Institute of Water Problems and Land Reclamation, NAAN Ukraine

REPORT

BIO-GEL application in watermelon cultivation technology under drip irrigation

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2017

Introduction

The South of Ukraine is characterized by unique natural conditions that are favorable for the cultivation of melons. The optimal ratio of thermal and insolation resources as well as sandy soils have become the main precondition for the production of high quality melon products. One of the peculiarities of commercial watermelon production in Ukraine is the concentration of its crops in the zone of inadequate moistening - in the steppe semi-arid areas, which is why the watermelon yield is directly dependent on the amount of precipitation which in recent years is disastrously lacking. As a result, producers of melon products are paying more attention to irrigation.

1. Problem study

While before watermelon grown under irrigation was watered by sprinkling machines (more often) or with furrows (less often), drip irrigation is becoming more widespread. Along with the advantages of drip irrigation, it also has disadvantages, among which the most painful is the refusal of the producers to grow perennial legumes (alfalfa, sainfoin, sweet clover, etc.) on irrigated land, these crops being a source of organic matter, nitrogen, ash nutrients for the soil and possessing phytomeliorative abilities. Soil depletion and its intensive use lead to gradual degradation if nutrients and organic matter do not go back into it.

One of the most significant diagnostic signs of soil degradation is the decrease of organic matter and its main component – humus in it. The primary dependence of productive potential on the content of humus in the soil determines the need for such agronomic measures that are aimed at reproducing humus content, namely: increasing the inflow of soil organic compounds; improvement of the conditions of plant remains humification; reduction of soil humus mineralization during crop cultivation.

Under the conditions of the Ukrainian steppe the annual humus losses by soil make about 0.6 t/ha and are caused by the organic substances mineralization rate which is higher than their inflow rate. Taking into account this indicator, the reproduction of soil fertility requires 6-8 t of manure per hectare of crop rotational area. The production of such amount of manure in the modern agriculture in Ukraine is evidently unreal. In most steppe areas it is introduced only at the rate of 0.4-0.5 t / ha at best and at worst it is not applied at all, as a result the decrease in humus content over the last 10-15 years has reached 0.2-0.4%.

According to the concept of soil fertility reproduction in the crisis conditions new technologies and standards for the application of organic fertilizers have been developed. An element of the new technology is a system of agronomic measures which involves reducing the number of cultivated crops in the crop rotation, minimizing soil cultivation and using green manure and plant remains as organic fertilizers.

Among the measures aimed at ensuring humus balance vegetative remains and organic fertilizers are of paramount importance. The humus balance can be essentially improved by the introduction of organic matter with roots and field crops remains into soil. Row crops are characterized by consuming great amounts of nutrients and are more demanding as to humus content and soil fertility. Losses of humus under row crops are 2 times larger than under other ones. The measures that make it possible to increase the inflow of organic substances into the soil include the spreading of perennial grasses, especially legumes, the cultivation of intercrops and green manure, the departure from bare fallow.

When growing melons under drip irrigation it is not always possible to implement the above-mentioned measures aimed at preserving soil fertility, in particular, crop rotation, perennial grasses, mainly legumes, straw, etc.

Therefore, under drip irrigation a binary micro-row method of growing melon and vegetable crops should become an effective way of increasing soil fertility. According to this method ground covering crops are grown in the wide spaces between rows before sowing the main row crop. Green manure typical of conventional agriculture such as annual legumes, crucifers, cereals or their mixtures can be used as ground cover. Ground covering crops are the source of organic matter and are completely or partially embedded into soil 10-12 days before sowing the main crop. The importance of ground covering crops consists in the fact that they create a layer of mulch in spaces between rows, thus improving the phytosanitary, thermal, water and nutrient conditions in the soil, its fertility and increasing vegetable and melon crops productivity. The peculiarity of the binary micro-row method of row crops cultivation is that the following year the dripping pipe and consequently the rows of the main crop are shifted towards the space between rows. Thus, the row with the main crop returns to its initial place in 4-5 years.

Green manuring is plowing in herbage in order to enrich soil with organic matter and nitrogen. The green manure herbage weight of 30-80 t/ha ensures 150-200 kg of nitrogen in the soil. It is conducive not only to soil fertility recovery but also to its physical properties improvement due to its enrichment with organic matter and biological nitrogen. Green fertilizers are equivalent to introducing manure at the rate of 43 t / ha. Green manure (winter rye, mustard, peas, winter rape) is also efficient for cultivating melon crops.

In the last 20-30 years the attitude towards microbial products and the very idea of artificial bacteritisation has changed dramatically due to a number of reasons. First of all the possibility has been proved to control soil biological processes in order to optimize crop productivity and preserve soil fertility. The necessity to improve the structure of microorganisms in agrocenoses is particularly relevant for modern agriculture since during the last half-century in most Ukrainian soils the ratio between beneficial and pathogenic microorganisms changed essentially as a result of unjustified use of mineral fertilizers, pesticides, wrong crop rotations, etc. Certain types of bacteria which have always been considered indicators of fertile soils are on the brink of extinction. They are replaced with microorganisms which are not typical of the plant root zone and perform non-typical functions: instead of optimizing root nutrition they parasitize on the plant organism. The consequences are well known: even with sufficient soil fertilization, the crop cannot realize its genetic potential since the inflow of nutrients to the roots is limited, while the development of harmful microorganisms is unchallenged.

However, technologically it is quite possible to artificially introduce agronomically useful microorganisms "in the right place, in the right amount, at the right time". This makes the basis of the ides to use microbial products in ecologically safe crop production technologies. Increasingly an alternative to traditional agriculture is becoming biological agriculture, one of its aspects is the creation and application of microbiological products in order to optimize plants nutrition, their protection against diseases and pests and preservation of soil fertility.

At present the importance of the rhizospheric microflora in providing the crops with necessary nutrients has been proven, and the peculiarities of the microorganisms relationships with plants have been studied to a large extent, the microbiologists have established the phenomenon of sociative nitrogen fixation. Intensive research in the field of soil microbiology in the above-mentioned areas allows us to find out the subtle mechanisms of the system functioning (soil-microorganisms-plant) and the applied aspects of the beneficial microflora use in agricultural production.

In Ukraine, a number of biological products have been created for most agricultural crops, including non-legumes. Numerous field experiments, lysimetric units, studies of N_{15} application have shown that the effectiveness of these products can be equivalent to 40-60 kg/ha of mineral nitrogen and 15-30 kg/ha of phosphorous. This is due to both the increase of the coefficient of active substance assimilation from fertilizer and to the improvement of plant constructive metabolism; at this nitrogen and phosphorous mineral compounds in plants promote the synthesis of organic compounds and accumulate in the plant organism.

Nitrogen-fixing microorganisms develop using plant root discharge, supplying them with bound nitrogen from the atmosphere and discharging various growth substances and vitamins in the process of their life. In this way they improve the assimilation of mineral nutrients by plant roots. Under associative nitrogen fixation there is no such dense interaction as in legumes with nodule bacteria. At the same time the life activity of nitrogen-fixing microorganisms in direct contact with the root system is beneficial both for plants and for microorganisms.

Detection of increased nitrogen-fixing activity in non-leguminous plants (associative nitrogen fixation) can be called one of the most important achievements of science. Further research has expanded the number of bacteria belonging to the specified genera. Significant success in the study of associative bacteria is largely associated with the study of the genus Azospirillum bacteria. The research of this bacteria genus and the possibilities of their use in agricultural practice revealed their high nitrogen-fixing activity and expressed ability to develop in the rhizosphere of different plants, which testifies to the promising associations of these microorganisms with different plants. It is now evident that associative nitrogen fixation is carried out by a variety of bacteria in the formation of plant rhizosphere in all natural zones and is of great environmental importance. Nitrogen fixation was detected in the rhizosphere of cereals - wheat, rice, corn, sorghum, millet, barley and other non-leguminous plants.

The nitrogen-fixing ability is inherent in the representatives of various groups of soil microorganisms, besides in different biocenoses their number and nitrogen fixation productivity are different. Non-nodule nitrogen fixators of atmospheric nitrogen which are widely used in agricultural practice include *Azotobacter, Klostridium pasterianum, Agrobacter, Azospirillum, Enterobacter, Flavobacterium, Mycobacterium flavum and Mycobacterium mycoplana*.

According to the results of recent studies, higher activity of non-symbiotic nitrogen fixation in rhizosphere and plant rhizoplane than in adjacent soil has been established. The closer to the plant root is the soil, the more bacteria in it. It is the microorganisms that are the main factor in the soil-forming process, plant nutrition and the phytosanitary state of crops. Therefore, the use of biologics based on associative nitrogen-fixing, phosphorus-mobilizing microorganisms and phytopathogen antagonist microorganisms is one of the methods for increasing the crop productivity together with the preservation of soil fertility without degrading the environment state. Modern microbial preparations make it possible to reduce the application of synthetic agrochemicals and, accordingly, the risk of contaminating plant products and the environment.

Quite often no positive effects are recorded due to bacteria application. This can be explained by the influence of various factors in specific conditions, among which are non-compliance with the conditions of seeds pre-sowing inoculation, ignoring recommended soil preparation, the use of pesticide incompatible with microorganisms, etc. For each agricultural crop there are special conditions for the effective use of microbial preparations which take into account both the plant properties and the microorganism strains introduced into agrocenosis.

