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PROTECTION OF HOP PLANTATIONS FROM ROOT ROT PATHOGENS IN THE FACE OF CHANGING CLIMATE FACTORS

O. V. Wenger, PhD, venger_o@ukr.net, https://orcid.org/0000-0002-2213-4670

I.P. Shtanko, PhD, shtanko_hop@meta.ua, https://orcid.org/0000-0001-7847-0772

H. A. Fedorchuk, fedorchuk1978@ukr.net, https://orcid.org/0009-0006-2324-1239

O. P. Shevchuk, olga88shevchuk@ukr.net, https://orcid.org/0009-0009-5436-0531

Institute of Agriculture of Polissya NAAS, 131 Kyivske Shosse, Kyivske Shosse, м. Zhytomyr, 10007, Ukraine

The purpose of the *study is to investigate the harmfulness of root rot and tolerance of hop plants to their action using different methods of their control.* **Research methods.** *Field - inspection of hop plantations, records and studies of the dynamics of hop root rot development, assessment of plant damage, determination of the effectiveness of drugs; laboratory - analysis of affected hop plants; weight - determination of the stored yield; morphophysiological - determination of biometric parameters of plants; mathematical and statistical - assessment of the reliability of the results, establishment of correlations and calculations.* **Research results.** *In 2016-2022, the species composition of root rot pathogens in hop agrocenoses in the Zhytomyr region was determined, among which Fusarium humuli* Kom. *dominated 90.0%. Plenodomous rot (Plenodomus humuli* Kusnetz.*) was 6.0%,* tiffulosis *(Tufula humulina* Kusn.*) - 2.0%, and verticillium (Verticilium alboatrum* Reinke et Berthold.*) and bacteriosis (Bakterium tumefaciens* Smith et Towns.*) were found only on 1.0% of the affected hop plants. The analysis of the five-year dynamics of root rot pathogens in hop plants made it possible to determine the impact of changes in hydrothermal conditions on their spread in the agrocenosis of hop plantations and yield losses. It was found that an increase in temperature by 1.5^{o} C in the Polissya region of Ukraine promotes the spread of hop root rot and increases their impact. The harmfulness of these types of diseases in certain growing seasons can increase several times. Watering of hop queens with solutions of Impact 25 SC, hp - 0.5 l/ha + Teravet, 7.5 g and Sclerocide, p. - 2.0 l/ha + Teravet 7.5 g provides a decrease in the incidence of root rot pathogens by 0.30-0.35 points, respectively. Due to the effect of fungicides on plants in the experiments, the spread of diseases was reduced by 45.5% in the variety Xantha; 40.1% in Zagrava.* **Conclusions. The** *level of prevalence and species composition of root rot in hop agrocenoses of Zhytomyr region was determined. Changes in climatic factors in the*

Polissya region of Ukraine contribute to the spread of hop root rot pathogens and increase the degree of their impact. The introduction of certain solutions of chemical and biological preparations into the soil effectively counteract the damage to the root system of hop plants by root rot pathogens in experiments, reducing their impact by 22.0-57.0% depending on the hop variety.

Key words: *hops, root rot pathogens, climatic factors, chemical and biological preparations*

Analysis of recent research and publications. Stable functioning of the perennial hop agrocenosis in the context of global climate change largely ensures the protection of plants from harmful organisms, in particular, from a complex of root rot pathogens (Fusarium, plenodomain rot, typhoid, bacterial cancer, etc.), which cause significant economic losses and require the expansion of the range of new drugs for their control [1].

The harmfulness of root rot pathogens is extremely high, as a rule, they can reduce yields by 25-30%, and in some years to the loss of half of the crop, to deterioration of technological quality of products, as well as to partial death of plants, which causes liquefaction of hop plantations, reduction of their productivity and profitability of hop production [2].

Fusarium rot, the causative agent of which is the fungus *Fusarium humuli* Kom, is most common in hop plantations in all regions of cultivation. Our research has shown [3] that the disease manifests itself during the growing season. The fungus overwinters on affected plants or in the soil. It can withstand both drought and severe winters. According to V. M. Wenger [4] and a number of American scientists [5, 6], the disease mainly damages the uterus and the underground part of hop stems. As noted by O. I. Tymchuk [7], O'Neal, S.D., [8], the underground part of the affected plant thickens, turns brown and dies. The disease affects hops most of all on heavy, moist soils. Scientists have shown that late pruning of queens and low humidity (40%) aggravates the disease. According to F., Araujo, the yield is reduced by 50% or more [9].

