Sunflower productivity dependence on inter-row cultivation methods

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Abstract. Currently using the system Clearfield combined with other technologies of cultivation, given the state of the fields, soil and climatic conditions, the availability of soil mineral nutrients is a promising direction in the cultivation of sunflower in the Lower Volga region. In this regard, the experience of studying various technologies of cultivation for sunflower hybrids was laid on ordinary chernozems. The highest biological yield on average for 2015-2017 was created in the hybrid Mowgli with the herbicide Eurolighting fungicide Pictor with the introduction of liquid complex fertilizer in the phase of 2-4 leaves at the rate of 120 l/ha. On average, it was 2.57 t/ha in terms of repetitions. The lowest biological yield of sunflower was obtained from the Bosphorus hybrid with the herbicide Gezagard and the fungicide Thanos without the use of mineral fertilizers and was 1.61 t/ha. According to the factor B "Mineral fertilizers" in the control variants the average yield was 1.55 t/ha. In the variants with the introduction of NP (12:52) 80 kg/ha of ammonium, the average yield was 1.99 t/ha. In the variants with spraying in the phase of 5-6 leaves of liquid complex fertilizer NP (11:37) 120 l/ha, the average yield was 2.13 t/ha.

1. Introduction

The main features of the sunflower cultivation main regions natural conditions are aridity without a clear association with certain summer periods, high temperatures, and the predominance of heavy to varying degrees saline soils in arable land, characterized by high density and high connectivity. Hence, the correct system of care work for sunflower crops is primarily aimed at constant replenishment, conservation and rational use of all precipitation [1].

The correct choice of caring methods for sunflower crops in combination with other agricultural techniques allows, on the one hand, to replenish the water balance of the soil by reducing snow removal and runoff of meltwater and rainwater, and on the other - to sharply reduce unproductive water consumption from the soil by reducing diffuse-convection evaporation of moisture [2, 3].

Previously, sunflower was cultivated according to the usual, so-called traditional technology. At first, they were varieties. Then there were hybrids, which were marked by increased productivity in comparison with varieties, higher technological efficiency, alignment. The system of crop care was mainly agrotechnical and consisted of inter-row cultivation and hoeing. In the future, with the development of chemical means of protection, and in particular herbicides and fungicides, more often began to use chemical control measures [4, 5, 6].

The infestation took place in the sunflower fields, but was not so common. The fight against it was mainly reduced to observing the correct crop rotation – the return of sunflower to the field no earlier...
than 6-8 years. About 10 years ago, the Clearfield system appeared, based on the use of the herbicide Eurolighting, which suppresses infestations and hybrids resistant to this herbicide. Later, the milder herbicide Eurolighting Plus appeared and the system became known as Clearfield Plus [7, 8, 9].

Currently using the system Clearfield combined with other technologies of sunflower cultivation, given the specific state of the fields, soil and climatic conditions, the availability of soil mineral nutrients is a promising direction in the cultivation of sunflower in the Lower Volga region [10, 11].

2. Materials and methods

The research was carried out from 2015 to 2017 at the experimental field in LLC "Agroproduct" of the Kikvidzensky district of the Volgograd region. The experience diagram is: factor A “Hybrids with a system of protection against weeds and diseases” (1 - Mowgli KL OL hybrid with Eurolighting herbicide and Thanos fungicide; 2 - Mowgli KL OL hybrid with Eurolighting herbicide and Pictor fungicide; 3 - a hybrid of the Bosphorus with Gezagard herbicide and Thanos fungicide) and factor B “Mineral fertilizers” (1 - control without fertilizers; 2 - when sowing: ammonophos NP (12:52) 80 kg/ha; 3 - in the phase of 2-4 leaves: liquid complex fertilizer (LCF) NP (11:37) 120 l/ha).

The experience is deployed in time and space. The repetition of the experience is 3-fold. The scheme of the experiment is based on the method of split plots, the total area of plots of the first order is 756 m$^2$ (25.2 × 30 m), the total area of plots of the second order is 252 m$^2$ (8.4 × 30 m), the accounting area is 156 m$^2$ (6 × 26 m).