The southern state agricultural research station in 2015 developed an ecological technology of melon crops cultivation on non-irrigated lands. The technology is designed to increase the productivity of watermelon, to preserve and use rationally soil fertility, to reduce the agrochemical load on the soil, to obtain high-quality products.

The content of the environmental technology is as follows: mineral fertilizers are introduced under watermelons in spring at the dose of $N_{30}P_{45}K_{30}$ before the first cultivation locally in the zone of the future row by a cultivator equipped with a marker, the seeds used for sowing being inoculated with BIOGRAN (a combined action microbiological product). Studies conducted during 2011-2015 found that seeds inoculation with microbiological agents contributes to the development of useful rhizosphere microflora, improves nutrition through the mobilization of soil nutrients, stimulates plants growth and development, inhibits the development of phytopathogenic fungi and bacteria. The effect of biologics is equivalent to the effect of 30 kg / ha of mineral nitrogen, 45 kg / ha of phosphorus and 30 kg / ha of potassium.

Therefore, for the first time in southern Ukraine in the sandy black soils we are studying the effect of using biological agents based on nitrogen fixing and phosphorous-mobilizing microorganisms in combination with the recommended and ½ of the recommended dose of mineral fertilizers in melon (watermelon) agrocenosis under drip irrigation. In addition to microbiological products from the Institute of Agricultural Microbiology and Agro-Industry (ABT, Albobacterin and Biogran) the research program included BIO-GEL, an organic fertilizer with pronounced inoculation properties. We believe that the research on the effect of watermelon seeds pre-sowing inoculation with microbial agents and BIO-GEL complex organic fertilizer on soil fertility, growth conditions, yield and fruit quality, the economic efficiency of the watermelon cultivation technology is topical.

2. Research methods and conditions

2.1 Characteristic of experimental site soil

Field experiments are carried out on the experimental farm within the Lower Dnieper sand area, Kherson region. The main soil here is loam, from sandy to sandy loam granulometric composition. The dominant fraction is a sand fraction making from 39.97 to 80.32%. The content of silt is insignificant: 6.60 - 24.37%. The soils are represented by southern sandy-loam black earth. A characteristic feature of these soils is the great humus profile - up to 76 cm, with humus content from 0,5 to 1,0%. Humus is dominated by humic acids. Absorption capacity of soils is low – 5.46 mg-eq. Soil hydrolytic acidity is 1.06-1.77 mg-eq. The reaction of the soil solution is close to neutral, downward the profile it becomes subalkali, the average pH of the water extract is about 7.0. Soils are not saline with readily soluble salts. The analysis of the granulometric composition of the southern black earth shows that the soil belongs to the sandy species with a content of particles less than 0.01 mm 10.70 - 14.15%, fine sand fraction making 52.55 - 55.28%.

2.2 Irrigation water quality

The source of irrigation is a well 83 m deep. Water intake was carried out using a pump, 32 kW / h capacity, the water supply being 120 m^3 / h. Total mineralization of groundwater is 0.5 g / dm^3. The maximum content of CO_3 in water is 164.7; SO_4^{-2} – 4.0; Cl – 56.8; Ca^{2+} - 52.0; Mg^{2+} - 9.6; Na^+ - 24.0; K^+ - 1.5 mg/d^3; pH – 7.8. Carbonates that influence the increase of pH value are absent. In irrigation water there are permissible doses of nitrate nitrogen (NO_3^- - 13.6 mg/d^3), its ammonia and nitrate forms are absent (table 2.1).

Table 2.1. Irrigation water chemical composition

pH	NO_2^-	NO_3^-	NH_4^-	P_2O_5	K^+	N^+	Ca^{2+}	Mg^+	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3	Total salts, mg/d^3
7.8	-	0.219-13.6	-	0.003-0.16	1.5	1.043-24.0	2.6-52.0	0.8-9.6	1.6-56.8	0.083-4.0	-	2.7-164.7	326.4

According to the irrigation parameters in accordance with State Standard 2730-94 water is suitable for irrigation and does not cause soil salting, the ratio of sodium to calcium content is 0.5, the standard being 1.0.

2.3 The climate of the region and weather conditions in the year of the experiment

The territory of the experimental farm is located in the second (southern) agro-climatic region of the Kherson region, the climate is very hot and dry. According to long-term data, the average annual air temperature is +9.9°C. The coldest month is January, its average temperature is – 2.6°C, the hottest month is July, its average temperature is 22.8°C. The average annual precipitation is 418 mm. The sum of temperatures above 10°C is 3300-3400°C, the amount of precipitation for this period is 200-220mm. Hydrothermal coefficient (HTC) of vegetation period is 0,5.

The average duration of the non-frosty period is 180-200 days, and the vegetative period is 225-230 days. The last frosts in the spring are observed on April 13, and the first frosts in the autumn - on October 24. High air temperature and low moisture are conducive to intensive evaporation from the soil surface and to transpiration. Evaporation from the surface of the fallow land (April-October) is 200-220 mm, that is, the same or even more than the amount of precipitation over this period. The evaporation during the warm period of the year (April-October) is 900-1100 mm which is 3.0-3.5 times the annual rate of precipitation. The farm is located in the zone of incomplete spring watering. The maximum reserves of productive moisture in the meter layer are observed in the spring and after the wet autumn-winter periods and can reach 100-120mm. In arid years the reserves are only 50-70mm, and the depth of the soaking - 40-60cm.

Table 2.2. Agronomical meteorological conditions, 2017

Month	Three-day period	Air temperature, °C		Precipitation, mm	
		average	average over years	over period	average over years
April	I	9.0	8.8	17.0	10
	II	8.2	9.5	31.0	11
	III	10.6	11.9	20.0	12
	per month	***9.2***	***10.0***	***68.0***	***33***
May	I	17.2	14.1	4.0	15
	II	14.4	16.6	21.0	14
	III	17.2	17.4	0.7	13
	per month	***16.3***	***16.9***	***26.9***	***42***

June	I	21.1	19.2	3.0	13
	II	20.6	19.5	20.0	18
	III	24.3	21.2	10.0	14
	per month	***22.0***	***19.9***	***33.0***	***45***
July	I	22.0	21.3	12.0	22
	II	22.4	22.3	-	14
	III	25.6	22.1	-	13
	per month	***23.4***	***21.9***	***12.0***	***49***
August	I	28.9	22.4	-	7
	II	27.0	21.6	10.0	13
	III	20.6	20.0	2.0	18
	per month	***25.4***	***21.3***	***12.0***	***38***
September	I	21.0	18.6	-	16
	II	23.1	16.4	-	10
	III	11.8	14.2	-	14
	per month	***18.6***	***16.4***	***-***	***40***

Agrometeorological conditions of the 2017 spring period were quite favorable for replenishing soil moisture reserves. Only in the last two spring months the amount of precipitation was 94 mm, at the standard of 75 mm. Rainfall in the spring was irregular, so in April the amount of precipitation was 68 mm at the standard of 33 mm, whereas in May - 26 mm at the standard of 42 mm. The largest amount of precipitation during a short period fell in the middle of April - 31 mm, with an average annual rate of 11 mm for the second ten-day period and in the middle of May - 21 mm at the rate of 14 mm for the second ten-day period.

In spring the rainfall was quite irregular, in April it amounted to 68 mm, the standard being 33 mm, while in May it was 26 mm, the standard being 42 mm. The greatest amount of rainfall during a short period (31 mm) was in the middle of April, the average standard over years being 11 mm, and in the middle of May (21 mm), the standard for the second ten-day period being 14 mm (table 2.2).

If the average monthly temperature in April 2017 was 0.7 ° C lower than normal, in May this indicator was slightly higher than the average yearly figures. The summer period along with much higher than the average long-term, temperature regime was characterized by a small amount of precipitation. In general, during the summer period of 2017 the total rainfall was 57 mm at the standard of 132 mm, which is 75 mm less than the long-term data characterizing this period of the year.

The lack of precipitation and high day and night air temperatures significantly reduced the moisture content in the soil. The deficiency of atmospheric precipitation was compensated by maintaining the optimal regime of watermelon and tomato root zone moisture by means of drip irrigation.

2.4 Experiment scheme

The experiments were made using the Knyazhich watermelon variety in a field multiple-factor experiment where:

Factor A (soil covering crop – green manure): a) no soil covering crop; b) cereals (winter rye); c) crucifers (white mustard); d) leguminous (vetch).

Factor B (mineral nutrition level): a) ($N_{60}P_{90}K_{60}$) recommended dose – control according to State Standard 5045:2008; b) half of the recommended dose ($N_{30}P_{45}K_{30}$).

Factor C (seed inoculation with bacterial product): a) no inoculation; b) ABT; c) Albobacterin; d) Biogran; e) BIO-GEL (table 2.3).

