Impact of the seeding rate on the yield and its quality of the new sunflower hybrids

A S Bushnev¹, O M Borisenko, Yu V Mamyro and A K Gridnev

V.S. Pustovoit All-Russian Research Institute of Oil Crops, 17, Filatova str., Krasnodar, 350038, Russia

¹E-mail: vniimk-agro@mail.ru

Abstract. The effect of different seeding rates, providing the density of 40, 60, and 80 thousand plants/ha, on the yield and its quality of the new sunflower hybrids of VNIIMK breeding (Immi, Arneb, Gorfild) was studied at the V.S. Pustovoit All-Russian Research Institute of Oil Crops (VNIIMK) (Krasnodar) in 2019-2020. The purpose of the research is to determine the effect of different seeding rates on the elements of plant productivity, yield, oil content of seeds, and oil yield of promising sunflower hybrids. The sunflower hybrid Arneb appeared to be the most stable in terms of productivity at different seeding rates. It has a high tolerance to its increase even under a water deficiency. Hybrids Immi and Gorfild are more susceptible to plant thickening. Their productivity is decreasing in unfavorable water conditions.

1. Introduction

The productivity potential of modern sunflower hybrids is more than 4 t/ha. In 2020, in the Southern Federal District, sunflower occupied 23% (2045.4 thousand hectares) of the total crop acreage in the Russian Federation [1]. However, its actual productivity in the past years was only 1.76 t/ha, which is significantly lower than the potential one. Currently, in sunflower production, the foreign hybrids successfully compete with the Russian ones by productivity. But mainly their introduction did not lead to an increase in productivity in different regions of crop cultivation, since some of them are not sufficiently adapted to Russian soil and climatic, ecological, and production conditions. Therefore, foreign hybrids are often unable to fulfill their potential completely. For example, in 2018, the increase in productivity of foreign hybrids in the Krasnodar and Stavropol regions was only 10 and 30 kg/ha [2]. Meanwhile, it is known that one of the keys to increasing sunflower productivity is the selection of the best genotypes that would be adapted to specific natural cultivation conditions. In addition, it is also essential to strictly comply with the elements of their cultivation technology. As part of the program for import substitution in agriculture, currently, Russian breeders are trying actively to overcome the dependence on the import of seeds of foreign hybrids in the oil crops segment. This program involves a significant increase in the share of sunflower hybrids of the Russian breeding. The change towards the cultivation of the Russian sunflower cultivars and hybrids will help to increase the level of food security in the country.

Within the import substitution program, the breeders of V.S. Pustovoit All-Russian Research Institute of Oil Crops develop new highly productive sunflower hybrids for different uses that require certain technological methods of plant cultivation. The breeding parameters of the modern Russian hybrids Immi, Arneb, and Gorfild are at the level of the best world variety samples. Hybrids are
characterized by high ecological plasticity and constant productivity in various soil and climatic zones of the country. Under equal cultivation conditions, they can successfully compete with the foreign hybrids by productivity and significantly surpasses them in terms of production costs.

For example, the feature of the sunflower hybrid Immi is its usage in the Clearfield production system. This hybrid is mid-early maturing, has high seed productivity, wide ecological plasticity, and is tolerant to Phomopsis blight.

The hybrid Arneb is intended for cultivation in dry-farming lands and at irrigation with classic technology. It is mid-maturing, of intensive type, resistant to a complex of races of broomrape (A-E) and downy mildew, highly tolerant to Phomopsis blight, white and gray rot of sunflower.

Gorfild is a hybrid of an intensive type, intended for classic cultivation technology. It is mid-maturing, with good response to high soil fertility, tolerant to Phomopsis blight and seven broomrape races (A-G), resistant to downy mildew (race 330). In the field conditions, it is not affected by Verticillium blight, rust, and Alternaria blight [3].

With various cultivation technologies of hybrids, the most important varietal feature of sunflower cultivation is an individual approach to the selection of the optimal seeding rate depending on the water availability of soil [2, 3, 4]. In the case of hybrid cultivation by the Clearfield technology with the application of the Euro-Lightning herbicide, the seeding rate depends on the methods of hybrid intensification and the individual characteristics of its genotype, such as a certain response to the thinning or thickening of sowing. In the case of hybrid cultivation by the classical technology, a part of the plants will be lost during pre-emergence or post-emergence harrowing, so it is usually suggested to increase the seeding rate by 15-30% [5].

