PLANT AND SOIL SCIENCE

Plant and Soil Science

Том 15, № 1. 2024

Засновник:
Національний університет біоресурсів і природокористування України

Рік заснування: 2010

Рекомендовано до друку та поширення
через мережу Інтернет Вченою радою
Національний університет біоресурсів і природокористування України
(протокол № 8 від 28 лютого 2024 р.)

Державна реєстрація: Ідентифікатор медіа R30-02296.
Рішення Національної Ради України
з питань телебачення і радіомовлення
№ 1795, протокол № 31 від 21.12.2023 р.

Журнал входить до переліку наукових фахових видань України

Категорія «Б». Галузь науки: Сільськогосподарські. Спеціальності:
201 «Агрономія», 203 «Садівництво та виноградарство»
(наказ Міністерства освіти і науки України
від 17 березня 2020 року № 409)

Журнал представлено у міжнародних наукометричних базах даних, репозитаріях та пошукових системах:

Google Scholar, Index Copernicus, Фахові видання України,
НБУ ім. В. І. Вернадського, BASE, Research Bible

Адреса редакції:
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
E-mail: info@agriculturalscience.com.ua
https://agriculturalscience.com.ua/uk

Plant and Soil Science

Volume 15, No. 1. 2024

Founder:
National University of Life and Environmental Sciences of Ukraine

Year of foundation: 2010

Recommended for printing and distribution
via the Internet by the Academic Council
of National University of Life and Environmental Sciences of Ukraine
(Minutes No. 8 of February 28, 2024)

State registration: Media identifier R30-02296.
Decision of the National Council of Television
and Radio Broadcasting of Ukraine
No. 1795, Minutes No. 31, dated 21.12.2023.

The journal is included in the List of Scientific Professional Publications of Ukraine
Category "B". Branch of sciences: Agricultural.
Specialties: 201 "Agronomy", 203 "Horticulture and Viticulture"
(order of the Ministry of Education and Science of Ukraine
No. 409, dated March 17th, 2020)

The journal is presented international scientometric databases, repositories and scientific systems: Google Scholar, Index Copernicus,
Professional publications of Ukraine, Vernadsky National Library of Ukraine,
BASE, Research Bible

Editors Office Address:
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
E-mail: info@agriculturalscience.com.ua
https://agriculturalscience.com.ua/en

Plant and Soil Science

Редакційна колегія

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Міжнародні члени редколегії:

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ЗМІСТ

Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 15(1), 9-25
Received: 01.11.2023 Revised: 01.02.2024 Accepted: 28.02.2024

UDC 635.1/.8:631.147

DOI: 10.31548/plant1.2024.09

Serhiy Vdovenko*
Doctor of Agricultural Sciences, Professor
Vinnytsia National Agrarian University
21008, 3 Sonyachna Str., Vinnytsia, Ukraine
https://orcid.org/0000-0003-4991-7234

Inna Palamarchuk
PhD in Agricultural Sciences, Associate Professor
Vinnytsia National Agrarian University
21008, 3 Sonyachna Str., Vinnytsia, Ukraine
https://orcid.org/0000-0001-8582-3855

Oleksandr Mazur
PhD in Agricultural Sciences, Associate Professor
Vinnytsia National Agrarian University
21008, 3 Sonyachna Str., Vinnytsia, Ukraine
https://orcid.org/0000-0002-2237-5116

Olena Mazur
PhD in Agricultural Sciences, Associate Professor
Vinnytsia National Agrarian University
21008, 3 Sonyachna Str., Vinnytsia, Ukraine
https://orcid.org/0000-0003-0132-7470

Ivanna Havrys
PhD in Agricultural Sciences, Associate Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0001-5965-9916

Influence of biological preparations on organic cultivation of vegetable plants

Abstract. The introduction of organic technology for growing vegetable plants will help to reduce the environmental burden of pesticides and produce safe vegetable products with high yields. The purpose of the study was to investigate the effect of biological preparations on the organic cultivation of vegetable plants. Field, measuring and weighing, mathematical and statistical methods were used to determine the efficacy of the preparations. The study was conducted in 2018-2021 in different

Suggested Citation:

Vdovenko, S., Palamarchuk, I., Mazur, O., Mazur, O., & Havrys, I. (2024). Influence of biological preparations on organic cultivation of vegetable plants. *Plant and Soil Science,* 15(1), 9-25. doi: 10.31548/plant1.2024.09.

*Corresponding author

regions of Ukraine. It was established that the systemic use of biologics during the growing season of vegetable plants provided rapid growth and development, helped to increase immunity to diseases, reduced the activity of pathogenic microorganisms in the soil, and provided an increase in overall yield. The general use of biologic preparations in open ground conditions contributed to a total potato yield of 25.4 t/ha, and the complex use of preparations on Brussels sprouts forms a larger number of heads – 90 units. The Organic Balance biological product provided an increase in yield of up to 3.5 t/ha and 90% marketability of products when growing Chinese cabbage. Chemical analysis showed that the use of biologics increased the dry matter in tomato fruits by 1.03% – in the Rio Fuego variety and 1.39% – in the Missouri variety. The yield increase in the studied varieties of asparagus beans Laura and Purpurova was 0.5 and 0.6 t/ha compared to the variants without seed inoculation. The use of biological preparations provided a higher yield in tomato plants of the Asvon variety by 2.2 t/ha, significantly reduced the content of nitrates in fruits to 50-80 mg/kg, while in the control – 110-170 mg/kg, increased the content of dry matter by 1.03 and 1.39%, depending on the variety. The gross yield of winter garlic with the use of biologics increased by 5%, and the marketability of potato tubers increased by 5%. Organic technologies would allow farmers to minimise the use of pesticides, produce environmentally friendly products, and increase yields

Keywords: biologics; organic technology; vegetable plants; productivity; quality, yield

INTRODUCTION

Vegetables contain high concentrations of vitamins, antioxidants, minerals and dietary fibre, and are low in fat, soluble sugars, and calories, so they are a supportive component of a healthy diet. The consumption of vegetables rich in vitamins, antioxidants, minerals and dietary fibre, with a low content of fat, soluble sugars and calories, is relevant, as it contributes to human health and the favourable development of industry, avoiding the problem of insufficient consumption of vegetables of plant origin worldwide. Human health and sustainable industrial production are under threat due to the imbalance and scarcity of plant-based vegetable consumption around the world, as indicated in papers by B.R. Havalli & S.N. Pradeep (2020) and J. Dong *et al.* (2022).

