Research Institute of Irrigated Farming, NAAS

REPORT

on BIO-GEL organic product application to soybean crops in order to reduce pesticide load on the environment and promote agriculture biologization

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Introduction

The cultivation of any agricultural product is associated with industrial technologies that provide crop systemic protection (herbicides, insecticides, fungicides) and fertilization with mineral fertilizers in the calculated dosage for programmable crop. Under irrigation the greatest load on soil is produced by fertilizers and chemical weed and pest killers per hectare as more than half of agricultural lands suffered from chemicals applied in order to keep up artificially the yields, to obtain a certain temporary effect, which in most cases results in the decrease of soil fertility and the environment pollution. The main sources of these undesirable phenomena are chemical weed and pest killers, including herbicides and mineral fertilizers. Therefore, the state of the environment and its negative impact on human health causes considerable concern in society. Recently the interest in organic food has increased in the world.

Organic biological farming is aimed at reducing the negative effects of agricultural chemistry, improving soil fertility and preserving the balance of the plant - animals - humans, that is, the balance between natural conditions and the activities of man.

At the present stage of the agro-industrial complex development in Ukraine a large number of products and technologies are proposed that in one way or another affect the intensity of growth processes.

Over the past years national and foreign scientists have created fundamentally new highly effective growth regulators that stimulate plant growth processes and significantly contribute to increased grain yield. Most of the scientific research results show that the use of new synthesized compounds and immune response modifiers, stimulants, trace elements can contribute to a significant intensification of agricultural production and preservation of the environment. This allows the use of such products for the development of modern crop cultivation technologies including soybeans.

Therefore of great scientific and practical value is the development of soybean cultivation technologies under irrigation using organic fertilizers. The study of BIO-GEL biologically active product is relevant.

Carrying out such research provides an opportunity to study the effect of biologically active substances on soybean growth and development and the soybean seeds treatment with inoculants. The experimental testing of BIO-GEL application will make it possible to deny the total use of chemicals and to decrease the pesticide load on the environment.

1. Research conditions and methods

1.1 Soil and climatic conditions of the experiment area

Soil and climatic conditions as well as crop cultivation characteristics are of great importance for carrying out the research. The field experiments according to agreement 11 of March, 06, 2017 on the subject “Application of BIO-GEL ecologically friendly organic product to soybean crops in order to decrease pesticide load on environment and to promote environment protection” were made on the fields of the Institute of Irrigated Farming, National Academy of Agrarian Sciences, which are on the Dnieper right bank, Kherson Region.

This is a soil and climatic zone of the southern steppe comprising the southern parts of Odessa, Nikolayev and Zaporozhye regions, the north of the Crimean autonomous republic and the whole territory of the Kherson region, all in all 20.7% of the Ukrainian territory.

The steppe zone soils are mainly black earth, dark chestnut and chestnut. They are quite fertile but are characterized by poor texture, hard mechanical composition, salinity, erosion processes. There are also light-textured sandy and sandy-loam soils with rather low humus content (2-3%). These are poor soils.

Irrigation is ensured by the water from the Ingulets irrigation system. The humus layer of soils is 47-52 cm, the humus content in the 0-25 cm layer is 2.15% (table 1).

Table 1. Content of humus and main plant nutrients in the soil of experimental plot

Soil layer, cm	Humus content, %	Gross nitrogen, %	Gross phosphorous, %	Exchangeable potassium, mg/kg
0-25	2.15	0.183	0.099	340
25-40	1.65	0.159	0.083	276
40-60	1.08	0.116	0.058	229
100-150	0.50	0.047	0.057	231
150-200	0.44	0.055	0.053	235

In lower layers the content of humus is lower, in the 25-40 cm layer its content is 1.65%. The analysis of aqueous extract for the concentration of ions H^+ indicates its proximity to neutrality and is pH = 7.1-7.3. The volumetric mass of 0-200 centimeters of soil layer is 1.43 g / cm^3. Ground water within the experimental field lies at a depth of more than 15 meters and has no effect on the moisture regime of the upper root layer. When dry, the soil is characterized by high density, low permeability and susceptibility to swelling. Soil porosity at the 0-40 cm depth is 47%. The experiment was carried out on irrigated lands.

From the above data it is clear that the soil of the experimental field is characterized by low content of humus in the arable layer, low nitrogen content, medium phosphorus content and high potassium content. In order to ensure the optimum level of plant nutrition and compensate the insufficient content of nitrogen and phosphorus, it is necessary to apply mineral and organic fertilizers containing these elements. The content of exchangeable potassium is high enough and its addition with fertilizers is not required.

Insufficient rainfall during most of the years, low relative humidity, frequent hot dry wind, warm autumn and winter, long frost-free period are characteristic of the southern Ukrainian steppe zone climate. One of the most important components of climate - precipitation - is unstable in terms of both its distribution and its intensity during the vegetation period. Most of the rainfall comes in warm period. In summer the amount of precipitation is 34-40% of the yearly rate. The precipitation cannot be consumed by plants in full because it often falls as shower, sometimes as hail. Thus in most cases it wets soil insufficiently. A significant part of rainfall evaporates immediately. Dry periods lasting 50-60 days are quite frequent as well. According to the long-term observations by Kherson meteorological station the frost-free period lasts 180-190 days. The sum of active air temperature varies within 9.7-11.7^{0}C, and in July, the hottest month of the year, it is 21.3-23.0^{0}C above zero. The annual solar radiation is 115- 116 kcal / cm^2 and is quite high. The hydrothermal coefficient which characterizes the relative amount of precipitation before evaporation during the vegetation period in the Kherson region is 0.6-0.7.

