Plant and Soil Science

Journal homepage: https://agriculturalscience.com.ua/en
Plant and Soil Science, 14(3), 22-34
Received: 02.04.2023 Revised: 07.07.2023 Accepted: 11.08.2023

UDC 632.3:632.95:633.64 DOI: 10.31548/plant3.2023.22

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Influence of drugs produced by electropulse ablation methods on the development of soybean phytopathogenic bacteria

Abstract. The causative agents of soybean blotch (*Pseudomonas savastanoi pv. glycinea*) and soybean pustular bacteriosis (*Xanthomonas axonopodis pv. glycines*) are common phytopathogenic bacteria. However, the lack of officially registered drugs against them stimulates the search for new solutions. The research aims to determine the effect of these micronutrient preparations

Suggested Citation:

Hnatiuk, T., Kravchenko, O., Abarbarchuk, L., Churilov, A., & Chobotar, V. (2023). Influence of drugs produced by electropulse ablation methods on the development of soybean phytopathogenic bacteria. *Plant and Soil Science,* 14(3)*,* 22-34. doi: 10.31548/plant3.2023.22.

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obtained by electropulse ablation on bacteria during artificial infection of soybean with museum strains of pustular bacteriosis and angular spot pathogens. The antibacterial activity of the studied preparations was compared with the untreated variants and the effect of traditional chemical pesticides based on Fludioxonil and Metalaxyl-M. The spread and development of the disease were assessed by the number of affected plants using a scale from 0 to 4 points. It was found that varietal characteristics of soybeans affect the degree of infection by phytopathogenic bacteria. It was found that weather conditions, in particular air temperature, are a significant factor in the development of disease manifestations. It was proved that seed treatment with a chemical pesticide based on Fludioxonil and Metalaxyl-M in the absence of additional foliar treatment does not reduce the manifestations and degree of damage compared to the control (without treatment). Dressing and foliar treatment with a chemical pesticide based on Fludioxonil and Metalaxyl-M only partially reduce the manifestations of bacteriosis compared to the control variants (by about 15%). At the same time, the use of preparations obtained by electropulse ablation methods is promising against phytopathogenic bacteria in the system of soybean cultivation technology – namely, it was determined that under the condition of soybean plants treatment with experimental preparations according to the Comfort scheme (consumption – 150 ml/t of seeds) + Dobrodiy fertilizer (consumption – 2, 4 l/t of seeds) + microelement preparation "Micro Protect" (consumption of 500 ml/t of seeds) + two foliar treatments with the specified mixture of microelement preparations, the delay in the manifestation of plant damage until the time of harvesting is increased, which in turn is likely to lead to an increase in yields. The practical significance of the work is to determine effective methods of controlling phytopathogenic bacteria that harm soybeans

Keywords: bacterial plant pathogens; legumes; angular spot; pustular bacteriosis; nanoaquahelaths; ablation technologies

INTRODUCTION

Phytopathogenic bacteria that cause economic losses to agriculture usually exhibit significant resistance to chemical and often biological agents, which hinders plant protection against bacteriosis (Kolomiiets *et al.*, 2019). Plant pathogens, disrupting the normal course of physiological processes of the plant organism, lead to its partial or complete death. This worsens product quality and significantly reduces yields. Therefore, the issue of effectively limiting their spread, minimising or even preventing significant economic losses, remains relevant and worthy of attention (Martins *et al.*, 2018).

Among the legume plants, soybeans are the most widely used in agriculture and are economically and environmentally beneficial. According to T.T. Hnatiuk *et al.* (2019), the most common bacterial phytopathogens that can cause legume epiphytoties in Ukraine are *Pseudomonas savastonoi pv. glycinea* (the causative agent of soybean angular spot) and *Xanthomonas axonopodis pv. glycinea* (the causative agent of desert bacteriosis), and the most common ones are *Curtobacterium flaccumfaciens pv. flaccumfaciens* (rusty brown spot or wilt of soybean), *Xanthomonas fuscans subsp.fuscans* (small brown spot of soybean), *Pantoea agglomerans* (stem stripe).

Phytopathogenic *Pseudomonas* bacteria have a high adaptive potential in different agroecological conditions and cause significant damage to the host plant organism but are also resistant to the toxic effects of chemical and biological agents (Yin *et al.*, 2022). The causative agents of bacterial diseases of leguminous plants of the *Pseudomonas* family are both highly specialised groups of bacteria (*P. savastanoi pv. phaseolicola, P. savastanoi pv. glycinea*) and polyphages (*P. syringae pv. syringae, P. syringae pv. tabaci*) (Hnatiuk *et al.*, 2019), which do not always show the same sensitivity to certain pesticides.

