Forest pathological monitoring of different types protective planting in Lower Volga region

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Abstract. In maintaining the material and energy balance of dry-steppe and semi-desert ecosystems, the main active component is forest-reclamation complexes of various purposes. In addition to environmental stabilization and other economic functions, protective plantings are also reserves of regional biodiversity. Research was carried out on permanent test sites in dendrological collections and protective forest stands of the Federal Research Center of Agroecology of RAS, as well as in recreational and landscaping plantings using route and stationary methods in different types of forest plantations that differ in condition, level of anthropogenic impact and maintenance regime. The assessment of the forest pathology status of stands was carried out using standard methods and in accordance with the current guidelines for forest pathology survey of plantings and forest pathology monitoring. It was found that in the spectrum of the examined plants, the most prosperous state of the dendroflora is distinguished by arboretums and forest belts. Urban plantings are dominated by severely weakened and shrinking trees (up to 80.0%). The main pathologies in them were shrunken tops and skeletal branches, xylophages, diseases of foliage, wood and trunks. The least pronounced anomalies of woody plants in forest belts (10.7-22.0% lower than in other types of plantings).

1. Introduction

The preservation of forest complexes, which have a predominantly artificial nature of origin, at the level of stable functioning without absolute destruction, regardless of the external influence degree, is today a priority task in sparsely wooded regions with an unstable moisture-thermal regime [1, 2, 3].

For this, it is necessary to carry out constant forest pathological monitoring, which allows timely detection of disturbances in the plantations stability from a number of stress factors [4, 5, 6].

The weakening of the forest stands viability mainly depends on the ecological conditions of growth: age, mixing pattern, degree of anthropogenic pollution, recreational load, etc. In this regard, urgent measures are required to identify the woody plants adaptive potential and carry out a set of measures, aimed at improving and increasing the durability of plantings [7].
The most indicative indices of the plantings sustainability are pests, their number, distribution and features of spatial distribution in plantings [8, 9, 10].

In addition to the main phytosanitary indicators of the forest stands state (damage by insects and phytopathogens), external anomalies of the plant organism are distinguished, varying in a wide range. These are butt hollows, multi-stems, frost cracks, mechanical damage to branches and trunk, boughs drying up, external manifestations of various etiologies diseases, consequences of insects’ destructive activity, etc. Analysis of the qualitative and quantitative characteristics of external pathological signs allows to concrete the results monitoring of the stands state in general and also individual trees [11, 12].

So, the spread and development of external pathologies on various generic complexes woody plants contributes to the destructive insects and wood-destroying fungi activation, the progression of fungal and bacterial diseases (for example, open frost cracks become an excellent source for the development of stem rot) [13, 14, 15, 16].

Under these conditions, it is of particular interest to study the interaction of biotic components in anthropogenically created ecosystems, which are forest plantations, and to search for ways to optimize the plantings state, to design sustainable biocenoses while maximizing the preservation and enhancement of the existing biological diversity [17].

2. Materials and methods

The research work was carried out on permanent sample plots in dendrological collections and protective forest plantations of the Federal Scientific Centre of Agroecology, Complex Meliorations and Protective Afforestation of the Russian Academy of Sciences, as well as in the recreational and landscaping plantings using route and stationary methods in forest plantations different types/categories, differing in state, level of anthropogenic impact and the mode of detention.

The assessment of the forest stands pathological state was carried out by using standard methods and in accordance with the current guidelines for stands forest pathological examination and forest pathological monitoring at the federal and regional levels.

In the course of observations, abnormal trunk shapes (the percentage of occurrence of each species on the site) were identified and the state of a tree with one or another morphological anomaly was assessed. From the variety of external anomalies, the most common pathological signs affecting the woody plant viability were taken. Trunk defects, non-infectious damage (frost crack, inbark, hollow, dry side, trunk tilt, trunk curvature) were also taken into account.

To assess the degree of diseases manifestation, the authors used generally accepted visual scales specific to diseases with the corresponding number of points.

3. Results and discussion

Increasing the protective plantations for various purposes stability and viability is realized through the development of effective environmental protection measures based on forest pathological monitoring data. In this regard, the algorithm was developed for assessing the sanitary state of plantings for various purposes in sparsely wooded regions (Figure 1, 2). In the spectrum of the surveyed plantations, the most favorable state of dendroflora is distinguished by arboretums and forest belts (Figure 3).

The main pathologies were sphacelate tops and boughs, xylophages, diseases of foliage, wood and trunks. These signs are least expressed on trees in forest belts (by 10.7-22.0% compared to plantings of a different type) (Table 1).
Figure 1. External anomalies of the woody plants trunks.

Figure 2. Viability of woody plants in different types of plantings.
Figure 3. Algorithm for assessing the plantings sanitary state in forest agricultural and urbanized ecosystems.
maximum damage to the tree species was noted in recreational and green plantations (1.6-4.7%), where strongly weakened and dying up trees predominate - up to 80.0%. The main reasons for the irreversible weakening of trees are the antagonism of foliage damage by pests, drought, as well as the intensification of anthropogenic stress. The weighted average value of the prospective gene pool woody plants state varies greatly (Table 2).

