The cultivation of *Sorghum Bicolor* using no-till technology and a complex biological substance

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**Abstract.** This research is aimed at studying the influence of no-till technology on the cultivation of *Sorghum bicolor* using a complex biological substance in comparison with traditional technology. Such parameters as growth and development of plants, yield, the quality of crops based on the quality of previous winter barely crops are considered. The research was carried out in 2016–2018 during a stationary experiment in the steppe of Crimea. The soil of an experimental plot is represented by a mycelial-calcareous black soil. The plough layer contains 4.4 mg of movable phosphates and 39.1 mg of exchangeable potassium per 100 g of soil. The weighted pH average is 7.5. The climate of the steppe agroclimatic region is extremely continental. The annual precipitation is 413 mm. The annual temperature is 10.4 °C.

The yield of sorghum cultivated with traditional methods was 1.51 t/ha and 1.44 t/ha in the case of no-till technology (the least significant difference at 0.5 is 0.21 t/ha). That means there is no decrease in yield in terms of direct seeding. Despite the lack of tilling in case of direct seeding, the yield is on the same level with both techniques. The use of a complex biological substance increased the yield of sorghum by 0.11 t/ha. The inoculation of seeds in the case of no-till technique helped to positively increase the yield by 0.22 t/ha in comparison with classic technology. In the case of traditional methods, the inoculation of seeds in the biological substance didn’t impact the yield. The mass fraction of ash varied depending on the studied variants from 2.40% to 2.58%, which didn’t provide a positive increase in this parameter. The traditional method, accompanied by the use of a microbial substance, gave a positive increase in the mass fraction of protein by 1.34% in comparison with a control sample and by 1.66% in comparison with direct seeding, accompanied by inoculation. The content of crude fat varied between 3.34% and 4.43%. In the case of no-till + inoculation, this parameter is 0.53% higher than in the case of no-till without inoculation. The traditional seeding with and without inoculation positively decreased the content of crude fat in comparison with direct seeding.

1. **Introduction**

*Sorghum* (*Sorghum bicolor* (L.) Moench) is a perspective grain crop used as food by millions of people in the world. It is used in different industrial sectors, forage and biofuel production [1, 2].

*Sorghum* is undemanding for the conditions of precipitation. It handles long dry periods well and is one of the most drought-resistant crops in the world [3, 4]. This is due to an extensive root system that has a high suction power. At the same time, the crop gives a big yield when properly irrigated [5]. In
the south of Russia sorghum gives stable harvests even after dry periods if there are rains in the second part of summer [6].

A huge amount of research that recommended tilling technologies for different field crops in various agroclimatic zones and for different soils was carried in Russia. It should be noted that tilling is the costliest technological operation which accounts for 30–35% of all expenses for field crops cultivation. Thus, there is a great interest in no-till technologies currently. In this case, all the weeds are eliminated by glyphosates, while seeding is done by special seed drills used for direct seeding with disk or hoe openers [7, 8].

The recreation of soil fertility can be achieved by introducing biological principles in agriculture, one of which is the use of microbial substances [9].

However, there are no research papers that would describe the influence of direct seeding accompanied by the use of different micro-organisms on different parameters of plants, e.g. yield, in the south of Russia, including sorghum. Thus, this research is aimed at studying the influence of no-till technology on the cultivation of *Sorghum bicolor* using a complex biological substance in comparison with traditional technology. Such parameters as growth and development of plants, yield, the quality of crops based on the quality of previous winter barely crops are considered.

2. Methods and conditions.

The stationary experiment according to B.A. Dospekhov methodology aimed at studying the agricultural systems was started in 2015 on the field of Research Institute of the Agriculture of Crimea, located in the village of Klepinino in the steppe region of Crimea. [10]. The following results are for 2016–2018. The soil of the experimental plot is represented by a mycelial-calcareous black soil above loessoid light clays, containing 2.2–2.5% humus. It is characterised by high microaggregation. The dispersion ratio is between 2.3–5.6. The groundwaters are at the depth of 60 m and they don’t influence the soil formation processes. The plough layer contains 4.4 mg of movable phosphates and 39.1 mg of exchangeable potassium per 100 g of soil. The weighted pH average is 7.5. The annual precipitation is 428 mm. The annual temperature is 10.4 ºC. The climate of the steppe agroclimatic region is extremely continental [11].

