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BIOLOGICAL PLANT PROTECTION IN THE EUROPEAN UNION (IN GERMANY AS AN EXAMPLE)

The application of ecological plant protection products against diseases, pests, and weeds is relevant for modern science-provided crop production. Much attention is paid to this problem in the European Union, where the use of pesticides is strictly adjusted by the European Food Safety Authority. Great hopes are pinned on biological plant protection products. However, among the thousands of biological products included in the BioPesticide DataBase, only a small number are authorized for use in agriculture. The requirements for the use of biological protectants in organic farming are even more stringent, regulating not only the properties of the product but also the crops in which they can be used. The ***aim*** *of the work was to present the main requirements for the safety of biopesticides in the EU countries and to give an overview of biopesticides authorized for use in traditional and organic farming using Germany as an example.* ***Methods****. Analysis of EU documents on the requirements for registration of active substances in biological products for plant protection, biopesticide databases, and the list of biopesticides approved for use in general and organic farming in Germany.* ***Results.*** *According to the EU requirements for biopesticide safety, registration of biological plant protection products based on bacteria, fungi, and viruses, individual microbial cellular components or metabolites, as well as insect predators, pheromones, and plant-origin substances is allowed. Among the biopesticides with bactericidal and fungicidal effects registered in Germany, the preparations based on microbial antagonizing plant pathogens are prevalent, as well as preparations elaborated on the fungus Aureobasidium pullulans, Trichoderma asperellum, Verticillium albo-atrum, Coniothyrium minitans, bacteria Pseudomonas chlororaphis, Bacillus amyloliquefaciens, and also the preventive drug Cerevisan based on the cell walls of Saccharomyces cerevisiae. The following bioformulations based on Bacillus thuringiensis, Beauveria bassiana, Cydia pomonella Granulovirus, avermectin antibiotic Abamectine A, herbal products Azadirachtin A and Piretrin, and Maltodextrin are registered as insecticides. A bioformulation based on Bacillus firmus is authorized for use as a nematocide.* ***Conclusions****. Registration of biological plant protection products in Germany is carried out in accordance with the EU requirements for the safety of biopesticides. The list includes*

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preparations based on antagonistic microorganisms, predatory microorganisms, microbial metabolites with antibiotic activity, substances for stimulation in plants nonspecific resistance to infectious agents. The fungicidal products are the widest represented. The number of products to control bacterial and nematode infections as well as the bioinsecticides spectrum is very limited. These are the well promising areas for further research and development of biological products.

Keywords: *biopesticides, antagonistic microbes, plant pathogen-parasites, nematicides, bioinsecticides, acaricides, bioherbicides.*

The intensive application of chemical plant protection products against diseases, pests, and weeds (collectively referred to as pesticides) in the late twentieth century led to environmental pollution by these substances and their incomplete decomposition products. This causes great concern for both scientists and the wider public, as toxic pesticides affect not only non-target objects, such as beneficial microbiota and plants but also animals and humans through trophic chains. Therefore, more and more attention is being paid to the use of environmentally friendly biopesticides for plant protection. The purpose of this review is to present the main requirements for the safety of biopesticides in the EU countries and to give an overview of biopesticides authorized for use in traditional and organic farming using Germany as an example.

The term «biopesticides» includes plant protection products based on natural objects, such as bacteria and fungi, their cellular components or metabolites, as well as viruses, insect predators, pheromones, and plant-produced substances. The biopesticide databases contain more than 10.000 names (Pesticide Properties Database; Bullock, 2020). The consensus is that environmental risks from biopesticide implementation are lower than those from the application of chemical pesticides, but this is not always the case. The use of each of them requires a preliminary examination of possible physiological and environmental consequences. That is why only a small part of the biopesticides available in the database is applied in agricultural practice.

International safety requirements for the registration of plant protection products are defined by the European Food Safety Authority (EFSA). Each product, both chemical and biological, must have a Conclusion on Pesticide Peer Review published in the EFSA Journal. The conclusion is based on a peer review of the pesticide risk assessment. An expert assessment should take into account the identity and physical, chemical, and technical properties along with methods for analysis of mammalian toxicity, residues of active substance, environmental fate and behavior, ecotoxicology (including persistence and impact on air, soil, groundwater, surface water, and sediment), and data gaps identified by Bullock (2020) for the maximum residue level applications, in particular conditions proposed for the representative uses evaluated, and critical areas of concern.