The laying of the experiment, observations and accounting were carried out in accordance with the methodology of field experiments by B.A. Dospekhov (1985). When conducting specific observations, appropriate methods were used.

Sunflower in the experiment was sown in the crop rotation after winter wheat. According to all variants of the experiment, sunflower was grown by using direct seeding technology, so no soil treatments were carried out after harvesting winter wheat. But in August, the continuous herbicide Hurricane Forte was sprayed with a rate of 3 liters per hectare and a working fluid consumption of 200 liters per hectare.

In winter, due to the stubble of winter wheat left on the surface of the field, there was an additional accumulation of snow. In the spring, no soil treatments were also carried out. The field was divided into plots and repetitions. Sunflower sowing was carried out by the Italian seeder for row crops "Gaspardo" in the optimal agrotechnical terms, when the soil temperature at the depth of seeding (6-8 cm) reached 8 °C. Sowing was carried out with a seeding rate of 55 thousand plants per hectare.

The innovative technology of sunflower cultivation is system Clearfield. Translated from English, it means "pure field". This system fully justifies its name, because it allows to get almost clean crops even in heavily clogged fields.

This is a unique combination of the herbicide Eurolighting, which contains two active substances of the imidaazolinone class, and high-yielding hybrids resistant to this herbicide and obtained by traditional breeding methods without the use of genetic engineering.

The care of the crops was carried out according to the scheme of the experiment. The control of weeds in sunflower crops on plots of the first order in the first and second variants was carried out with the herbicide Eurolighting in the phase of 2-4 leaves of 1.2 l/ha, in the third variant with the herbicide Gezagard to seedlings of 1.2 l/ha. The disease control in the first and third variants was carried out with the help of the fungicide Thanos, in the second variant - with the help of the fungicide Pictor.

Mineral fertilizers were also applied to the plots according to the scheme of the experiment. In the second variant of plots of the second order, when sowing by seeders, ammonophos NP (12:52) 80 kg/ha was introduced, in the plots of the third variant of the second order, in the phase 2-4 of leaves, the LCF NP (11:37) 120 l/ha was sprayed.
3. Results and discussion
On average, for three years of research, the soil density in the spring in a layer of 0-0.3 m from 2015 to 2017 before sowing sunflower was in the range of 1.22 t/m$^3$, in the phase of 4-6 leaves - 1.25 t/m$^3$, in the phase of basket formation - 1.27 t/m$^3$, to harvest - 1.34 t/m$^3$ (Table 1).

| Definition time               | 2015       | 2016       | 2017       | Average   |
|------------------------------|------------|------------|------------|-----------|
| Before sowing                | 1.24       | 1.21       | 1.22       | 1.22      |
| 4-6 leaves                   | 1.27       | 1.25       | 1.24       | 1.25      |
| Phase of baskets formation   | 1.29       | 1.26       | 1.26       | 1.27      |
| After harvesting             | 1.35       | 1.33       | 1.34       | 1.34      |
| LSD$_{05}$                   | 0.004      | 0.006      | 0.004      |           |

The soil density in the experiment in all the years of research did not depend on the studied technologies of sunflower cultivation "Hybrids with a system of protection against weeds and diseases" (Hybrid Mowgli KL OL with herbicide Eurolighting and fungicide Thanos; Hybrid Mowgli KL OL with herbicide Eurolighting and fungicide Pictor; Hybrid of the Bosphorus with herbicide Gezagard and fungicide Thanos) and the use of mineral fertilizers. The difference in the options was within the error of experience.

In addition to the density of the soil, its important agrophysical indicators are also the total and capillary porosity.

In our studies, the values of the total borehole (porosity) on average for the sunflower growing season in all years of research with direct sowing, i.e. without basic tillage, were beyond the optimal limits, starting from the basket formation phase and further until the end of the growing season.