According to I. V. Yakubenko [10], plenodomous rot was discovered on hops only in the spring of 1937. Annual phytosanitary inspections by scientists of the Polissia Institute have established that the disease is currently found in all hop farms in Ukraine,

leading to a 25% crop failure. Plant loss from plenoderma causes plant thinning in hop fields, sometimes up to 15-30% [11]. The causative agent of plenoderma is mainly a traumatic parasite, i.e. it most often affects plants with mechanical damage (improper pruning of the uterus and frostbite). It has been proven that the damage to hops on cuts is 87%, in the bud zone - 9.1%, in the internode - 13.4% [12].

The fungus Tuphula humulina Kusn causes a disease of the underground part of hop stems, or tifulosis. According to Abdul Wahid O. A. [13], the disease manifests itself as dry rot on the buds in spring. Bushes affected by typhulosis develop poorly and die in 2-3 years. The yield of diseased plants is reduced to 40%. The disease causes the greatest damage to hops in the northern regions [3].

Losses on each hectare from root rot amount to 2.0-2.5 thousand UAH. They are the primary cause of intensive liquefaction of hop plantations, which in turn forces to spend significant funds to eliminate liquefaction and reduce their productivity and profitability of production already in the 5-7th year of hop cultivation [12].

Due to changes in climatic factors in the hop growing zone, the conditions of interaction between the biological components of the hop agrocenosis system are changing, so due to a significant increase in humidity during certain periods of vegetation and rising air temperatures, an increase in the harmfulness of Fusarium, Typhoid and Plenodomus has been recorded in recent years.

The complexity of protective measures against these diseases is primarily due to the limited access to the hop root system, which is located directly in the soil, as well as the absence of drugs against hop root rot pathogens in the "List of Pesticides and Agrochemicals Permitted for Use in Ukraine" [14].

To solve this urgent problem, it is necessary to establish the level of prevalence and species composition of root rot pathogens in hop agrocenoses of Zhytomyr region, to determine the dynamics of the spread of fungal diseases depending on changes in the growing environment and to find out the technological aspects of agroecological regulation of the degree of damage to the underground part of hops by root rot pathogens.

Research methods. The research was conducted at the ISGP NAAS and in hop farms of Zhytomyr region. Hop plantations in the study region are located on sod-podzolic, meadow, dark gray soils and black soils, which are characterized by heterogeneity of chemical and mechanical compositions of soil forming rocks and different depths of groundwater.

The climatic conditions are characterized by a moderately continental, predominantly mild climate, which is formed by the atmospheric circulation of Atlantic air masses with uneven precipitation throughout the year and has trends in changes in climatic factors associated with global climate warming processes on Earth. Analysis of the weather conditions in the region over the past five years shows the existing changes in weather conditions during the growing season of hop plants, namely: cool and wet May, increased duration of periods with a lack of moisture and short periods with excessive critical air temperatures in summer and early autumn, critically high temperatures during flowering of hop plants (Fig. 1). In general, despite these trends, the agrometeorological conditions of the region are favorable for hop growing.