The average daily air temperature during the years of research deviated from the average long-term values.

Winter in the southern steppe of Ukraine is short and not snowy. According to many years of observation the average monthly air temperature in January is - 3.2^{0}C (Kherson).

Spring is short (30-50 days) and is characterized by rapid temperature increase. The transition of average daily temperatures over 0^{0}C is observed in early March, and in the third ten-day period of March – first ten-day period of April there is a transition over +5^{0}C. Spring frosts can be observed even in the second ten-day period in April, in some years – in the third ten-day period of May.

Summer in the southern steppes of Ukraine is characterized by hot and dry weather. The average number of days with hot dry winds amounts to 24 but in some years their number can reach 54. Such days according to long-term observations are distributed in the following way: 7 days in April, 8 days in May, 8 days in July, 9 days in August and 5 days in September. The average temperature of the hottest month (July) is +23°C. On some days the temperature reaches 40°C.

Autumn is usually dry and warm. In the first ten-day period of September the temperature is 18.7°C but in the third ten-day period it goes down below 15°C. The first frosts are characteristic of the second half of October but the earliest frosts can happen even on September, 17.

1.2 Weather conditions during the *Aratta* soybean variety vegetation period, 2017

The amount of rainfall during the vegetation period was 78.2 mm, 66.6 mm, or 85.2% falling in May – first ten-day period of July. The rest of the rainfall (11.6 mm, or 14.8%) fell in the second half of soybean vegetation period (third ten-day period of July – September). During the second ten-day period of July and in August there was no rainfall at all. During the vegetation period of July-September 9 vegetation irrigations were conducted, the total rate being 450-500 m^3/ha. For the purpose ДДА-100МА sprinkling machine was used. The main meteorological characteristics are given in table 2.

The first ten-day period in May was characterized by warm weather without any substantial rainfall. The maximum air temperature was 26.7°C, while on the soil surface it was 54.8°C. The minimum air temperature was 7.8°C, on the soil surface it was +6.0°C, while 2 cm above it – 4.0°C. The average temperature in this ten-day period was +17.9°C, which is 3.1°C higher than the normal. The rainfall amount at the end of the ten-day period was 3.9 mm, the norm being 15 mm. The maximum wind speed reached 11 m / s. During the ten-day period 4 days were observed with dew, 2 days with rain and 1 with frost. The meteorological conditions of the period were quite beneficial for crops. Because of the rapid air temperature rise the moisture reserves in the soil gradually diminished.

The second ten-day period of May was characterized by cool and wet weather. The maximum air temperature was +24.1°C, on the soil surface – +48.1°C. The minimum air temperature was +2.2°C, on the soil surface - +0.4°C, 2 cm above the surface – 1.8°C. The average air temperature during the ten-day period was +14.4°C, which is 2.2°C lower than normal. The rainfall amount was 21.0 mm, the norm being 14 mm. The maximum wind speed was 13 m/s. During the period there were 3 days with dew, 4 days with rain and 1 day with thunderstorm and hail. The meteorological conditions of the period were quite satisfactory for crops.

The third ten-day period of May was characterized by warm weather and little rainfall. The maximum air temperature was +27.8°C, on the soil surface – +62.6°C. The minimum air temperature was +6.3°C, on the soil surface - +4.0°C, 2 cm above the surface – 2.9°C. The average air temperature during the ten-day period was +17.2°C, which is 0.2°C lower than normal. The rainfall amount was 0.7 mm, the norm being 13 mm. The maximum wind speed was 10 m/s. During the period there were 4 days with dew, 3 days with rain and 1 day with thunderstorm. The meteorological conditions of the period were quite satisfactory for crops.

The first ten-day period of June was characterized by hot and dry weather. The maximum air temperature was +32.3°C, on the soil surface – +62.6°C. The minimum air temperature was +9.3°C, on the soil surface - +8.6°C. The average air temperature during the ten-day period was +21.1°C, which is 1.9°C higher than normal. The rainfall amount was 1.4 mm, which is 11% of the norm. During the period there were 3 days with dew, hot dry wind and rain. The maximum wind speed was 11 m/s. The meteorological conditions of the period were unsatisfactory for crops.

The second ten-day period of June was characterized by warm and dry weather. The maximum air temperature was +31.3°C, on the soil surface – +59.6°C. The minimum air temperature was +10.7°C, on the soil surface - +10.4°C. The average air temperature during the ten-day period was +20.6°C, which is 1.1° higher than normal. The rainfall amount was 4.4 mm, which is 24% of the norm. During the period there were 2 days with dew, 1 day with hot dry wind, 1 day with thunderstorm and 4 days with rain. The maximum wind speed was 18 m/s. The duration of sunshine was 100.2 hours. The meteorological conditions of the period were unsatisfactory for crops.

The third ten-day period of June was characterized by hot and dry weather. The average air temperature during the ten-day period was +24.3°C, which is 3.1° higher than normal. The maximum air temperature was +33.7°C, on the soil surface – +64.1°C. There were 6 days with temperature of above +30°C or higher. The minimum air temperature was +13.9°C, on the soil surface - +13.0°C. The rainfall amount was 4.5 mm, which is 32% of the norm. The duration of sunshine was 122.6 hours. During the period there were 5 days with dew, 1 day with hot dry wind, 2 days with thunderstorm and 3 days with rain. The maximum wind speed was 11 m/s.