Organic vegetable production is becoming increasingly important and is spreading in 162 countries. Their annual increase is about 2 million hectares. The largest increase in agricultural land certified under organic standards was noted in Europe. The International Federation of the movement for organic agriculture, which unites participants from 108 countries of the world, promotes the development of organic production. Moreover, it covers the agricultural and processing industry, and other areas of activity. The most important and main segment of organic farming is the production of environmentally friendly, safe food. For this purpose, special agricultural land is allocated, and in particular, 37.2 million hectares of agricultural land have already been certified (Kundilovska, 2019).

Data from Organic Market in Ukraine (2020) indicate that high-quality organic products grown on agricultural land comply with the European Union regulation on organic production, and the areas respectively have the status of organic or transitional. Their total number is 309,100 hectares, including the area of agricultural land with a certified organic status – 233,500 hectares. The possibility of increasing the production of organic products is ensured by the fact that Ukraine can sell its products in Western countries. The main organic products supplied to Western markets are cereals, oilseeds and legumes, mushrooms, nuts, wild berries, and medicinal plants, but the variety of products is constantly growing.

Stress resistance of the variety is important when using organic vegetable products. V. Mazur *et al.* (2020) found that a variety should be characterised by high adaptability, which allows metabolic processes to be restored to an optimal level after a stress factor, which is especially important due to climate change and instability. The effectiveness of the organic technology

used on farms also depends on the quality of soil cultivation. Ultimately, proper tillage will help to preserve moisture in the soil and increase yields. The quality of tillage directly depends on agricultural machinery, as noted by O. Solona *et al.* (2020), O. Tkachuk & N. Telekalo (2020).

Since organic farming is a dynamic system that responds to internal and external requirements and conditions, T. Ilakiya *et al.* (2020) concluded that practicing organic agriculture contributes to increased efficiency and productivity, but this should not be at the expense of human health and well-being. Over nearly two decades, people have become aware of the harmful effects of chemical fertilisers on human health and have started to move towards organic farming.

In the traditional cultivation method, as noted by B. Alaoui & R. Hamimaz (2023), excessive use of pesticides and fertilisers leads to an imbalance of nutrients in the soil, an increase in pests and diseases, and a decrease in the quality and yield of vegetables. Therefore, the demand for organic food is mainly motivated by health and nutrition issues. Much attention is paid to biological control methods as an alternative to traditional chemical fungicides against plant diseases. A. Allayarov *et al.* (2021) showed that one of the most promising new areas of crop protection against phytopathogens is to increase the induction of plant resistance to pathogens and adverse environmental factors provided by the use of biologics.

The development of organic farming is observed in almost all countries of the world. The demand for organic products is growing, which has led to people's awareness to consume eco-friendly products. The technology has been developed to produce fresh food in both off- and on-season, while maintaining traditional agriculture and organic production, but export markets are increasingly demanding organic products for further sale.

The purpose of the study was to investigate the effect of biological preparations on organic cultivation of vegetable plants in various soil and climatic conditions of Ukraine.

MATERIALS AND METHODS

The research on the effective action of biological products was conducted in 2018-2021 at farms in Vinnytsia, Odesa and Volyn oblasts and at the experimental plots of Vinnytsia National Agrarian University (Vinnytsia Oblast), Mykolaiv National Agrarian University (Mykolaiv Oblast), Uman National University of Horticulture (Cherkasy Oblast) and the Institute of Vegetable and Melon Growing of the National Academy of Agrarian Sciences of Ukraine (Kharkiv Oblast).

In particular, the investigation of the effect of biologics on the growth, development and yield of garlic was carried out in the conditions of LLC NZCh of the Volyn Oblast (Ukraine). The Lyubasha winter garlic variety was used in the experiment. The design of the experiment involved the use of the existing technology on the farm, which was taken as a control, and a technology with the introduction of biological products. Biological preparations were applied during the growing season of plants in the phase of 2-4 leaves: Fitocide 2.0 l/ha, Azotofit 0.3 l/ha, HelpRost Vegetables 2.0 l/ha. Organic balance 0.5 l/ha, Bitoxibacillin BTU 10.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.5 l/ha; phase 8-9 leaves – Fitohelp 2.0 l/ha, HelpRost Vegetables 2.0 l/ha, Organic Balance 0.5 l/ha, Bitoxibacillin BTU 10.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.5 l/ha; head development and growth – Mycohelp 2.0 l/ha, HelpRost Boron 2.0 l/ha, Organic Balance 0.5 l/ha, Bitoxibacillin BTU 10.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.5 l/ha; leaf yellowing – technical ripeness – Mycohelp 2.0 l/ha, HelpRost Boron 2.0 l/ha, Organic balance 0.5 l/ha, Bitoxibacillin BTU 10.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.5 l/ha. The predecessor was winter wheat, grey podzolic soil, soil pH: 6.6.

In the conditions of the farm of M.M. Shkuryna, Odesa Oblast (Ukraine), the effect of biological products was studied during the cultivation of the Tiras potato variety. The design of the experiment included the following variants: no biological products were used (control) and a variant with the introduction of biological preparations. Biological products were applied during the following periods: pre-sowing tillage – Groundfix 5.0 l/ha, Mycohelp 2.0 l/ha; before planting – Mycofrend 1 l/t; during the growing season of the plant in the phase of 5-6 leaves – Fitohelp 2.0 l/ha, Humifrend 0.6 l/ha, Lyposam 0.3 l/ha; the period of growth of vegetative mass – Fitohelp 2.0 l/ha, Humifrend 0.6 l/ha, Lyposam 0.3 l/ha;

before flowering – Mycohelp 3.0 l/ha, Humifrend 0.6 l/ha, Lyposam 0.3 l/ha; after flowering – Mycohelp 3.0 l/ha, Humifrend 0.6 l/ha, Lyposam 0.3 l/ha. The predecessor was barley, grey podzolic soil, soil pH: 6.6.