According to K.A. Abo-Elyousr *et al.* (2022), the pathogens of soybean pustular bacteriosis (*Xanthomonas axonopodis. pv. glycines*) and brown bean bacteriosis (*Xanthomonas axonopodis. pv. phaseoli*) are highly active and widespread among yellow-pigmented pathogens of legume bacterioses, affecting the aerial parts of plants and seeds. When using pesticides of both chemical and biological origin, these phytopathogens show sensitivity or resistance to them in a wide range of population heterogeneity, which leads to the continuing search for fundamentally new approaches to crop protection technologies (Varympopi *et al.*, 2022; Oliveira *et al.*, 2023; Halfeld-Vieira *et al.*, 2023). As of 2023, there are no officially registered drugs against phytopathogenic bacteria in Ukraine and the world, which increases the urgency of finding such drugs (Atiq *et al.*, 2022, Taheri *et al.*, 2023).

With the development of integrated plant protection ideas, the use of preparations obtained by electropulse ablation (preparations based on metal nanoaccumulates) is becoming increasingly popular. In particular, they are characterised by antimicrobial properties, contribute to increasing plant resistance to adverse abiotic and biotic factors, and complement and enhance the effect of traditional plant protection products (Pruntseva, 2018; Huliaieva *et al.*, 2018). M. Alavi *et al.* (2022) also noted that bacteria cannot develop resistance to several metals.

Thus, given the aforesaid properties, nanoaccitrates are promising agents capable of restraining and counteracting the development of large-scale epiphytoties caused by bacteria and microsporidia. The research relevance is determined as large-scale epiphytoties caused by bacteria and micromycetes pose a serious threat to soybean cultivation and can lead to significant yield losses. Given the absence of officially registered drugs against phytopathogenic bacteria in agriculture, the search for new effective solutions becomes extremely important. Thus, the research aims to determine the effect of preparations obtained by electropulse ablation on the main phytopathogenic bacteria of soybean under artificial infection *in vivo*.

MATERIALS AND METHODS

The study was conducted in temporary field experiments based on the Mohyliv-Podilskyi territorial community in 2021 and 2022. The soil is dark grey podzolic, coarse-dusted, and light loamy. The soybean predecessor in 2021 is black fallow, and in 2022 – soybeans. Agricultural practices for soybean cultivation are common. The sowing rate is 450 thousand germinating seeds per 1 ha, the sowing method is wide row, with a row spacing of 45 cm. The soybean varieties to be released in 2021 are Strike and Drayton and in 2022 Kyoto.

During the research in July 2021, the average ten-day temperature in the research area was 1.1°C above normal, and significant daily temperature fluctuations were recorded. Despite the above favourable temperature conditions for bean formation, in July 2021, in Mohyliv-Podilskyi district, an excess of the average monthly rainfall was recorded (250-300% of the norm), which in turn contributed to the development of soybean phytopathogens.

During the experiment in 2022, the average daily temperature in the Mohyliv-Podilskyi district was close to normal, but during the experiment, the highest seasonal temperatures of 31-33°C were recorded for 5 days, and the amount of precipitation was 150% of the annual average.

The pathogens of angular spot (*Pseudomonas savastanoi pv. glycinea* UCM B-9190) and pustular bacteriosis (*Xanthomonas axonopodis pv. glycineaes* UCM B-9192) of common soybean, which is stored in the Ukrainian Collection of Microorganisms (UCM) of the Zabolotny Institute of Microbiology and Virology of the National Academy of Sciences of Ukraine, Department of Phytopathogenic Bacteria. For inoculation of common soybean plants, a suspension of one- to two-day-old bacterial cultures with a density of 1×10^9 CFU (Number of Optical Units) per ml of purified tap water was used, which was applied to the leaf surface followed by a triple needle wound or injected into the stems and beans of plants by syringe injection (Klement *et al.*, 1990).

The experiments were repeated five times, and the recordings were made on days 7, 15 and 30. Purified tap water was used as a control.

The effect of drugs obtained by electropulse ablation was studied, namely:

1) Microelement preparation "Comfort Universal" (Ukraine) based on nanoaccitrates of S, Se, Cu, I, Al, V, Ni, Co.