The first ten-day period of July was characterized by warm and hot (at the beginning of the period) weather. On some days during the passage of the cold front, moderate rainstorms were observed. The average air temperature during the ten-day period was +22.0°C, which is 0.7° higher than normal. The maximum air temperature was +34.7°C, on the soil surface – +59.0°C. The minimum air temperature was +12.4°C, on the soil surface - +10.4°C. The rainfall amount was 30.7 mm, the norm being 22 mm. The maximum wind speed was 14 m/s. During the period there were 6 days with dew, 1 day with hot dry wind, and 4 days with rain.

The meteorological conditions of the period for developing the vegetative mass and subsequent growth of plants were mixed. At the beginning of the period dry and hot weather inhibited plant growth as there was severe air and soil drought. Later rainfall and drop in temperature stopped the drought and replenished moisture reserves a bit. But as the rainfall was mainly in the form of showers the moisture reserves were replenished mostly in the upper layer. By the end of the period the amount of moisture both in the arable and in the 1 m soil layer were unsatisfactory. Because of this the leaves of the plant lower layer turned yellow in most plants.

The second ten-day period of July was characterized by hot dry weather. The average air temperature during the ten-day period was +22.4°C, which is 0.1° higher than normal. The maximum air temperature was +32.1°C, on the soil surface – +61.0°C. There were 4 days with temperature of above +30°C or higher. The minimum air temperature was +11.5°C, on the soil surface - +10.2°C. The rainfall amount was 0.0 mm, the norm being 14mm. The duration of sunshine was 120.4 hours. During the period there were 4 days with dew, 2 days with fog and 1 day with scattered rain. The maximum wind speed was 11 m/s.

The third ten-day period of July was characterized by hot dry weather. The average air temperature during the ten-day period was +25.6°C, which is 3.5° higher than normal. The maximum air temperature was +36.8°C, on the soil surface – +65.0°C. There were 9 days with temperature of above +30°C or higher. The minimum air temperature was +16.2°C, on the soil surface - +13.6°C. The rainfall amount was 9.1 mm, the norm being 13mm. The duration of sunshine was 124.8 hours. During the period there were 3 days with hot dry wind, 2 days with rain and 1 day with dew. The maximum wind speed was 11 m/s.

The meteorological conditions for vegetative mass accumulation and development of plants were quite adverse. The rainfall at the end of the period flew down, thus the moisture reserves were not replenished. The hot weather contributed to the spread of pests. Due to air drought drying and falling of unripe beans was noted.

The first ten-day period of August was characterized by hot dry weather. The average air temperature during the ten-day period was +29.0°C, which is 6.6° higher than normal. The maximum air temperature was +40.0°C (05.08), on the soil surface – +66.8°C. There were 10 days with temperature of above +30°C or higher. The minimum air temperature was +17.6°C, on the soil surface - +15.2°C. The duration of sunshine was 126.1 hours. During the period there were 5 days with hot dry wind, 1 day with thunderstorm. The maximum wind speed was 13 m/s. Because of hot dry weather the conditions for plants were very hard. Soil and air drought increased. The 1 m soil layer was almost completely dry, thus imperiling the ripening of late thermophilic crops.

Table 2. Meteorological data, 2017

Month	**10-day period**	**Average air temperature, °C**	**Relative air humidity, %**	**Rainfall, mm**	**Notes**	
					t min	**t max**
May	I	17.2	60	3.9	7.8	26.7
	II	14.4	66	21.0	2.2	24.1
	III	17.2	67	0.7	6.3	27.8
	total	16.3	64	25.6	2.2	27.8
June	I	21.1	59	1.4	9.3	32.3
	II	20.6	62	4.4	10.7	31.3
	III	24.3	63	4.5	13.9	33.7
	total	22.0	61	10.3	9.3	33.7
July	I	22.0	63	30.7	12.4	34.7
	II	22.4	59	0	11.5	32.1
	III	25.6	57	9.1	16.2	36.8
	total	23.4	60	39.8	11.5	36.8
August	I	29.0	50	0	17.6	40.0
	II	27.1	42	1.8	16.4	37.3
	III	20.6	60	0	11.2	35.3
	total	25.4	51	1.8	11.2	40.0
September	I	21.0	65	0	12.9	30.4
	II	23.1	57	0	12.5	35.4
	III	15.6	62	0.7	3.6	32.0
	total	19.9	61	0.7	3.6	35.4

1.3 Methods of research

Object of research: soybean.

Research method: field experiment, laboratory analysis, statistical processing of data.

Aim of experiment: studying the effect of BIO-GEL biologically active product on the *Aratta* soybean variety growth and development, conducting industrial implementation and experimental verification of BIO-GEL product on soybean crops on the farms in the Kherson region, studying the symbiotic nitrogen fixation of soybeans with BIO-GEL applied.

The research was carried out on the *Askaniyske* farm, Kherson region (16 ha), in *UTC-Agroproduct plus* company, Kherson region (17 ha) and at the Institute of Irrigated Farming, NAAS, in three experiments with the *Aratta* soybean variety using *Hortus* soil herbicide (2 l/ha), *Bazagran* postemergent herbicide (bentazon, 480 g/l), *Abacus* herbicide (1.4 l/ha), *Mero* sticking agent (0.8 l/ha) and ABM inoculants (180 g/ha). The experiments were carried out under irrigation.

