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RANKING OF SILVICULTURAL AREAS BY THE THREAT OF ANNOSUM ROOT ROT IN PINE STANDS

The paper presents a ranking of forest sites according to the threat of infection of planting *Pinus sylvestris* stands by *Heterobasidion annosum.* 8 degrees of treat of infection are marked out according to the site characteristics and types of habitat and moisture conditions. Presented gradation underlined planning of forest stands with susceptible species, that would allow to make for creation of more stable stands, reduction of infection and decrease costs of protection measures.

Introduction. Intensive reforestation and afforestation by creating of forest crops is provided by the State program of forestry development in the Republic of Belarus for 2011–2015, that is primarily aimed at improving the productivity of forest lands [1]. In order to achieve the defined task sowing and planting of forest on the area of 94.8 thousand hectares is planned. According to the State forest inventory in 2012 in the Republic 24.1 thousand hectares of plantations were created, 14.9 thousand hectares of which are plantations of Scots pine.

However, pathological phenomena emerging as a result of mistakes made at the stage of development of the tree planting technology often impede the formation of highly stable stands. It is known that the creation of pine monocultures with a high initial planting density, as a rule, when forestation of lands out of agricultural use, reduces the stability of plantings and increases the susceptibility of plants to the defeat of root pathogens [2]. The highest spread and harm prevalence in such terms acquires the fungus *Heterobasidion annosum*.

Considering the negative consequences of intensive disease development in the form of plants productivity decrease, costs on forest protection activity, emergence of not productive dead forest areas, extra cost of reforestation, time terms increasing of forests cultivation and other things, a special attention should be paid to preventive measures in the system of annosum root rot control.

In forestry practice of the Republic of Belarus the division of forest Fund into land categories is adopted based on history of the site, natural regeneration of the target species, the possibility of preplanting soil processing, vegetation conditions (the humidity and the richness of the soil). Depending on the combinations of these factors on specific silvicultural area TKP 047-2009 "Guidelines for reforestation and afforestation in the Republic of Belarus" [3] regulates the standard technology of the forest crops creation. The most important component of designing forest crops should be to assess the possible threat of mass pathological processes, in particular, destruction of stands by *H. annosum*. TKP 047-2009 rather superficially deals with the differentiation of forest areas by this trait, which results to mass creation of unstable pure coniferous stands.

Thus, the aim of this work was to determine forest conditions favourable for the development of *Heterobasidion* spp. in the pine forests of Belarus at the state of the art forest management, and to rank forest areas by the annosum root rot threat of created forest crops.

Materials and methods. On the basis of the materials contained in "The records book of pests foci and forest diseases", available in every forestry enterprise, as well as the results of the forest pathology surveys of plantations, the base of affected pine stands by annosum root rot, including information of about 22 194 foci of the disease was made by the staff of the enterprise "Belarus forest protection".

A relative *H. annosum* infection of different age pine stands growing in different forest types and habitat conditions, was estimated for each forestry as the ratio of the foci area in a definite age class, forest type, or the type of habitat conditions to the total area of pine forests of the corresponding age class, forest type, or the type of habitat conditions in forestry.

Main part. Among forest types represented in the forests of Belarus the pine bracken (5.8%) and moss (4.8%) forests are affected by *H. annosum* in the greatest extent (Table 1). It should be noted that the intensity of affection is heterogeneous in forest enterprises and forest areas: in Neman-Predpolesie, Berezinsky-Predpolesie and Bug-Polesie forest regions bracken pine forests are affected in the greatest extent, while in others – the mossy pine forests. Quite resistant to root decay are pine blueberry forests: a sufficiently wide distribution of this forest type in the country (530 443.9 ha) being affected only 0.3% of their total area.

Table 1

Relative *H. annosum* infection in the pine stands of different forest types, %

Forest region	Type of pine forest										
	mossy	bracken	heather	oxalis	bilberry	cowberry	long-mossy	green-mossy	lichen	sedge	ledum
Western Dvina	1.8	1.2	1.1	0.2	0.04	0.7	–	–	–	–	–
Oshmyany-Minsk	2.0	1.5	0.9	0.8	0.2	0.2	–	0.1	0.8	–	–
Orsha-Mogilev	3.9	2.5	1.7	0.5	0.2	0.2	–	0.5	0.7	–	–
Neman-Predpolesie	4.5	13.0	1.8	0.9	0.3	0.3	0.02	–	0.1	–	–
Berezinsky-Predpolesie	5.7	7.6	4.6	1.0	0.4	2.0	0.01	2.0	6.6	0.04	–
Bug-Polesie	5.3	6.1	1.6	0.1	0.1	0.2	0.02	–	–	–	–
Polesie-Pridnieper	6.9	5.1	3.8	0.8	0.5	2.0	0.06	–	1.5	0.2	0.3
Total	4.8	5.8	2.6	0.7	0.3	0.8	0.02	0.5	1.3	0.1	0.1

The least affected pine plantations growing on damp and wet soils: annosum root rot foci occur in single instances in the ledum and sedge pine forests, the relative infection of which is 0.1%.