The study of the influence of biological preparations on the development of the Brussels sprouts crop took place in the Vinnytsia National Agrarian University (Ukraine) for growing hybrids Franklin F_1, Diamant F_1, Bokser F_1, and Dolores F_1. The design of the experiment considered the following options, namely: without the use of biological preparations – control; introduction of the products at the recommended dose – in the phase of 5-6 leaves: Fitohelp 2.0 l/ha, Organic Balance 0.5 l/ha, Bitoxibacillin BTU 10.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha; before the development of heads – Mycohelp 3.0 l/ha, HelpRost Boron 2.0 l/ha, Azotofit 0.5 l/ha, Organic Balance 0.5 l/ha, Actoverm formula 8.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha; during the development of heads – Mycohelp 3.0 l/ha, HelpRost Boron 2.0 l/ha, Organic Balance 0.5 l/ha, Actoverm formula 8.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha; growth of heads – Mycohelp 3.0 l/ha, HelpRost Boron 2.0 l/ha, Azotofit 0.5 l/ha, Organic Balance 0.5 l/ha, Actoverm formula 8.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha. The predecessor was sweet pepper, podzolized chernozem, soil pH: 6.6.

The study of the effect of biological preparations on the yield of Chinese cabbage was carried out in the Uman National University of Horticulture when growing the Willie F_1 hybrid. Predecessor: winter garlic. Soil type: podzolized chernozem, soil pH: 6.3. The design of the experiment included the following options: without the introduction of biologics (control); foliar top dressing was carried out with organic balance 0.5 l/ha, Bitoxibacillin 8 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha; foliar top dressing in the phase of head development – HelpRost Vegetables 2.0 l/ha, Bitoxibacillin 8 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha; foliar top dressing during head growth – HelpRost Vegetables 2.0 l/ha, Organic Balance 0.5 l/ha, Bitoxibacillin 8.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha.

A study on the influence of biologics on the yield of carrots was conducted during 2019-2021 at the Organic-D farm in the Vinnytsia Oblast for hybrids Olympus F_1, Abaco F_1, Bolivar F_1, Miroflores F_1. Biologic preparations were applied in the following stages: 1) pre-sowing tillage – Groundfix 5.0 l/ha, Mycohelp 2.0 l/ha; 2) during the growing season of the plant in the phase of 2-5 leaves – Fitohelp 1.0 l/ha, Azotofit 0.3 l/ha Organic Balance 0.5 l/ha, Lyposam 0.3 l/ha; 3) in the phase of 6-9 leaves – Fitohelp 1.0 l/ha, Azotofit 0.3 l/ha ha, Organic Balance 0.5 l/ha, Actoverm formula 6.0 l/ha, Lepidocide 7.0 l/ha, HelpRost Boron 1.0 l/ha, Lyposam 0.3 l/ha; 4) during molting of the root crop – Azotofit 0.3 l/ha, Organic Balance 0.5 l/ha, HelpRost Vegetables 2.0 l/ha, Actoverm formula 6.0 l/ha, Lepidocide 7.0 l/ha, Fitohelp 1.0 l/ha, Lyposam 0.3 l/ha; 5) during root fruit development – Azotofit 0.3 l/ha, Organic Balance 0.5 l/ha, HelpRost Vegetables 2.0 l/ha, HelpRost Boron 2.0 l/ha, Actoverm formula 6.0 l/ha, Lepidocide 7.0 l/ha, Mycohelp 3.0 l/ha, Lyposam 0.3 l/ha. The control was based on the technology used on the farm.

The efficacy of the preparations in tomato cultivation technology was investigated at the Institute of Vegetable and Melon Growing in the Selektsiyne village, Kharkiv Oblast, during the cultivation of Topaz tomato variety. The design of planting seedlings was 140×25 cm, they were planted in the 3rd ten days of May using drip irrigation. The design of the experiment included the application of the recommended cultivation technology for Kharkiv Oblast (control), the variant where humus 10 t/ha, wood ash 1 t/ha were used; during the growing season, treatment with Actophyt 1 l/ha, Mycohelp 3 l/ha; a variant with an optimised nutrition system, namely humus 10 t/ha, wood ash 1 t/ha in pre-sowing soil tillage, Roundup 3.0 l/ha, Mycohelp 3.0 l/ha. During the growing season of the plant in the phase of 5-6 leaves – Fitohelp 1.0 l/ha, HelpRost Vegetables 2.0 l/ha, Organic Balance 0.5 l/ha, Bitoxibacillin BTU 7.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha; before flowering – Mycohelp 3.0 l/ha, HelpRost Boron 2.0 l/ha Azotofit 0.3 l/ha, Organic Balance 0.5 l/ha, Bitoxibacillin BTU 7.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha; at the beginning of fruiting – Mycohelp 3.0 l/ha, HelpRost Boron 2.0 l/ha, Azotofit 0.3 l/ha, Organic Balance 0.5 l/ha, Bitoxibacillin BTU 7.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0,3 l/ha; during the period of mass fruiting – Mycohelp 3.0 l/ha, HelpRost Boron 2.0 l/ha, Azotofit 0.3 l/ha, Organic Balance 0.5 l/ha, Bitoxibacillin BTU 7.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha.

The effect of biological preparations on the yield of seedling tomatoes was studied in the conditions of the farm private enterprise Trebukin of the Vinnytsia Oblast during the cultivation of hybrids Asvon F_1 (Kitano seeds), Bobcat F_1(Syngenta), Solerosso F_1 (Nunhems). The design of the experiment provided for Ecostern 2.0 l/ha in autumn tillage; and pre-sowing tillage with Groundfix 5.0 l/ha and Mycohelp 2.0 l/ha. During the growing season of plants in the phase of 5-6 leaves – Organic Balance 0.5 l/ha, Azotofit 0.3 l/ha, Actoverm formula 6.0 l/ha, Lepidocide 7.0 l/ha, Fitohelp 1.0 l/ha, HelpRost Vegetables 2.0 l/ha, Lyposam 0.3 l/ha; before flowering – Azotofit 0.3 l/ha, Organic Balance 0.5 l/ha, Actoverm formula 6.0 l/ha, Lepidocide 7.0 l/ha, Mycohelp 2.0 l/ha, HelpRost Boron 2.0 l/ha, Lyposam 0.3 l/ha; in the phase of the beginning of fruiting – Azotofit 0.3 l/ha, Organic Balance 0.5 l/ha, Actoverm formula 7.0 l/ha, Lepidocide 7.0 l/ha, Mycohelp 2.0 l/ha, HelpRost Boron 2.0 l/ha, Lyposam 0.3 l/ha; during mass fruiting – Azotofit 0.3 l/ha, Organic Balance 0.5 l/ha, Lepidocide 7.0 l/ha, Mycohelp 3.0 l/ha, HelpRost Boron 2.0 l/ha, Lyposam 0.3 l/ha.