Experiment 1 scheme (*Aratta* soybean variety)

1. Control (no chemical protection)
2. Treatment with Bazagran postemergent herbicide (benzaton, 480 g/l) (3.0 l/ha)
3. Treatment with Bazagran postemergent herbicide (benzaton, 480 g/l) (1.5 l/ha) + BIO-GEL (1.5 l/ha), herbicide amount is decreased by 50%
4. Treatment with Bazagran postemergent herbicide (benzaton, 480 g/l) (1.8 l/ha) + BIO-GEL (1.5 l/ha), herbicide amount is decreased by 40%
5. Treatment with Bazagran postemergent herbicide (benzaton, 480 g/l) (2.1 l/ha) + BIO-GEL (1.5 l/ha), herbicide amount is decreased by 30%

Experiment 2 scheme (*Aratta* soybean variety)

1. Control (no treatment)
2. Spraying with BIO-GEL at the budding stage (1.5 l/ha)
3. Spraying with BIO-GEL (1.5 l/ha) + fungicide (0.7 l/ha) + sticking agent (budding stage), fungicide amount is reduced by 50%
4. Spraying with BIO-GEL (1.5 l/ha) + fungicide (0.85 l/ha) + sticking agent (budding stage), fungicide is reduced by 40%
5. Spraying with BIO-GEL (1.5 l/ha) + fungicide (1.0 l/ha) + sticking agent (budding stage), fungicide is reduced by 30%
6. Spraying with fungicide (1.4 l/ha) + sticking agent (budding stage).

Experiment 3 scheme (*Aratta* soybean variety)

1. Seed treatment with water (control)
2. Seed treatment with BIO-GEL (1.5 l/t)
3. Seed treatment with ABM
4. Seed treatment with ABM + BIO-GEL (1.5 l/t)
5. Spraying with BIO-GEL at the budding stage (1.5 l/ha)
6. Seed treatment with BIO-GEL (1.5 l/t) + spraying with BIO-GEL at the budding stage (1.5 l/ha)

Determination of weediness was carried out quantitatively. This method consists in putting a frame (1 square meter) on the soil surface diagonally in five locations at equal distances. The number of weeds in each frame is counted.

The assessment of the nitrogen-fixing capacity of soybean plants was carried out by the quantitative and weight method, by selecting monoliths and further counting the number of tubercles in the monolith and determining their mass. From each plot four 0.4 m long monoliths were selected in a row (0.24 m wide) perpendicular to the row at 0.2 m depth. Tubercle recording was performed at the stage of bean filling.

Plant development observation and recording was conducted according to the recommendations: General Unified Classifier [1], All-Russian Institute of feed [2, 3], “Identification of legume characteristics” [4], “Seed infection” [5].

Statistical processing of the obtained data was carried out according to the method of Dospekhov B.A. [6], Volf V. [7], Rokitsky P.F. [8].

Agro-technical conditions for carrying out experiments on farms:

1. *Askaniyske* farm: the farm technology + BIO-GEL at the budding stage (2 l/ha) + at the flowering stage (1.5 l/ha).
2. *UTC-Agroproduct plus* company: reduction of herbicide rate by 40% with BIO-GEL applied (1.5% solution) + the farm technology.

The agro-technical conditions of the experiments made at the Institute of Irrigated Farming were typical of the south of Ukraine. Winter wheat was the precursor. СКС-6-10 sowing machine was used in the experiment. Sowing was performed in the first 10-day period of May. Coming-up was recorded ten days later.

Ammonium nitrate (0.1 t/ha) was applied to the soil, crops were sprayed with the *Hortus* soil herbicide (2 l/ha).

Experiments were conducted in triple repetition. The experimental plots had 4 rows with 0.45 m space between rows. The plot length was 12 m, the total area was 21.6 m^2.

During the vegetation period 9 sprinklings were made using ДДА- 100МА sprinkling machine, the rate being 450-500 m^3/ha.

Harvesting was conducted at the stage of complete ripeness using Сампо-130 harvester combine. The crop was recalculated to standard humidity (14%).

2. Research results

Optimization of soybean mineral nutrition as a nitrogen-fixing crop is one of the most important factors for the formation of favorable conditions both for the fixation of nitrogen from the air and for the process of photosynthesis which depends, first of all, on the presence of available nutrients in the soil. The main reserve for increasing soybean yields is the scientifically based use of the soil nutrient potential, the environment and new soybean varieties [9].

The amount of nutrients used by soybeans from soil depends on many factors: the biological characteristics of the variety, soil fertility, moisture provision, the activity of symbiotic nitrogen fixation, climatic conditions, the intensity of the photosynthetic process, the yields, etc. [10, 11].

There is no doubt about the positive effect of nitrogen on crops but as far as soybeans are concerned, an important source of nitrogen for them is the *Rhizobium* bacteria [12-15]. Therefore along with studying the effect of the BIO-GEL biologically active product on soybeans growth, we studied the possibility of soybean seeds treatment with inoculant and BIO-GEL simultaneously and the soybean symbiotic nitrogen fixation with BIO-GEL applied.

Three field experiments were carried out at the Institute of Irrigated Farming, NAAS, located in the southern steppe zone of Ukraine.