According to N. I. Fedorov [2] and Y. M. Poleshchuk [4], in the conditions of Belarus 20–30 years ago the spread of *H. annosum* in mossy pine forests was in several times higher than in the bracken pine stands that is unequal to the results of modern research.

The spread of the pathogen in the planting largely depends on the types of habitat conditions, characterized, primarily, by presence of nutrients and moisture of the soil which determine the ecological environment of soil microflora and vegetation. Based on the analysis of annosum root rot foci distribution in pine plantations according to the types of habitat conditions it is stated that the disease foci are found in 9 types of habitat conditions: from dry to wet by the degree of hydration and the poor (A) ones to the relatively rich (C) ones by the degree of soil rich conditions.

The largest relative *H. annosum* infestation is characteristic for pine trees that grow in fresh mesotrophic (B_2) – 6.2% and fresh boreal (A_2) and 5.2% (Table 2). This pattern is typical for pine plantations of all forest areas, with the exception of Orsha-Mogilev, in which the maximum lesion intensity (13.9%) is observed in the pine plantations that grow in dry boreal forests (A_1). In the whole country a relative infestation of pine forests in the conditions A_1 is 2.3%. At the least extent the pine stands in poor wet (A_4) and very wet conditions being outside of the ecological pathogen optimum are susceptible to root decay (0.02%) in the least extent.

Many authors attribute the peculiarities of the disease with environmental conditions [5]. So, in the pine stands of Khrenovsk boron the most prevalent annosum root rot is in fresh methotrophic (B_2) and fresh boreal (C_2), and in fresh boron (A_2), wet and dry mesotrophic (B_3 and B_1) pathogen occurs in single instance. In Lithuania *H. annosum* is distributed everywhere and represents the greatest threat to pine forests growing in dry and fresh boron forest (A_1 and A_2) and fresh mesotrophic (B_2) [6].

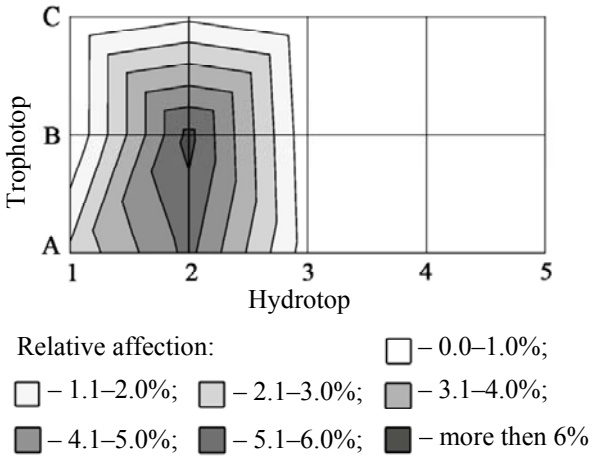
According to studies of the pine forests in Belarus by Y. M. Poleshchuk, the most optimal for the development of root decay are the conditions for growing of pine plantations from A_1 to A_3 and the conditions of fresh mesotrophic (B_2) [4], which harmonize with our results.

Thus, the prevalence of *H. annosum* in pine stands, as well as the intensity of their dying is in close relation with environmental conditions. Therefore, differentiation of forest areas under threat of the pathogen lesions comes, primarily, to the ranking of the types of habitat conditions.

Table 2

Relative *H. annosum* infection of the pine stands in different types of habitat conditions, %

Forest region	Type of habitat conditions								
	A_1	A_2	A_3	A_4	A_5	B_2	B_3	B_4	C_2
Western Dvina	–	2.2	0.1	–	–	1.2	0.04	–	0.2
Oshmyany-Minsk	1.1	2.2	0.05	–	–	1.5	0.3	–	0.9
Orsha-Mogilev	13.9	4.3	0.4	–	0.01	2.7	0.1	–	0.4
Neman-Predpolesie	1.7	4.6	0.5	0.02	–	13.7	0.2	2.0	1.1
Berezinsky-Predpolesie	7.4	6.7	0.6	0.02	–	8.0	0.4	–	1.2
Bug-Polesie	1.4	4.7	0.1	0.02	–	5.6	0.2	–	0.3
Polesie-Pridnieper	1.8	7.7	0.1	0.1	0.1	6.1	0.6	0.4	1.3
Total	2.3	5.3	0.5	0.02	0.02	6.2	0.3	0.4	0.8