The European Union has a principle of mutual recognition of preparations. It is one of the means of ensuring the free movement of goods within the Community. To avoid any duplication of work, reduce the administrative burden for industry and for Member States, and provide for more harmonized availability of plant protection products, authorizations granted by one Member State should be accepted by the other Member States where agricultural, plant health, and environmental (including climatic) conditions are comparable.

Special requirements apply to products authorized for use in organic farming. They are determined by the Commission Implementing Regulation (EU) authorizing certain products and substances for use in organic production. The basis for the selection of biopesticides is Regulation (EU) 834/2007 and Implementing Regulation (EU) 2021/1165 (Authorising, 2021). A plant protection product, consequent on application consistent with good plant protection practice and having regard to realistic conditions of use, is to meet

the following requirements: (a) to be sufficiently effective; (b) to have no immediate or delayed harmful effects on human health, including those of vulnerable groups, or animal health, directly or through drinking water (taking into account substances resulting from water treatment), food, feed or air, or consequences in the workplace or through other indirect effects, taking into account the known cumulative and synergistic effects where the scientific methods accepted by the authority to assess such effects are available with no unacceptable ones on plants or plant products; (d) not to cause unnecessary suffering and pain to vertebrates to be controlled; it shall have no unacceptable effects on the environment, having particular regard to the following considerations where the scientific methods accepted by the authority to assess such effects are available: (i) its fate and distribution in the environment, particularly contamination of surface waters, including estuarine and coastal waters, groundwater, air and soil taking into account locations distant from its use following long-range environmental transportation; (ii) its impact on non-target species, including on the ongoing behaviour of those species; (iii) its impact on biodiversity and the ecosystem.

In Germany, the approval of plant protection products is a two-stage process. The active ingredients for plant protection products are approved by the EU Commission. Plant protection products with the approved active ingredients are approved nationally. The approval body in Germany is the Federal Office of Consumer Protection and Food Safety, which is responsible for the registration of plant protection products. All biopesticides are divided into two large groups: 1 — authorized plant protection products and 2 — plant protection products for organic farming.

1. Authorized plant protection products. This group contains a list of products approved for traditional agriculture and includes both chemicals that are the vast majority and a small number of biological products (Table 1).

Biopesticides with bactericidal action — this group contains mainly chemicals and only one registered biological product based on the strains of the fungi *A. pullulans* DSM 14940 and DSM 14941, which are positioned as antagonists of bacterial and fungal diseases (Galli et al., 2021). It is recommended to use these strains of fungi to control diseases caused by *Erwinia amylovora* and several fungal pathogens.

The list of *fungicidal biological products* is wider and includes bacterial and fungal antagonists of mycoses agents. Preparations based on *T. asperellum, T. gamsii, T. atroviride* were registered to control the number of phytopathogenic fungi of the genera *Pythium, Rhizoctoni, and Fusarium* (Brunner, 2005). The low-virulence strain of the phytopathogenic fungus *V. albo-atrum* WCS850, the causative agent of Verticillium wilt, is used as a vaccine for the prevention of Dutch Elm disease (Conclusion, 2013b).

Recently, a lot of attention has been drawn to the use of the oomycete *P. oligandrum* as a biopesticide. The biological control exerted by strain

Table 1. **Plant protection biological products approved for use in traditional farming systems**

Active ingredient	Manufacturer	Field of application
Bactericides		
Aureobasidium pullulans DSM 14940 and 14941	Blossom Protect	Fruit growing
Fungicides		
Trichoderma asperellum FG, Z (T. harzianum), T. gamsii ICC 080*, T. viride, T. atroviride* I-FG 1237	Bioten, Xilon, Tri-Soil	Agricultural crops, Vegetable growing, Ornamental growing, Viticulture
Verticillium albo-atrum WCS850	Dutch Trig	Ornamental growing