2) Organo-mineral fertiliser "Dobrodiy" (Ukraine). Component characteristics (g/kg): (N) nitrogen – Nitrogen-containing compounds in terms of nitrogen – 330, K – in terms of K_2O – 60,

Trace elements chelated with carboxylic acids: B – 0.36, Mo – 0.013, Fe – 1.44, Mn – 1.44, S – 9.6, Cu – 2.4, Zn – 1.2, Mg – 33, Co – 0.037; Humic and fulvic acids 30 g/kg.

3) Micronutrient preparation "Protect Micro" (Ukraine). The drug is produced using an original technology by chelation of active elements with natural di- and tricarboxylic organic acids (including succinic, tartaric, and malic acids): Cu – 15, Zn – 16, Mn – 7.2, Mo – 2, Co – 1.5, Fe – 8.

A comparison of the two field trials in 2021 and 2022 is shown in Table 1.

Table 1. Field experiments in 2021-2022

For the first field trial (in 2021), a variant scheme was used:		For the second field experiment (in 2022), a modified scheme was used. Soybean seeds of the Kyoto variety were treated according to the variants:	
1.	Plants treated with Comfort (consumption – 250 ml/tonne of seeds) + Dobrodiy organic-mineral fertiliser (consumption – 2.4 litres/tonne of seeds).	1.	A chemical disinfectant based on Fludioxonil and Metalaxyl-M (recommended consumption – 1 l/t).
2.	Plants without preliminary treatment.	2.	Treatment with Comfort (consumption – 150 ml/t of seeds) + Organo-mineral fertiliser "Dobrodiy" (consumption – 2.4 litres/t of seeds) + microelement preparation "Micro Protect" (consumption – 500 ml/t of seeds)
		3.	A chemical disinfectant based on Fludioxonil and Metalaxyl-M (recommended dose of 1 l/t) + two foliar treatments with the same drug.
		4.	Treatment with Comfort (consumption – 150 ml/t of seeds) + Organo-mineral fertiliser "Dobrodiy" (consumption – 2.4 litres/t of seeds) + microelement preparation "Micro Protect" (consumption – 500 ml/t of seeds) + two foliar treatments with the specified mixture of micronutrient drugs.
		5.	Control (without preliminary treatment).

Source: compiled by the authors

Two foliar treatments were carried out as follows: the first foliar treatment was carried out (with appropriate concentrations of drugs) before artificial infection of plants, and the second – 14 days after inoculation with bacterial phytopathogens. Artificial infection occurred at the beginning of bean formation. Under conditions of natural infection, the spread of the disease by the number of affected plants and the development of the disease on a 5-point scale (from 0 to 4 points) were considered. The symptoms of plants in the corresponding points are presented in Table 2.

Table 2. Gradations (by points) of the degree of development of artificial injury

Score	Symptoms
0	No lesions, no injection marks
1	The onset of lesions, small necrotic spots/strips
2	Development of lesions and necrotic spots increase
3	A fairly high degree of damage
4	The high degree of lesion development: increase in the size and spread of necrotic spots/strips, possible complete death of the affected parts

Source: compiled by the authors

The software packages used for calculations were Statistica and Microsoft Excel-365. The study was conducted following the requirements of the Convention on Biological Diversity (1992).

RESULTS AND DISCUSSION

The preliminary results of the *in vitro* study indicate that phytopathogenic bacteria show a fairly high sensitivity to the studied micronutrient preparations, unlike chemical pesticides, regardless of the genus and species of pathogens at a significant dilution, without causing toxic effects on the inoculant bacteria of the genus *Bradyrhizobium* and *Rhizobium*. This indicates the potential for positive use of such preparations in the field. The need for research is caused by the fact that under natural conditions, the activity of the applied preparations is influenced by a significant number of biotic and abiotic factors, which can level the effect of the preparations.

Thus, after these results were obtained in laboratory studies, it became necessary to conduct *in vivo* experiments. The results of field studies on artificial infection with soybean phytopathogenic bacteria in 2021 are presented in Table 3.