On average, over the three years of research, the total borehole rate in spring in the layer of 0-0.3 m before sowing was within 51.6%, in the phase of 4-6 leaves - 51.1%, in the phase of basket formation - 49.7%, and by harvesting - 49.2% (Table 2).

| Definition time               | 2015       | 2016       | 2017       | Average   |
|------------------------------|------------|------------|------------|-----------|
| Before sowing                | 51.3       | 51.9       | 51.7       | 51.6      |
| 4-6 leaves                   | 50.7       | 51.1       | 51.3       | 51.1      |
| Phase of baskets formation   | 49.3       | 49.9       | 49.9       | 49.7      |
| After harvesting             | 49.1       | 49.1       | 49.3       | 49.2      |
| LSD$_{05}$                   | 0.08       | 0.12       | 0.09       |           |

When comparing technologies of sunflower Mowgli hybrid cultivation by technology Clearfield treatments of the herbicide Eurolighting cultivation and hybrids of the Bosphorus with treatments by the herbicide of Gezagard, was the most clogged crops of sunflower hybrid.

The Bosphorus treated with the herbicide of Gezagard. The difference in the number of weeds ranged from 6 weeds per square meter in 2015 to 10 weeds per square meter in 2017. The difference in weight measurement ranged from 163.9 g/m$^2$ in 2015 to 267.4 g/m$^2$ in 2017, with the increase in infestation being mainly due to infestations.

In the analysis of the weeds spreading in the cultivation of sunflower Mowgli hybrid technology Clearfield treatments of the herbicide Eurolighting cultivation and hybrids of the Bosphorus with treatments with the herbicide of Gezagard on average over three years of research from 2015 to 2017, the difference in the number of weeds was between 7.0 pcs/m$^2$ in the cultivation of sunflower without fertilizers to 7.3 pcs/m$^2$ in the cultivation of sunflower with the introduction of LCF is based 120 kg/ha.
in the phase of 2-4 leaves and up to 7.7 pcs/m² in the cultivation of sunflower with the introduction of ammophos rate of 80 kg/ha at planting.

The difference in the amount of broomrape ranged from 7.0-7.3 pcs/m² when cultivating sunflower without fertilizers to 7.0 pcs/m² when cultivating sunflower with the introduction of housing and communal services at the rate of 120 kg/ha in the phase of 2-4 leaves and up to 7.0-7.4 pcs/m² when cultivating sunflower with the introduction of ammophos at the rate of 80 kg/ha when sowing.

To determine the area of the leaves, a die-cut method was used, a plate with an area of 50 cm² (5 × 10 cm) was used. 20 leaves were cut and weighed. Knowing the weight and area of the cuttings, as well as the total weight of the leaves, the leaf area of the entire sample was determined, followed by conversion to the density of standing plants per hectare.

At the beginning of the growing season, the formation of the leaf apparatus is slow. At this time, it is still difficult to notice the advantage of a particular agricultural approach. Noticeable differences in leaf area between variants are observed only from the basket formation phase. During the three years of research from 2015 to 2017, the leaf area in this phase ranged from 13.5 thousand m²/ha for the Bosphorus hybrid with the Gezagard herbicide and the Thanos fungicide without the use of fertilizers to 16.8 thousand m²/ha of the Mowgli hybrid on the variant with the herbicide Eurolighting, the fungicide Pictor and the use of housing and communal services in the phase of 2-4 leaves at the rate of 120 l/ha.

By the flowering phase, the leaf area increased in all variants and reached its maximum values. The difference between the options for factor A in this phase was 0.3-2.1 thousand m²/ha, and the difference between the options for factor B was 0.7-3.4 thousand m²/ha. The largest leaf area was formed in the hybrid Mowgli on the variant with the herbicide Eurolighting, fungicide Pictor and the use of housing and communal services in the phase 2-4 of leaves at the rate of 120 l/ha and was equal to an average of 27.9 thousand m²/ha over 3 years. The smallest leaf area in the flowering phase was formed in the Bosphorus hybrid on the variant with the herbicide Gezagard and the fungicide Thanos without the use of fertilizers and was equal to 23.7 thousand m²/ha. Further, there was a decrease in the leaf area (Table 3).

Thus, the leaf area in our experiments depended on both the sunflower protection technology and the use of mineral fertilizers.