Continuation of Table 1

Active ingredient	Manufacturer	Field of application
Pythium oligandrum M1	Polygandron STP Polyversum	Agricultural crops
Coniothyrium minitans CON.M.91-08	LALSTOP CONTANS WG	Agricultural crops, Vegetable growing, Ornamental growing
Pseudomonas chlororaphis MA 342	Cedomon Cerall	Agricultural crops
Bacillus amyloliquefaciens MBI 600, QST 713 (*B.subtilis*)	Integral Pro Texio	Vegetable growing, Fruit growing, Viticulture, Ornamental growing
Cerevisane	Romeo	Vegetable growing, Fruit growing, Viticulture, Ornamental growing
	Insecticides	
Bacillus thuringiensis subsp. *kurstaki* ABTS-351 (HD-1), *B. thuringiensis* subsp. *israelensis* (Serotype H-14) AM65-52, *B. thuringiensis* subsp. *aizawai* ABTS-1857	DiPel DF, Lizetan	Agricultural crops, Vegetable growing, Fruit growing, Viticulture, Ornamental growing, Forestry
Beauveria bassiana ATCC 74040	Naturalis	Vegetable growing, Ornamental growing
Cydia pomonella Granulovirus mexikanisches Isolat, *C. pomonella Granulovirus* Isolat CV R5	Carpovirusine	Fruit growing
Abamectine A	Vertimec Pro	Vegetable growing, Fruit growing, Ornamental growing
Azadirachtin A	Bayer Garten Organic	Agriculture, Vegetable growing, Fruit growing, Viticulture, Ornamental growing
Maltodextrin	Eradicoat, Eradicoat Max	Agricultural crops, Vegetable growing, Hop growing, Fruit growing, Viticulture, Ornamental growing
Pyrethrin + rapeseed oil	Bayer Garten	Vegetable growing, Fruit growing, Ornamental growing
	Nematicides	
Bacillus firmus S.I-1582	VOTiVO	Agricultural crops
	Acaricides	
Abamectin A	COMPO Fazilo, COMPO, Triathlon	Ornamental growing
Azadirachtin A	Bayer Garten	Agriculture, Vegetable growing, Fruit growing, Viticulture, Ornamental growing
Maltodextrin	Eradicoat, Eradicoat Max	Agricultural crops, Vegetable growing, Hop growing, Fruit growing, Viticulture, Ornamental growing
Pyrethrin + rapeseed oil	Bayer Garten	Vegetable growing, Fruit growing, Ornamental growing
	Herbicides	
Pelargonic acid	Beloukha Garden, COMPO	Agricultural crops, Hop growing, Fruit growing, Viticulture, Ornamental growing, Non-cultivated soil

P. oligandrum M1 is the result of a complex process involving direct effects through pathogen control and/or indirect effects mediated by resistance induction and growth stimulation. This fungus penetrates the root tissues, causing the plant to form a complex of defense responses against all possible invasions. However, after that inducted resistance *P. oligandrum* M1 also cannot remain alive inside the plant for a long time. After root colonization by this fungus, plants form nonspecific defense systems that act against a number of pathogens (Gerbore et al., 2013). The mycoparasitic fungus *C. minitans* was registered as a biocontrol agent, the use of which has shown positive results against powdery mildew of legumes (Li et al., 2005).

The antagonistic activity of bacteria is used for biocontrol of mycoses. The Gram-negative soil bacterium *P. chlororaphis* MA 342 is used to treat seeds of monocotyledonous crops to control seed-borne fungal diseases. The application of the strain is effective for cereals including wheat, rye, and triticale and vegetables including carrots and peas (Anderson & Kim, 2018). This strain is classified as plant probiotic since it synthesizes metabolites that provide plant resistance to a lot of microbial pathogens, insects, and nematodes. Among *P. chlororaphis* MA 342 metabolites, siderophore, phenazine antibiotic, alkyl resorcinols, gluconate, phenolics, and insecticidal proteins were found.

A preparation based on *B. amyloliquefaciens* MBI 600 was registered as a biocontrol agent. The studies have shown that the growth rate of this strain exceeds the growth characteristics of pathogens. In addition, the strain activates plant defense responses by turning on a complex network of hormones and redox signaling (Dimopoulou et al., 2019).