Table 3. The results of artificial damage by bacterial pathogens of soybeans with pre-treatment with a mixture of the studied preparations in comparison with the control

Plant treatment options and varieties	*P. savastanoi* pv. *glycinea* (pcs. 9190)						*X. axonopodis* pv.*glycines* (pcs. 9192)					
	Leaves			Stems/beans			Leaves			Stems/beans		
	Day											
	7	14	30	7	14	30	7	14	30	7	14	30
Seeds pre-treated with a mixture of test products												
"Drayton"	1.6	2.2	2.2	-	1.8/2.2	2.4/2.6	0.6	0.4	1.8	-	2.2/2.2	2.8/2.6
"Strive"	0	1.8	2.0	-	1.0	2.4	0	0	0	-	0	2.2
No treatment												
"Drayton"	1.6	2.8	3.4	0	3.2/1.8	4/3.6	1.0	1.4	2.4	0	2.4/2.4	2.2/2.2
"Strive"	1.0	1.8	3.2	-	2.6	2.8	0	0.6	0.8	-	1.8	2.0

Note: "digital mark" – level of plant infection (arithmetic mean of all plots), "0" – no infection, injection mark, "n/y" – n – assessment of stem damage, and y – assessment of bean damage, "-" – no data available
Source: compiled by the authors

The results of field studies on artificial infection of soybean with phytopathogenic bacteria in 2021 (Table 2) indicate, first of all, the positive effects of the use of experimental micronutrient compositions. As can be seen from the results obtained, traditional seed treatment with experimental preparations shows a positive trend towards plant resistance to the main pathogens of soybean bacterial diseases (the causative agent of angular spot and the causative agent of pustular bacteriosis) and also allowed for comparative resistance of the soybean varieties used in the experiments to phytopathogens.

It is necessary to note the differences in the development of the pathological process depending on the varietal characteristics of plants. As a result, it was found that common soybean plants of the Drayton variety showed lower resistance to the disease in terms of the level and speed of its manifestation compared to the Strive variety. Despite the identified varietal characteristics, the results obtained demonstrate a general trend in the reactions of the plant organism to infection, in particular, in the variant with the treatment with the studied preparations, the lesions develop more slowly, partially having a lower intensity, compared to the variant without treatment. Moreover, on the variety "Strive" with the treatment for *Xanthomonas axonopodis* pv. *glycine* infection, no infection was observed on the leaves at all.

Regarding the phytopathogenic activity of the studied microorganisms, its manifestation in the bacteria *Xanthomonas axonopodis* pv. *glycines* (9192 pcs.) was noted to be weaker compared to *P. savastanoi* pv. *glycinea* (9190 pcs.), which is consistent with the literature data (Baltrus *et al.*, 2016). At the same time, a decrease in the intensity of infection with *Xanthomonas axonopodis* pv. *glycines* were observed after treatment with the studied preparations. This can be explained by the fact that both microorganisms differ in virulence factors. After all, the main factor of aggressiveness of *Xanthomonas axonopodis* pv. *glycines* are indirectly caused by extracellular polysaccharides, which from the very first steps of plant development begin to move through the vessels and gradually clog them. At the same time, obligate phytopathogenic pathogens of the genus *Pseudomonas* gradually accumulate in the plant and produce a significant amount of toxins that either gradually or instantly poison or kill the plant organism, which can lead to significant crop losses (Hnatiuk, 2019; Sánchez-Hernández *et al.*, 2023).

The obtained results confirmed the conclusions of previous laboratory tests of the investigational drugs regarding the effectiveness of delaying the growth of bacterial colonies by the investigational drugs and their complexes.

In the variant with seed treatment, regardless of varietal characteristics, a delay in the appearance of pronounced symptoms of the disease was observed for up to 15 days. Compared to the control, the level of plant infection was significantly lower (on average by one position), but after 15 days of observation in the experimental variant and control, the infection of plants increased significantly. We assume that weather conditions also had a minor impact on the duration of infection symptoms in the experimental plants. It is noted in the sources (Muluneh, 2021) that even an increase in the average monthly temperature by 0.798°C with significant waterlogging affects the number of pathogens and their activity, and also reduces the ability of plant organisms to resist the development of bacterial diseases, which in turn leads to a decrease in yield by more than 30%.

Taking into account the results of the previous experiment (in all the results of the 2021 experiment, there is a pattern that the manifestation of disease symptoms increases on days 14-15, i.e. the intensity of inhibition of the pathogen decreases), it became necessary to compare the effect of the studied drugs with traditional chemical pesticides and repeated treatments. Therefore, the second stage of the study was conducted in 2022 on the same field, but with two additional foliar treatments in terms of variants (one treatment was carried out before artificial infection, the second – on the 14th day after infection) and compared with the variant where plants were treated with a traditional chemical pesticide.