2.1 The effectiveness of the combined action of BIO-GEL biologically active product and *Bazagran* postemergent herbicide on weeds (experiment 1)

Soybeans can poorly resist weeds, especially in the first 40-50 days of vegetation period. Crop losses caused by weediness are much greater than those caused by diseases and pests and amount to 27-36%. Taking into account such great harmfulness of weeds which consume much soil moisture and nutrients, inhibit crop development, of great importance is the application of soil herbicides, especially under irrigation.

Among weeds in irrigated soy crops most dangerous are creeping-rooted weeds (sow thistle, milk thistle, etc), biennial dicotyledon weeds (saltbush, amaranth, ambrosia, field mustard, houndsberry, mayweed, etc) and annual monocotyledonous weeds (wild oat, June grass, etc).

Modern soybean cultivation technologies require such weed protection systems, which can timely and reliably control weediness at the crop early growth stages, while their implementation is environmentally safe and economically viable. Exactly for solving such problems experiment 1 was conducted, it envisaged the study of the soybean chemical protection effectiveness and the possibility of reducing the herbicidal load. So the main goal facing the agriculture of the developed countries is the reduction of pesticides in general and herbicides in particular.

In 2016 while studying this problem BIO-GEL (1 l/ha) was applied in combination with half of the *Bazagran* postemergent herbicide (bentazon, 480 g/l) dose (1.5 l/ha), the result appeared to be positive, so the experiments continued to confirm it. In 2017 instead of 1 l/ha of BIO-GEL, 1.5 l/ha were applied, besides in different variants herbicide rates were reduced by 30-40% (table 3).

On applying the full dose of the *Bazagran* postemergent herbicide (bentazon, 480 g/l) (3.0 l/ha) the herbicide effectiveness compared to the control was 90.6%, while on applying half of the *Bazagran* postemergent herbicide (bentazon, 480 g/l) dose (1.5 l/ha) in combination with BIO-GEL (1.5 l/ha), the herbicide effectiveness in comparison with the control was 85.9%. On decreasing the rate of the postemergent herbicide by 40% the effect increased, on decreasing the rate to 30% the herbicide effectiveness equaled its full rate (table 3).

Analyzing the effect of the *Bazagran* postemergent herbicide (bentazon, 480 g/l) when its rate was decreased by 30-50% and it was used with BIO-GEL (1.5 l/ha) we come to the conclusion that we can reduce the herbicide load by half adding BIO-GEL, the best result being at 30% herbicide reduction.

Table 3. Effectiveness of the *Bazagran* postemergent herbicide (bentazon, 480 g/l), *Aratta* soybean variety, 2017

	Variant, herbicide dose, l/ha	**Weediness before harvesting, pc/m^2**	**Herbicide effectiveness, % to control**
1	Control (no chemicals)	37.7	-
2	*Bazagran* postemergent herbicide (bentazon, 480 g/l), (3.0 l/ha)	3.7	90.2
3	*Bazagran* postemergent herbicide (bentazon, 480 g/l) (1.5 l/ha)+BIO-GEL (1.5 l/ha), herbicide reduction by 50%	5.3	85.9
4	*Bazagran* postemergent herbicide (bentazon, 480 g/l) (1.2 l/ha)+BIO-GEL (1.5 l/ha), herbicide reduction by 40%	4.7	87.6
5	*Bazagran* postemergent herbicide (bentazon, 480 g/l) (0.9 l/ha)+BIO-GEL (1.5 l/ha), herbicide reduction by 30%	3.7	90.2

So when growing soybeans, it is necessary to use Bio-gel (1.5 l / ha) with a 30% reduction in the amount of postemergent herbicide which will reduce environmental pollution and will be economically beneficial.

2.2 Studying BIO-GEL fungicidal effect on the *Aratta* soybean variety (experiment 2)

Recently along with the use of mineral fertilizers and growth regulators, plant protection products and in particular fungicides are becoming increasingly popular in the soybean cultivation technology [18-23].

If 15-20 years ago when cultivating this crop the main use was made of protectants, herbicides and insecticides, recently it has become impossible to obtain stable soybean yields without using fungicides [21-24].

Conducting experiment 2 was aimed at reducing the pesticide load on the environment and at studying the fungicidal action of BIO-GEL biologically active product.

Experiment 2 provided for testing BIO-GEL application as a natural biological and ecologically friendly fungicide on soybean crops. For the purpose different variants of the *Aratta* soybean crop treatment were tested (table 4).

Table 4. *Aratta* soybean variety yield and some morphological and biological characteristics when using fungicidal protection, 2017

	Variant	**Veg. period, days**	**Diverge, days**	**Height**		**Resistance to diseases, points**		**Yield, t/ha**	**Diverge, t/ha**	**Gain, %**
				plants	**lower beans**	**downy mildew**	**bacteriosis**			
1	Control	116	-	104.2	14.2	7.0	7.5	1.89	-	-
2	Seed treatment with BIO-GEL, 1.5 l/t	117	+1	105.6	14.4	7.5	8.0	2.10	+0.21	11.1
3	Fungicide (1.4 l/ha) (100% dose + sticking agent (0.8l/ha)	118	+2	106.3	13.9	7.5	8.0	2.13	+0.24	12.7
4	Fungicide (0.7 l/ha (50% dose)+BIO-GEL (1.5 l/ha)	117	+1	104.9	14.8	7.5	8.0	2.18	+0.29	15.3
5	Fungicide (0.56 l/ha)(40% dose)+BIO-GEL (1.5 l/ha)	117	+1	106.0	14.4	8.0	8.5	1.99	+0.10	5.2
6	Fungicide (0.42 l/ha)(30% dose)+BIO-GEL (1.5 l/ha)	117	+1	105.4	14.1	7.5	8.0	1.98	+0.09	4.8
	HIP_{05}							2.36		

Using fungicidal protection at the budding stage causes insignificant lengthening of the vegetation period by 1-2 days.