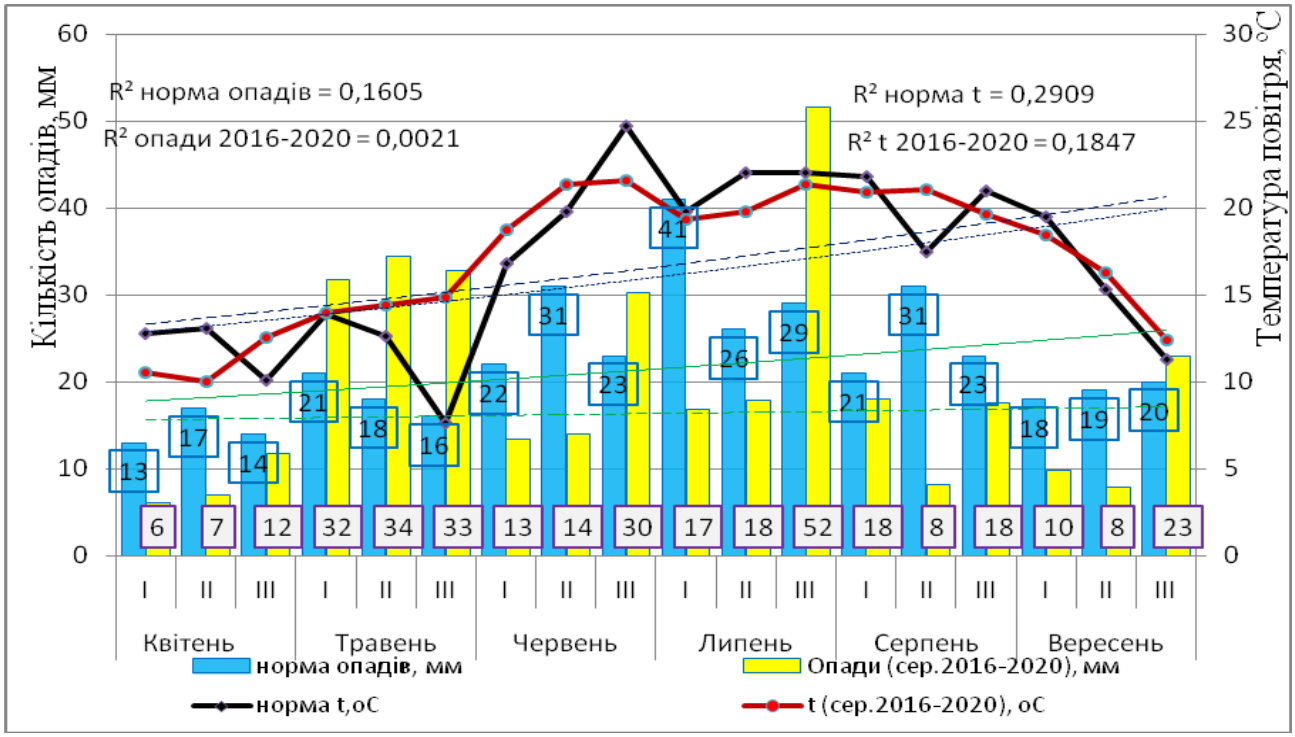

Fig. 1. **Comparative analysis of long-term indicators (normal) of precipitation and average air temperatures (per decade) and average values of weather indicators for 2016-2020,** Zhytomyr, ISGP NAAS

The study of protective agents was carried out using methodological approaches used in international practice for hops, according to the "Regulations on State Testing and Registration of Chemical, Biological Protective Agents, Pheromones and Plant Growth Regulators and Fertilizers in Ukraine"; Methods of Testing and Application of Pesticides, 2001; Technology of Growing and Protecting Hops from Pests, 2011 [15, 16, 17].

Assessment of the condition of hop queens for the degree of damage by root rot pathogens was carried out in the spring during the pruning of the main rhizomes before the application of the studied preparations and in the fall, after harvesting.

The area of the accounting plot is^2 15 m, the variant plot is^2 60 m. The total area of the experiment is 540 m^2 . The experiment was replicated four times in 9 variants.

The prevalence of each detected disease (percentage of plant damage) was determined by the formula:

P = Nn100,

where P is the disease prevalence, %; n is the number of affected plants, pcs.

The degree of plant damage by the identified disease was determined on a 9-point scale. The average score of root rot damage was determined by the formula:

$$B = \frac{\sum n \cdot b}{N},$$

where B is the average damage score; Σn-b is the sum of the products of the number of affected plants and the corresponding damage score; N is the total number of plants examined, pcs.

The solutions of the preparations were applied immediately after pruning the main rhizomes of hops, by watering them and then covering them with soil. The consumption rate of the working fluid of the preparations per plant was one liter.

Results of the research.

Based on the analysis of the phytosanitary condition of hop agrocenoses in hop farms of Zhytomyr region in 2016-2022, the species composition of root rot pathogens was determined, among which *Fusarium humuli* Kom. was the most widespread - 90.0%. *Plenodomus humuli* Kusnetz (*2.0%*) was affected by 6.0%, *Tufula humulina*

Kusn. by 2.0%, and Verticillium *alboatrum* Reinke et Berthold (2.0%) and *Bakterium tumefaciens* Smith et Towns (1.0%) were found on only 1.0% of the affected hop plants (Fig. 2).

The results of the research show that hop plantations in Berdychiv district are most affected by Fusarium - 18%. The damage to hop plants in Zhytomyr, Cherniakhiv and Chudniv districts amounted to 15.7-14.9-14.3%, respectively. The highest plenoderma damage was found in hop plantations of Chudniv district - 2.8%. Plantations of Cherniakhiv, Berdychiv and Zhytomyr districts were affected by this root rot pathogen at the level of 1.3-1.4-2.1%, respectively. Verticillium was most prevalent in Zhytomyr and Cherniakhiv districts - 0.7-0.5%. Hop plantations in Berdychiv and Chudniv districts were affected by it at the level of 0.3-0.1%. Manifestations of bacterial infection were detected in Chudnivskyi district on 2.6% of plants, Berdychivskyi district - 1.5%, Zhytomyrskyi district - 1.4%, and Cherniakhivskyi district - 1.2% of hop plantations.

