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EFFICACY INCREASE OF SILVICULTURAL MEASURES WITH BIOLOGICAL METHODS IN THE PINE STANDS

Based on the analysis of database of the pine stands of Belarus affected by annosum root rot, and the results of longstanding research the substantiation of silvicultural criteria for designation of stump treatment with biological preparations in the pine forests to limit the severity of the pathogen is given. It is proposed to differ site selection for stump treatment according to the regional-typological principle because of significant differences in the relative infestation of pine stands in different forest conditions. It was found that that the treatment should be carried out in pine stands of mossy and bracken series of forest types I–III age classes, and in the pine forests of Gomel and Mogilev region also in age class IV, as well as heather, lichen and cranberry series of forest types. In this case, the use of biological agents on the basis of the fungus *Phlebiopsis gigantea* is useful when conducting selective and complete sanitary felling (regardless of intensity), as well as thinning and cleaning litter (with a sample of at least 20% of a physiologically live pine wood is cut down from the stock) at steady daily average temperatures of at least +5°C.

Key words: Scots pine, *Heterobasidion annosum*, forest protection, biological method, *Phlebiopsis gigantea*, stump treatment.

Introduction. The main task of forest protection is the damage limitation, caused to forestry by activity of harmful organisms, plantings resistance increase and prevention of pathological processes in forests while carrying out economic measures. The greatest damage to coniferous forests of Belarus is caused by the root rots the intensive development of which leads to resistance loss of forest stands, their premature disintegration and destruction.

It was found out by analyzing the data about pinetums of the Republic of Belarus affected by *Heterobasidion annosum* that native foresters use only felling to improve pine forests: cleaning felling (stands thinning, accretion cutting), selective sanitary felling, felling refuse removal [1]. At the same time high periodicity of such measures and ongoing growth of the disease loci area on the territory of the country show low efficiency of all kinds of felling in resistance increase of pine stands, and that is connected with absence of their influence on the causing agent.

After various kinds of felling in pine stands there is unnaturally considerable quantity of a nutritious substratum for root pathogens in the form of wood of stumps and roots of felled trees. Artificial colonization of such wood with competitive fungi-antagonists permits to prevent not only the primary planting infestation with spores, but also the vegetative infestant diffusion among root systems [2]. Treatment of fresh stumps of coniferous trees after felling with biological compounds on the basis of *Phlebiopsis gigantea* (Fr.) Jülich fungus is widely used in a complex of forest-protection measures in many European countries.

We selected a local strain of basidiomycetes *P. gigantea* with outstanding antagonistic properties, having the same antagonistic abilities as the strains taken as basis for foreign biological preparations. Laboratory regulations of the biological preparation production are developed. The following research problem was application technology development of biological method and its integration into the system of forestry practices.

Main part. Typological structure analysis of pinetums damaged by *Heterobasidion annosum* permitted to find out that 97.9% of all affected pine forests fall on three forest types (mossy pine forest, brake pine forest, heath pine forest) [3]. According to many researchers, in the pine forests growing on sandy and sandy loam wet soils favorable temperature-humidity conditions for development of *H. annosum* are formed. Pine develops here the most pathogen vulnerable surface creeping root system with a large number of roots in the ground litter [4]. Pine stands in such forest types, apparently, are in the ecological optimum, and that is expressed in high productivity of forest stands and in delayed trees differentiation in the growth process. Intra-specific competition intensification among even-aged plants already in age class II causes an essential trees weakening and creates preconditions for their infestation with pathogen organisms. These processes are especially sharp during formation of forest environment in the forest cultures created on agricultural or waste lands. High density of young plants and middle-aged cultures [4] favors fast infection diffusion outside the drying locus perimeter, and that causes a high saturation of rhizosphere with nutritious substratum for pathogen – pine roots.

Taking into consideration that relative infection rate of pinetums in different forest vegetation conditions has essential differences [3], it is proposed to differentiate the choice of plots for biological preparation processing, first of all, according to regional-typological principle. The minimum territorial unit of differentiation is expedient to choose at the level of SPFA. On the basis of relative infection rate data of pinetums by the pine fungus on forest types it is proposed as a criterion for bioprocessing to define level of relative infection rate as 3.0%. Using this criterion the pine stands, vulnerable to focal lesion by the pine fungus (Table 1) are most accurately found out.

Table 1

Criteria for stumps biological treatment at intermediate fellings

Region	Forestry criteria		
	Age class	Forest type	Participation of pine in the stand structure, units
Brest	I–III	Mossy pine forest, brake pine forest	≥7
Vitebsk	–	–	–
Gomel	I–IV	Heath pine forest, mossy pine forest, brake pine forest	≥7
Grodno	I–III	Mossy pine forest, brake pine forest	≥7
Minsk	I–III	Mossy pine forest, brake pine forest	≥8
Mogilev	I–IV	Cowberry pine forest, heath pine forest, hylocomiosum pine forest, lichen pine forest, mossy pine forest, brake pine forest	≥7

In spite of the fact that the highest relative infection rate by the pine fungus is found in pinetums of age class III, primary infestation of plantings and loci formation beginning falls on young plants. Therefore, biological processing, having a prophylactic role, should cover plantings from age class I, preventing loci formation. In ripening stands there is the highest differentiation of relative infection rate of pine forests on SPFA. The maximum rate it reaches in timber enterprises of Gomel and Mogilev associations, almost twice exceeding the average infection rate of pine forests of Minsk timber enterprise. Thus, biological treatment is expedient to carry out in pine stands of age classes I–III, and in pine forests of Gomel and Mogilev SPFA – also in age class IV. High resistance to the pine fungus of pine forests of Vitebsk SPFA permits to carry out felling without accompanying stumps treatment by biological preparations.