Studies on the development of the bean yield depending on seed inoculation were conducted in the experimental fields of the Uman National University of Horticulture. The treatment was carried out with Anderiz preparation. The soil was characterised by the following agrochemical indicators: humus content – 3.91%; pH – 6.1; mobile phosphorus – 110 mg/kg of soil; exchange potassium – 195 mg/kg of soil. Inoculation of bean seeds was carried out on the day of sowing at the rate of 1 litre of the biological preparation per 1 tonne of seeds.

The influence of biological products on the yield of tomato was investigated in the Mykolaiv National Agrarian University with the cultivation of Rio Fuego (Lark Seeds) and Missouri (Seminis vegetable seeds) varieties. The design of the experiment provided for the use in pre-sowing tillage: Groundfix 5.0 l/ha + Mycohelp 2.0 l/ha + Metawhite 8 l/ha; during the growing season of plants in the phase of 5-6 leaves: Fitohelp 1.0 l/ha + HelpRost Vegetables 2.0 l/ha + Organic Balance 0.5 l/ha + Lyposam 0.3 l/ha; before flowering: Mycohelp 2.0 l/ha + HelpRost Vegetables 2.0 l/ha + Azotofit 0.2 l/ha + Organic Balance 0.5 l/ha + Actoverm formula 7.0 l/ha + Lepidocide 7.0 l/ha + Lyposam 0.3 l/ha; beginning of fruiting: Mycohelp 3.0 l/ha + HelpRost Boron 2.0 l/ha + Azotofit 0.3 l/ha + Organic Balance 0.5 l/ha + Actoverm formula 7.0 l/ha + Lepidocide 7.0 l/ha + Lyposam 0.3 l/ha; mass fruiting: Mycohelp 3.0 l/ha + HelpRost Boron 1.0 l/ha + Azotofit 0.3 l/ha + Organic Balance 0.5 l/ha + Actoverm formula 7.0 l/ha + Lepidocide 7.0 l/ha + Lyposam 0.3 l/ha.

All studies were carried out in accordance with generally accepted modern methods in crop production by A.O. Rozhkov *et al.* (2016), and the Greentest device (China) was used to determine the total nitrate content in the product organs of tomato and carrot roots. Based on the existing instructions for the device and the established recommendations, the permissible nitrate content in tomato berries should not exceed 300 mg/kg of product, and in carrot roots – 400 mg/kg. All values above the specified value are considered to be exceeded and must not be used for further consumption.

The study complied with all the requirements set out in the Convention on Biological Diversity (1992) and Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973).

RESULTS AND DISCUSSION

Based on the results of studies conducted to study the effect of a complex of biologics, their positive effect on the growth, development and formation of the crop of vegetable plants was established. The effect of biological preparations on the growth, development, and yield of garlic is shown in Table 1.

Table 1. Yield of the Lyubasha garlic variety using a complex system of biological preparations in the Volyn Oblast (Ukraine), t/ha

Control			Experimental			Yield increase, t/ha
Area, ha	Gross harvest, t	Yield, t/ha	Area, ha	Gross harvest, t	Yield, t/ha	
0.5	3.6	7.2	0.5	3.8	7.6	0.4

Source: compiled by the authors

Systemic use of biological preparations during the growing season of garlic plants of the Lubasha variety ensures rapid growth and development, helps to increase immunity to diseases, reduces the activity of pathogenic microorganisms in the soil, and provides an increase in overall yield. On the variant with the use of a complex of biological preparations, a yield of 7.6 t/ha was obtained, which is 0.4 t/ha more compared to the control version. The gross yield at the study site was 3.8 t/ha, which is 0.2 t/ha (5%) more than the control. The activity of bacteria that form the basis of biological preparation contributes to the timely formation of a typical product organ, the cloves are characterised by a standard size, the plant is more resistant to bacterial diseases.

The use of biologics during the growing season of the potato plant ensures optimal plant development, especially in its early stages; increases its immunity, growing process, and the overall yield (Fig. 1). The activity of bacteria that form the basis of Mycofrend preparation ensures the development of mycorrhiza on the surface of tubers and the root system, and the development of a larger number of commercial tubers. When studying the complex effect of biological preparations in the conditions of the Odesa Oblast (Ukraine), an increase in the potato yield was noted (Table 2).

a b

Figure 1. Development of potato tubers depending on the use of biological preparations

Note: a – control, b – experiental

Source: compiled by the authors

Table 2. Yield of Tiras potatoes using a comprehensive system of biologics in the Odesa Oblast (Ukraine), t/ha

Control			Experimental			Increment, t/ha
Area, ha	Gross harvest, t	Yield, t/ha	Area, ha	Gross harvest, t	Yield, t/ha	
0.5	10.85	21.7	0.5	12.7	25.4	3.7

Source: compiled by the authors

The general use of biologics of bacterial origin in open ground conditions contributed to the total potato yield of 25.4 t/ha, or 17.1%. Plants develop tubers weighing 50-80 g. The content of tubers in the total crop weighing 80 g is 18.7%, and tubers weighing from 50-80 g – 81.3%, and are characterised by a more stable immunity to diseases, the marketability of products increases by 5%. According to biometric measurements, the average weight of the Brussels sprouts head was higher in hybrids grown using organic technology and provided an increase in the indicator of relatively intensive technology by 0.1-0.6 g, depending on the hybrids under study (Table 3).

Table 3. Biometric indicators of Brussels sprouts

Variant	Average head weight, g	Number of heads per plant, units	Plant height, cm
Organic cultivation technology			
Franklin F_1 (control)	9.8	90	82
Diamant F_1	9.2	87	80
Bokser F_1 (control)	8.9	86	75
Dolores F_1	8.4	85	73
Intensive cultivation technology			
Franklin F_1 (control)	9.2	88	80
Diamant F_1	8.7	86	76
Bokser F_1 (control)	8.5	86	72
Dolores F_1	8.3	83	70

Source: compiled by the authors

The complex use of biological preparations contributed to the development of a much larger number of heads on the plant. In particular, the largest number of heads was obtained using organic technology from plants of the Franklin F_1 hybrid – 90 units, while with intensive technology, this hybrid on average developed 88 heads per plant. The use of biological preparations during the cultivation of Brussels sprouts ensures rapid survival of the plant in the open ground, stimulates growth processes. Fungicidal and insecticidal preparations help to increase the plant's resistance to damage. Biological preparations, especially stimulating ones, and organo-mineral fertiliser HelpRost increase plant resistance to stress factors and improve plant nutrition. Plants of Franklin F_1 hybrid (control) had the highest height under organic cultivation technology, where the increment relative to intensive technology was 2 cm (Table 4). A strong correlation was found between plant height and the number of heads per plant (r = 0.91).