Table 2.3 Experiment scheme

<table>
<tr><td rowspan="2"></td><td colspan="3">Experiment factors</td></tr>
<tr><td>Factor A (soil covering crop – green manure)</td><td>Factor B (mineral nutrition level)</td><td>Factor C (seed inoculation with bacterial product)</td></tr>
<tr><td>1</td><td rowspan="10">No soil covering crop (c)</td><td rowspan="5">Recommended dose ($N_{60}P_{90}K_{60}$) control according to State Standard 5045:2008</td><td>No inoculation (c)</td></tr>
<tr><td>2</td><td>ABT</td></tr>
<tr><td>3</td><td>Albobacterin</td></tr>
<tr><td>4</td><td>Biogran</td></tr>
<tr><td>5</td><td>BIO-GEL</td></tr>
<tr><td>6</td><td rowspan="5">Half of the recommended dose ($N_{30}P_{45}K_{30}$)</td><td>No inoculation (c)</td></tr>
<tr><td>7</td><td>ABT</td></tr>
<tr><td>8</td><td>Albobacterin</td></tr>
<tr><td>9</td><td>Biogran</td></tr>
<tr><td>10</td><td>BIO-GEL</td></tr>
<tr><td>11</td><td rowspan="10">Cereals (winter rye)</td><td rowspan="5">Recommended dose ($N_{60}P_{90}K_{60}$) control according to State Standard 5045:2008</td><td>No inoculation (c)</td></tr>
<tr><td>12</td><td>ABT</td></tr>
<tr><td>13</td><td>Albobacterin</td></tr>
<tr><td>14</td><td>Biogran</td></tr>
<tr><td>15</td><td>BIO-GEL</td></tr>
<tr><td>16</td><td rowspan="5">Half of the recommended dose ($N_{30}P_{45}K_{30}$)</td><td>No inoculation (c)</td></tr>
<tr><td>17</td><td>ABT</td></tr>
<tr><td>18</td><td>Albobacterin</td></tr>
<tr><td>19</td><td>Biogran</td></tr>
<tr><td>20</td><td>BIO-GEL</td></tr>
<tr><td>21</td><td rowspan="10">Crucifers (white mustard)</td><td rowspan="5">Recommended dose ($N_{60}P_{90}K_{60}$) control according to State Standard 5045:2008</td><td>No inoculation (c)</td></tr>
<tr><td>22</td><td>ABT</td></tr>
<tr><td>23</td><td>Albobacterin</td></tr>
<tr><td>24</td><td>Biogran</td></tr>
<tr><td>25</td><td>BIO-GEL</td></tr>
<tr><td>26</td><td rowspan="5">Half of the recommended dose ($N_{30}P_{45}K_{30}$)</td><td>No inoculation (c)</td></tr>
<tr><td>27</td><td>ABT</td></tr>
<tr><td>28</td><td>Albobacterin</td></tr>
<tr><td>29</td><td>Biogran</td></tr>
<tr><td>30</td><td>BIO-GEL</td></tr>
<tr><td>31</td><td rowspan="10">Leguminous (vetch)</td><td rowspan="5">Recommended dose ($N_{60}P_{90}K_{60}$) control according to State Standard 5045:2008</td><td>No inoculation (c)</td></tr>
<tr><td>32</td><td>ABT</td></tr>
<tr><td>33</td><td>Albobacterin</td></tr>
<tr><td>34</td><td>Biogran</td></tr>
<tr><td>35</td><td>BIO-GEL</td></tr>
<tr><td>36</td><td rowspan="5">Half of the recommended dose ($N_{30}P_{45}K_{30}$)</td><td>No inoculation (c)</td></tr>
<tr><td>37</td><td>ABT</td></tr>
<tr><td>38</td><td>Albobacterin</td></tr>
<tr><td>39</td><td>Biogran</td></tr>
<tr><td>40</td><td>BIO-GEL</td></tr>
</table>

The area of an elementary experimental plot is 70 m^2. Accounting area is 50 m^2. The total experimental area is 1.2 ha. The experiment replication is 4 times. The width of the row spacing is 350 cm, the growing scheme is 350 × 50 cm (plant nutrition area is 1.75 m^2). Pre-irrigation soil moisture content in watermelon crops is 75-75-70%.

Factor B (mineral nutrition level)	Factor C (seed inoculation)	Replication															
		I				II				III				IV			
		Factor A (soil covering crop)															
Recommended dose ($N_{60}P_{90}K_{60}$)	BIO-GEL	No soil covering	Winter rye	Mustard	Vetch	No soil covering	Winter rye	Mustard	Vetch	No soil covering	Winter rye	Mustard	Vetch	No soil covering	Winter rye	Mustard	Vetch
	Biogran																
	Albobacterin																
	ABT																
	No inoculation																
Half of the recommended dose (N30P45K30)	BIO-GEL	No soil covering	Winter rye	Mustard	Vetch	No soil covering	Winter rye	Mustard	Vetch	No soil covering	Winter rye	Mustard	Vetch	No soil covering	Winter rye	Mustard	Vetch
	Biogran																
	Albobacterin																
	ABT																
	No inoculation																
		56,0 m															

Fig. 1 The experiment scheme on the site

2.5 Methods of studies

In the course of the research, the general scientific standardized methods were used:

1. ***Agrometeorological observations***.

The recording of the main meteorological elements (precipitation and air temperature) in the course of field studies was carried out during the vegetation season in 2017. To characterize plant heat supply use was made of such indicators as the average temperatures per month and per a ten-day period, the number of days with a temperature lower and higher than the biological maximum and minimum, the sum of positive daily average (above 0ºC) as well as effective and active temperatures. To measure the temperature the minimum and maximal thermometers were used.

The amount of precipitation was determined by the height (mm) of the water layer formed on a layertal surface due to rain, mist, dew, fog, hail, etc in the absence of drainage, impregnation and evaporation. They were measured using a rain gauge measuring cup with marking of 0.1 mm. The soil temperature was measured with a soil thermometer-probe AM-6 by dipping it into soil for 5 minutes, after which it its indications were recorded.

2. ***Phenological observations***.

The phases of plant growth and development were determined depending on the studied factors. The beginning of the phase was recorded when it was noted in 10% of plants in the area, massively - in 75% of plants. Note was taken of the date of sowing, 5-6 leaves period, halm formation, female flowers, ovary formation, fruit ripening, harvesting.

3. ***Agrophysical properties of the soil***

soil moisture content was measured according to State Standard ISO 11465:2001 using thermostatic-weighing method in the meter layer every 10 cm. Sampling was carried out before sowing and at the end of crops growing. Selected soil samples weighing 40-70 g were placed in calibrated metal weighing bottles and weighed on the VLTK-500 electronic scales (3-4 fold repetition), the accuracy being 0.01 g. Later they were dried in an exsiccator at 105°C for 7-8 hours. Soil moisture was determined by the formula:

$$B=\frac{100(B1-B2)}{B2-B0}, \text{ where}$$

B – soil moisture content, % of its dry mass;

B_0 – weighing bottle weight, g;

B_1 – weight of the weighing bottle with soil before drying, g;

B_2 – weight of the weighing bottle with soil after drying, g.

- determination of soil productive moisture content, total water consumption and water consumption coefficient were carried out proceeding from the dynamic determinations of the arable soil layer moisture and density.

Total water consumption, that is the amount of moisture in 1 m^3/ha (or mm/ha) which was used by watermelon during the vegetation period including the rainfall. The total water consumption ΣW (mm/ha, m^3/ha) was determined by the formula:

$\Sigma W = W_0 - W_k + \Sigma O$, where

W_0 - reserves of productive moisture in the meter layer of soil before sowing crops (mm/ha, m^3/ha);

W_k – reserves of productive moisture in the meter layer of soil at the end of the vegetation (mm/ha, m^3/ha);

ΣO – the amount of precipitation during the growing season.

Water consumption coefficient characterizing the water consumption needed for forming 1 t of fruit (m^3/t) is calculated on the basis of total water consumption and crop yields in the experiment variants.

Water consumption coefficient K_w (m^3/t) was determined by the formula:

$K_w = \Sigma W : Y$ where

ΣW is total water consumption (mm/ha, m^3/ha);

Y is yield (t/ha).

4. ***Biochemical analysis***.

Watermelon fruit quality was determined in a certified laboratory. For the analysis the 5-10 fruits were selected at the stage of ripening (2 replications). The fruit quality was characterized by the following: vitamin C (ascorbic acid) quantity according to State Standard 24556 – 89; the quantity of sugars by cyanide method according to State Standard 4954:2008; dry soluble matter by refractometric method according to State Standard 28562-90; nitrate content by ionometric method according to State Standard 4948:2008.

5. ***Agrochemical analysis***.

Soil sampling (samples) for agrochemical studies was carried out according to State Standard 4287:2004. Soil samples were taken to the depth of the arable layer. The mixed sample from an experiment variant consisted from 4-5 separate samples taken with the help of a borer. For this purpose, the borer was placed vertically to the soil surface, the pedal was pressed and the borer immersed into the soil to a depth of 10 cm. Soil samples were taken from an arable layer from the layers of 0-10 cm, 10-20 cm and 20-30 cm. The sample was poured into a numbered bag where all separate samples were placed. Thus a mixed sample with a mass of 0.3-0.5 kg was formed. On top a label was put which recorded the name of the experiment, sample numbers, date and depth of sampling. Separate samples were taken diagonally to the experiment variant plot. Mixed soil samples were sent to a certified laboratory of analytical measurements. Soil sampling for agrochemical studies was carried out in each plot at the beginning and at the end of the watermelon vegetation. In the laboratory the soil samples were dried, crushed and sifted through a sieve with 1.0 mm diameter openings.