In addition to preparations based on live microbial cells, certain cellular components of microorganisms are used. For example, the active ingredient of Cerevisane is the cell walls of the yeast *S. cerevisiae* LAS117 (Conclusion, 2014). The use of this product induces the plants' defense mechanisms. Therefore, it is recommended to use it preventively as it ensures that infection does not develop. It is emphasized that Cerevisane cannot cure an infection that has already occurred, but it can reduce the spread of a new one. The preparation is recommended for the prevention of diseases caused by *Botrytis cinerea, Peronosporus* spp., and other pathogenic fungi.

Among the *biopesticides with the insecticidal action,* preparations based on the spore-crystal complex of *B.thuringiensis* are generally acknowledged (Saxena & Stotzky, 2000). Representatives of this species have high amylolytic and low proteolytic activity: they release proteases into the culture liquid that have caseinolytic, fibrinolytic, and hemolytic (type β hemolysis) activity. Preparations based on *B. thuringiensis* var. *kurstaki* have an intestinal effect, the effectiveness of which is manifested when they colonize the insect intestines, where bacteria synthesize toxins. When activated in the intestinal tract, the toxin causes damage to the inner lining of the caterpillar's intestines, resulting in a violation of osmotic balance, which leads to the leakage of alkaline intestinal contents into the body of the caterpillar. This leakage can lead to the death of insects or cause changes that create conditions for the development of bacterial spores, resulting in septicemia. The damage to the intestinal tract disrupts the caterpillar's ability to digest food and causes it to stop feeding. In Germany, preparations based on *B.thuringiensis* subsp. *kurstaki* ABTS-351, *B.thuringiensis* subsp. *aizawai* ABTS-1857, and *B. thuringiensis* subsp. *israelensis* (Serotype H-14) AM65-52 strains have been registered.

The entomopathogenic fungus *B. bassiana* is also one of the most studied biopesticides. After invading the body of insect hosts, it synthesizes toxic secondary metabolites, namely bovericin, bassianin, bassianolide, boverolides, tenelin, oosporein, and oxalic acid. These toxins help *B. bassiana* to parasitize and kill its hosts (Wang et al., 2021). To control the number of pests, insect

viruses have been applying, in particular, *C. pomonella Granulovirus* Isolat CV R5 and *C. pomonella Granulovirus* mexikanisches Isolat. They were used to control the Codling moth in top fruit and nut orchards (Stará & Kocourek, 2003).

Abamectin A is widely used as a bioinsecticide with anthelmintic properties, which belongs to the macrocyclic lactones avermectins synthesized by soil *S. avermitilis* (Bai & Ogbourne, 2016; Dong & Zhang, 2022). The products based on antibiotic avermectin are considered the most promising plant protectors against pests. Avermectin is a complex of eight closely related components: four major ones (A1a, A2a, B1a, B2a) and four minor ones (A1b, A2b, B1b, B2b). The B-components have a broad spectrum of insecticide, acaricide, and anthelmintic effects. The mechanism of the insecticidal action of avermectins is that the antibiotic blocks the nerve impulse, as a result of which the pest loses the ability to move and feed, which causes its death.

Azadirachtin is a secondary metabolite present in neem seeds. It is a chemical compound belonging to the group of limonoids, highly oxidized tetranorotriterpenoid that has many oxygen functional groups, including enol ether, acetal, hemiacetal, tetrasubstituted epoxy, and various carbon esters. The first complete synthesis of this compound was carried out by Stephen Lay's research group at Cambridge University in 2007 (Veitch et al., 2007). This well-known maltodextrin is used as a horticultural insecticide. Its effectiveness is based on spraying a diluted solution on insect pests, after which the solution dries, blocks the insect's breathing, and causes death by asphyxiation (Conclusion, 2013a). In the *Dalmatian* chamomile *D.pyrethrum L.,* all plant organs, mainly flowers, contain pyrethrins that are poisonous to insects and harmless to humans. Pyrethrins are divided into two forms: «pyrethrin I» and «pyrethrin II». By chemical nature, they are esters: pyrethrin I is an ester of keto alcohol pyrethrolone and chrysanthemum monobasic acid; pyrethrin II is an ester of the same pyrethrolone and methyl ester of chrysanthemum bicarboxylic acid. Their synthetic analogs, pyrethroids, together with rapeseed oil, are registered as insecticidal preparations (Matsuo, 2019; Jeran et al., 2021).