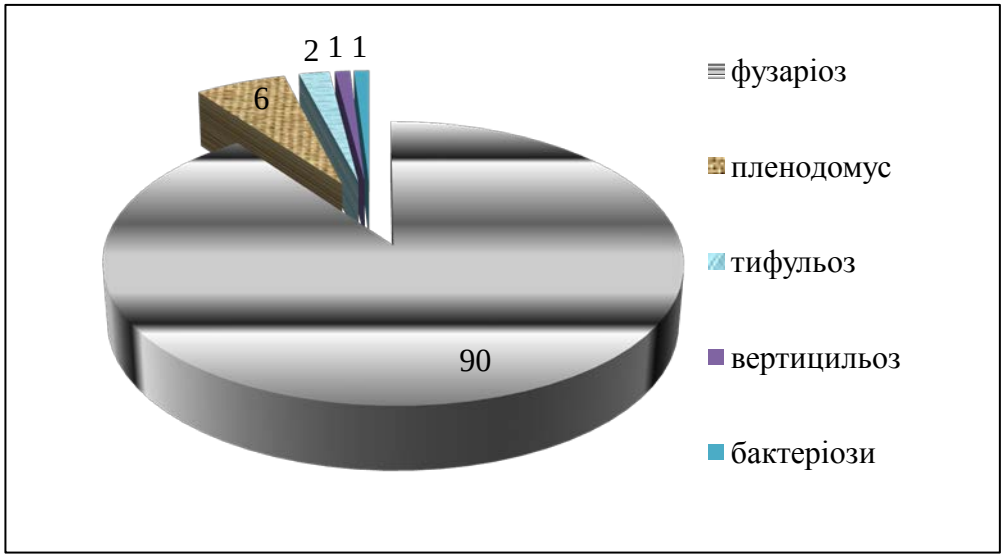

Fig. 2. **Species composition of hop root rot pathogens**

(according to our own research in hop farms in Ukraine, 2016-2020)

The analysis of the five-year dynamics of hop root rot pathogens allowed us to find out the influence of hydrothermal conditions on their spread in the agrocenosis of hop plantations and yield losses. It was found that an increase in temperature by 1.5^{o} C in the Polissya zone of Ukraine had a positive effect on the spread of hop root rot pathogens - Fusarium, Plenodocus, and Typhulus. The harmfulness of all these types of

fungal diseases can increase significantly in some unfavorable years. In our opinion, such phenomena are caused by intra-population mechanisms, which can be enhanced or suppressed by external meteorological factors, in particular, an increase in moisture levels combined with higher air temperatures.

Using the linear regression method, the level of influence of changes in climatic factors in 2016-2020 on the dynamics of the increase in the incidence of major diseases of the hop root system in Polissya of Ukraine was determined (Fig. 3). At the same time, the ranking of the coefficient of determination of the linear regression (R^2) by the degree of influence made it possible to divide the studied pathogen species into insignificant (R^2 = 0.36) and with the most positive influence of environmental factors (R^2 = 0.86-0.93).