In mixed soil samples the following was determined:

- nitrate nitrogen according to State Standard 4729:2007;
- movable phosphorous compounds according to the modified Machigin's method (State Standard 4114:2002);
- movable potassium compounds in 1% carbon monoxide extract on a flaming photometer using the modified Machigin's method (State Standard 4114:2002);
- pH - in water extraction by potentiometric method (State Standard 26423-85). Calculations were made at the beginning and at the end of the vegetation period. Soil samples were taken from an arable layer from the layers of 0-10 cm, 10-20 cm and 20-30 cm.

6. ***Soil biological activity***

was determined by the field adsorption method for determining CO_2 production by soil according to V.I. Shtatnov. For this isolating vessels and vessels for absorbing solution were taken. Plastic caps 15 cm tall and 20 cm diameter were used as insulating vessels. To avoid overheating, the caps were white. The vessels for the solution that absorbed CO_2 were Petri dishes. A vessel for absorbing solution was set on the soil surface using a stand, 0.25 ml of 0.1 N alkaline solution (KOH or NaOH) was poured into it, after that the vessel was immediately covered with an insulator, its edges being pressed into the soil to 1.5-2.0 cm depth or covered with a small soil layer on the outside. At the same time a vessel with alkali and an insulator was installed in a flat-bottomed vessel with a strong solution of cooking salt. After 4-5 hours the insulators were removed, 1 ml of 20% barium chloride solution (for binding absorbed CO_2) was poured into a vessel with the solution, stirred, transferred to a flask and titrated to phenolphthalein with 0.1 N HCl solution until the pink color disappeared. Titration was carried out directly in Petri dishes. Similarly the content of CO_2 in control vessels was determined. The amount of the released CO_2 was calculated according to the formula:

$$Ba = \frac{(a-b)}{St} \text{ where}$$

Ba – the amount of CO2 released, mg/m^2 x hour; *a* – amount of 0.1 N HCl solution which was used to titrate alkali in the control, ml; *b* – the same in the experiment, ml; *K* – the coefficient for converting 0.1 N alkaline solution to CO2 milligrams (K = 2.2); *S* – isolating vessel area, m^2; *t* – experiment duration, hour. At the same time soil moisture content and temperature were determined.

7. Yield records have been conducted on selected accounting plots of the same size and configuration.

For recording yields weighing method was used in all experiments. All fruits from the accounting plot were weighed. The fruits were divided into groups (< 15cm, 15-20, 20-25 and > 25cm). The yields were calculated in t/ha. The accounting area was 100 m^2 [1,2].

The accounting of the soil covering crop top was performed by weighing in all experiment repetitions. The yields were calculated in t/ha. The area covered by green manure was 5 m^2.

8. **The economic evaluation of agro-measures** and the calculation of the experiment economic efficiency were based on the main indicators: yield, gross output in monetary terms, labor productivity, cost of production, profitability of production.

9. **Statistical processing of research results** was carried out according to B. A. Dospechov (Field experiment technique with basics of statistical processing of research results).

3. *Research results*

3.1 Growing soil covering crops

The studies conducted before the experiment showed that the profile of the experimental plot soil was quite compact as evidenced by poor layering of the sub-topsoil (30-33%), topsoil – 40-44%. This is due to the weak humus of the soil and its sand granulometric composition. Great porosity of the soil results in high air and water permeability.

The density of the topsoil after harvesting the predecessor (melon) was 1.38 g / cm^3, at the boundary of the wetting zone - 1.43 g / cm^3. At deepening the soil density was higher starting from 1.55 g/cm^3 in the 41-70 cm layer to 1.83 g/cm 3 in the 71-100 cm layer. The specific mass of the soil in the meter layer was almost independent of the genetic layer and was within the range of 2.59-2.61 g / cm^3 (Table 3.1).

Table 3.1 Soil agrophysical characteristics

Genetic layer, cm	Soil density, g/cm^3	Soil specific weight, g/cm^3	Total soil porosity, %
0 – 30	1.38	2.59	44
31 – 40	1.43	2.61	40
41 – 70	1.55	2.61	33
71 – 100	1.83	2.60	30

On studying the soil permeability, it was found that the total amount of water absorbed in the first hour was 211 mm, and 6 hours later - 773 mm, which is 7730 m^3 of water per hectare. The soil of the experimental plot is characterized by a significant rate of water absorption which was 1.51-3.06 mm / min. 6 hours after the beginning of water penetration determination the absorption passed gradually into the filtration process. The filtration coefficient was 0.19 – 0.22 mm/min. The lowest moisture content of the soil on experimental plots was in the range of 12.0-12.8% of the absolutely dry soil mass. The maximum total moisture reserves in the meter layer at the lowest field moisture content was 1700 m^3/ha, the moisture available to plants being 1200 m^3/ha. Soil water yield coefficient was 65-70%. Moisture unavailable to plants was 3.0%, or 425 m^3/ha.

Studies preceding the sowing of soil covering crops identified some factors of the initial soil fertility. It was established that in the arable soil layer the content of humus is, on average, 0.71%, the amount of nitrate nitrogen is 5.6 mg / kg, that of P_2O_5 is 41.0 mg / kg and K_2O is 220.0 mg / kg of absolutely dry soil.

3.2 Soil covering crop yield and organic matter yield

The highest average yield of ground covering crop herbage was obtained in the variant with winter rye - 19.4 t / ha, while with the mustard it was 13.4 t / ha and the vetch - 7.7 t / ha (Table 3.2).

Table 3.2. The yield of ground covering crop herbage, t/ha

Soil covering crop	Replication				Average
	I	II	III	IV	
Winter rye	19.0	22.5	19.3	16.8	19.4
White mustard	13.2	13.0	13.5	13.9	13.4
Vetch	8.0	7.4	7.5	7.9	7.7
				HIP_{05}	2.66 t

According to the working hypothesis that we have put forward while developing the scientific project, the biomass of the soil covering crop will be of great importance in improving the technology for growing watermelon and tomato under drip irrigation. It plays the role of the source of organic matter, nitrogen and ash elements, as well as a powerful phyto-improver of soil. At present wide-space sowing of vegetable and melon crops is practiced under drip irrigation, therefore the introduction of continuous sowing method into the agrophytocenoses of intermediate soil covering crops will be of great importance for soil improvement. It will help to regulate the salt regime, root loosening of underlying soil layer, mulching the space between watermelon and tomato rows.

One of the criteria for assessing the state of soil fertility is the general reserve of humus which, in turn, characterizes the productivity of natural vegetation. There is a close relationship between the total reserve of humus and the crop yield which testifies to the potential soil fertility provided high farming standards are observed. In our case where the soil is the southern sandy-loam black earth, its total humus reserve amounting to about 50 t/ha and the total rainfall amounting to 120 mm in the November – April period, the natural productivity is less than 1.6 t / ha. Because of the low potential soil fertility considerable attention has been paid to the accumulation of plant remains in the field after harvesting and after plowing green manure. It is them that make one of the alternative sources of replenishing organic matter, nitrogen and ash elements reserves if organic fertilizers of animal origin are unavailable.

The introduction of the organic matter from plant remains replenishes significantly the soil humus balance. Among the studied soil covering crops the largest herbage mass was yielded in the variant with winter rye – an average of 19.4 t/ha while the variant with white mustard yielded just 13.4 t/ha and vetch – 7.7 t/ha. A significant addition to the total plant herbage mass was the root remains which made up 45-60% of it. Thus, the greatest yield of total biomass among the studied soil covering plants was obtained in variant with winter rye - 31.0 t / ha, while in the experiment with mustard - 19.4 t / ha and vetch - 11.5 t / ha. Taking into account the iso-humus coefficient the largest amount of dry organic matter entering the soil with top and root remains was provided by winter rye - 3.72 t / ha. In the variant with mustard the actual organic matter amounted to 2.33 t/ha and with vetch it was 1.38 t/ha (Table 3.3).

Table 3.3. Inflow of organic matter from soil covering crop herbage

Soil covering crop	Average herbage yield, t/ha	% of roots to plant tops	Organic matter from roots and herbage, t/ha	Dry organic matter from herbage	
				% of dry organic matter	Actual inflow, t/ha
Winter rye	19.4	60	31.0	12	3.72
Mustard	13.4	45	19.4	12	2.33
Vetch	7.7	50	11.5	12	1.38

Thus, we can state that when using winter rye as a soil cover, the actual inflow of dry organic matter into the soil is 1.6 times higher than that of the white mustard and 2.7 times higher than tat of the vetch.

At the same time, despite the fact that winter rye formed the highest yield of herbage with a relatively low nitrogen content (0.4%), the actual amount of this essential nutrient in the soil was the lowest - 77.6 kg / ha, whereas in the case of white mustard - 93.8 kg / ha and vetch - 107.8 kg / ha (Table 3.4).

Table 3.4. Nutrients inflow into soil after green manure plowing

Soil covering crop	Average herbage yield, t/ha	% of nutrients in the top herbage			Inflow into soil after plowing, kg/ha		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
Winter rye	19.4	0.40	0.26	1.0	77.6	50.4	194.0
Mustard	13.4	0.70	1.0	0.25	93.8	134.0	33.5
Vetch	7.7	1.40	0.27	0.63	107.8	20.8	48.5

Vetch (a leguminous plant) is superior as to other green manure as for nitrogen intake. Even at the lowest yield of vetch herbage (7.7 t/ha), the nitrogen yield was 30.2 kg/ha higher than that of winter rye (19.4 t/ha herbage) and 14.0 kg/ha higher than that of mustard (13.4 t/ha herbage). At the same time winter rye and white mustard had advantages in terms of the ash nutrients inflow into the soil. Thus, growing and plowing winter rye provided the highest inflow of potassium into the soil (194.0 kg / ha), while the vetch yielded 48.5 kg / ha and white mustard - 33.5 kg / ha. As for the phosphorous inflow into the soil after plowing green manure, white mustard was much more beneficial (134.0 kg/ha), while winter rye yielded 50.4 kg/ha and vetch – 20.8 kg/ha.