Only biopesticide based on *B. firmus* I-1582 is registered among nematicidal products, approved in Europe for the control of meloidosis on vegetable crops. The bacteria are able to grow and colonize plant roots; they break eggshells, invade nematode eggs, and induce systemic resistance depending on the plant species (Ghahremani et al., 2020).

Abamectin A (Bai & Ogbourne, 2016; Dong & Zhang, 2022), Azadirachtin (Veitch et al., 2007), maltodextrin (Conclusion, 2013a), and pyrethrin (Matsuo, 2019; Jeran et al., 2021) have been registered as biological products with *acaricidal action.*

A plant-based *bioherbicide,* pelargonic acid, has been registered for weed control (Loddo et al., 2023). It was shown that the sensitivity of different species of both monocotyledonous and dicotyledonous weeds is highly variable. The effectiveness of pelargonic acid in field conditions depends on the botanical composition of the weeds and environmental conditions. Hot and dry weather decreases the sensitivity of weeds, reducing the penetration of the herbicide into the leaves. This product has been recommended for use in combination with chemical herbicides, reducing their dose.

2. Biopesticides approved for implementation in organic farming. The selection of products for organic farming is carried out in accordance with Implementing Regulation (EU) 2021/1165 and Regulations (EU) No 834/2007 and No 1107/2009. The German federal states may grant additional individual authorizations following the Plant Protection Act. The German law does not provide that the Federal Office for Consumer Protection and Food Safety officially decides on and authorizes organic farming. The user remains responsible for ensuring that his plant protection products comply with the above-mentioned EU regulations.

A list of biopesticides approved for application in organic farming and detailed information on the use of these products can be found in the online database (www.bvl.bund.de/psmdb). The list includes microorganism-based products, pheromones, and other semi-synthetic substances (e.g. pyrethrins), as well as fatty acid salts, copper compounds (allowed only where the total amount of application is a maximum of 28 kg of copper per hectare over 7 years).

Microorganisms as the basis of biological products for organic farming should not be genetically modified. Depending on the specific action, the products are registered as bactericides, fungicides, molluscicides, and acaricides (Table 2).

Only two bactericidal bioformulations are recommended: a biological product based on the antagonist of phytopathogenic bacteria the strain *B. amyloliquefaciens* QST 713 (formerly *B. subtilis*), approved for use against bacterial diseases of sweet peppers and tomatoes caused by *P. syringae* and several representatives of genus *Xanthomonas* (Dimopoulou et al., 2019; Sabo et al., 2020). Copper oxychloride, which has a broader spectrum of action against bacterial pathogens, is also approved for use on vegetable crops.

The list of biofungicides is much longer. Many products based on different *B. amyloliquefaciens* strains have been registered (Dimopoulou et al., 2019; Sabo et al., 2020). The strains have antagonistic effects against phytopathogenic fungi. Thus, strain FZB24 is recommended for use against powdery mildew of legumes (peas, beans), strain MBI 600 — against phytopathogenic fungi *Leptosphaeria maculans, B. cinerea, Sclerotinia minor,* and *S. sclerotiorum*, which affect rapeseeds, tomatoes, melon, zucchini, pumpkin, beans, peas, turnip, spinach, and related types of lettuce, radish, and purslane. A wide spectrum of antagonistic action against *Cercospora beticola, B. cinerea,* and *P. violae* is characteristic for strain *B. amyloliquefaciens* QST 713, which is recommended for industrial and vegetable crops such as sugar beet, eggplant, bell pepper, tomatoes, eggplant,

Table 2. **List of plant protection products approved for use in organic farming in Germany**