Change of *H. annosum* infestation of the pine stands in dependence on habitat conditions

With growing of the soil richness, the prevalence of annosum root rot decreases what can be explained by so limiting development of the *H. annosum* factors as increasing of competition with saprophytic fungi-antagonists in rich soil conditions [7]. Change of hydrotop relatively fresh conditions as in the way of increasing humidity, and in the way of decrease also results in deterioration of conditions for the development of the pathogen (figure). Based on the data on the relative infestation of pine trees Heterobasidion spp. Depending on the condition of the habitat, and taking into account earlier studies 8 degrees of Heterobasidion spp. lesions threat of pine plantations (table 3). It is obvious that the gradation of the lesions threat of future tree stand by Heterobasidion spp. has to be basic designing of forest susceptible species.

This differentiation will promote creation of more sustainable stands, will allow to avoid accumulation of diseases foci, will decrease the number of infections and will reduce the costs of forest protection activities. Taking into account the enormous layer of domestic and foreign experience, we have developed and proposed to create the technologies of sustainable forest crops.

The technology is found on the following principal postulates, having a good demonstrative base:

– sustainability of forest crops increases with the proportion decrease of susceptible (coniferous) species [2, 8, 7];

– intensity of crops lesion decreases with reduction of planting density [5];

– the formation of the forest environment in monocrops created on land withdrawing of agricultural use, is quite slow, creating new ecological niches for optional parasites, increasing here their number and aggressiveness [9];

– soil-improving and allelopathy deciduous species contribute to the accelerated formation of forest environment and inhibit the development of Heterobasidion spp. pathogens [8];

– mycorhiza of planting material increases the resistance and productivity of forest crops [10];

– compacted subinguinal horizon of the soil prevents the formation of a proper pine root system, that reduces its resistance to root decay [11].

Proceeding from the above, in areas with high and very high risk of lesions, planting creation of Scots pine should be excluded, replacing this species by deciduous crops (birch, Norway maple, tillet) or European larch. At high and average lesions threat exclusively mixed pine-birch crops should be created with the compulsory introduction of auxiliary species, among which can be mountain ash, ramanas rose, common barberry, arrow wood, Juneberry and others.

Table 3

Distribution of forest areas by *H. annosum* infection threat of created pine stands

Threat of pine stands affection by annosum root rot	General characteristics of the site	Type of habitat conditions
The greatest	Not grubbed felling areas after clear sanitary cuttings in foci of *Heterobasidion* spp.	All
Very high	Grubbed felling areas after clear sanitary cuttings in foci of *Heterobasidion* spp.	All
High	Former agricultural (arable land, fallow, hay, pasture) and non-forest (developed peat swamp, quarries, sands and so on) lands in the types of vegetation conditions	A_1, A_2, B_2
Average	Not grubbed cutting areas after carrying out of clear cuttings including the sanitary ones, in pine plantations, which are not the foci of *Heterobasidion* spp. in the habitat conditions	A_1, A_2, B_2
Below average	The same	A_3, B_3, B_4, C_2
Low	Grubbed felling areas after carrying out of clear cuttings including sanitary, in the pine stands which are not foci of *Heterobasidion* spp. in the habitat conditions	A_1, A_2, B_2
Very low	The same	A_3, B_3, B_4, C_2
Absent	Wet and very wet types of habitat conditions	A_4, A_5, B_5

When lesions threat is below average, low or very low, designing of plantings should be guided by TKP 047-2009, and still it is wanted to avoid creating pure crops.

Conclusion. 1. In the terms of Belarus the most frequent *H. annosum* foci occur in pure pine stands of the III age class, growing in fresh boron and mesotrophic (A_2 and B_2) in the bracken, mossy and heather forest types.

2. At present the relative infestation of eagle ray pine stands that exceeds moss pine stands infestation in 1.2–1.8 times significantly increased. Pine plantations, established in the period of mass afforestation transfer of lands that were in agricultural use, reaching III–IV classes of age, kept a low resistance to root decay, and were affected to the greatest degree.

3. The threat of mass pine stands lesions by *H. annosum* largely depends on the type of habitat conditions and lands categories of forest Fund. Hence, based on the history of forest areas and their soil conditions, it is possible to distinguish 8 threat lesions degrees of created forest crops pine pathogen.

4. The design of forest stands, taking into account their threat lesions by *H. annosum* will permit to create sustainable stands, reducing the damage caused by root decay to forestry in the country.

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