As for watermelon cultivation under drip irrigation, the active moisture zone is the upper 40-centimeter layer of soil. Analysis of the average content of productive moisture in this layer of soil showed that the largest amount was contained in the variant without a soil cover - 23.7 mm, whereas after vetch cultivation – 20.1 mm, after mustard cultivation – 19.6 mm, and the smallest content was after rye – 15mm. These data show that the cultivation of interspace soil coverers significantly affected the distribution of moisture in the meter soil layer.

3.2 Watermelon cultivation conditions and productivity

3.2.1 Moisture content and moisture balance in watermelons

In the southern Ukrainian steppe moisture content in soil is of great importance for cultivating any crop. Moisture reserves were formed during cultivation and before sowing soil covering crops both in autumn-winter period, 2016-2017 and during the spring, 2017.

Soil covering crops were grown without irrigation. Before sowing watermelons the moisture content in the meter soil layer amounted to 84.4 mm in the control and to 42.6 – 65.7 mm in the variants with soil covering crops. The lowest moisture content was in the meter layer of the plot where winter rye was grown as green manure (42.6 mm) (table 3.5).

Table 3.5. Moisture content in the meter soil layer in watermelon cultivation

Soil cover	Mineral nutrition	Seed inoculation with bacterial product	Productive moisture content in 0-100 cm soil layer, mm		Rainfall during vegetation period, mm	Irrigation, m^3/ha	Total water consumption at watermelon ripening, m^3/ha	Water consumption coefficient, m^3/t
Control	$N_{60}P_{90}N_{60}$ control	No inoculation	84.4	56.4	57	20/800	1650	50.8
		ABT	84.4	52.6	57	20/800	1688	47.0
		Albobacterin	84.4	60.2	57	20/800	1612	44.6
		Biogran	84.4	60.6	57	20/800	1608	41.8
		BIO-GEL	84.4	59.6	57	20/800	1618	43.4
	$N_{30}P_{45}N_{30}$	No inoculation	84.4	54.6	57	20/800	1668	52.4
		ABT	84.4	56.8	57	20/800	1646	47.1
		Albobacterin	84.4	55.5	57	20/800	1659	47.5
		Biogran	84.4	60.4	57	20/800	1610	42.9
		BIO-GEL	84.4	59.6	57	20/800	1618	43.8
Winter rye	$N_{60}P_{90}N_{60}$ control	No inoculation	42.6	57.8	57	22/880	1298	39.7
		ABT	42.6	62.4	57	22/880	1252	33.9
		Albobacterin	42.6	58.6	57	22/880	1290	37.8
		Biogran	42.6	60.7	57	22/880	1269	31.2
		BIO-GEL	42.6	59.4	57	22/880	1282	32.8
	$N_{30}P_{45}N_{30}$	No inoculation	42.6	59.6	57	22/880	1280	43.1
		ABT	42.6	57.9	57	22/880	1297	39.2
		Albobacterin	42.6	62.4	57	22/880	1252	38.8
		Biogran	42.6	61.1	57	22/880	1265	32.6
		BIO-GEL	42.6	59.4	57	22/880	1282	35.0
White mustard	$N_{60}P_{90}N_{60}$ control	No inoculation	62.3	64.3	57	22/880	1430	46.7
		ABT	62.3	57.6	57	22/880	1497	47.2
		Albobacterin	62.3	59.3	57	22/880	1480	47.4
		Biogran	62.3	57.7	57	22/880	1496	43.6
		BIO-GEL	62.3	57.8	57	22/880	1495	46.3
	$N_{30}P_{45}N_{30}$	No inoculation	62.3	62.6	57	22/880	1447	50.6
		ABT	62.3	54.9	57	22/880	1524	51.7
		Albobacterin	62.3	57.6	57	22/880	1497	51.3
		Biogran	62.3	58.7	57	22/880	1486	47.0
		BIO-GEL	62.3	58.4	57	22/880	1489	48.2
Vetch	$N_{60}P_{90}N_{60}$ control	No inoculation	65.7	61.7	57	22/880	1490	50.3
		ABT	65.7	63.7	57	22/880	1470	39.8
		Albobacterin	65.7	58.9	57	22/880	1518	43.9
		Biogran	65.7	59.9	57	22/880	1508	42.2
		BIO-GEL	65.7	57.9	57	22/880	1528	42.7
	$N_{30}P_{45}N_{30}$	No inoculation	65.7	61.3	57	22/880	1494	51.0
		ABT	65.7	62.4	57	22/880	1483	42.9
		Albobacterin	65.7	63.3	57	22/880	1474	43.9
		Biogran	65.7	58.8	57	22/880	1519	43.4
		BIO-GEL	65.7	58.2	57	22/880	1525	44.0

At the watermelon ripening stage (the previous watering was 3 days before) the moisture content in the meter soil layer in different experiment variants was rather high and amounted to 52.6 – 64.3 mm. During the vegetation period the rainfall amounted to 57 mm which is much less than the average long-term data (119 mm). Considering that during the vegetation the amount of precipitation and the amount of moisture evaporated from the soil surface in the experiment were the same, the total moisture consumption of the watermelon plants depended on the irrigation rate, the soil cover, the level of mineral nutrition and the inoculation of the seeds. During the watermelon vegetation period, depending on the presence or absence of the soil cover, 20 to 22 irrigations were conducted, the irrigation rate being 800-880 m^3/ha, in order to maintain the soil moisture content at the level of 75-75-70%. Lower irrigation rate (800 m^3/ha at 20 irrigations) was recorded in the variant where watermelons were grown without a soil coverer, whereas the higher one (880 m^3/ha at 22 irrigations) - where soil coverer was used. The highest total water consumption was recorded in the variants without soil covering crops and amounted to 1608 – 1688 m^3/ha depending on mineral nutrition and biological products use. The lowest rate was in the experiment variants with winter rye where it amounted to 1252 – 1298 m^3/ha depending on mineral nutrition and biological product use. The total water consumption in the variants with white mustard and vetch was almost the same and varied from 1430 to 1524 m^3/ha depending on mineral nutrition and biological product use.

An important indicator of effective moisture use watermelon plants depending on the factors studied is water consumption coefficient or total moisture use to form 1 t of watermelons. Thus, the lowest amount of water (31.2 m^3 per 1 t of fruit) was consumed in the variant with winter rye as a soil cover using the recommended mineral nutrition and pre-sowing seed treatment with Biogran. A bit lower (32.8 m^3/1 t of fruit) was water consumption coefficient on applying BIO-GEL in the same variant with winter rye as a soil coverer and the recommended mineral nutrition.

The average water consumption coefficient in the variants without a soil cover (control) amounted to 50.2 m^3/t while with soil covers it was 39.7 m^3/t (winter rye), 50.3 m^3/t (vetch) and 46.7 m^3/t (white mustard).

3.2.2. Effect of the factors under study on nutrient content in arable soil layer during watermelon cultivation

The studies carried out before the experiments (sowing winter rye as a soil covering crop) recorded the amount of nitrate nitrogen in the arable soil layer equaling on average 5.6 mg/kg, P_2O_5 – 41.0 mg/kg and K_2O – 220.0 mg/kg of absolutely dry soil. Subsequently according to the experiment scheme soil covering crops cultivation and plowing, seeds inoculation and mineral fertilizers application were carried out which affected the nutrient content in the soil. Thus, at the stage of watermelon top formation the greatest nitrate nitrogen content (at the control level of nutrition and without seeds bacterization) was in the arable soil layer with no soil cover and amounted to 8.6 mg/kg of absolutely dry soil, whereas with winter rye it was 7.2 mg/kg, with white mustard – 7.4 mg/kg, with vetch – 8.0 mg/kg (table 3.6).