As for soybean resistance to diseases, it appeared to be higher in all variants compared to the control. Even seed treatment with BIO-GEL (1.5 l/ha) ensures plants protection which testifies to the product natural fungicidal characteristics. If the amount of fungicide applied at the budding stage was reduced by 30-50%, the fungicidal effect remained the same as with the 100% dose. In case of the 40% dose applied the fungicidal effect was even better than (table 4).

Thus, using BIO-GEL product together with fungicide in order to ensure plants fungicidal protection the dose of fungicide can be reduced by 30-50% which promotes environment protection.

As to the soybean yield, it was greater in all variants, from 0.12 to 0.24 t/ha, or 8.8-13.2% (table 4). After harvesting samples were selected from experiment 2 for biochemical analysis. Table 5 gives qualitative characteristics of the *Aratta* variety under various fungicidal treatments.

Table 5. Qualitative characteristics of the *Aratta* soybean variety under various fungicidal treatments, 2017

	Variants	**Protein, %**	**Fat, %**	**Yield, t/ha**	**Protein issue, t/ha**	**Fat issue, t/ha**
1	Control	29.26	20.30	1.82	0.532	0.369
2	Seed treatment with BIO-GEL, 1.5 l/t	30.00	19.68	2.06	0.618	0.405
3	Fungicide (1.4 l/ha) (100% dose + sticking agent (0.8l/ha)	27.93	20.91	2.03	0.567	0.424
4	Fungicide (0.7 l/ha (50% dose)+BIO-GEL (1.5 l/ha)	29.89	20.42	2.00	0.598	0.408
5	Fungicide (0.56 l/ha)(40% dose)+BIO-GEL (1.5 l/ha)	30.42	19.75	2.04	0.620	0.403
6	Fungicide (0.42 l/ha)(30% dose)+BIO-GEL (1.5 l/ha)	29.52	20.89	1.98	0.584	0.414

Fungicidal treatment does not promote increase in protein and fat content but in the variants with BIO-GEL application these qualitative characteristics tend to increase (table 5).

2.3 BIO-GEL application to the *Aratta* soybean variety (under irrigation)

Analyzing the phenological observations in experiment 3 we can state that the vegetation period duration did not change this year except for the combined use of inoculants and BIO-GEL in which case soybean ripening sped up by 1 day compared to the previous year when due to BIO-GEL application vegetation period duration was 1-3 days longer compared to the control. This testifies to soybean insignificant response to BIO-GEL. Besides, BIO-GEL did not affect either plant height or the formation of lower beans, in all variants these indicators were slightly increased but on the whole did not differ from the control (table 6). Beans cracking and lodging was minimal in all experiment variants.

Table 6. Agrobiological characteristics of various treatments of the *Aratta* soybean variety with the BIO-GEL biologically active product, 2017 (under irrigation)

	Variant	Veg. period, days	Diverge, days	Height		Resistance to lodging points	Yield, t/ha	Diverge, t/ha	Gain, %
				plants	lower beans				
1	Treatment with water (control)	116	-	106.0	14.7	8.0	1.82	-	-
2	Seed treatment with BIO-GEL, 1.5 l/t	116	±0	108.4	14.9	8.0	2.06	+0.24	13.2
3	Seed treatment with ABM (180 g/t)	116	±0	103.4	13.8	7.3	2.03	+0.21	11.5
4	Seed treatment with ABM (180 g/t)+BIO-GEL (1.5 l/t)	115	-1	104.7	15.3	7.3	2.00	+0.18	9.8
5	Spraying with BIO-GEL at budding stage, 1.5 l/ha	116	±0	108.5	14.8	8.0	2.04	+0.22	12.1
	HIP_{05}						0.218		

Using BIO-GEL like in experiment 1 (seed treatment with BIO-GEL,1.5 l/t) promotes plant fungicidal protection, besides spraying plants also increases their resistance to plant pathogens, thus plants show greater resistance to different diseases both to fungal and bacterial. In all variants the yield gain amounts to 0.1 – 0.29 t/ha, 5.2 – 15.3%. The significant gain was recorded in two variants: the first one (seed treatment with inoculants) and the second one (seed combined treatment with inoculants + BIO-GEL) (table 6).

The best effect of BIO-GEL was achieved after the combined seed treatment with BIO-GEL and ABM inoculants (USA), in this case the yield gain was 0.285 t/ha on average for two years.

According to many years of research on soybean selection at the Institute of Irrigated Agriculture, the National Academy of Sciences, it has been concluded that one of the main elements of the soybean productivity is the number of beans per plant, the number of seeds per plant and the weight of seeds per plant. These elements depend to a greater extent on the genotype and growing conditions [15, 18].