Table 4. Yield of Brussels sprouts under various technologies in the conditions of Vinnytsia National Agrarian University

No.	Hybrids (A)	Yield, t/ha	± to control		Average for factor A	Average by factor B
			t/ha	%		
Intensive cultivation technology (B)						
1	Franklin F_1 (c)	8.1	-	-	-	7.4
2	Diamant F_1	7.5	0.6	-7.4	7.8	
3	Boxer F_1 (c)	7.3	-	-	-	
4	Dolores F_1	6.9	-0.4	-5.4	7.1	
Organic cultivation technology (B)						
1	Franklin F_1 (c)	8.8	-	-	-	7.8
2	Diamant F_1	8.0	0.8	-9.0	8.4	
3	Boxer F_1 (c)	7.6	-	-	-	
4	Dolores F_1	7.1	-0.5	-6.5	7.3	
	LSD_{05} (A)	0.3	-			
	LSD_{05} (B)	0.4				
	LSD_{05} (AB)	0.7				

Source: compiled by the authors

The action of biological preparations contributes to the development of marketable cabbage heads. In order to obtain a high-quality product of Brussels sprouts, there is a combination of using organo-mineral fertiliser HelpRost Vegetables with Organic Balance biological

preparation three times in the phase of development and growth of the product organ, where the yield increase is 0.4 t/ha.

The use of biologics during the growing season of Chinese cabbage plants has a positive effect on growth, development, and yield. Biological products, especially those with a stimulating effect, and organo-mineral fertiliser HelpRost ensure plant resistance to stress factors, namely biotic, anthropogenic, climatic, and edaphic, improve product quality, and provide balanced plant nutrition (Table 5).

Table 5. Chinese cabbage yield, t/ha

Experiment variant	Yield, t/ha				Marketability, %
	Harvest on 15.06	± to control	Total	± to control	
Control	1.7	-	18.1	-	78
Organic Balance 0.5 l/ha, Bitoxibacillin BTU 8.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha	2.7	+1.0	20.1	+2.0	87
HelpRost Vegetables 2.0 l/ha, Bitoxibacillin BTU 8.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha	2.2	+0.5	19.2	+1.1	85
HelpRost Vegetables 2.0 l/ha, Organic Balance 0.5 l/ha, Bitoxibacillin BTU 8.0 l/ha, Lepidocide 7.0 l/ha, Lyposam 0.3 l/ha	3.3	+1.6	21.6	+3.5	90

Source: compiled by the authors

Organic products are becoming increasingly popular in Ukraine, and there are a number of farms that grow them. Among these farms is Organic-D enterprise. Growing carrots with the introduction of a complex of biological preparations, a yield increase of 3.7 t/ha was obtained, and the gross yield increased by 1.9 t (Table 6).

Table 6. Yield of table carrots of the Olympus F_1 hybrid for the use of a comprehensive system of biological preparations at the Organic D farm, t/ha

Control			Experimental			Increment, t/ha
Area, ha	Gross harvest, t	Yield, t/ha	Area, ha	Gross harvest, t	Yield, t/ha	
0.5	25.4	50.9	0.5	27.3	54.6	3.7

Source: compiled by the authors

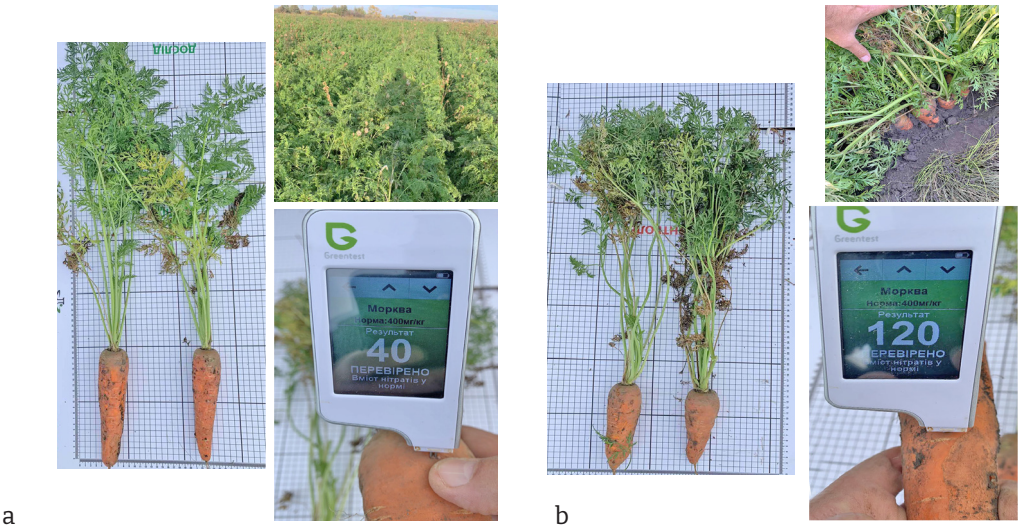
By increasing the production of organic goods, the farm in the following years also received an increase in the carrot yield due to the introduction of biological preparations in combination with the use of high-quality high-yielding hybrids of foreign selection (Table 7).