In 2019-2020, at V.S. Pustovoit All-Russian Research Institute of Oil Crops, there was carried out a field experiment to select the optimal plant density when cultivating new sunflower hybrids. The experiment was carried out on a farm “Berezanskoye”, Korenovsk district, Krasnodar region according to the following scheme: the seeding rate providing a density of 40, 60, and 80 thousand plants/ha. The purpose of the research was to study the effect of different seeding rates on changes in morphometric traits, productivity, oil content of seeds, and oil yield of new promising sunflower hybrids bred at V.S. Pustovoit All-Russian Research Institute of Oil Crops: Immi, Arneb, and Gorfild.

2. Research results

In 2019, the growth season of sunflower was characterized by an uneven distribution of precipitation: a lack of precipitation in April and June, and then exceeding the average annual level in May and July. In 2020, the weather conditions were extremely dry. The April water deficiency, which amounted to 9% of the long-term norm, complicated the sunflower development at the beginning of growth and in subsequent stages of plant development. A lack of precipitation in May and June (79 and 39% of the norm, respectively) contributed to the low productivity of hybrids. The average daily temperature of the air in June of 2019-2020 and in July of 2020 was significantly (by 4.7 °C) higher than the norm, which negatively affected the crop productivity.

The response of sunflower plants to an increase in their plant density during the growth period can be evaluated by several morphological and economically important traits. Moreover, the effect of this method can also vary depending on the cultivation conditions of hybrids. Thus, 2019 was characterized by higher water availability at the early stages of plant development, which inevitably affected the height and head diameter in the studied hybrids compared to the data of 2020, when there was a severe soil drought at the initial stages of sunflower vegetation (table 1).

The sunflower hybrid Gorfild was the tallest in two years of experiment. Moreover, in 2019 the plant height at the studied seeding rates of 40 and 60 thousand pcs/ha differed significantly, while in 2020 this difference was not important. In 2020, the hybrids Immi and Arneb, on the contrary, showed significant differences between the extreme values of the seeding rates for a plant height, while in a previous year these differences were random. The reason for such a contrast in the plant height of the studied hybrids may be the genetic component in the implementation of the phenotypic variability of the trait, a kind of specific response of the genotype to the vegetation conditions that are quite severe by
water availability. Mainly, in 2020, the plant height of the three hybrids was 6-8 % lower compared to 2019.

**Table 1.** Changes in morphometric traits of sunflower hybrids depending on the year of cultivation and the seeding rate, V.S. Pustovoit All-Russian Research Institute of Oil Crops.

| Hybrid | Seeding rate, thousand pcs/ha | Plant height, cm | Head diameter, cm | Plant height, cm | Head diameter, cm |
|--------|-------------------------------|------------------|------------------|------------------|------------------|
|        | 2019                          | 2020             |                  |                  |                  |
| Immi   | 40                            | 167              | 21.4             | 156              | 18.8             |
|        | 60                            | 169              | 18.7             | 157              | 17.0             |
|        | 80                            | 172              | 18.0             | 162              | 15.3             |
|        | 40                            | 155              | 20.0             | 142              | 19.1             |
| Arneb  | 60                            | 153              | 18.9             | 148              | 17.9             |
|        | 80                            | 158              | 17.0             | 149              | 14.6             |
|        | 40                            | 186              | 21.9             | 173              | 18.2             |
| Gorfild| 60                            | 193              | 20.1             | 178              | 15.8             |
|        | 80                            | 190              | 16.9             | 174              | 15.0             |
| LSD05  |                               | 6                | 1.3              | 6                | 1.2              |

During the research period, the diameter of sunflower heads naturally decreased with an increase in the seeding rate. In 2020, the diameter of an inflorescence of the hybrid Gorfild decreased most significantly in comparison with 2019. For example, at 40 thousand pcs/ha, the head diameter decreased by 17%, and at 60 thousand pcs/ha it decreased by 21%. At the highest seeding rate of 80 thousand pcs/ha, this indicator of the hybrid decreased by 11%. The head diameter of the sunflower hybrid Arneb had a maximum decrease of 14% at the seeding rate of 80 thousand pcs/ha. At the same time, the head diameter of the hybrid Immi decreased by 12% at the minimum seeding rate and by 15% at the maximum seeding rate. Such response of sunflower to a change in the plant density during the stages of flowering-maturity in 2020 is related to water deficiency at the initial stages of development when the setting and development of the generative organs of plants took place.