Table 7 presents the biometric characteristics of the *Aratta* soybean variety in 2016-2017. We have observed an insignificant increase in the plant height and in the height of lower beans formation but in some variants this height is decreased. After structural analysis we can state that in variants 4 and 5, which are the best, the number of beans per plant increased on average by 7.1 – 11.7 pc, the number of seeds per 1 plant grew by 24.2-35.1 pc in comparison with control. In all other variants these elements increase compared to the control was insignificant (table 7).

Table 7. Biometric characteristics of the *Aratta* soybean variety, 2016-2017

	Variant	Plant height, cm		Height of lower bean formation, cm		Number of beans per plant, pc		Number of grains per plant, pc	
		2016	2017	2016	2017	2016	2017	2016	2017
1	Seed treatment with water (control)	92.2	106.0	13.7	14.7	51.8	55.8	101.3	132.4
2	Seed treatment with BIO-GEL (1.5 l/t)	92.5	108.4	13.9	14.9	56.2	59.6	122.4	142.2
3	Seed treatment with ABM (180 g/t)	93.4	103.4	13.3	13.8	53.3	56.4	112.4	135.6
4	Seed treatment with ABM (180 g/t)+BIO-GEL (1.5 l/t)	94.7	104.7	14.1	15.3	62.6	68.2	138.6	165.3
5	Spraying with BIO-GEL at budding stage, 1.5 l/ha, 2017	91.5	108.5	13.8	14.8	59.5	62.3	125.1	157.1

Thus, using BIO-GEL in combination with ABM inoculant for soybean seed treatment and spraying soybean crops with BIO-GEL promotes greater number of beans per plant.

Of great importance is the amount of protein and fat in beans as it is exactly because of it that soybeans are in great demand. Not many crops can compete with soybeans as to this characteristic.

There is no cholesterol in soy protein, therefore the protein has dietary properties. Soybeans are the most valuable and the cheapest source of high-quality protein for people to eat. Soybean oil belongs to the most valuable products and is 98% digestible. The use of soy food products significantly improves health reducing the risk of cancer and cardiovascular diseases [17].

After harvesting samples were selected from all experiment variants for making biochemical analysis and establishing the amount of fat and protein in soybeans. Table 8 gives the amounts of fat and protein in beans per hectare.

Table 8. Qualitative characteristics of the *Aratta* soybean variety on treating with BIO-GEL, 2017

	Variant	Protein, %	Fat, %	Yield, t/ha	Protein issue, t/ha	Fat issue, t/ha
1	Treatment with water (control)	29.26	20.30	1.89	0.553	0.384
2	Seed treatment with BIO-GEL (1.5 l/t)	28.94	20.87	2.10	0.608	0.438
3	Seed treatment with ABM (180 g/t)	29.89	20.83	2.13	0.637	0.444
4	Seed treatment with ABM (180 g/t) + BIO-GEL (1.5 l/t)	28.62	19.12	2.18	0.624	0.417
5	Spraying with BIO-GEL at budding stage, 2017 (1.5 l/ha)	30.00	19.68	1.99	0.597	0.396

On studying the qualitative characteristics of soybeans we can state that BIO-GEL did not have a significant effect on fat and protein content. BIO-GEL application did not change essentially these contents compared to the control.

2.4 Effect of BIO-GEL biologically active product on soybean nitrogen fixation

Symbiotic interaction of microorganisms is very important in plant life as it provides for their mineral nutrition and adaptation to abiotic stress.

Nitrogen fixation is a complex process of binding inert molecular nitrogen from the atmosphere and transforming it into complex organic compounds using nitrogen fixing microorganisms [25], this is a kind of remedy for the environment deterioration and a panacea for increasing cost and energy efficiency of agricultural products when mineral fertilizers are applied.

Use of biological nitrogen by plants is very important as it is cheap and ecologically friendly, besides molecular nitrogen reserves in atmosphere are practically inexhaustible. Biological nitrogen is absorbed by almost 100% whereas mineral nitrogen absorption is only 50-60%. In this regard an experiment was conducted in which the nitrogen fixing ability of soybean plants was studied depending on the genotype and soybean seeds inoculation with bacterial agents.

The assessment of the nitrogen-fixing capacity of soybean plants was carried out by the quantitative and weight method, by selecting monoliths and further counting the number of tubercles in the monolith and determining their mass (Table 9).

Table 9. Characteristics of the *Aratta* soybean variety nitrogen fixing ability and productivity, 2017

	Variant	**Tubercles weight per plant, g**	**Tubercles weight per ha, kg**	**Yield, t/ha**
1	Seed treatment with water (control)	0.15	99.0	1.89
2	Seed treatment with BIO-GEL, 1.5%	0.26	171.6	2.10
3	Seed treatment with ABM	0.76	516.8	2.13
4	Seed treatment with ABM=BIO-GEL (1.5%)	0.83	564.4	2.18
5	Spraying with BIO-GEL at budding stage, 1.5%	0.21	138.6	1.99

So in the course of the research it was found that the greatest effect on tubercles number and weight was achieved in two variants: seed treatment with ABM inoculants (USA) and the combined seed treatment with inoculants and BIO-GEL, in this case the weight gain of tubercles per plant was 0.41-0.58 g compared to the control, while the weight of tubercles per hectare increased by 273.6-382.8 kg. In other variants the weight of tubercles per plant and per hectare increased as well (table 9).

In the course of the research it has been found that soybean seed treatment either only with BIO-GEL or with BIO-GEL and inoculants as well as spraying with BIO-GEL is conducive to the improvement in the plant rhizobial apparatus functioning which provides the highest values of tubercles weight per area unit.