Success of stumps inoculation by the antagonist depends on the wood condition of roots and butts of dead wood. It is already, as a rule, colonized and partially destroyed by xylotroph organisms to the number of which the pine fungus belongs. Stumps treatment after felling of such trees is inexpedient because of very low efficiency [5]. Hence, there is no necessity to carry out stumps biological treatment while carrying out dead wood felling, for example, at felling refuse removal (Table 2). While doing selective and final sanitary felling in pinetums the stumps treatment with a biological preparation is the obligatory measure.

Table 2

Forestry and sanitary-improving measures, with accompanying stumps treatment

Measure type	Additional conditions for stumps biological treatment
Sanitary-improving: – felling refuse removal	At taking out of not less than 20% of physiologically alive wood (fresh wind fall, windbreak, snowbreak) from the stock being fallen
– selective sanitary fellings	Always
– final sanitary fellings	Always
Cleaning cuttings: – liberation	At giving to felling of not less than 20% of pine from the stock being fallen
– thinning	The same
– accretion cuttings	The same

Taking into consideration that the pine fungus and the bio-protection agent, fungus *P. gigantea*, are destructors of mainly soft wood, the stumps biological treatment is inexpedient at thinning chiefly of deciduous component of the forest stand, for example, at opening out.

Sanitary-improving and forestry measures with stumps treatment should be carried out in favorable for the antagonist introduction period, i.e. at stable daily average temperatures not less than +5ºC.

Comparison of foreign analogues of the biological preparation for stumps treatment to restrict injuriousness of the pine fungus permitted to draw a conclusion that the most technological preparative form is a liquid concentrate of oidiospores *P. gigantea* with special-purpose additives. Experiments results show that with spores density increase in the working fluid the stumps inoculation success increases. According to data of Yu. M. Poleshchuk, in the conditions of Belarus the minimum density for full colonization of the treated stumps is 20 million pieces on 1 liter of the

working fluid [6]. Tests of different concentrations in working conditions even with concentration of 2,200 million pieces on 1 liter didn't show establishment of more than 95%. Finnish preparation Rotstop is recommended to use in a wide range of working concentrations – 1–10 million spores on 1 liter. However according to data of K. Korhonen, at concentration of 1–3 million spores on 1 liter the preparation not always shows high efficiency [7]. PG Suspension producer recommends to use the preparation in concentration of 1 million spores on 1 liter. Taking into consideration the operational experience of scientists and practitioners, and also the results of our researches, the recommended average concentration of spores in the working fluid is not less than 10 million pieces on 1 liter.

Establishment of the introduced antagonist on the stumps surface depends on trees felling remoteness. With time stumps wood dries up, is colonized by wood-coloring and wood-damaging fungi, and becomes less suitable for development of *P. gigantea*. According to the data of Yu. M. Poleshchuk, the maximum establishment of *P. gigantea* is observed within the first seven days after felling [6]. Hence, it is necessary to carry out the stumps treatment simultaneously with felling or not later than the first week after felling.

Recommended methods of putting the working fluid on the stumps surface can be divided into three groups:

– manual putting;
– mechanized putting;
– automated putting.

Manual treatment is done by soft green besoms from branches of small-leaved or bush species. Advantage of this method is that no special stock is needed. However at the given treatment method the consumption control of the working fluid is difficult. Mechanical treatment is carried out using knapsack sprayers. Automated putting of the working fluid is done by special devices on harvester heads at a tree felling. Several principles of the fluid putting on a stump surface are developed and used now: through openings in a chain blade, through a sprayer in the attachment point of a chain blade, through pair sprayers in the harvester head. Automated putting of the working fluid is the most progressive and less difficult method. Feed devices usage does not slow down the harvester work, since the treatment is done simultaneously with a tree felling. Refilling of special cans by the working fluid is carried out once in a shift during the service.

Conclusion. The forest pathological condition of pine forests is determined by their low resistance to the motley roots rot caused by pathogen basidial fungus *Heterobasidion annosum* (Fr.) Bref. The pine fungus loci compose from 55 to 89% of all loci of pests and diseases in the forests of Belarus. Essential infection rate of pine forests testifies to a high infestant adaptation to modern forestry technologies. Long anthropogenic influence on forest ecosystems led to gradual decrease of biological resistance of forests with a piny formation, facilitated accumulation of a large quantity of the pathogen infection and increase of its virulence, and that together with climatic changes led to essential limits changes of the ecological geographic range of annosum root rot [8, 9].

Unlike other forest pathologies the loci area of the pine fungus is rather static. At the beginning of 2014 the disease loci covered 137.3 thousands of hectares, or 3.6% of pine stands area on waterless valleys. Absence of a decrease tendency of the disease loci area, in spite of increasing efforts in struggle against it during the last decades, shows low measures efficiency of protection and resistance increase of pine forests [1]. There is no integrated approach in the country to this problem solving which should accompany all stages of forest growing, based, first of all, on the disease prophylaxis. One of the important measures, which showed a high efficiency and is widely practiced in the system of forest protection of many European countries, is biological recovery of stumps and roots wood after felling at the expense of their artificial inoculation by saprotroph organisms.

The developed technology of the biological method application to prevent appearance and development of the pine fungus loci in pinetums of Belarus passed industrial testing in Negorelsky experimental, Starodorozhinsky experimental and Liubansky timber enterprises. The first stage of introduction of the pine stands protection with biological method is planned on 2015; this stage will be realized in Smorgonsky experimental, Baranovichsky and Klichevsky timber enterprises.

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