No	Active substance	Manufacturer	Crops pertmitted	Organisms being affected
		Bactericides		
1	*B. amyloliquefaciens* QST 713 (*B. subtilis)*	Serenade ASO	Sweet pepper, tomatoes	*Pseudomonas syringae, Xanthomonas* spp.
2	Copper oxychloride	Flowbrix	Tomatoes, eggplants	Bacterial pathogens
		Fungicides		
1	*B. amyloliquefaciens,* FZB24	TAEGRO	Field peas, beans	Powdery mildews fungi
2	*B. amyloliquefaciens* MBI 600	Integral Pro, Serifel	Rapeseed, peas, tomatoes, melon, zucchini, beans, pumpkin, lettuce, turnips, spinach and related species, lettuce, radish, purslane	*Leptosphaeria maculans, Sclerotinia minor, S. sclerotiorum, B. cinerea,*
3	*B. amyloliquefaciens* QST 713	Serenade ASO, Texio	Sugar beets, eggplant, fresh herbs, bell peppers, tomatoes, carrots, salads	*Cercospora beticola* *B. cinerea* *Pythium violae*
4	*B. amyloliquefaciens* subsp. *plantarum* D747	Amylo-X WG	Zucchini, sweet pepper, tomatoes, eggplant, melon, cucumbers, spinach	*T. aggressivum, B. cinerea, Sclerotinia minor, S. sclerotiorum*
5	*P. chlororaphis* MA 342	Cedomon	Spelt, barley, rye, triticale, wheat	*Pyrenophora graminea, P. teres*

Continuation of Table 2

No	Active substance	Manufacturer	Crops pertmitted	Organisms being affected
6	*C. minitans* CON/M/91-08	LALSTOP CONTANS WG	Arable crops, beans, potatoes, sunflower, tobacco	*Sclerotinia* spp.
7	*Ampelomyces quisqualis* AQ 10	AQ 10 WG	Sweet pepper, tomatoes, eggplant hybrids, melon, pumpkin, zucchini, cucumbers	*Erysiphe cichoracearum, Sphaerotheca fuliginea*
8	*P. oligandrum* M1	Polygandron STP, Polyversum	Potatoes, barley, rapeseed, wheat, mustard, lupine, soybeans	*Helminthosporium* spp., *Peronospora* spp., *Alternaria brassicae, Leptosphaeria maculans, B. cinerea, S. sclerotiorum*
9	*T. atroviride* I-1237	Tri-Soil	Celery, chicory, lettuce, fennel, coriander	*Pythium* spp., *Rhizoctonia* spp.
10	*T. asperellum* T34	Xilon	Corn, soybeans, sunflower, winter rape	*S. sclerotiorum*
11	*Clonostachys rosea* J1446 *(Gliocladium catenulatum)*	Verdera, BIOFA	Fruits and vegetables	*B. cinerea, Didymella bryoniae Mycospharella, Pythium* spp.., *Fusarium* spp., *Phytophthora* spp., *Rhizoctonia* spp.
12	Cerevisane	Intrachem	Fresh greens, cucumber, zucchini, pumpkin	*B. cinerea, Peronospora* spp.
13	Sulfurus	Polyversum, COMPO Bio	Wheat, barley, rye, oats, triticale, sugar beet	*Blumeria graminis,* Powdery mildews
		Insecticides		
1	*B. thuringiensis* subs. *kurstaki* ABTS-351, HD-1	DiPel DF, Dipel ES, Lizetan	Corn, field peas	Corn butterfly
2	Spinosad	Bayer Garten, ORGANIC, CELAFLOR, COMPO BIO	Potatoes, maize	Colorado potato beetle
3	Azadirachtin	Bayer Garten Organic, CELAFLOR, COMPO BIO	Potatoes	Colorado potato beetle
4	Pyrethrin + rapeseed oil	COMPO, Spruzit Neu, Spruzit	Potatoes, peas, beans, fruits, vegetables	Colorado potato beetle
5	Potassium salts of fatty acids	Neudosan Neu	Peas, beans, fruits, vegetables	Aphids
		Molluscicides		
1	Iron 3-phosphate	COMPO BIO, Derrex, Doff Power, Doff DuraTech, ETISSO FERREX, IRONCLAD,	Potatoes, soybeans, peas, oats, barley, rye, triticale, sunflower, corn, rapeseed	Slugs
		Acaricides		
1	Maltodextrin	Kantaro	Arable crops	Spider mites
2	Pyrethrin + rapeseed oil	Pyreth Natur Spruzit AF	Tomatoes, legumes	Spider mites
3	Rapeseed oil	COMPO Grün Celaflor	Vegetable crops, fresh greens	Spider mites

carrots, salads, and fresh herbs. *B. amyloliquefaciens* subsp. *plantarum* D747, registered as a biocontrol agent for fungi *T. aggressivum, B. cinerea, S. minor, and S. sclerotiorum*, which cause diseases of zucchini, sweet pepper, tomatoes, eggplant, melon, cucumbers, and spinach, and have a similar spectrum of action. The bacterial antagonist for *Pyrenophora graminea* and *P.teres* (causative agents of stripe and net leaf spot of cereal crops) is *P. chlororaphis* MA 342, registered for use in growing cereal crops such as spelt, barley, rye, triticale, and wheat (Anderson & Kim, 2018; Tombolini et al., 1999).