The experiments involved the Krimbel variety of sorghum bred by the Academy of Biological Resources and Environmental Management of V.I. Vernadsky Crimean Federal University. The experiment is carried out with three-time repetition. The area of plots is 300 m², while the accounting area is 50 m². The observations and calculations were carried out based on common methods. The sorghum in the experiments with both technologies was preceded by winter barley.

The soil in control experiment that involved traditional methods was tilled based on the recommendations given in [12]. The direct seeding was carried out based on recommendations in [13]. The direct seeding didn’t involve any tilling. Weeds were eliminated by the herbicides, for example, Fakel that was used in the form of water solution (360 g of glyphosate per litre) with the ratio of 2 litres per hectare. The herbicide was applied after harvesting the previous crop (winter barley), the appearance of weeds and drops and after seeding. If the number of weeds in the sorghum tillering period was higher than a set threshold, the area was treated by Balerina herbicide in the form of emulsion (2.4-D (2-Ethylhexyl ether), 410 grams per litre + Florasulam, 7.4 g/l) with the ratio of 0.4 litres per hectare. The Kinfos insecticide was used against aphids (Bethe-cypermethrin 40 g/l + Dimetato 300 g/l) with the ratio of 0.25 l/ha. Before harvesting the Fakel herbicide was applied again in the form of water solution (360 g of glyphosate per litre) with the ratio of 2 litres per hectare.

Fertilizers in the N<sub>45</sub>P<sub>40</sub> norm were applied during the pre-seeding cultivation in the case of traditional methods and during the direct seeding. In both cases the seeding ratio was 130 thousand seeds per 1 ha, applying different seeders: CH-16 (traditional technique) and Gherardi G-117 (direct seeding). The depth was 5–6 cm.

The seeding was carried out when the temperature of the soil at the depth of 10 cm reached 14 ºC which happened in the third decade of April (2016 and 2018) and the first decade of May (2017).
The impact of a complex biological substance on crops was also studied. To do this the seeds on the half of plots were treated with a complex biological substance, and the seeds of the second half were treated by a chemical dresser [14]. The dresser contains several components.

1. Associative nitrogen-fixing micro-organisms that improve the nitrogenous nutrition of plants, increase the nitrogen-fixing potential and the resistance of plants to biotic and abiotic stress factors, stimulate the growth and development of plants.
2. Micro-organisms that mobilize hard to access phosphates, increase the use factor of phosphorous fertilizers and soil phosphates, stimulate the growth and development of plants.
3. Micro-organisms that suppress the growth of plant pathogenic fungi and bacteria. Their impact is not weaker than that of chemical dressers.

The parameters of growth and development of sorghum were determined based on the state methodology of variety testing for agricultural plants [15].

The evaluation of yield was carried out based on the methodology by B.A. Dospekhov [10].

The quality of grains was evaluated based on the hands-on manual on agriculture chemistry [16].

The weather conditions during the research are shown in Table 1.

The average temperature for the vegetation of sorghum in different years was 19.4; 19.3 and 20.4 °C with the long-time annual average equal to –19.2 °C i.e. higher by 0.2; 0.1; 1.2 °C respectively.

Table 1. The weather conditions during the research on sorghum, 2016–2018 (the meteorological station in the village of Klepinino), years

| Month   | The average daily temperature, °C | The precipitation during vegetation, mm. |
|---------|----------------------------------|-----------------------------------------|
|         | 2016    | 2017    | 2018    | 2016 | 2017 | 2018 |
| April   | 13.0    | 9.3     | 13.2    | 33.4 | 39.9 | 3.10 |
| May     | 15.7    | 15.7    | 19.0    | 146.6| 23.6 | 15.6 |
| June    | 21.4    | 21.4    | 22.7    | 209.9| 20.5 | 46.3 |
| July    | 23.6    | 23.8    | 24.1    | 24.4 | 12.6 | 136.8|
| August  | 25.1    | 25.1    | 25.1    | 22.5 | 53.2 | 4.3  |
| September | 17.6  | 20.5    | 18.8    | 85.1 | 0.1  | 88.8 |
| Per vegetation | 19.4 | 19.3    | 20.4    | 521.9| 149.9| 294.9|