Table 7. Yield of carrot hybrids using a complex system of biological preparations at the Organic D farm, t/ha

Carrot hybrids (A)	Introduction of biological preparations (B)	Yield, t/ha	± to control	
			t/ha	%
Bolivar F_1 (control)	without introduction of biological preparations (control)	61.4	-	-
Abaco F_1	introduction of biological preparations (experiment)	60.5	-0.9	-1.5
Miroflores F_1	introduction of biological preparations (experiment)	63.7	+2.3	+4
LAS_{05} (AB)		0.9	-	

Source: compiled by the authors

Among the studied hybrids, the highest yield was provided by the Miroflores F_1 – 63.7 t/ha, which is 2.3 t/ha more than the control, which is 4% more. The significance of this difference is confirmed by the results of the variance analysis. Considering the biological and genetic characteristics of the Abaco F_1 hybrid and the use of biologics in this variant, the yield was at the level of 60.5 t/ha, which is 0.9 t/ha less compared to the Bolivar F_1 hybrid. It is important when growing agricultural products, including vegetables, to obtain their high quality indicators, and the nitrate content should not exceed the permissible norm. The high content of nitrates primarily causes the use of high doses of mineral fertilisers. That is why the use of biological preparations ensures the production of products with a lower content of nitrates (Fig. 2).



a b

Figure 2. Nitrate content in carrot vegetables (2021)

Note: a – experiment: introduction of biological preparations; b – control: without introduction of biological preparations

Source: photo by authors

The use of biologics during tomato cultivation ensures good survival of the plant in the open ground, increasing the total and marketable yield. Preparations of fungicidal and insecticidal action contribute to increasing the plant's resistance to damage, and biological preparations of stimulating action and organo-mineral fertiliser HelpRost improve plant resistance, improve plant nutrition, and stimulate the development of more fruits (Table 8).

Table 8. Efficiency of tomato cultivation technology (Institute of Vegetable and Melon Growing of the National Academy of Agrarian Sciences of Ukraine, 2019)

Variants	Total yield t/ha	Yield of marketable products, t/ha	Marketability, %	Biochemical parameters of fruits			
				Dry soluble substance, %	Total sugar, %	Ascorbic acid, mg/100 g	Acidity, %
Reference (control)	55.8	41.3	74.0	4.05	3.42	20.55	0.55
BTU-centre system	66.8	56.7	84.9	4.32	3.85	20.68	0.55
$LSD_{0.95}$	5.3	4.4		0.37	0.36	1.55	0.05

Source: compiled by the authors

The effect of these biologics contributes to the formation of a total 66.8 t/ha and a marketable yield of 56.7 t/ha. To obtain high-quality tomatoes, the use of organo-mineral fertiliser HelpRost Boron at a dose of 2 l/ha with Organic Balance biological product with a dose of 0.5 l/ha and Azotofit with a dose of 0.3 l/ha during the flowering and fruiting phase of the plant improves the quality of products (Table 9).

Table 9. Yield of tomatoes of the Asvon variety for the use of a comprehensive system of biological preparations in the conditions of Ukraine in 2020, t/ha

Control			Experimental			Increment, t/ha
Area, ha	Gross harvest, t	Yield, t/ha	Area, ha	Gross harvest, t	Yield, t/ha	
0.25	6.82	27.3	0.25	7.37	29.5	2.2

Source: compiled by the authors

The use of biological products contributes to better plant survival in the soil, provides nutrients to the plant during the growing season, increases immunity to diseases, reduces the total number of pathogens, and increases overall yields. The activity of bacteria that form the basis of biologics contributes to the development of a typical and marketable product organ. In open ground conditions, the use of biologics increases the total yield of tomatoes by 8%, which is 29.5 t/ha. Plants are characterised by more resistant immunity to diseases, and plant productivity increases by 9%, significantly reducing the nitrate content in the fruit (Fig. 3).

a b

Figure 3. Actual value of nitrate content in tomato fruits

Note: a – experimental tomato variety Asvon; b – control tomato variety Asvon Permissible rate – 300 mg/kg

Source: photo by authors

Research on biological products was also carried out at the Mykolaiv National Agrarian University (NAU), where tomatoes were grown in open ground. Biological preparations were used in the cultivation of tomatoes. Biochemical analysis showed that the use of biological preparations contributed to an increase in the dry matter in tomato fruits by 1.03% – for the Rio Fuego variety and 1.39% – for the Missouri variety (Table 10).

Table 10. Dry matter content in tomato fruits depending on the use of biological preparations for organic cultivation in the conditions of the Mykolaiv NAU, %

No.	Variant	Repeatability			Average	± to control, %
		1	2	3		
Rio Fuego variety						
1	Treatment with water (control)	3.59	3.54	3.62	3.58	-
2	Introduction of biological preparations	4.52	4.71	4.61	4.61	+1.03

Table 10, Continued

No.	Variant	Repeatability			Average	± to control, %
		1	2	3		
Missouri variety						
1	Treatment with water (control)	3.04	2.83	2.97	2.95	-
2	Introduction of biological preparations	4.42	4.32	4.28	4.34	+1.39

Source: compiled by the authors

Harvest accounting showed that the applied biological products contributed to an increase in yield (Table 11). Thus, for the Rio Fuego variety, the increase was 17.7 t/ha, that is, 33.3% more than the control, and for the Missouri variety, the increase was 14.2 t/ha, which is 36.8% more compared to the variant where biologics were not introduced. In order to determine the effect on the growth, development, and yield of asparagus beans, seed material was treated with an inoculant. According to Table 12, it was found that the biological preparation Anderiz has a positive effect on the assimilation surface, plant height, number and weight of beans, and the overall yield. The increase in leaf surface area in Laura and Purpurova asparagus bean varieties was 0.8 and 1.0 m^2/ha, respectively. The height of plants increased by 1.2 cm when using the inoculant. The number and weight of beans on the plant also increased by 0.6 units/plant and 1 g/plant – in the Laura variety, as well as 0.8 units/plant and 1.4 g/plant – in the Purpurova variety.

Table 11. Commercial yield of tomato fruits depending on the use of biological preparations for organic cultivation in the conditions of the Mykolaiv NAU, t/ha

No.	Variant	Repeatability			Average	± to control, t/ha	± to control, %
		1	2	3			
Rio Fuego variety							
1.	Treatment with water (control)	31.4	41.3	33.4	35.4	-	-
2.	Introduction of biological preparations	55.7	58.8	46.8	53.1	+17.7	+33.3
Missouri variety							
1.	Treatment with water (control)	23.9	25.1	23.8	24.3	-	-
2.	Introduction of biological preparations	41.8	37.4	36.4	38.5	+14.2	+36.8

Source: compiled by the authors

Table 12. Productivity of asparagus beans based on seed inoculation, 2021

Variant	Leaf area of crops, m^2/ha	Plant height, cm	Number of beans per plant, units/plant	Weight of beans, g/plant	Yield of green beans, t/ha
Asparagus beans, Laura variety					
Control	25.0	38.5	16.0	40.0	8.9
Anderiz 2 l/t	25.8	39.7	16.6	41.0	9.4
Asparagus beans, Purpurova Koroleva variety					
Control	22.0	36.3	15.0	38.0	8.4
Anderiz 2 l/t	23.0	37.5	15.8	39.4	9.0

Source: compiled by the authors

The use of a nitrogen fixer significantly increases the activity of nodule bacteria, which contributes to the development of more nodules in the main root zone, which increases the effectiveness of their action (Fig. 4).