Table 3.6. Nutrient content in the arable soil layer, mg/kg of absolutely dry soil

Soil cover	Mineral nutrition	Seed inoculation with bacterial product	Top formation			Fruit ripening		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O
No soil covering crop	$N_{60}P_{90}K_{60}$	no bacterization	86	49.0	244	6.2	41.2	220
		ABT	9.8	55.2	280	9.0	51.3	260
		Albobacterin	10.0	58.9	262	8.8	52.3	262
		Biogran	10.6	64.4	304	9.0	54.1	268
		BIO-GEL	9.8	55.2	280	9.0	51.3	260
	$N_{30}P_{45}N_{30}$	no bacterization	6.2	42.6	206	5.4	40.2	200
		ABT	7.2	44.8	242	7.0	40.8	220
		Albobacterin	6.8	46.1	240	6.0	42.2	240
		Biogran	7.5	45.9	280	6.5	40.9	200
		BIO-GEL	7.2	44.8	242	7.0	40.8	220
Winter rye	$N_{60}P_{90}K_{60}$	no bacterization	7.2	44.1	288	6.1	39.8	224
		ABT	8.0	46.8	300	6.8	42.6	260
		Albobacterin	7.9	48.4	282	5.6	43.3	240
		Biogran	8.3	50.1	320	6.4	47.5	280
		BIO-GEL	8.0	46.8	300	6.8	42.6	260
	$N_{30}P_{45}N_{30}$	no bacterization	6.6	41.7	244	5.4	39.6	198
		ABT	6.9	39.4	262	5.7	35.9	220
		Albobacterin	6.8	38.8	258	5.5	34.2	220
		Biogran	7.0	40.2	240	6.4	36.6	240
		BIO-GEL	6.9	39.4	262	6.2	36.4	240
Mustard	$N_{60}P_{90}K_{60}$	no bacterization	7.4	45.1	238	6.0	39.9	226
		ABT	7.8	46.0	236	6.2	42.4	242
		Albobacterin	8.2	44.6	260	7.0	41.6	240
		Biogran	8.2	47.7	298	6.8	43.7	266
		BIO-GEL	7.8	46.0	236	7.0	41.6	220
	$N_{30}P_{45}N_{30}$	no bacterization	7.0	42.6	240	5.1	39.3	220
		ABT	7.2	43.3	260	6.0	40.3	224
		Albobacterin	7.4	39.1	258	5.6	34.4	244
		Biogran	7.4	41.1	236	6.1	36.7	240
		BIO-GEL	7.2	43.3	260	6.0	40.3	224
Vetch	$N_{60}P_{90}K_{60}$	no bacterization	8.0	48.2	300	6.9	42.2	268
		ABT	10.4	53.3	222	8.9	48.6	186
		Albobacterin	8.4	56.2	244	7.7	51.2	222
		Biogran	8.8	59.9	240	8.0	53.5	208
		BIO-GEL	10.4	53.3	222	8.9	48.6	186
	$N_{30}P_{45}N_{30}$	no bacterization	7.8	43.6	278	6.6	38.8	248
		ABT	7.4	44.9	276	7.0	41.0	244
		Albobacterin	6.9	46.5	298	5.9	42.2	262
		Biogran	7.7	46.6	280	6.8	41.9	226
		BIO-GEL	7.4	44.9	276	7.0	41.0	244

The use of products for pre-sowing watermelon seed inoculation increased the nitrate nitrogen content in the soil compared to the control (no inoculation). Thus, in the variant without a soil covering crop seed inoculation with ABT and BIO-GEL increased the nitrate nitrogen content from 8.6 mg/kg to 9.8 mg/kg, the inoculation with Albobacterin – to 10.0 mg/kg, with Biogran – to 10.6 mgt/kg of absolutely dry soil.

In the variant with winter rye as a soil cover and the recommended nutrition the seed inoculation with ABT and BIO-GEL increased the nitrate nitrogen content in the soil from 7.2 mg/kg to 8.0 mg/kg, the inoculation with Albobacterin – to 7.9 mg/kg, with

Biogran – to 8.3 mg/kg of absolutely dry soil. The other soil covering crops showed the same tendency as for nitrate nitrogen. At the control level of mineral nutrition and without seed inoculation at the top formation stage the highest content of movable phosphorus in the arable soil layer was noted in the variant without soil cover - 49.0 mg / kg of absolutely dry soil, whereas with winter rye - 44.1 mg / kg, white mustard - 45.1 mg / kg and vetch - 48.2 mg / kg. Watermelon seed inoculation promoted higher movable phosphorous content compared to the control (no inoculation). Thus, in the variant without a soil covering crop seed inoculation with ABT and BIO-GEL P_2O_5 content in soil increased from 49.0 mg/kg to 55.2 mg/kg, with Albobacterin – to 58.9 mg/kg, with Biogran – to 64.4 mg/kg of absolutely dry soil.

In the variant with winter rye seed inoculation with ABT and BIO-GEL increased the movable phosphorous content in soil from 44.1 mg/kg to 46.8 mg/kg, with Albobacterin – to 48.4 mg/kg, with Biogran – to 50.1 mg/kg of absolutely dry soil. The other soil covering crops showed the same tendency as for movable phosphorous content.

In the process of watermelon cultivation there was a gradual inflow of nutrients into the soil with mineral fertilizers (fertigation) as well as due to the activity of bacterial preparations and mineralization of soil coverer residues that promoted plant growth and development. Therefore the difference between the nutrient content in soil at the beginning of watermelon vegetation and fruit ripening was insignificant.

3.2.3. Soil biological activity under watermelon

It is known that the main factor determining the soil life is the microorganisms existing in it which in the process of life interact with the factors of the environment, provide a gradual change in soil composition and its agronomically useful properties. Soil microbial metabolism is accompanied by the release of a certain amount of carbon dioxide which serves as a kind of indicator of the soil biological activity. The biological activity of the soil in the watermelon rhizosphere from its fixation at the beginning of the vegetation (coming-up stage) to its gradual fading (ripening stage) according to the experiment variants was characterized by stable changes. Plowing a ground cover contributed to an increase in the soil biological activity under watermelon crops even at the beginning of its cultivation. If the use of bacterial preparations in the watermelon cultivation without soil covers increased the intensity of CO_2 release from the soil at the 5-6 leaves stage by 9.7% at best, in case of soil cover this indicator increased by 15.4% (winter rye), 13.7 % (vetch) and 15.7% (white mustard). The highest soil biological activity in the flowering phase was noted in the variant with winter rye on applying half of the recommended dose of fertilizers and using Biogran - 94.9 mg CO_2 / $m^2 \times$ year as well as using BIO-GEL - 92.8 mg CO_2 / $m^2 \times$ year (Table 3.7).

Table 3.7. Soil biological activity in various watermelon growth phases depending on soil covering crops, mineral nutrition and seed inoculation, mg CO_2/m^2 x year

Soil cover	Mineral nutrition	Bacterial product	5-6 leaves stage	Flowering	Ripening
No soil cover	$N_{60}P_{90}K_{60}$	No bacterization	52.1	61.8	52.6
		ABT	54.0	74.3	63.1
		Albobacterin	53.3	76.3	60.2
		Biogran	55.9	76.4	63.0
		BIO-GEL	54.2	74.6	63.0
	$N_{30}P_{45}K_{30}$	No bacterization	50.6	56.9	48.3
		ABT	53.8	65.1	59.3
		Albobacterin	55.4	66.3	60.1
		Biogran	55.5	64.9	54.1
		BIO-GEL	55.5	66.0	60.0
Winter rye	$N_{60}P_{90}K_{60}$	No bacterization	57.7	72.9	59.6
		ABT	62.9	88.8	68.9
		Albobacterin	62.2	89.3	70.4
		Biogran	63.4	90.9	80.9
		BIO-GEL	62.9	90.8	68.9
	$N_{30}P_{45}K_{30}$	No bacterization	56.5	70.1	58.1
		ABT	62.2	81.8	64.2
		Albobacterin	61.4	86.1	69.9
		Biogran	65.2	94.9	76.9
		BIO-GEL	62.6	92.8	64.2
Mustard	$N_{60}P_{90}K_{60}$	No bacterization	56.6	66.3	58.1
		ABT	64.5	81.9	65.4
		Albobacterin	61.9	83.3	68.4
		Biogran	64.6	84.9	67.1
		BIO-GEL	64.8	83.9	65.4
	$N_{30}P_{45}K_{30}$	No bacterization	55.4	65.0	57.1
		ABT	60.0	79.8	61.3
		Albobacterin	62.2	80.0	64.4
		Biogran	64.1	85.3	69.8
		BIO-GEL	62.0	82.0	64.4
Vetch	$N_{60}P_{90}K_{60}$	No bacterization	55.3	58.6	52.1
		ABT	61.1	77.1	69.3
		Albobacterin	61.9	76.3	67.3
		Biogran	62.7	80.0	71.3
		BIO-GEL	61.7	76.3	67.3
	$N_{30}P_{45}K_{30}$	No bacterization	55.5	59.3	50.3
		ABT	60.4	73.6	62.8
		Albobacterin	62.2	74.3	63.3
		Biogran	63.1	75.1	63.9
		BIO-GEL	62.4	76.3	63.3

The peak of soil biological activity in all experiment variants was noted in the flowering phase, in the ripening phase there was a gradual fading of the intensity of soil "breathing".

3.2.4. Watermelon yield depending on the factors under study

All the studies factors affected watermelon yield. Thus, the watermelon yield in the control with the recommended nutrition ($N_{60}P_{90}K_{60}$) and no soil covering crop and pre-sowing seed inoculation amounted to 32.5 t/ha, while the application of the half of the dose resulted in 31.8 t/ha yield (table 3.8).