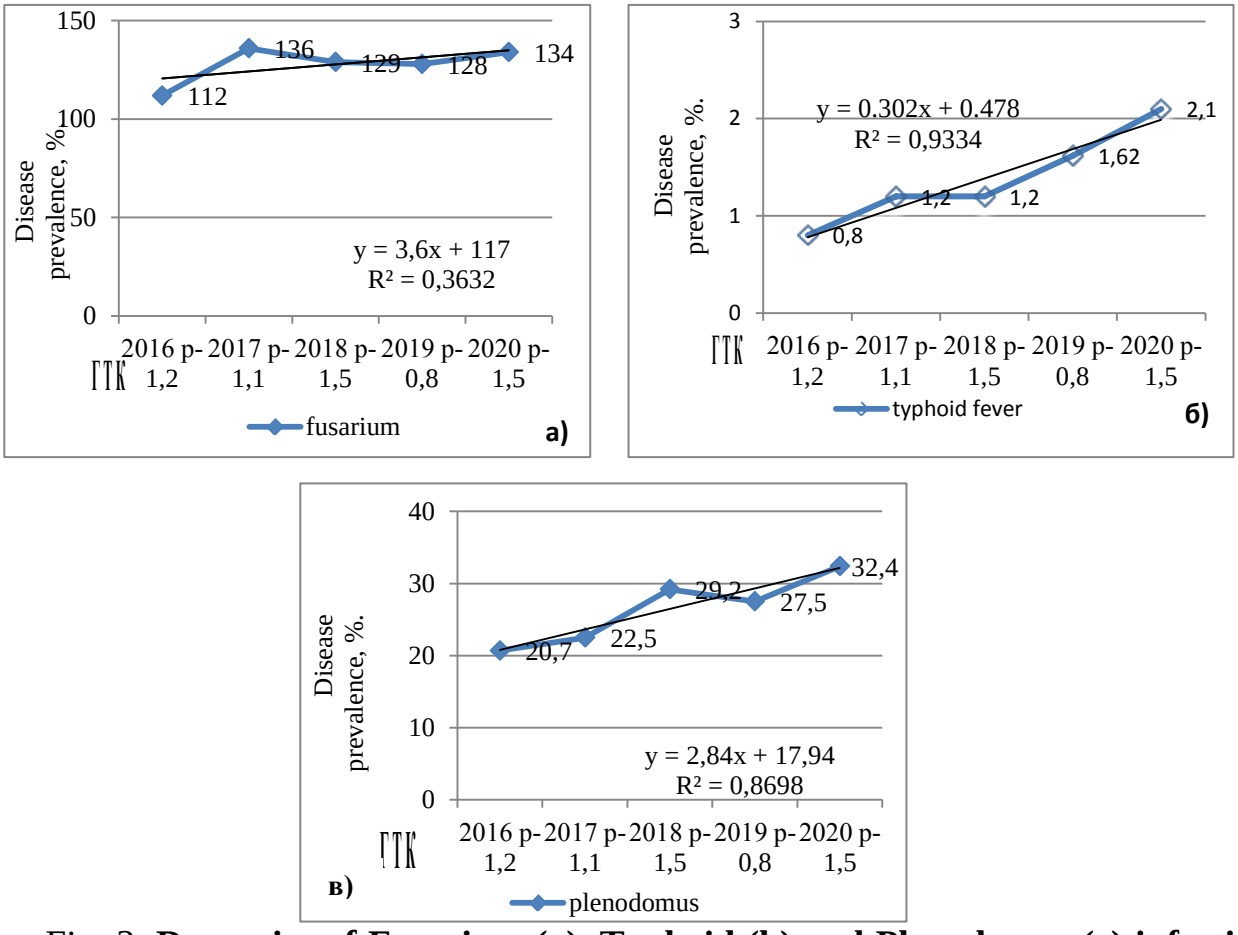

Fig. 3. **Dynamics of Fusarium (a), Typhoid (b) and Plenodomus (c) infection in hop plantations, 2016-2020.**

The dynamics of the number of diseases of hop plants by these diseases in plantations shows that changes in the hydrothermal coefficient due to climate change

cause an increase in the prevalence of root rot pathogens. The greatest positive impact of environmental factors on the dynamics of the increase in damage was found for plenodomes and typhulosis. The share of the factor "weather conditions" was the largest and amounted to 86-93% ($R^2 = 0.86$ and $R^2 = 0.93$, respectively).

During 2020-2022, the fungicidal effect of various preparations applied in April by treating (watering) the queens during pruning of the main rhizomes of perennial hop plantations was studied (Table 1).

Table 1 **Effect of fungicides on the root system of hop plants affected by root rot pathogens and their spread (average 2020-2022)**

