budding | budding – flowering | flowering – ripening | sprouting – flowering | vegetation period (sprouting – ripening) |
| 20                     | 16                      | 45   | 29   | 33   | 74   | 107 |
| 25                     | 17                      | 44   | 28   | 34   | 72   | 106 |
| 30                     | 16                      | 45   | 28   | 34   | 73   | 107 |
| 35                     | 16                      | 45   | 28   | 34   | 73   | 107 |
| 40                     | 16                      | 45   | 29   | 33   | 74   | 107 |

LSD<sub>0.05</sub> (2017) = 3.1 cm  
LSD<sub>0.05</sub> (2018) = 1.3 cm  
LSD<sub>0.05</sub> (2019) = 7.3 cm

Figure 2. Height of confectionary sunflower LFS depending on plant stand, Research Institute of Agriculture of Crimea, 2017–2019.

During the years of study, the maximum diameter of the plant head was recorded in the plants of confectionary sunflower in the variant with the plant stand of 20 thousand pcs/ha and amounted to 21.5 cm in 2017, 19.7 cm – in 2018, 21.2 cm – in 2019 (Figure 3).

It should be noted that the increase in the plant stand density from 30 to 40 thousand pcs/ha contributed to the reduction of the plant head diameter and the increase in the diameter of the void middle of the plant head (without formed seeds), which is caused by the change of the region of plant alimentation and the annually observed lack of moisture during the “flowering-seed formation” period. Thus, the largest value of the last indicator was recorded in the plant stand of 40 thousand pcs/ha and amounted to 4.1 cm in 2017, 3.3 cm – in 2018, 3.2 cm – in 2019.
Accordingly, with the seed overcrowding, the productive area of the plant head decreased (Figure 4). Its largest value in the years of study was noted at the plant stand of 20 thousand pcs/ha and amounted to 360.5 cm$^2$ in 2017, 301.2 cm$^2$ – in 2018, 348.6 cm$^2$ – in 2019.

![Figure 3. Diameter of the plant head of confectionary sunflower LFS depending on plant stand, Research Institute of Agriculture of Crimea, 2017–2019.](image)

LSD$_{05}$ (2017) = 0.2 cm  
LSD$_{05}$ (2018) = 0.3 cm  
LSD$_{05}$ (2019) = 0.3 cm

Consequently, the effect of the plant stand on the biometric performance of LFS confectionary sunflower plants was observed, which affected the productivity of the culture.

Thus, in the years of study, with the increase in the region of plant alimentation, sunflower heads were formed with the maximum number of seeds: at a plant stand of 20 thousand pcs/ha in 2017 – 1,298 pieces, in 2018 – 1,130 pieces and in 2019 – 1,487 pieces (Table 3).

The smallest number of seeds was formed in 2018, which is caused by a strong drought in the budding stage, when the plants have an increasing need for life factors to fully form the number of flowers in a flower head, as a result of which the loss of the sunflower leaves turgor was also recorded. However, due to heavy rainfall in the flowering phase, these seeds were the largest and most filled than in the other years of study.

Thus, in 2017 the thousand-seed weight amounted to 102.1 g, the plumpness of seeds – 95.3 %, in 2018 – 114.0 g and 98.3 %, in 2019 – 112.6 g and 98.0 % respectively (Figure 5 and Table 3).

In 2018, the highest set of seeds was recorded – 97.2 %, in other years it was slightly lower: in 2017 – 93.5 %, in 2019 – 96.5 % (Table 3). In 2017–2019 the maximum values were obtained in the variant with the plant stand of 20 thousand pcs/ha.

Analyzing the given data, it can be concluded that in favorable conditions of 2019 at the plant stand of 20 thousand pcs/ha the largest number of large and filled seeds were formed in the plant head compared to 2017 and 2018.

![Figure 4. Productive area of the plant head of confectionary sunflower LFS depending on plant stand, Research Institute of Agriculture of Crimea, 2017–2019.](image)

LSD$_{05}$ (2017) = 6.5 cm$^2$  
LSD$_{05}$ (2018) = 7.3 cm$^2$  
LSD$_{05}$ (2019) = 6.8 cm$^2$
The highest yield was observed at the plant stand of 30 thousand pcs/ha and amounted to 2.38 t/ha in 2019, 1.99 – in 2017 and 1.17 t/ha – in 2018 (Figure 6). The decrease was noted in the overcrowding of crops from 30 to 40 thousand plants per ha.

Table 3. Elements of LFS confectionary sunflower structure depending on plant stand

| Plant stand, th. pcs/ha | Total number of seeds in a head, pcs. | Number of filled seeds in a head, pcs. | Set of seed, % | Plumpness, % |
|-------------------------|----------------------------------------|----------------------------------------|----------------|--------------|
|                         | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| 20                      | 1367 | 1162 | 1540 | 1298 | 1130 | 1487 | 93.5 | 97.2 | 96.5 | 95.3 | 98.3 | 98.0 |
| 25                      | 1282 | 1145 | 1280 | 1175 | 1107 | 1219 | 91.7 | 96.7 | 95.3 | 91.5 | 97.3 | 97.3 |
| 30                      | 1205 | 969  | 1152 | 1100 | 897  | 1095 | 91.3 | 92.5 | 95.0 | 92.8 | 98.2 | 96.6 |
| 35                      | 1193 | 960  | 1099 | 1069 | 836  | 1036 | 87.1 | 94.3 | 90.8 | 97.7 | 96.1 |
| 40                      | 1108 | 940  | 1036 | 975  | 784  | 1095 | 88.1 | 83.4 | 93.9 | 90.3 | 47.3 | 94.9 |
| LSD<sub>0.05</sub>      | 24.5 | 23.0 | 52.6 | 25.2 | 40.6 | 45.6 | 2.4  | 4.6  | 1.3  | 1.9  | 4.2  | 0.8  |

![Graph](image1)

**Figure 5.** Thousand-seed weight of confectionary sunflower LFS depending on plant stand, Research Institute of Agriculture of Crimea, 2017–2019.

![Graph](image2)

**Figure 6.** Yield of confectionary sunflower LFS depending on plant stand, Research Institute of Agriculture of Crimea, 2017–2019.

As it is known, as the number of sunflower plants per unit area increases, the amount of fat in the seeds increases as well. Such a pattern was noted in 2019, where the highest value of seed oil content
was recorded at the plant stand of 40 thousand pcs/ha – 46.3 % (Figure 7). In 2017 and 2018, its level was slightly lower and there were no significant changes in this indicator depending on the plant stand during these years. With the overcrowding of crops, there is a clear tendency towards the increase of this indicator.

Figure 7. Oil content in seeds of confectionary sunflower LFS depending on plant stand, Research Institute of Agriculture of Crimea, 2017–2019

5. Conclusion
The productivity of LFS confectionary sunflower in arid conditions of the Crimean Peninsula depends on the elements of cultivation technology, in particular on the plant stand. The minimum plant stand within the limits of optimal plant stand amounting to not more than 30 thousand plants/ha in the current climatic conditions of 2017–2019 allowed obtaining the yield within 1.17–2.38 t/ha with seed oil content of 39.0–46.3 %. With the overcrowding of crops from 30 to 40 thousand pcs/ha, there was a tendency to decrease the indicators of structural elements of crops and productivity of crops in general. In order to obtain large seeds (102.1–114.0 g), the optimal plant stand shall make 20 thousand/ha. The maximum yield of seeds is achieved in crops with the plant stand of 30 thousand/ha, but under this technology the thousand-seed weight is reduced to 92.4–103.2 g.

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