The distribution of precipitation in different years of research was uneven and scarcely favourable for the growth and development of sorghum. The rainfall in 2016 was 521.9 mm, but 75% of this amount was in April and June, followed by the period of drought with the precipitation equal to the half of the norm. The smallest amount of rainfall was in 2017 which amounted for 149.9 mm. This is 1.7 times smaller than the long-time annual average, which influenced the growth and development of sorghum negatively. The year 2018 was also uneven in precipitation. There was almost no rain before sowing in April. Its amount in May was 1/3 of the norm which resulted in the lack of moisture in the seed layer during sowing. Abundant rainfall was only during the vegetation in the second part of summer.

The sorghum was harvested by Sampo-500 harvester, equipped by a debris pulverizer and a chaff spreader, that spreads the leftovers of preceding crops evenly on a field. The results were interpreted using the analysis-of-variance method by B.A. Dospekhov [10].

3. Results

In average the biometric features of sorghum during the three-year research of applying different cultivation techniques had the following characteristics: the height of plants and the length of heads didn’t have a significant difference (Table 1). The mass of heads in the case of plants cultivated based
on traditional technique was 41.7 g/m² bigger than that of those cultivated based on no-till technology. Similarly, the mass of crops from 1 m² was 35.7 g/m² bigger in the first case than in the second one.

With the complex biological substance applied there was no positive difference in biometric parameters of growth and development on average for the years of research.

**Table 2.** The impact of seeds inoculation in the complex biological substances on the growth and development of sorghum in the cases of different techniques of cultivation, 2016–2018.

| Cultivation technique (Factor A) | Seeds inoculation in CBS (Factor B) | Parameters |
|---------------------------------|------------------------------------|------------|
|                                 |                                     | The height of plants, cm | The length of a head, cm | The mass of a head, g/m² | The mass of grains in a head, g/m² | The mass of 1 plant, g |
| Traditional system A1           | B1 – without treatment              | 101        | 19.7   | 140  | 104  | 130  |
|                                 | B2 – treatment by CBS               | 96.0       | 20.0   | 147  | 118  | 131  |
| The average based on A1 factor  |                                     | 98.5       | 19.8   | 143  | 111  | 130  |
| No-till A2                      | B1 – without treatment              | 103        | 19.7   | 100  | 77.1 | 152  |
|                                 | B2 – treatment by CBS               | 103        | 20.0   | 102  | 73.5 | 155  |
| The average based on A2 factor  |                                     | 103        | 19.8   | 101  | 75.3 | 153  |
| The average based on B factor   | Without treatment                   | 102        | 19.7   | 120  | 90.9 | 141  |
|                                 | Treatment by CBS                    | 99.5       | 20.0   | 125  | 96.0 | 137  |
| The least significant difference | A                                   | 8.44       | 1.81   | 25.8 | 22.1 | 25.4 |
|                                 | B                                   | 8.34       | 1.86   | 16.2 | 12.9 | 20.8 |
|                                 | AB                                  | 11.8       | 2.56   | 36.6 | 31.3 | 28.8 |

CBS* – complex biological substance

**Table 3.** The impact of pre-sowing treatment of seeds in the complex biological substances on the mass of 1000 grains and the yield of sorghum in the cases of different techniques of cultivation, 2016-2018

| Cultivation technique (Factor A) | Seeds inoculation in CBS (Factor B) | Parameters |
|---------------------------------|------------------------------------|------------|
|                                 |                                     | The mass of 1000 grains, g | Yield, t/ha |
| Traditional system A1           | B1 – control sample                | 22.7       | 1.51  |
|                                 | B2 – treatment by CBS               | 23.2       | 1.52  |
| A1 average                      |                                     | 22.9       | 1.51  |
| No-till A2                      | B1 – control sample                | 23.3       | 1.33  |
|                                 | B2 – treatment by CBS               | 23.1       | 1.55  |
| A2 average                      |                                     | 23.2       | 1.44  |
| B1 average                      |                                     | 23.0       | 1.42  |
| B2 average                      |                                     | 23.1       | 1.53  |
| The least significant difference | A                                   | 0.34       | 0.21  |
|                                 | B                                   | 0.34       | 0.09  |
|                                 | AB                                  | 0.48       | 0.20  |
Table 3 represents the data on the mass of 1000 seeds from one plant. In this case, there is no difference between the two studied cultivation techniques. With the complex biological substance, the mass of 1000 seeds in the control sample was 23.0 g and 23.1 g in the case of inoculation which can’t indicate a positive increase.