The growth conditions of 2020 also affected the development of seeds in the studied hybrids. For all genotypes, there was observed a decrease in the thousand-seed weight: by 23% in the hybrid Immi, by 27% in the hybrid Arneb, and by 31% in the hybrid Gorfild compared to 2019 (table 2).

**Table 2.** Changes in productivity indicators of sunflower hybrids depending on the year of cultivation and seeding rate, V.S. Pustovoit All-Russian Research Institute of Oil Crops.

| Hybrid | Seeding rate, thousand pcs/ha | Thousand-seed weight, g | Bulk weight of seeds, g/l | Thousand-seed weight, g | Bulk weight of seeds, g/l |
|--------|-------------------------------|--------------------------|---------------------------|--------------------------|---------------------------|
|        | 2019                          | 2020                     |                           |                           |                           |
| Immi   | 40                            | 62.9                     | 491.9                     | 48.0                     | 478.9                     |
|        | 60                            | 54.3                     | 511.1                     | 43.2                     | 482.2                     |
|        | 80                            | 54.5                     | 495.0                     | 40.0                     | 461.8                     |
|        | 40                            | 64.0                     | 477.6                     | 49.1                     | 433.4                     |
| Arneb  | 60                            | 61.8                     | 460.2                     | 44.1                     | 417.5                     |
|        | 80                            | 58.5                     | 463.4                     | 40.6                     | 416.9                     |
|        | 40                            | 77.7                     | 455.6                     | 56.8                     | 423.5                     |
| Gorfild| 60                            | 76.1                     | 467.1                     | 50.5                     | 409.1                     |
|        | 80                            | 67.2                     | 469.9                     | 45.1                     | 439.1                     |
| LSD05  |                               | 4.6                      | 11.4                      | 3.0                      | 15.9                      |

The bulk weight (seed weight) that depends on the size, shape, and plumpness of seeds can also be an indirect indicator of the plants response to the feeding area and water availability. Moreover, the bulk
weight of sunflower seeds is correlated with the costs of transportation and storage of the harvest. Thus, the more compactly well-filled seeds fit each other in a certain volume, the lower the cost of their logistics is. Over two years, the bulk weight of seeds of the studied hybrids varied with a different range of variability. In the hybrid Immi, this difference between the years of the research was about 5%, while its maximum value was obtained at the seeding rate of 60 thousand pcs/ha. The hybrids Arneb and Gorfeld had a high variability of this trait – about 9%. Moreover, the hybrid Arneb developed seeds with the maximum seed weight in both years of the research at the seeding rate of 40 thousand pcs/ha. At the same time, the hybrid Gorfeld showed the highest seed weight at the maximum seeding rate.

Under the conditions of unstable moistening of 2019, the productivity of the hybrids Immi and Arneb did not change significantly depending on the seeding rate, while the hybrid Gorfeld has the maximum productivity at the seeding rate of 60 thousand pcs/ha. In the dry weather conditions of 2020, the hybrids Immi and Gorfeld had the maximum productivity at 40 thousand pcs/ha. An increase of sowings rates for these hybrids to 60 and 80 thousand pcs/ha led to a decrease in productivity. The hybrid Arneb is characterized by stability and high productivity, which usually do not depend too much on the weather conditions of a year and the thickening of sowings. On average, over two years of research, its yield was 2.92-2.99 t/ha, depending on the seeding rate (table 3).

**Table 3.** Productivity and quality of sunflower hybrids depending on the year of cultivation and seeding rate, V.S. Pustovoit All-Russian Research Institute of Oil Crops.