3. Introduction and experimental verification of BIO-GEL product on farms in Kherson region

After the experiments conducted on the experimental plots at the Institute of Irrigated Farming and on getting positive results in 2016 the effect of BIO-GEL was tested when it was introduced on the following farms in Kherson region in 2017:

1. *Askaniyske* farm, Kherson region (16 ha)
2. *UTC-Agroproduct* company, Kherson region (17 ha)

On *Askaniyske* farm the *Aratta* soybean variety crops were sprayed twice with BIO-GEL at the budding stage (2 l/ha) + once at the flowering stage (1.5 l/ha), the conventional cultivation technology remaining the same.

Harvesting was conducted on October, 02, 2017 on 16 ha of the control and on16 ha of the plot where soybeans were treated with BIO-GEL.

On harvesting, weighing and calculating the yield of two variants the values were: 3.45 t/ha (the control) and 3.72 t/ha (the experimental plot).

The gain due to BIO-GEL application is 0.27 t/ha, or 7.82%.

In *UTC-Agroproduct* company tests were made on reducing the amount of herbicide. At the stage of 4-5 leaves crops were sprayed with *Ataman* postemergent herbicide, its rate being reduced by 40%. On the area of 17 ha 1.2 l/ha of *Ataman* herbicide and 2 l/ha of BIO-GEL product were used. On the control plot (17 ha) the full rate of *Ataman* herbicide (2 l/ha) with no BIO-GEL was applied. The effect of the herbicide reduced rate on weeds was absolutely the same as in the control.

On August, 26, 2017 soybean harvesting was conducted on *UTC-Agroproduct* company fields (control plot 17 ha and experimental plot with BIO-GEL applied 17 ha).

On harvesting, weighing and calculating the yield of two variants the values were: 2.408 t/ha (the control), 2.715 t/ha (the experimental plot).

The gain due to BIO-GEL application is 0.307 t/ha, or 12.5%.

The introduction and experimental verification of BIO-GEL product on two farms testify to the following: BIO-GEL application promote increase in plants height, number of beans and better functioning of the soybean rhizobial apparatus (greater number and bigger size of soybean root tubercles), the yield gain amounts to 0.27 – 0.307 t/ha.

3.1 Economic efficiency of BIO-GEL application on soybean crops on farms in Kherson region

The scientifically grounded system of agriculture is a complex of interconnected agrotechnical, organizational, technical and economic measures developed in accordance with the specific conditions of the economy and aimed at the effective use of each hectare and other material and technical resources, systematic increase of soil fertility, increase in yield and in gross agricultural product at the minimum costs [26].

Cost of products, production costs, costs of fixed and circulating assets, all these terms play an important role in drawing up business plans at any enterprise. It is the costs necessary for the production along with such an indicator as the profitability which are the main factors in determining which technology is most effective, which technological operations need to be applied for the best results.

Table 10. Economic efficiency of applying BIO-GEL product to soybean crops on farms in Kherson region, 2017

	Farm	**Area, ha**	**Gain per ha due to BIO-GEL, t/ha**	**Total gain, t/ha**	**Soybean price, UAH/t**	**Total profit, UAH**	**Price of BIO-GEL applied, UAH**	**Total net profit, UAH**
1	Askaniyske farm	16.0	0.270	4.320	10000	43200	4480	38720
2	UTC-Agroproduct	17.0	0.307	5.219	10000	52190	2720	49470

On introducing BIO-GEL product on *Askaniyske* farm (16 ha) the additional expenses amounted to 4480 UAH (price of BIO-GEL applied), while the additional profit was 43200 UAH. The net additional profit from 16 ha was 38720 UAH (table 10).

The economic efficiency of BIO-GEL application in *UTC-Agroporduct* company is much greater than on *Askaniyske* farm as the gain per hectare is higher though BIO-GEL was applied only once. Thus the additional net profit was 49470 UAH (table 10). Besides, the economy due to reducing the amount of the *Ataman* herbicide applied was 1285.2 UAH.

CONCLUSION

1. Reduction of the pesticide load on environment can be achieved by using BIO-GEL product. When cultivating soybean, it is necessary to use BIO-GEL (1.5 l/ha) together with a postemergent herbicide, its rate reduced by 30%, which ensures pollution reduction and is economically beneficial.

2. Studies have shown that BIO-GEL has a fungicidal effect on soy plants. When using BIO-GEL in combination with fungicide to protect plants, fungicide rate can be reduced by 30-50%, which ensures the reduction of pesticide load on the environment.

3. The best BIO-GEL effect on soybeans has been achieved by joint treatment of seeds with BIO-GEL and ABM (USA) inoculant, in this case the *Aratta* soybean variety yield increases by 0.285 t/ha, average over two years.

4. BIO-GEL use has not caused protein increase. The percentage of fat is equal to that in the control but unlike the protein there is a tendency to higher fat content.

5. It has been established that soybean seeds treatment with BIO-GEL both separately or in combination with inoculants as well as BIO-GEL application during vegetation improves soybean plant rhizobial apparatus, which ensures the highest tubercle raw weight value per area unit.

6. BIO-GEL affects the formation of soybean productivity elements and its ultimate yield.

7. After BIO-GEL commercial application and experimental verification of its effect on two farms in Kherson region, it can be stated that BIO-GEL use on soybean crops brings about the additional net profit of 2420 – 2986 UAH/ha.