The main parameter that defines the effectiveness of different agricultural techniques is yield. As a result of 2016–2018 research the yield of crops cultivated based on the traditional technique was 1.51 t/ha, while in case of no-till technique it was 1.44 t/ha (the least significant difference (0.5) − 0.21 t/ha) i.e. the direct seeding didn’t decrease the yield.

The use of a complex biological substance increased the yield of sorghum by 0.11 tonnes per hectare. The inoculation of seeds in the case of no-till technique helped to positively increase the yield by 0.22 tonnes per hectare in comparison with classic technology. In the case of traditional methods, the inoculation of seeds in the biological substance didn’t impact the yield.

The mass fraction of ash varied depending on the studied variants from 2.40% to 2.58%, which didn’t provide a positive increase in this parameter (Table 4).

The traditional method, when the seeds were treated by a microbial substance, gave a positive increase in the mass fraction of protein by 1.34% in comparison with the uninoculated sample and by 1.66% in comparison with direct seeding, accompanied by inoculation.

The content of crude fat varied between 3.34% and 4.43%. In the case of no-till + inoculation, this parameter is 0.53% higher than in the case of no-till without inoculation. The traditional seeding without inoculation positively decreased the content of crude fat in comparison with direct seeding.

**Table 4.** The impact of inoculation in the complex biological substance on the sorghum quality parameters and the content of chemical elements in the cases of different cultivation techniques, 2016–2018*; 2018**

| The variants of the experiment | The mass fraction of ash, %** | The mass fraction of protein on a dry basis, %* | The mass fraction of crude fat on a dry basis, %** | The mass fraction of total phosphorus P₂O₅ on a dry basis, %** | The mass fraction of total potassium K₂O on a dry basis, %** |
|-------------------------------|-------------------------------|-----------------------------------------------|-----------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Traditional technique without treatment | 2.55±0.25                    | 9.61±0.96                                     | 3.34±0.33                                     | 0.85±0.08                                       | 0.46±0.05                                       |
| Tradition technique + CBS treatment | 2.40±0.24                    | 10.95±1.09                                    | 3.64±0.36                                     | 0.86±0.08                                       | 0.45±0.04                                       |
| No-till without treatment | 2.58±0.26                     | 9.91±0.99                                     | 3.90±0.39                                     | 0.82±0.08                                       | 0.48±0.05                                       |
| No-till + inoculation | 2.48±0.25                     | 9.33±0.93                                     | 4.43±0.44                                     | 0.82±0.08                                       | 0.43±0.04                                       |

There wasn’t a positive increase in the mass fraction of total phosphorus and potassium in respect to all for variants studied. There is an opinion that using direct seeding in the first 5 years (the first stage) is a critical period for this technology. It is supposed that there is a decrease in the yield of agricultural plants and the quality of agricultural products as well as other negative things in the initial period of implementing no-till technology [17]. In the case of our three-year research on direct seeding, there is a trend for the decrease in yield and the quality of sorghum. To fully understand the issue, we will continue the research and try to find out how the direct seeding influences the yield of sorghum, the quality of crops, and other parameters.
4. Conclusion

1. As average the yield of crops cultivated based on the traditional technique during the three-years research was 1.51 tonnes per hectare, while in case of no-till technique it was 1.44 t/ha (the least significant difference (0.5), 0.21 t/ha).
2. The use of a complex biological substance increased the yield of sorghum by 0.11 tonnes per hectare.
3. The inoculation of seeds in the case of no-till technique helped to positively increase the yield by 0.22 tonnes per hectare in comparison with classic technology.
4. The traditional method, when the seeds were inoculated by a biological substance, gave a positive increase in the mass fraction of protein by 1.34% in comparison with the uninoculated sample and by 1.66% in comparison with direct seeding, accompanied by inoculation.

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