Table 3. The magnitude of photosynthetic capacity (average for the period of 2015-2017).

| Factor A                                      | Factor B                      | The duration of the emergence - the maturation of the day | Maximum leaf area, thousand m²/ha | FP, thousand m² day/ha |
|-----------------------------------------------|-------------------------------|--------------------------------------------------------|----------------------------------|------------------------|
| Hybrid Mowgli with Eurolighting herbicide Thanos fungicide | without fertilizers \(\text{ammophos } 80\) kg/ha LCF \(120 \text{ l/ha}\) | 131 | 24.2 | 1585 |
| Hybrid Mowgli with herbicide Eurolighting fungicide Pictor | without fertilizers \(\text{ammophos } 80\) kg/ha LCF \(120 \text{ l/ha}\) | 131 | 24.5 | 1605 |
| Hybrid Bosphorus with Gezagard herbicide and fungicide Thanos | without fertilizers \(\text{ammophos } 80\) kg/ha LCF \(120 \text{ l/ha}\) | 136 | 27.9 | 1897 |
|                                               |                               | 123 | 23.7 | 1458 |
|                                               |                               | 125 | 25.1 | 1569 |
|                                               |                               | 128 | 25.8 | 1651 |
Determination of the photosynthetic potential in sunflower crops of Mowgli and Bosphorus hybrids showed that the greatest photosynthetic potential was accumulated in the Mowgli hybrid on the variant with the herbicide Eurolighting, the fungicide Pictor and on average for 2015-2017 was from 1605 to 1897 thousand m² per day/ha depending on the application of fertilizers. In the hybrid Mowgli variant with the herbicide Eurolighting, the fungicide Thanos, the photosynthetic potential was 20-54 thousand m² per day/ha less. In the Bosphorus hybrid variant with the herbicide Gezagard and the fungicide Thanos the photosynthetic potential on average for 2015-2017 was 127-192 thousand m² per day/ha is less than that of the Mowgli hybrid on the variant with the herbicide Eurolighting, the fungicide Thanos and on 147-246 thousand m² per day/ha is less than that of the Mowgli hybrid on the variant with the herbicide Eurolighting, the fungicide Pictor.

According to factor B the lowest photosynthetic potential was in the control variant without fertilizers from 1458 to 1605 thousand m² per day/ha depending on the hybrid and the technology of protection against weeds and diseases. In the variant with the introduction of ammophos 80 kg/ha during sowing, the photosynthetic potential was 111-177 thousand m² per day/ha more, depending on the hybrid and the technology of protection against weeds and diseases. In the variant with the introduction of LCF 120 kg/ha in the phase of 2-4 leaves, the photosynthetic potential was 82-115 thousand m² per day/ha more than in the variant with the introduction of ammophos and 193-292 thousand m² per day/ha and is more than in the version without mineral fertilizers.

The average for the years 2015-2017, the density of the hybrid Mowgli with herbicide Eurolighting fungicide Thanos, the hybrid Mowgli with herbicide Eurolighting fungicide Pictor and hybrid of the Bosphorus with the herbicide, and fungicide Gezagard Thanos cleaning was almost the same and was in average years of research within 45.0 is 45.2 thousand pieces/hectare.

The number of seeds in the basket changes in hybrids of various technologies to protect themselves from disease, and also depended on the number and methods of mineral nutrients application.

The least number of seeds in the basket were formed hybrid of the Bosphorus with Gezagard herbicide and fungicide Thanos without the use of mineral fertilizers – 667 pcs, and the highest - 1018 pcs the hybrid Mowgli with herbicide Eurolighting fungicide Pictor with the introduction of LCF in the phase of 2-4 leaves from the calculation of 120 l/ha.

The mass of 1000 seeds ranged from 53.7 g of hybrid of the Bosphorus with Gezagard herbicide and fungicide Thanos without the use of mineral fertilizers to 55.9 g of hybrid Mowgli with herbicide Eurolighting fungicide Pictor with the introduction of LCF in the phase of 2-4 leaves from the calculation of 120 l/ha.

The mass of oilseeds from the basket varied from 35.8 g in the Bosphorus hybrid with the herbicide Gezagard and the fungicide Thanos without the use of mineral fertilizers to 56.9 g in the Mowgli hybrid with the herbicide Eurolighting and the fungicide Pictor with the introduction of LCF in the phase of 2-4 leaves at the rate of 120 l/ha.