Option, drugs, consumption rate	Variety	Root rot damage to the main rhizomes of hops					
		before the application of drugs		after the application of drugs		share of decline, %.	
		affected, point	distribution, %.	lesion, point	distribution, %.	defeat	distribution
Control	Zagrava	0,60	24,7	1,10	36,4	0	0
	Xantha	0,50	21,2	0,90	34,0	0	0
Reference - Teravet 7.5 g	Zagrava	0,50	22,3	0,80	33,8	0	0
	Xantha	0,45	20,5	0,70	30,4	0	0
The benchmark is RidomilGoldv.g. - 2.5 kg/ha	Zagrava	0,55	31,0	0,45	28,3	18,2	8,7
	Xantha	0,45	24,7	0,40	20,0	11,1	19,0
RidomilGoldv.g. - 2.5 kg/ha + Teravet 7.5 g	Zagrava	0,55	28,5	0,45	25,6	18,2	10,1
	Xantha	0,50	22,9	0,45	20,1	10,0	12,2
Impact 25 SC, hp - 0.5 l/ha + Teravet 7.5 g	Zagrava	0,60	25,7	0,45	15,4	25,0	40,1
	Xantha	0,45	23,5	0,30	12,8	33,3	45,5
Abacus, hp - 1.75 l/ha + Teravet 7.5 g	Zagrava	0,55	22,8	0,45	19,7	18,2	13,6
	Xantha	0,50	20,6	0,40	17,2	20,0	16,5
Sclerocide, p - 2.0 l/ha + Teravet 7.5 g	Zagrava	0,65	26,4	0,50	19,5	23,1	26,1
	Xantha	0,45	21,3	0,35	15,6	22,2	26,8
Phytolavin, p.c. - 2.0 l/ha + Teravet7.5 g	Zagrava	0,50	25,8	0,40	21,0	20,0	18,6
	Xantha	0,50	20,2	0,40	17,1	20,0	15,3
Phytoplasmin, p.c. - 12.0 + Teravet7.5 g	Zagrava	0,60	27,2	0,45	21,6	25,0	20,6
	Xantha	0,55	21,7	0,40	16,3	27,3	24,9
NIR 05				*0,36*	*1,75*		

Before setting up the experiment, before the introduction of the preparations, the damage to hop queens by root rot pathogens averaged 0.45-0.65 points with a spread of 20.2-31.0%. As a result of the autumn excavations, it was found that the score of damage by root rot pathogens decreased in both varieties, the most effective was watering the hop queens with a solution of the preparation Impact 25 SC, hp - 0.5 l/ha + Teravet, 7.5 g and Sclerocide, p - 2.0 l/ha + Teravet 7.5 g - 0.3-0.35 points, respectively. The application of Abacus, h.p. prevented the root rot pathogens from infecting the plants the least - by 13.4-16.5%, which is not effective enough in the conditions of changes in the factors of the hop growing environment. In the control variant, on the contrary, the damage score increased in all years of research from 0.5 to 1.1, and the prevalence - from 21.2% to 36.4%.

A convincing evidence of the effectiveness of the drug Impact 25 SC, h.p. against root rot pathogens on hops is that watering the queens with its solution reduced the spread of the disease by 45.5% in the Xantha variety; by 40.1% in the Zagrava variety, which is 2-3 times higher than the rest of the studied variants. The lowest efficiency was noted for the use of Abacus, h.p., when the spread of root rot pathogens was reduced by 13.4-16.5%.

Harvesting and calculation of the crop from the experimental plots showed the expediency of protective measures against root rot pathogens. The application of preparations by watering hop queens during their pruning with solutions of Impact 25 SC, c.s., Phytoplasmin p.c. and Sclerocide, p. together with the superabsorbent Teravet (7.5 g/bush) made it possible to obtain a yield increase of 0.12-0.44 t/ha of hop cones for both studied varieties.

Conclusions.

1. Among the species composition of hop root rot pathogens, Fusarium accounts for 90%, *Plenodomus humuli* Kusnetz *for* 6%, *Tufula humulina* Kusn. *for* 2%, *Verticillium alboatrum* Reinke and Berthold for 1%, and *Bakterium tumefaciens* Smith and Towns for 1%.

2. The greatest positive impact of environmental factors on the dynamics of the increase in lesions was found for plenodomosis and typhoid. The share of the factor

"weather conditions" was the largest and amounted to 86-93% (R^2 = 0.86 and R^2 = 0.93, respectively).

3. It was found that the introduction of solutions of chemical preparations Ridomil Gold, v.g. (2.5 kg/ha), Impact 25 SC, c.s. (0.5 l/ha) and Abacus, c.s. (1.75 l/ha) into the soil effectively counteract phytopathogenic fungi of the genus *Fusarium* and other species, reducing the damage by 22.0-57.0% depending on the variety. Among the biological preparations, Sclerocide, p. (2.0 l/ha) and Phytoplasmin, p.c. (12.0 l/ha) are effective, reducing the incidence of the main rhizomes of hops to 15.0-34.0%. The use of the recommended preparations and the established norms of their application allows to effectively restrain the development of hop root rot pathogens in the conditions of changes in climatic factors.

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