Natural parasites of phytopathogenic fungi are used as fungicidal agents. The preparation based on *C. minitans* CON/M/91-08, which is a natural parasite of this phytopathogenic fungus, was developed against *Sclerotinia* spp. (Peer review, 2016). The anamorphic fungus *A. quisqualis* AQ 10 is a parasite of the phytopathogenic fungi *Erysiphe cichoracearum, E. cichoracearum, Sphaerotheca fuliginea,* and *S. fuliginea,* which are the powdery mildews causative agents of vegetable crops (sweet peppers, tomatoes, eggplants, pumpkin, melon, zucchini, and cucumbers). This parasitic fungus can remain viable on the surface of plants for more than 20 days, and it prevents the development or significantly suppresses powdery mildew diseases (Sztejnberg et al., 1989). *P. oligandrum* M1 is a parasite of many fungi, including *Botrytis, Fusarium,* and *Phytophthora*. A preparation based on this fungus is registered as a fungicidal biocontrol agent for soil treatment with oospores, which reduces the pathogen load and related plant diseases (Ng et al., 2021). In addition, this fungus produces auxin-like substances that stimulate plant growth and contribute to the formation of defense responses against further infection by pathogenic fungi or bacteria. The oospores of this fungus are recommended for such crops as potatoes, barley, rapeseed, mustard, soybeans, lupine, and wheat.

The antagonistic activities of *T. atroviride* I-1237 and *T. asperellum* T34 were used against *Rhizoctonia* spp. and *S. sclerotiorum*, phytopathogens of the genera *Pythium* and *Fusarium* for cereals (corn, soybeans) and industrial (winter rape) and some green crops (Brunner et al., 2005; Mounier et al.. 2021).

In addition to the preparations based on live cultures of microorganisms antagonizing phytopathogens, it is recommended to use preventive preparations that stimulate plants' own defense reactions. Such a product is based on spores and mycelium of the soil fungus *C. rosea* J1446, natively presented in soil and decomposing organic matter (Funck Jensen et al., 2021). It effectively controls a wide range of pathogenic fungal diseases, including gray rot (caused by *B. cinerea*), cucumber ascochitosis and purple spot (caused by *Didymella bryoniae* or *Mycospharella*, etc.), wilt and root diseases (caused by a complex of pathogenic soil fungi of the genera *Pythium*, *Fusarium*, *Phytophthora,* and *Rhizoctonia*). After application, the fungal spores remain for several weeks in the rhizosphere, on the leaves and stems of crops, which protects them from various harmful fungi. It is approved for application on fruits and vegetables. Cerevisane, based on the cell walls of the yeast *S. cerevisiae* LAS117, is allowed to be used in organic and general agriculture (Conclusion, 2014) as an inducer of plant defense mechanisms for the prevention of diseases caused by *B. cinerea, Peronospora* spp.

Insecticidal products that can be used in organic farming are produced by a significant number of manufacturers. The live culture of *B. thuringiensis* subsp. *kurstaki* ABTS-351 (HD-1) has been allowed for corn and peas against corn borer (Saxena & Stotzky, 2000; Vimala Devi et al., 2020). The insecticidal preparation Spinosad has been obtained from metabolites of the actinomycete *Saccharopolyspora spinosa;* it contains spinosyns A and D, tetracycline antibiotics (Madhu, 2017). This preparation is recommended as a remedy against the Colorado potato beetle. In addition to microbial agents, Azadirachtin is allowed to be used against the Colorado potato beetle as well

(Veitch et al., 2007). It is also recommended to use pyrethrin with rapeseed oil against this pest (Matsuo, 2019; Jeran et al., 2021). Potassium salts of fatty acids, which are the basis of various detergents, are allowed to be used against aphids (for peas, beans, fruits, and vegetables).