According to G. Otálora *et al.* (2018), foliar feeding strategies can achieve greater nutrient use efficiency, reduce negative environmental impacts, and potentially increase consumer health benefits.

The use of foliar treatments was also since, according to N. Novytska *et al.* (2020), foliar feeding of soybeans increases the intensity of chlorophyll synthesis in leaves, promotes photosynthetic activity and stimulates the growth of the number of microorganisms that ensure the synthesis of auxins and other root stimulating substances. Thus, foliar nutrition triggers the so-called "pumping system" of the plant, increasing the volume of nutrient absorption from the soil.

The need for additional foliar treatments was since, based on the work of W.F.A. Mosa *et al.* (2021), seed treatment followed by foliar treatment with metal nanoparticles was highly effective not only against pathogens of the root system and root zone of plants, but also had a significant antibacterial effect on phytopathogens that affect leaves, stems, and fruits during the growing season.

The need for foliar treatment was based on the fact that at high temperatures (the period when artificial infection took place), some of the most important macro- and microelements for soybean development, namely potassium, calcium, copper, boron, etc., are poorly absorbed, so additional foliar treatments can be seen as a promising solution to this problem. Another important component of soybean protection technologies is their permeability and ability to stay on the leaves. Foliar application of the chelated form of the products ensures better absorption and biological activity of trace elements, their better compatibility with other chemicals and low toxicity (Niu *et al.*, 2021). The results of the study conducted in 2022 are shown in Figure 1.

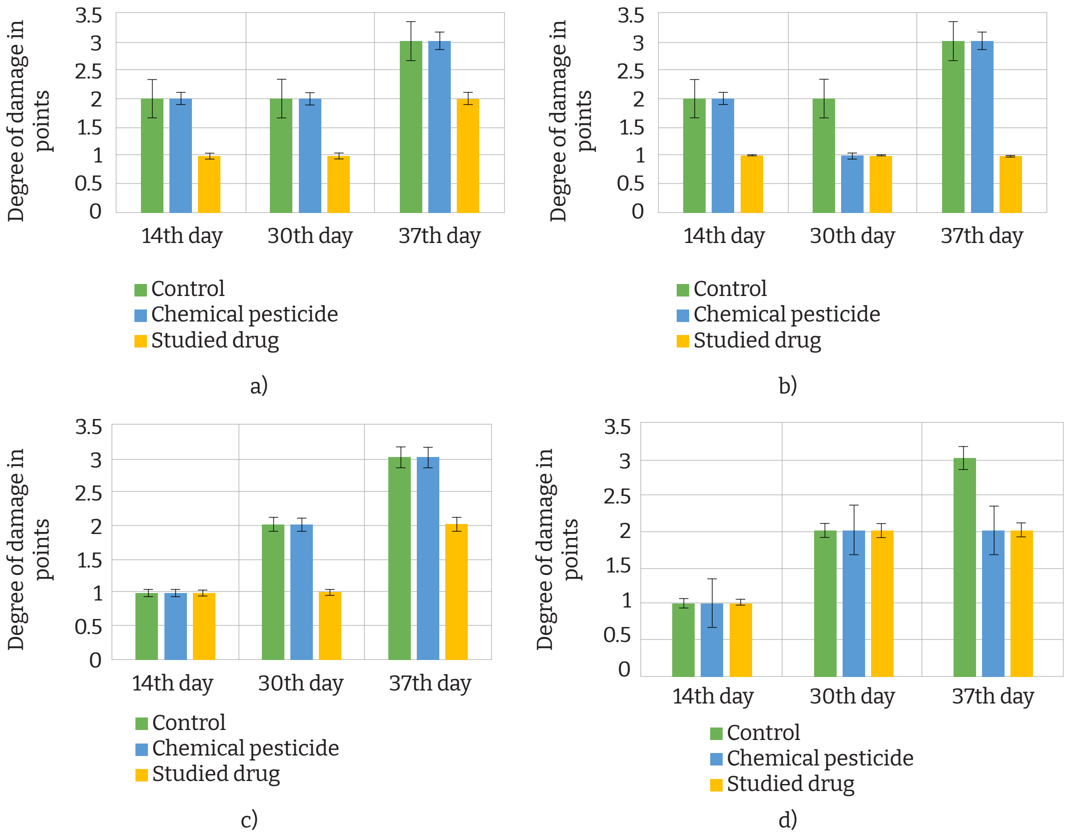

Figure 1. Degrees of plant damage under artificial inoculation with *P. savastanoi pv. glycinea*