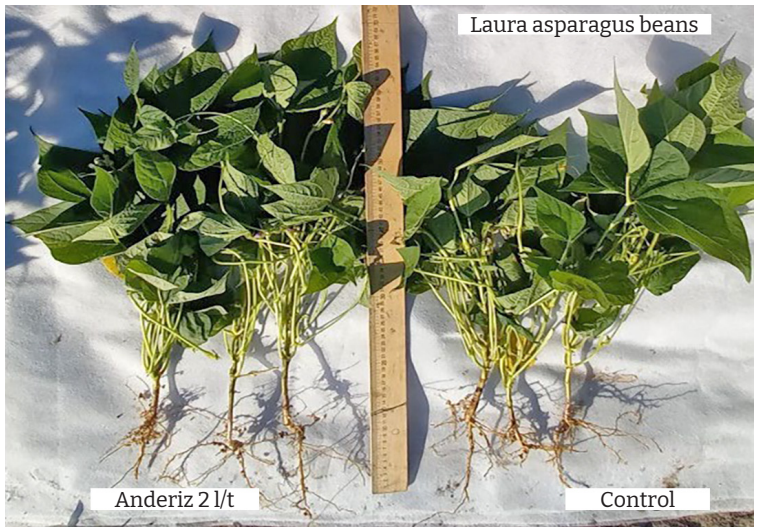


Figure 4. Development of nodules on the root system of asparagus beans (2021)
Source: photo by authors

Seed inoculation contributed to an increase in the yield of green asparagus beans. The yield increase in the Laura and Purpurova varieties was 0.5 and 0.6 t/ha compared to the variants where seed inoculation was not carried out. A strong direct correlation was found between the number of beans per plant and yield (r = 0.98), and a strong direct correlation between the weight of beans per plant and yield (r = 0.96).

The introduction of advanced technologies into production does not always allow producing high-quality vegetable products. As noted by I. Koblianska *et al.* (2022), every year more and more farmers are switching to organic production, which is possible in Ukraine. According to the findings of R.V. Logosha *et al.* (2019), L. Zarina *et al.* (2021), various methods and approaches to growing vegetable plants are used in agriculture. One way to increase yields is to use better precursors, which increase the nitrogen content due to the activity of nitrogen-fixing bacteria.

According to X. Feng *et al.* (2020), the use of microorganisms in the growing process can significantly improve the yield, quality, and antioxidant enzymatic activity of tomatoes. The use of straw mulching of soil significantly increases the growth, chlorophyll content, transpiration rate, and soluble sugar content in tomatoes, and at the same time improves soil properties. In addition, according to this study, it was found that the general condition of plants, the quality and resistance of tomatoes to diseases improves.

According to V.H. Serhiienko *et al.* (2023), fusarium wilt, alternariasis, vascular and mucosal bacteriosis prevailed on various varieties of white cabbage plants. The use of biological preparations significantly reduced the development of these diseases of white cabbage, including fungal and bacterial diseases. Researchers have found that biological preparations increase resistance to diseases by 62%, and protection against bacterial diseases by 65-79%. The positive effect of biological preparations on crop indicators was revealed, which increased it by 14.5-92%. The use of biological preparations significantly improves the biometric parameters of the plant and the overall yield.

Orgamika F biological product not only reduced the damage to cabbage vegetable crops by fusarium, but also helped to improve the quality indicators of seedlings. A. Allayarov *et al.* (2021) found that soaking seeds in a biological suspension showed the best efficiency. Biological efficiency of Orgamika F for growing white cabbage with titrated suspension 1×10^4 CFU/ml was 69.9%, and at a titer of 1×10^8 CFU/ml was 74.7%, cauliflower – 72.2% and 75.1%, respectively, Chinese cabbage – 72.5% and 76.2%, red cabbage –

70.4% and 76.8%, and savoy cabbage – 72.4% and 77.8%, respectively.

Market research shows that the number of organic products increases every year, but their price is also increasing. In order to produce high-quality environmentally friendly vegetable products, research is being conducted on further improvement in specialised farms (Koblianska *et al.*, 2022). I. Bender *et al.* (2020) showed that organic products are much better than those grown using traditional technology. Such products have smaller pesticide residues or do not accumulate them at all compared to vegetables grown using traditional technology. In addition to obtaining high-quality products, a clean environment is is preserved and maintained (Mazur *et al.*, 2020; Dydiv *et al.*, 2023). However, the accumulation of heavy metals in vegetable products may depend on the time of sowing. Therefore, it is important to optimise the growing conditions, in combination with the biological preparations used, it can ensure maximum effectiveness. Substances of organic origin have a positive effect on increasing and maintaining soil conditions at the appropriate level, namely, the physical, chemical, and biological characteristics of the soil (Lepse *et al.*, 2021).

Previous research by S.A. Vdovenko *et al.* (2018) established the influence of new strains of nodule bacteria on the development of the symbiotic apparatus of common beans (*Phaseolus vulgar*is L.). It was proved that the use of biological preparations provides an increase in interphase periods. The effect of inoculation with a complex of bacterial preparations Azotofit-L, Biomag, Biocomplex-BTU-L was investigated. The use of the bacterial preparation Biocomplex-BTU-L helped to increase the number and weight of nodules on the root system of the Zironka variety. The use of the bacterial preparation Biocomplex-BTU-L contributed to the production of 18.4 t/ha or 9.4 t/ha.

The effect of pre-sowing seed treatment with an inoculant and its combination with a plant growth stimulator on the development of symbiotic plant productivity and the accumulation of biological nitrogen in the soil was studied by I.M. Didur *et al.* (2019). Based on the results obtained, it was found that the use of pre-sowing treatment of alfalfa seeds with rhizobophyte in combination with Emistim S against the background of liming of the soil and the introduction of a full lime norm under hydrolytic acidity ensures the accumulation of the greatest amount of biologically fixed nitrogen. This average reached 236.1 hwt/ha over the years of research.