As a *molluscicidal* agent, it is recommended to use iron 3-phosphate salt against slugs in the cultivation of many crops (potatoes, soybeans, peas, oats, barley, rye, triticale, sunflower, corn, and rapeseed). *Acaricidal* agents in organic farming are maltodextrin (Conclusion, 2013a) and pyrethrin together with rapeseed oil (Matsuo, al 2019; Jeran et., 2021). These products are recommended against spider mites for various crops such as arable crops, legumes, tomatoes, vegetable crops, and fresh herbs.

Conclusions. The registration of biological plant protection products in Germany is carried out in accordance with the EU requirements for the safety of biopesticides. Their list includes products based on antagonistic microorganisms, predatory microbes, metabolites with antibiotic action, and products that stimulate the formation of nonspecific resistance to infectious agents in plants. The most widely represented are fungicidal products. The list of products for controlling bacterial and nematode infections and bioinsecticides is very limited. These areas are promising for further research and development of biological products.

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БІОЛОГІЧНИЙ ЗАХИСТ РОСЛИН В ЄВРОПЕЙСЬКОМУ СОЮЗІ (НА ПРИКЛАДІ НІМЕЧЧИНИ)

Застосування екологічних засобів захисту рослин від хвороб, шкідників та бур'янів є актуальним для сучасного науково обґрунтованого рослинництва. Цій проблемі приділяється велика увага в Європейському Союзі, де використання пестицидів суворо регулюється Європейським агентством з безпеки харчових продуктів. Великі надії покладаються на біологічні засоби захисту рослин. Однак серед тисяч біологічних препаратів, включених до Бази даних біопестицидів, лише невелика кількість дозволена для використання в сільському господарстві. Вимоги до використання біологічних засобів захисту в органічному землеробстві є ще більш суворими, регламентуючи не тільки властивості продукту, але й культури, на яких вони можуть застосовуватися. **Мета** роботи — представити основні вимоги до безпечності біопестицидів у країнах ЄС і зробити огляд біопестицидів, дозволених до використання в традиційному та органічному сільському господарстві на прикладі Німеччини. **Методи.** Аналіз документів ЄС щодо вимог до реєстрації діючих речовин у складі біологічних препаратів для захисту рослин, баз даних з біопестицидів, а також переліку біопестицидів, дозволених до використання у традиційному та органічному сільському господарстві Німеччини. **Результати.** Згідно з вимогами ЄС щодо безпеки біопестицидів, дозволена реєстрація біологічних засобів захисту рослин на основі бактерій, грибів і вірусів, окремих мікробних клітинних компонентів або метаболітів, а також комах-хижаків, феромонів і речовин рослинного походження. Серед зареєстрованих у Німеччині біопестицидів бактерицидної та фунгіцидної дії переважають препарати на основі мікробних антагоністів патогенів рослин, препарати, розроблені на основі грибів *Aureobasidium pullulans, Trichoderma asperellum, Verticillium albo-atrum, Coniothyrium minitans,* бактерій *Pseudomonas chlororaphis, Bacillus amyloliquefaciens*, а також профілактичний препарат Церевізан на основі клітинних стінок *Saccharomyces cerevisiae*. Біопрепарати на основі *Bacillus thuringiensis, Beauveria bassiana, Cydia pomonella Granulovirus,* авермектинового антибіотика абамектину А, рослинних препаратів Азадірахтин А і Піретрин, а також мальтодекстрин зареєстровані як інсектициди. Біопрепарат на основі *Bacillus firmus* дозволений до використання як нематицид. **Висновки.** Реєстрація біологічних засобів захисту рослин у Німеччині здійснюється відповідно до вимог ЄС щодо безпечності біопестицидів. До переліку входять препарати на основі мікроорганізмів-антагоністів, мікроорганізмів-хижаків, мікробних метаболітів з антибіотичною активністю, препарати, що стимулюють у рослин неспецифічну стійкість до збудників інфекцій. Найширше представлені фунгіцидні препарати. Кількість препаратів для боротьби з бактеріальними та нематодними інфекціями, а також спектр біоінсектицидів дуже обмежений. Це актуальні перспективні напрямки для подальших досліджень і розробок *біопрепаратів*.

Ключові слова: *біопестициди, мікроби-антагоністи, патогени-паразити рослин, нематоциди, біоінсектициди, акарициди, біогербіциди.*