Note: a – the degree of damage on the leaves (in variants without re-treatment); b – the degree of damage on the leaves (in variants with re-treatment); c – the degree of damage on the stems (in variants without re-treatment); d – the degree of damage on the stems (in variants with re-treatment)

Source: compiled by the authors

The dynamics of the indicators indicate the advantage of seed treatment with a mixture of preparations obtained by electropulse ablation compared to a chemical pesticide and control. In addition, it was found that after 14 days, the results of plant damage under the condition of chemical pesticide treatment and control values mostly coincide. Meanwhile, the mixture of the studied substances demonstrates a stable effect on the inhibition of the development of *P. savastanoi pv. glycinea* colonies, and, if re-treated on the 14th day, can restrain their further development, prolonging the period of resistance of common soybean plants. As can be seen from Figure 1, when applying the dressing with additional foliar treatments for artificial infection of plant parts, the level of disease manifestation by day 37 (harvesting period) did not exceed 1 point, i.e., only single necrotic spots were observed in the places of inoculation. At the same time, in plants without treatment and with treatment and treatment with a pesticide based on Fludioxonil and Metalaxyl-M, a significant increase in the size and spread of necrotic spots was recorded, and in some places complete drying and falling of the artificially affected leaf or bean. As for the degree of damage on the stems, up to 30 days in all variants the degree of damage was estimated at 2 points, but after that, a rapid spread of necrotic spots was observed in the control. At the same time, in the variant with repeated foliar treatment, this effect was not observed, which indicates the correct strategy for foliar feeding. Probably, during repeated treatment, there is also a direct contact effect with the components of the experimental preparations, which exhibit antimicrobial activity against bacterial pathogens.

Although beans and leaves are the most sensitive plant organs, in the case of the 2022 soybean trials, the stems were the most intense. This may be due to varietal characteristics or unfavourable abiotic factors. A similar series of experiments was conducted to determine the effect of primary and secondary seed treatment under artificial infection of soybean with phytopathogenic bacteria *X. axonopodis pv. glycines* 9192 pcs. The results are shown in Figure 2.

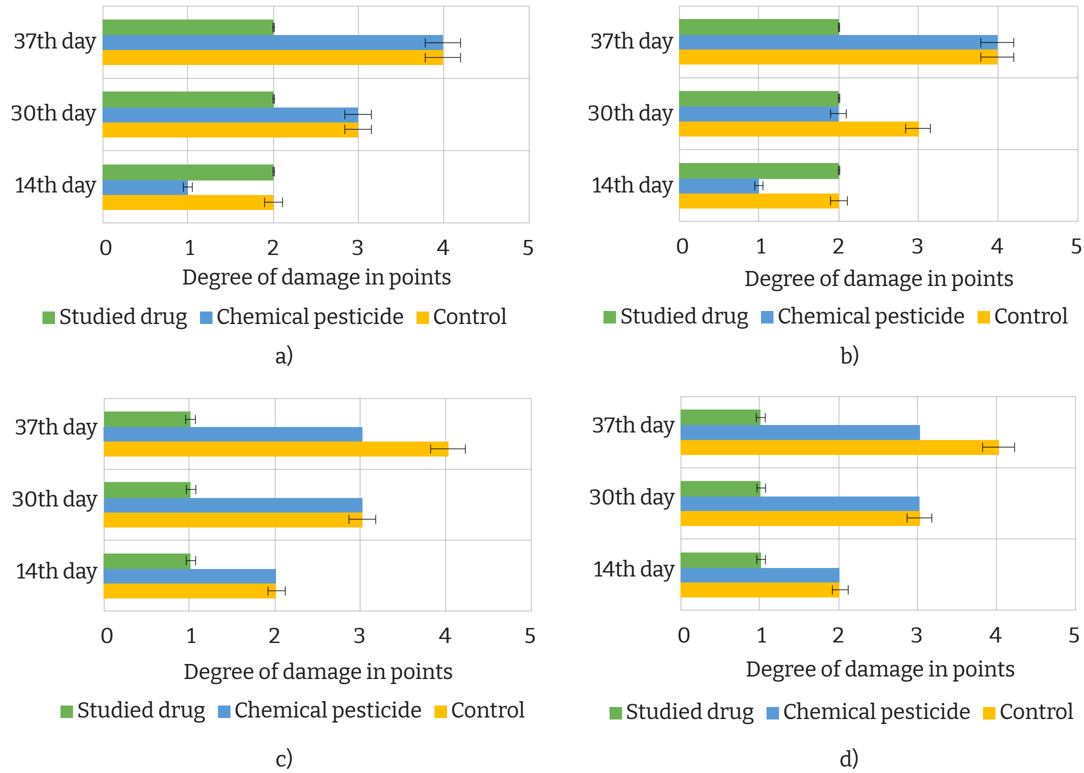

Figure 2. Degrees of plant damage under artificial inoculation with *X. axonopodis pv. glycines pcs.* 9192