According to S.A. Vdovenko & P.A. Shvydky (2022) found that by growing sweet peppers in open field conditions under organic farming, it is possible to obtain a significant increase in plant biometric parameters. It is important to apply the recommended rates of the biological product, as an increase in these rates does not give the desired result. Adhering to optimal standards, the number of fruits on the plant and the overall yield increase. Bacterial preparations contribute to an increase in fruit weight of up to 14.5 g.

Thus, the use of bacterial-derived preparations is an impetus for economic growth and the provision of quality products to the population. Given the constant increase in demand for organic products, it becomes possible to provide the population with high-quality vegetables and preserve the environment as a whole.

CONCLUSIONS

To provide the population with high-quality vegetable products, it is necessary to use organic technologies that can be implemented by using preparations of bacterial origin. As a result of the use of bacterial preparations, the yield of vegetable plants grown in open ground conditions significantly increased. The use of biologics ensured the total yield of potatoes at the level of 25.4 t/ha, and the marketability of potato tubers for the use of biological preparations increases by 5%; the complex use of biological preparations on Brussels sprouts formed the largest number of heads – 90 units; during the cultivation of Chinese cabbage, Organic Balance biological preparation provided an increase in yield to 3.5 t/ha and marketability of products of 90%; the use of biological preparations provided an increase in the yield of the Asvon tomato variety by 2.2 t/ha, and during the cultivation Laura and Purpurova asparagus beans, it increased by 0.5 and 0.6 t/ha. The use of biological preparations during the cultivation of winter garlic increased gross output by 5%.

Complex application of biological preparations had a positive effect on the biometric parameters of the plant, they contributed to the growth of the assimilation surface area in asparagus bean plants of Laura and Purpurova varieties by 0.8 and 1.0 m^2/ha, respectively, increase the height of the plant to 37.5-39.7 cm, and the weight of beans to 39.4-41.0 g. A positive effect of biological preparations on the biochemical parameters of products was revealed, namely: they increased the dry matter in tomato fruits by 1.03% – in the Rio Fuego variety and by 1.39% – in the Missouri Variety; the nitrate content in Asvon variety decreased to 50-80 mg/kg.

The prospect of further research is to expand the understanding of the effect of biological preparations on organic cultivation of vegetable plants to optimise their use. Possible areas of research include further analysis of the effects of various biological preparations on different types of vegetables, investigation of their impact on the quality and safety of products, and optimisation of methods and recommendations for farmers in the field of organic cultivation. The research will be aimed at the mechanisms of interaction between biological products and plants, which will help improve their effectiveness and adaptation to different growing conditions. Consideration of the environmental and economic aspects of the introduction of biological preparations is also an important aspect of further research for the development of sustainable and effective organic agricultural production practices. In the future, it is planned to investigate the effect of biological preparations on the yield and quality of vegetable plant products under greenhouse conditions.

ACKNOWLEDGEMENTS

None.

CONFLICT OF INTEREST

None.

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Сергій Анатолійович Вдовенко
Доктор сільськогосподарських наук, професор
Вінницький національний аграрний університет
21008, вул. Сонячна 3, м. Вінниця, Україна
https://orcid.org/0000-0003-4991-7234
Інна Іванівна Паламарчук
Кандидат сільськогосподарських наук, доцент
Вінницький національний аграрний університет
21008, вул. Сонячна 3, м. Вінниця, Україна
https://orcid.org/0000-0001-8582-3855
Олександр Васильович Мазур
Кандидат сільськогосподарських наук, доцент
Вінницький національний аграрний університет
21008, вул. Сонячна 3, м. Вінниця, Україна
https://orcid.org/0000-0002-2237-5116
Олена Василівна Мазур
Кандидат сільськогосподарських наук, доцент
Вінницький національний аграрний університет
21008, вул. Сонячна 3, м. Вінниця, Україна
https://orcid.org/0000-0003-0132-7470
Іванна Любомирівна Гаврись
Кандидат сільськогосподарських наук, доцент
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0001-5965-9916

Вплив біологічних препаратів на органічне вирощування овочевих рослин

Анотація. Впровадження органічної технології для вирощування овочевих рослин дасть можливість зменшити екологічне навантаження пестицидами, отримати безпечну овочеву продукцію з високими показниками врожаю. Метою дослідження було вивчення впливу біологічних препаратів на органічне вирощування овочевих рослин. Для вивчення ефективної дії препаратів було використано польовий, вимірювально-ваговий, математичний та статистичний методи. Дослідження проводилося в 2018-2021 рр в різних областях України. Встановлено, що системне застосування біопрепаратів в процесі вегетації овочевих рослин забезпечує швидкий ріст і розвиток, сприяє підвищенню імунітету до захворювань, знижує діяльність патогенних мікроорганізмів у ґрунті, забезпечується збільшення загальної врожайності. Загальне застосування біопрепаратів в умовах відкритого ґрунту сприяє в отриманні загальної врожайності картоплі на рівні 25,4 т/га, а комплексне застосування біологічних препаратів на капусті брюсельській формує більшу кількість головок – 90 шт. Біопрепарат Органік баланс під час вирощування капусти пекінської забезпечує приріст урожаю до 3,5 т/га і товарність продукції 90 %. Хімічний аналіз визначив, що застосування біопрепаратів збільшує суху речовину в плодах помідора на 1,03 % – у сорту Ріо-Фуего та 1,39 % – у сорту Міссурі. Приріст, урожаю у досліджуваних сортів квасолі спаржевої Лаура та Пурпурова складає 0,5 та 0,6 т/га

порівняно з варіантами де інокуляція насіння не проводилась. Використання біологічних препаратів забезпечує отримання більшої врожайності у рослин помідора сорту Асвон на 2,2 т/га, значно знижується вміст нітратів у плодах до 50-80 мг/кг, тоді як на контролі – 110-170 мг/кг, зростає вміст сухої речовини на 1,03 та 1,39 % залежно від сорту. Валовий збір продукції часнику озимого стрілкуючого за використання біопрепаратів зростає на 5 %, товарність бульб картоплі зростає на 5 %. Органічні технології дозволять фермерам зменшити використання пестицидів, отримати екологічно чисту продукцію та підвищити врожайність

Ключові слова: біопрепарати; органічна технологія; овочеві рослини; продуктивність; якість; врожайність