| Hybrid | Seeding rate, thousand pcs/ha | Productivity, t/ha | Oil content of seeds, % | Oil yield, t/ha |
|--------|-------------------------------|--------------------|------------------------|----------------|
|        | 2019                          | 2020               | 2019                   | 2020           | 2019 | 2020 | average |
| Immi   | 40                            | 2.48               | 2.49                   | 2.49           | 45.8 | 44.6 | 45.2 | 1.02 | 1.00 | 1.01 |
|        | 60                            | 2.49               | 2.19                   | 2.34           | 46.9 | 46.0 | 46.5 | 1.05 | 0.91 | 0.98 |
|        | 80                            | 2.50               | 2.28                   | 2.39           | 48.0 | 46.3 | 47.2 | 1.08 | 0.95 | 1.02 |
|        | 40                            | 3.21               | 2.77                   | 2.99           | 44.6 | 45.1 | 44.9 | 1.29 | 1.12 | 1.21 |
| Arneb  | 60                            | 3.19               | 2.76                   | 2.98           | 44.6 | 44.5 | 44.6 | 1.28 | 1.11 | 1.19 |
|        | 80                            | 3.17               | 2.66                   | 2.92           | 45.3 | 44.8 | 45.1 | 1.29 | 1.07 | 1.18 |
|        | 40                            | 3.00               | 2.79                   | 2.90           | 45.8 | 45.1 | 45.5 | 1.24 | 1.13 | 1.18 |
| Gorfeld| 60                            | 3.26               | 2.43                   | 2.85           | 47.7 | 45.6 | 46.7 | 1.40 | 1.00 | 1.20 |
|        | 80                            | 2.93               | 2.46                   | 2.70           | 48.4 | 46.4 | 47.4 | 1.28 | 1.03 | 1.15 |
| LSD05  | -                             | 0.11               | 0.07                   | -              | 0.35 | 0.40 | -    | 0.04 | 0.03 | -    |

In the experiment, the maximum productivity of the high oleic hybrid Gorfeld (oil content of seeds is 45.5-47.4%) was 3.26 t/ha at a plant density of 60 thousand pcs/ha in 2019 and 2.79 t/ha at 40 thousand pcs/ha in dry 2020. The hybrid Immi had the maximum productivity at the seeding rate of 40 thousand pcs/ha (2.49 t/ha), an increase in the oil content of seeds (by 0.7-2.0%) was also observed with the thickening of sowings.

On average, for two years of the research, seed yield and oil content of seeds were, respectively, 2.96 t/ha and 44.8% in the hybrid Arneb, 2.81 and 46.5 in the hybrid Gorfeld, and 2.42 t/ha and 46.3% in the hybrid Immi. An increase in the seeding rate for these hybrids contributed to a slight increase in oil content – by 0.2-0.5% against the background of minimal differences in their productivity.

On average, with an increase in the seeding rate from 40 to 60 and 80 thousand pcs/ha, there was observed a decrease in sunflower productivity. At the same time, its quantitative decrease was from 2.79 to 2.72 and 2.67 t/ha, respectively, while the oil content of seeds, on the contrary, increased with the thickening of hybrid sowings – from 45.2 to 45.9 and 46.5%, respectively. On average, oil yield for the variants of the experiment was higher in 2019 than in 2020: 1.02-1.40 t/ha versus 0.91-1.13 t/ha. Also, over the years of research, the hybrids Arneb and Gorfeld had the highest oil yield of 1.20-1.21 t/ha at the seeding rates of 40 and 60 thousand pcs/ha, respectively.
3. Conclusion

Testing of the new promising sunflower hybrids showed they can, to a certain extent, differ in their phenotypic response to changes in cultivation conditions. Thickening of sowings in combination with a water deficiency in some cases can lead to a significant decrease in yield. The hybrid Arneb was the most stable by productivity at the different seeding rates, which indicates its high tolerance to an increase in plant density even in the conditions of a water deficiency. The hybrids Immi and Gorfild were more susceptible to thickening, which in some cases was manifested through a decrease in productivity under unfavorable conditions of water availability. In conditions of unstable moistening, to obtain high-quality yields of sunflower hybrids Arneb, Immi, and Gorfild, the optimal seeding rates should ensure a density from 40 to 60 thousand plants/ha.

References

[1] Website of the Federal State Statistics Service Bulletins on the state of agriculture (electronic versions) Retrieved from: https://rosstat.gov.ru/compendium/document/13277
[2] Bokancha M 2018 Agrarian newspaper Zemlya i zhizn 13(165) 8
[3] Bochkaryov N I et al. 2020 Catalog of cultivars and hybrids of oil crops, cultivation technologies and means of mechanization (Krasnodar: VNIIMK) 166
[4] Kostenkova E V et al. 2021 IOP Conf. Ser.: Earth Environ. Sci. 624 012073 DOI: 10.1088/1755-1315/624/1/012073
[5] Kostenkova E V et al. 2019 IOP Conf. Ser.: Earth Environ. Sci. 341 012011 DOI: 10.1088/1755-1315/341/1/012011
[6] Nasiyev B, Zhanatalapov N and Bushnev A 2018 Asian Journal of Microbiology Biotechnology and Environmental Sciences 20(4) 1163-9
[7] Zheryakov E V et al. 2012 Productivity of sunflower hybrids depending on seeding rates Young scientist 10(45) 421-4