Note: a – the degree of damage on the leaves (in variants without re-treatment); b – the degree of damage on the leaves (in variants with re-treatment); c – the degree of damage on the stems (in variants without re-treatment); d – the degree of damage on the stems (in variants with re-treatment)

Source: compiled by the authors

As can be seen from Figure 2, the results of artificial inoculation with xanthomonads and pseudomonads are similar – it is the composition of the studied preparations that showed the greatest efficiency in all variants. The low efficiency of the treatment (without additional treatments) with a pesticide based on Fludioxonil and Metalaxyl-M in restraining the development of pustular bacteriosis was shown since the indicators of damage did not differ from the control values (Table 2, Figs. 1-2). With additional treatment, the degree of damage was reduced by about 15% compared to the control. At the same time, it should be noted that there was significant suppression of the development of soybean plant infection under artificial infection with phytopathogenic bacteria when their leaves and stems were treated with a mixture of trace element preparations. The degree of damage on the leaves did not exceed 2 points, and only single necrotic spots were observed on the stems. In addition, in contrast to the experiments with pseudomonads, only dressing without additional treatments was sufficient to restrain the development of *X. axonopodis pv. glycines*.

It should be noted that the chemical pesticide showed higher efficiency on the leaves during the first 14 days of the experiment and restrained the development of the disease, however, its efficiency by day 37 of the experiment was significantly reduced compared to the studied preparations. Thus, this confirms the probable heterogeneous effectiveness of the drugs obtained by ablation technology.

Usually, representatives of phytopathogenic bacteria of the genus *Pseudomonas* are more resistant to the effects of drugs of different origins compared to representatives of the genus *Xanthomonas*, which was consistent with laboratory controls (Kravchenko *et al.*, 2021) and field studies conducted in 2021. At the same time, in 2022, angular spot lesions developed more slowly and less intensively compared to the development of pustular bacteriosis. This may be due to abiotic factors, in particular, increased air temperature during the field experiment. According to the literature search, it can be argued that this feature of the effect is because representatives of the genus *Pseudomonas* develop better at 21-27°C under conditions of high humidity, and *Xanthomonas* spread faster and affect the plant to a greater extent at high temperatures of 30-33°C (Velasquez *et al.*, 2018; Burdon & Zhan, 2020), which is consistent with the climatic conditions recorded at the time of the experiment in August 2022.

At the same time, the development of disease symptoms on the stem under artificial infection with *X. axonopodis pv. glycines*, both without and with repeated treatment with micronutrient preparations, do not exceed 1 point (unlike variants with artificial infection with *P. savastanoi pv. glycinea*, where the manifestation of the lesion was from 1 to 2 points over time). This may mean that the pathogen will not circulate through the plant and infect new organs, and in particular the beans, which are the most important indicator for yield.

Thus, studies have shown that preparations obtained by electropulse ablation are promising tools in the soybean protection system. Their undoubted advantage is a pronounced antipathogenic effect and the simultaneous absence of toxic effects on symbiotic microorganisms of common soybean.

CONCLUSIONS

Soybean varietal characteristics have been found to affect the degree of infection with phytopathogenic bacteria. According to the results of the 2021 experiments, it was found that common soybean plants of the Drayton variety showed lower resistance to the disease in terms of the level and speed of its manifestation compared to the Strike variety. It was also found that the features of the Kyoto variety affect the damage to various plant organs.

A significant factor in the development of disease manifestations is weather conditions, in particular, exceeding the average ten-day air temperature, significant temperature fluctuations during the day and humidity at the level of 150-200% of the average annual norm.

It was determined that seed treatment with a chemical pesticide without additional treatments does not reduce the manifestations of pustular bacteriosis and angular spot of soybean compared to the control (no treatment) variant. The treatment and foliar treatment with a chemical pesticide based on Fludioxonil and Metalaxyl-M only partially reduce the manifestations of bacteriosis compared to the control variants (by about 15%), and the chemical pesticide show the greatest effectiveness only in the first 14 days, while its effectiveness significantly decreases in the period of 14-30 days after artificial infection.