Table 3.8. Watermelon yield depending on soil covering crops, mineral nutrition and pre-sowing seed inoculation, t/ha

Soil cover	Mineral nutrition	Bacterial product	Replication				On average
			I	II	III	IV	
No soil coverer (C-1)	$N_{60}P_{90}K_{60}$(c-2)	No bacterization (c-3)	34.3	31.4	32.9	31.6	32.5
		ABT	36.4	35.6	34.1	37.6	35.9
		Albobacterin	37.1	36.3	36.2	34.8	36.1
		Biogran	36.2	41.6	39.2	37.1	38.5
		BIO-GEL	38.4	36.6	37.0	37.2	37.3
	$N_{30}P_{45}K_{30}$	No bacterization (c-3)	32.0	33.6	30.6	31.1	31.8
		ABT	35.3	33.9	34.6	35.7	34.9
		Albobacterin	36.5	34.4	33.7	35.2	34.9
		Biogran	36.8	37.6	38.8	36.9	37.5
		BIO-GEL	38.2	36.1	34.4	38.9	36.9
Winter rye	$N_{60}P_{90}K_{60}$(c-2)	No bacterization (c-3)	30.0	34.9	33.1	32.9	32.7
		ABT	36.3	35.9	34.6	40.9	36.9
		Albobacterin	33.6	35.8	33.9	33.3	34.1
		Biogran	39.6	41.1	42.2	39.6	40.6
		BIO-GEL	40.0	37.9	39.0	39.5	39.1
	$N_{30}P_{45}K_{30}$	No bacterization (c-3)	29.9	30.8	28.4	29.7	29.7
		ABT	32.6	31.3	33.9	34.6	33.1
		Albobacterin	31.3	31.1	36.1	30.9	32.3
		Biogran	38.9	39.7	37.2	39.3	38.8
		BIO-GEL	35.8	37.2	38.0	35.4	36.6
Mustard	$N_{60}P_{90}K_{60}$(c-2)	No bacterization (c-3)	30.1	32.2	28.9	31.3	30.6
		ABT	31.2	32.2	29.6	34.0	31.7
		Albobacterin	32.6	33.3	28.9	29.9`	31.2
		Biogran	34.4	35.1	33.3	34.3	34.3
		BIO-GEL	33.1	31.5	32.0	32.6	32.3
	$N_{30}P_{45}K_{30}$	No bacterization (c-3)	29.4	29.0	26.3	29.6	28.6
		ABT	29.9	30.1	27.7	30.4	29.5
		Albobacterin	30.7	31.1	26.8	28.4	29.2
		Biogran	31.6	33.3	31.5	30.1	31.6
		BIO-GEL	29.5	31.1	30.5	32.5	30.9
Vetch	$N_{60}P_{90}K_{60}$(c-2)	No bacterization (c-3)	31.6	29.8	27.6	29.4	29.6
		ABT	35.5	38.4	36.9	37.0	36.9
		Albobacterin	34.6	37.4	32.6	34.0	34.6
		Biogran	36.1	37.0	35.3	34.4	35.7
		BIO-GEL	34.8	36.1	36.8	35.5	35.8
	$N_{30}P_{45}K_{30}$	No bacterization (c-3)	32.0	30.6	26.6	28.1	29.3
		ABT	31.3	35.9	34.6	36.5	34.6
		Albobacterin	33.5	32.2	33.7	35.2	33.6
		Biogran	34.5	32.8	35.9	36.9	35.0
		BIO-GEL	33.7	35.4	35.9	33.4	34.6

The efficiency of mineral fertilizers was high with soil covering crops as well. Growing watermelon with various soil covering crops, with recommended mineral nutrition (control 2) and without seed inoculation (control 3), higher watermelon yield was obtained in the variant with winter rye (32.7 t/ha) and mustard (30.6 t/ha) ($HIP_{05}A$ – 0.79 t). Pre-sowing watermelon seed treatment with the products under study affected positively the watermelon yields. The highest yield was obtained in the variant with winter rye as a soil cover, with recommended dose of fertilizers applied and with pre-sowing seed treatment with Biogran (40.6 t/ha) and BIO-GEL (39.1 t/ha), while in the control it was 32.5 t/ha.

Thus, growing winter rye in spaces between watermelon rows as a soil cover, its mowing and then plowing back, sowing watermelon seeds inoculated with Biogran, application of the recommended dose of mineral fertilizers ($N_{60}P_{90}K_{60}$) resulted in the watermelon yield of 40.6 t/ha, which is 8.1 t/ha or 24.9% more than in the control (with no soil cover and no pre-sowing seed treatment). As for BIO-GEL, its application for pre-sowing seed treatment together with winter rye as a soil cover and recommended mineral fertilizer dose ($N_{60}P_{90}K_{60}$) resulted in the yield of 39.1 t/ha, which is 1.5 t/ha less compared to Biogran but 2.2 t/ha and 5.0 t/ha more compared to ABT and Albobacterin, respectively. The increase of watermelon yield caused by BIO-GEL application for seed inoculation in the best experiment variant (winter rye and the recommended fertilizer dose) amounted to 6.4 t/ha, or 19.6% compared to the variant with no inoculation.

In general, the efficiency of BIO-GEL as an inoculant was quite high but depended on the agronomist’s practice. Thus, with no soil cover but with recommended dose of fertilizers BIO-GEL promoted the yield increase by 4.8 t/ha, or by 14.8% and with half of the fertilizer dose applied – by 5.1 t/ha, or 16.0%.

In the variants with soil covers the least effective was BIO-GEL application for seeds inoculation in the variant with mustard, the yield increase amounted to just 1.7 t/ha, or 5.5% with the recommended dose of fertilizers and to 2.3 t/ha, or 8.0% with half of the recommended dose. When BIO-GEL was used for seed inoculation and vetch as a soil cover the yield increased by 6.2 t/ha,or 20.9% with the recommended dose and by 5.3 t/ha, or 18.1% with half of the recommended dose.

BIO-GEL application for seeds inoculation in the variants with rye insured the highest yield increase 6.4 t/ha, or 19.6% with the recommended dose and 6.9 t/ha, or 23.2% with half of the recommended dose.

It should be noted that BIO-GEL application and soil covering crop were most effective in the variant with winter rye. In this case watermelon yield was higher than in the control (without a soil cover) with the same dose of fertilizers, while in the variants with mustard and vetch it was lower.

3.2.5. Watermelon quality

Watermelon chemical composition depended more on the amount of mineral nutrition and seed inoculation than on the soil cover. Thus, greater amount of dry matter sugar was in the fruit in the variants with the recommended fertilizer dose, not with the reduced one (table 3.9)

Table 3.9. Watermelon biochemical composition depending on the soil covering crop, mineral nutrition and pre-sowing seed inoculation

Soil covering crop	Mineral nutrition	Bacterial product	Content			
			dry matter, %	total sugar, %	vitamin, mg/100 g	nitrates, mg/kg
No soil cover	$N_{60}P_{90}K_{60}$	No bacterization (c)	8.8	7.40	5.49	13.3
		ABT	9.0	8.08	4.25	16.7
		Albobacterin	9.0	8.08	4.25	14.2
		Biogran	9.1	8.20	5.85	11.7
		BIO-GEL	9.1	8.20	5.90	11.0
	$N_{30}P_{45}K_{30}$	No bacterization (c)	8.6	7.28	4.96	12.8
		ABT	8.8	7.92	6.38	18.3
		Albobacterin	9.0	8.08	3.54	16.0
		Biogran	9.0	8.06	4.61	12.5
		BIO-GEL	9.0	8.10	4.61	11.0
Winter rye	$N_{60}P_{90}K_{60}$	No bacterization (c)	9.0	8.04	5.32	10.5
		ABT	9.2	8.26	4.61	9.8
		Albobacterin	9.5	8.52	4.25	10.2
		Biogran	9.6	8.98	4.61	14.2
		BIO-GEL	9.4	8.46	4.66	10.2
	$N_{30}P_{45}K_{30}$	No bacterization (c)	9.0	7.88	4.96	12.8
		ABT	9.1	8.02	6.38	18.3
		Albobacterin	9.2	8.68	3.54	16.0
		Biogran	9.2	8.64	4.61	12.5
		BIO-GEL	9.2	8.70	4.70	11.4
Mustard	$N_{60}P_{90}K_{60}$	No bacterization (c)	9.2	8.06	5.32	10.5
		ABT	9.0	7.84	4.61	9.9
		Albobacterin	9.4	8.42	4.25	10.2
		Biogran	9.4	8.44	4.61	14.2
		BIO-GEL	9.3	8.34	4.32	12.1
	$N_{30}P_{45}K_{30}$	No bacterization (c)	9.0	8.88	3.54	16.0
		ABT	9.0	8.00	4.61	12.5
		Albobacterin	9.2	8.06	5.32	10.5
		Biogran	9.0	7.84	4.61	10.8
		BIO-GEL	9.0	8.04	4.81	9.8
Vetch	$N_{60}P_{90}K_{60}$	No bacterization (c)	9.0	8.6	5.32	10.5
		ABT	9.2	7.84	4.61	9.9
		Albobacterin	9.2	7.92	4.25	10.2
		Biogran	9.2	7.94	4.61	14.2
		BIO-GEL	9.2	8.00	4.85	11.1
	$N_{30}P_{45}K_{30}$	No bacterization (c)	8.8	7.40	5.49	13.3
		ABT	9.0	8.08	4.25	16.7
		Albobacterin	9.0	8.08	4.25	14.2
		Biogran	9.0	8.20	5.85	11.7
		BIO-GEL	9.0	8.08	5.15	9.7

Seed inoculation with the products under study and with the recommended rates of nutrition was also conducive to higher content of dry soluble matter in the fruit.

The greatest amount of dry matter and total sugar was noted in the fruit was in the variant with winter rye as a soil cover, the recommended fertilizer rate and with Biogran used for seeds inoculation. In this case it amounted to 9.6% and 8.98%, respectively whereas the fruit in the control contained 8.8% and 7.40%. Among the variants with BIO-GEL used for inoculation the best quality was noted in the variant with winter rye as a soil cover and the recommended fertilizer rate: 9.4% and 8.46%, respectively, which is higher than in the control.