As the result, the highest biological yield on average for 2015-2017 was created in the hybrid Mowgli with the herbicide Eurolighting fungicide Pictor with the introduction of LCF in the phase of 2-4 leaves at the rate of 120 l/ha. On average, it was 2.57 t/ha in terms of repetitions.

The lowest biological yield of sunflower on average for 2015-2017 was obtained from the Bosphorus hybrid with the herbicide Gezagard and the fungicide Thanos without the use of mineral fertilizers and was 1.61 t/ha.

If we consider the yield of sunflower on the experimental plot on average for 2015-2017 according to the factor B "Mineral fertilizers", it should be noted that in the control variants, that is, without fertilizers, the average yield was 1.55 t/ha. In the variants with the introduction of NP (12:52) 80 kg/ha of ammophos during sowing, the average yield was 1.99 t/ha, that is, 0.44 t/ha more than in the control variant. In the variants with spraying in the phase of 5-6 leaves of LCF NP (11:37) 120 l/ha, the average yield was 2.13 t/ha, that is by 0.58 t/ha more than in the control variant and 0.14 t/ha more than in the variants with the introduction of NP (12:52) 80 kg/ha during sowing (Table 4).
Table 4. Sunflower yield.

| Variants | 2015  | 2016  | 2017  | Average |
|----------|-------|-------|-------|---------|
| Hybrid Mowgli with Eurolighting herbicide Thanos fungicide | | | | |
| without fertilizers | 1.32  | 1.62  | 1.83  | 1.59    |
| Ammophos      | 1.74  | 2.05  | 2.30  | 2.03    |
| LCF           | 1.85  | 2.18  | 2.45  | 2.16    |
| Hybrid Mowgli with herbicide Eurolighting fungicide Pictor | | | | |
| without fertilizers | 1.35  | 1.67  | 1.91  | 1.64    |
| Ammophos      | 1.79  | 2.13  | 2.42  | 2.11    |
| LCF           | 1.92  | 2.29  | 2.60  | 2.27    |
| Hybrid Bosphorus with Gezagard herbicide and fungicide Thanos | | | | |
| without fertilizers | 1.17  | 1.45  | 1.64  | 1.42    |
| Ammophos      | 1.58  | 1.87  | 2.09  | 1.85    |
| LCF           | 1.66  | 1.98  | 2.20  | 1.95    |

2015 LSD05 A = 0.02 t/ha; IN LSD05 = 0.05 t/ha; LSD05 AV = 0.04 t/ha;
2016 LSD05 A = 0.02 t/ha; IN LSD05 = 0.05 t/ha; LSD05 AV = 0.04 t/ha;
2017 LSD05 A = 0.02 t/ha; IN LSD05 = 0.05 t/ha; LSD05 AV = 0.04 t/ha.

The highest oil content in average of three years of research observed for hybrid Mowgli with herbicide Eurolighting fungicide Pictor with the introduction of LCF in the phase of 2-4 leaves from the calculation of 120 l/ha and accounted to 49.2%. The lowest oil content was observed in the hybrid of the Bosphorus with Gezagard herbicide and fungicide Thanos without the use of mineral fertilizers and it was 47.5%.

The highest oil harvest was observed in the cultivation of the hybrid Mowgli with the herbicide Eurolighting fungicide Pictor with the introduction of LCF in the phase of 2-4 leaves at the rate of 120 l/ha, on average for three years of research it was 1116.8 kg/ha. The lowest oil harvest was observed when cultivating a hybrid of the Bosphorus with the herbicide Gezagard and the fungicide Thanos without the use of mineral fertilizers and amounted to 674.5 kg/ha.

4. Conclusion

Summarizing the results of the research on improving the technology of sunflower cultivation in the chernozem zone of the Lower Volga region with direct sowing in 2015-2017, we can recommend the production of cultivating a hybrid of sunflower Mowgli according to the Clearfield system with the herbicide Eurolighting at the rate of 1.2 l/ha and the fungicide Pictor at the rate of 0.5 l/ha. As mineral fertilizers, housing and communal services in the phase of 2-4 leaves at the rate of 120 l/ha are used.

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