Micronutrient drugs based on metal aqua-chelates were found to significantly slow down the development and reduce the intensity of soybean damage by the main bacterial diseases – angular spot (pathogen *Pseudomonas savastanoi pv. glycinea*) and pustular bacteriosis (pathogen *Xanthomonas axonopodis pv. glycines*) when treating seeds.

Treatment of soybean plants with experimental preparations according to the Comfort scheme (at consumption of 150 ml/t of seeds), fertiliser "Dobrodiy" (at consumption of 2.4 l/t of seeds) and microelement preparation "Micro Protect" (at a consumption of 500 ml/t of seeds), as well as two foliar treatments with the specified mixture of microelement preparations, delays the manifestation of plant damage until the time of harvest, which is likely to increase yields. The probability of coordination of foliar treatment of plants with the peculiarities of the functioning of pathogens of different systematic groups of bacterial pathogens of soybean diseases was noted.

The results obtained pointed to several promising tasks for further research. Firstly, the results of 2022 indicate a pronounced effectiveness of additional foliar treatments during the growing season along with traditional seed treatment, however, the question of their number remains open. Secondly, comparing the results of 2021 and 2022, the effectiveness of further combining the products was noted. However, the creation of composite preparations is impossible without thorough laboratory research to determine effective doses and concentrations. Thirdly, since Comfort has already received the Organic Standard certificate, the next step may be to enter the European and global markets for innovative medicines. At the same time, this requires further research on their bio- and eco-safety, as well as clarification of the mechanism of action of these compositions. Finally, there is the issue of checking the effectiveness of such micronutrient preparations obtained utilizing electropulse ablation for seeds and adult plants already affected by bacterial pathogens.

ACKNOWLEDGEMENTS

None.

CONFLICT OF INTEREST

None.

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Вплив препаратів, отриманих методами електроімпульсної абляції, на розвиток фітопатогенних бактерій сої

Анотація. Збудники плямистості сої *(Pseudomonas savastanoi pv. glycinea)* та пустульного бактеріозу сої (*Xanthomonas axonopodis pv. glycines*) є поширеними фітопатогенними бактеріями. Проте відсутність офіційно зареєстрованих препаратів проти них стимулює пошук нових рішень. Метою дослідження було визначення впливу вказаних мікроелементних препаратів, отриманих електроімпульсною абляцією, на бактерії за штучного зараження сої музейними штамами збудників пустульного бактеріозу та кутастої плямистості. Антибактеріальну активність досліджених препаратів порівнювали з варіантами без обробки й дією традиційного хімічного пестициду на основі Флудиоксонілу та Металаксилу-М. Поширення і розвиток хвороби оцінювали за кількістю уражених рослин, використовуючи шкалу від 0 до 4 балів. З'ясовано, що сортові особливості сої впливають на ступінь ураженості фітопатогенними бактеріями. Виявлено, що значимим фактором у розвитку проявів хвороби є погодні умови, зокрема температура повітря. Доведено, що протруєння насіння хімічним пестицидом на основі Флудиоксонілу та Металаксилу-М за відсутності додаткової позакореневої обробки не зменшує прояви та ступінь ураження, порівняно із контролем (без протруювання). Протруювання та позакоренева обробка хімічним пестицидом на основі Флудиоксонілу та Металаксилу-М лише частково зменшують прояви бактеріозів, порівняно з контрольними варіантами (приблизно на 15 %). В той же час, застосування препаратів, отриманих методами електроімпульсної абляції, є перспективним проти фітопатогенних бактерій в системі технології вирощування сої – а саме визначено, що за умови протруювання рослин сої дослідними препаратам за схемою Комфорт (витрата – 150 мл/т насіння) + добриво «Добродій» (витрата – 2,4 л/т насіння) + мікроелементний препарат «Мікро протект» (витрата 500 мл/т насіння) + дві позакореневі обробки вказаною сумішшю мікроелементних препаратів посилюється затримка прояву ураженості рослин до часу збору врожаю, що в свою чергу найімовірніше призведе до підвищення показників урожайності. Практичне значення роботи полягає у визначенні ефективних методів боротьби з фітопатогенними бактеріями, що шкодять сої

Ключові слова: бактеріальні патогени рослин; бобові; кутаста плямистість; пустульний бактеріоз; наноаквахелати; абляційні технології