In all experiment variants the amount of nitrates was lower (60 mg/kg of the soft part). BIO-GEL use was conducive to a small decrease in nitrate content compared to the control (no inoculation).

3.2.6. Economic efficiency of watermelon cultivation

Though the procurement prices of watermelons were not high (about 1500 UAH/t) in September 2017 while the production costs were considerable, the economic efficiency of watermelon cultivation appeared rather high. The gross revenue depends on the yield which, in its turn, depends on the technology elements under study.

The highest gross revenue was obtained in the variant with winter rye as a soil cover, the recommended rate of fertilizers and the pre-sowing seeds inoculation with Biogran, which amounted to 60900 UAH/ha, which is 12150 UAH/ha more than in the control (with no soil cover and no inoculation). But to access the economic efficiency of watermelon cultivation the net profit indicator is used as it takes into account the production costs depending on the technology elements under study.

The production costs of watermelon cultivation depended on all the factors under study but mainly on soil covering crops and fertilizers. As the cost of the recommended dose of mineral fertilizers amounted to 7200 UAH/ha in the control, in other variant where half of the dose was applied the expenses decreased by 3600 UAH/ha. As for soil covering crops and biological products, their cost increased the production expenses. The use of various products for seeds inoculation increased production expenses from 1 UAH/ha (BIO-GEL) to 62 UAH/ha (Biogran) while growing and plowing various soil covering crops increased production expenses from 824 UAH/ha to 2260 UAH/ha. It should be noted that the most significant was the price of the soil cover seeds: 824 UAH/ha with mustard, 1120 UAH/ha with winter rye and 2260 with vetch (table 3.10).

Table 3.10 Economic efficiency of watermelon cultivation

Soil cover	Mineral nutrition	Seed inoculation	Yield, t/ha	Gross profit, UAH/ha	Factor cost, UAH/ha	Net profit, UAH/ha	Prime cost, UAH/t	Profitability %
No soil cover	$N_{60}P_{90}K_{60}$	No bacterization (c)	32.5	48750	35051	13699	1078	39
		ABT	35.9	53850	35105	18745	978	53
		Albobacterin	36.1	54150	35101	19049	972	54
		Biogran	38.5	57750	35113	22637	912	64
		BIO-GEL	37.3	55950	35051	20899	940	60
	$N_{30}P_{45}K_{30}$	No bacterization (c)	31.8	47700	31450	16250	989	52
		ABT	34.9	52350	31504	20846	903	66
		Albobacterin	34.9	52350	31500	20850	903	66
		Biogran	37.5	56250	31512	24738	840	78
		BIO-GEL	36.9	55350	31450	23900	852	76
Winter rye	$N_{60}P_{90}K_{60}$	No bacterization (c)	37.2	49050	36171	12879	1106	36
		ABT	36.9	55350	36225	19125	982	53
		Albobacterin	34.1	51150	36221	14929	1062	41
		Biogran	40.6	60900	36233	24667	892	68
		BIO-GEL	39.1	58650	36171	22479	925	62
	$N_{30}P_{45}K_{30}$	No bacterization (c)	29.7	44550	32570	11980	1097	37
		ABT	33.1	49650	32624	17026	986	52
		Albobacterin	32.3	48450	32620	15830	1010	48
		Biogran	38.8	58200	32632	25568	840	78
		BIO-GEL	36.6	54900	32570	22330	890	68
Mustard	$N_{60}P_{90}K_{60}$	No bacterization (c)	30.6	45900	35875	10025	1172	30
		ABT	31.7	47550	35929	11621	1133	32
		Albobacterin	31.2	46800	35925	10875	1151	30
		Biogran	34.3	51450	35937	15513	1048	43
		BIO-GEL	32.3	48450	35875	12575	1111	35
	$N_{30}P_{45}K_{30}$	No bacterization (c)	28.6	42900	32274	10626	1128	33
		ABT	29.5	44250	32328	11922	1096	37
		Albobacterin	29.2	43800	32324	11476	1107	35
		Biogran	31.6	47400	32336	15164	1023	47
		BIO-GEL	30.9	46350	32274	14076	1044	43
Vetch	$N_{60}P_{90}K_{60}$	No bacterization (c)	29.6	44400	37311	7089	1260	19
		ABT	36.9	55350	37365	17985	1013	48
		Albobacterin	34.6	51900	37361	14539	1080	39
		Biogran	35.7	53550	37373	16177	1047	43
		BIO-GEL	35.8	53700	37311	16389	1042	44
	$N_{30}P_{45}K_{30}$	No bacterization (c)	29.3	43950	33710	10240	1150	30
		ABT	34.6	51900	33764	18136	976	54
		Albobacterin	33.6	50400	33760	16640	1005	49
		Biogran	35.0	52500	33772	18728	956	55
		BIO-GEL	34.6	51900	33710	18190	974	54

The highest net profit which amounted to 25568 UAH/ha and the profitability which amounted to 78% at the lowest prime cost of 840 UAH/t were obtained in the variant with winter rye as a soil covering crop, half of the mineral fertilizer application rate and seed inoculation with Biogran, while in the control the figures were 13699 UAH/ha, 39% and 1078 UAH/t, respectively.

When BIO-GEL was used the highest economic effect was obtained in the variant without a soil covering crop and with half of the recommended mineral fertilizer dose applied, it was a bit lower than with Biogran. The net profit after seed inoculation with BIO-GEL was 23900 UAH/ha, watermelon prime cost was 852 UAH/t, the profitability was 76%, while in the case without seed inoculation, without soil covering crop and half of the recommended fertilizer dose the figures were 16250 UAH/ha, 989UAH/t and 52%, respectively.

CONCLUSIONS

1. Seed inoculation with ABT and BIO-GEL in the variant without a soil covering crop promoted higher nitrate nitrogen content in soil (from 8.6 mg/kg to 9.8 mg/kg), with Albobacterin – up to 10.0 mg/kg, with Biogran – up to 10.6 mg/kg of dry soil.
2. The highest soil biological activity at the watermelon flowering stage was noted in the variant with winter rye as a soil covering crop, half of the recommended fertilizer dose applied and Biogran use (94.9 mg CO_2/m^2 x hour) as well as with BIO-GEL application (92.8 mg CO_2/m^2 x hour).
3. The lowest water consumption coefficient (the total amount of water used to form 1 t of fruit) 31.2 m^3/t was in the variant with winter rye as a soil covering crop, the recommended dose of mineral nutrition and pre-sowing seed treatment with Biogran. Approximately the same (32.8 m^3/t) water consumption coefficient was in the same variant with winter rye as a soil covering crop and the recommended mineral nutrition dose.
4. Growing winter rye as a soil covering crop in the space between rows, its cutting, plowing back and partially mulching soil, pre-sowing seed treatment with BIO-GEL and the recommended fertilizer dose application ($N_{60}P_{90}K_{60}$) resulted in the yield of 39.1 t/ha, which is 1.5 t/ha less than with Biogran but 2.2 t/ha and 5.0 t/ha more than with ABT and Albobacterin, respectively.
5. Yield gain after using BIO-GEL for seed inoculation in the best experiment variant (winter rye and recommended fertilizer dose) was 6.4 t/ha, or 19.6% compared to the variant without inoculation.
6. High BIO-GEL efficiency as a watermelon seed inoculant was noted at various soil states. Thus, with no soil covering crops but with recommended dose of mineral fertilizers BIO-GEL promoted yield increase by 4.8 t/ha, or by 14.8%, while with half of the fertilizer dose – by 5.1 t/ha, or 16.0%.
7. In variants with soil covering crops the least efficient was BIO-GEL use for watermelon seed inoculation in the variants with mustard, the yield gain was 1.7 t/ha, or 5.5% with the recommended dose of nutrition and 2.3 t/ha, or 8.0% - with half of the recommended dose.
8. In the variants with vetch the yield gain was 6.2 t/ha, or 20.9% with the recommended nutrition dose and 5.3 t/ha, or 18.8% - with half of the recommended dose.
9. BIO-GEL use for watermelon seed inoculation insured the highest yield gain of 6.4 t/ha, or 19.6% with the recommended dose and 6.9 t/ha, or 23.2% with half of the dose.
10. In case of BIO-GEL combined use with soil covering crops watermelon cultivation was most efficient in the variant with winter rye. The watermelon yield was higher than in the control (without a soil covering crop) at the same level of mineral nutrition though it was lower in the variants with mustard and vetch.

11. The greatest amount of dry matter and sugar was noted in the variant with winter rye as a soil covering crop, the recommended mineral nutrition and pre-sowing seed treatment with Biogran, the figures being 9.6% and 8.98%, respectively, while in the control the figures were 8.8% and 7.40%, respectively.
12. The best quality fruit was obtained in the variants with BIO-GEL use for inoculation, winter rye as a soil covering crop and the recommended fertilizer dose: 9.4% and 8.46% respectively, which is higher than in the control.
13. With BIO-GEL applied the highest economic effect was noted in the variant without a soil covering crop and with half of the mineral fertilizer dose applied, it was just a bit lower than with Biogran. In this case the net profit amounted to 23900 UAH/ha, watermelon prime cost was 852 UAH/t, the production profitability being 76%, while without seed inoculation, without a soil covering crop and with half of the mineral fertilizer dose applied the figures were 16250 UAH/ha, 989 UAH/t and 52%, respectively.