Table 1. The incidence of pathological signs in different types of ecosystems.

| Pathological signs               | Ecosystem                              | forest agrarian | urbanized |
|----------------------------------|----------------------------------------|-----------------|-----------|
|                                  | Ulmus | Populus | Robinia | Acer | Ulmus | Populus | Robinia | Acer |
| Sphacelate tops and boughs       | 32.9  | 13.8    | 4.0     | 11.9 | 41.8  | 84.6    | 6.8     | 27.6 |
| Mechanical damage                | 21.5  | 7.2     | 2.1     | 36.1 | 17.6  | 42.7    | 31.2    | 46.3 |
| Trunk shape pathology            | 17.9  | 13.6    | 9.8     | 12.7 | 31.5  | 29.9    | 7.3     | 29.4 |
| Knars/warts                      | 11.4  | 2.8     | 10.1    | 31.6 | 39.3  | 24.8    | 6.1     | 44.7 |
| Butt stump                       | 0.8   | 2.6     | –       | 3.2  | 13.5  | 9.1     | 0.2     | 26.4 |
| Water sprout                     | 1.6   | 8.2     | –       | 2.4  | 10.1  | 37.2    | 4.6     | 13.5 |
| Trunk pests                      | 62.4  | 12.9    | 0.9     | 7.9  | 82.8  | 41.3    | 2.2     | 39.7 |
| Defoliation of the crown         | 5.7   | 2.1     | 2.6     | 0.4  | 21.9  | 11.5    | 3.8     | 0.9  |
| Foilage desease                 | 7.6   | 13.9    | 2.5     | 14.3 | 12.3  | 17.0    | 10.8    | 25.2 |
| Trunk bacteriosis, including leaks | 12.1 | 0.3     | 1.1     | 4.9  | 39.3  | 25.7    | 3.5     | 31.4 |
| Wood-destroying fungi            | 15.4  | 21.3    | 0.4     | 20.6 | 36.9  | 10.7    | 0.3     | 19.8 |
| Frost cracks                     | 27.7  | 26.9    | 19.4    | 17.1 | 33.1  | 37.3    | 31.4    | 28.3 |

The peculiarity of the forest stands species composition, depending on the growing conditions in forest-reclaimed territories, determines the biodiversity, quantitative abundance and bioecenotic role of dendrophilos insects inhabiting forest plantations. More than 400 species of arthropods were recorded in the plantations, damaging the trees assimilation apparatus. The dendrophage communities of individual species range from 23 to 160 ones (Table 3). The maximum faunal richness is characteristic of Quercus robur L. - 160 species.

Lepidoptera is the leading order of the class Insecta in the communities. These insects are found in all plantings types and ecological categories. At the same time, their maximum number was noted in the field-protective forest belts.

The species richness of phyllophages of the genus Ulmus complex is somewhat lower - 145 species. They are distributed unevenly in plantings of different types. The species of the order Coleoptera of the family Chrysomelidae dominate in recreational and landscaping plantings, among which Xanthogaleruca luteola is the leader (Muller, 1766). In field-protective forest stands, the number of this species is rather low. An insignificant quantitative abundance of the order Lepidoptera representatives was also recorded here.

Table 2. Changes in the forest stands state in different ecosystems.

| Woody plants genus | Weighted average value of the tree species state in the ecosystem, % | forest agrarian ecosystem | urbanized ecosystem |
|--------------------|---------------------------------------------------------------|---------------------------|---------------------|
|                    | 2018 | 2020 | 2018 | 2020 | 2018 | 2020 | 2018 | 2020 |
| Ulmus              | 1.3  | 1.5  | 2.6  | 3.6  |       |       |       |       |
| Populus            | 2.0  | 2.1  | 3.8  | 4.7  |       |       |       |       |
| Robinia            | 1.2  | 1.3  | 1.6  | 2.0  |       |       |       |       |
| Acer               | 2.4  | 2.6  | 4.0  | 4.2  |       |       |       |       |
In urban plantations, the Ulmus arboreal species are actively inhabited by representatives of Cecidomyiidae. Their number in different biotopes varies greatly: they are least represented in garden squares. In parks and local open parks plantings, their quantitative abundance increases by 5.0 and 10.0 times, respectively. This family representatives’ maximum number is typical for street plantings, where they damage up to 12.0-16.0% of the leaves in the tree crown.

A significant place in species and quantitative abundance in the entomocomplexes of the genus Populus plants belongs to insects of the family Pemphiginae (5 species). Moreover, they are more numerous in urban green spaces (3.9-18.8 individuals/unit). In forest belts of different categories, their number averages 2.19 individuals/unit.

Among other phyllophages inhabiting genus Populus woody species, representatives of the family Tenthredinidae (8 species) are distinguished by a high frequency of occurrence. The number of this insects group obligate species averages 9.01 individuals/unit. Plant mites of the genera Eriophyes and Aceria are quite common under these conditions. This community is represented by four species, of which representatives of the first genus are more numerous. The maximum density of mites distinguishes garden squares. Here they damage from 5.0 to 12.0% of trees.

The population of phyllophages living on plants of the Acer family is especially poor in composition. They account for a little more than 5.0% of the foliage pests identified species total composition in protective plantations. They damage different species of this spice. Moreover, more than 90.0% of identified arthropods are localized in urban landscaping plantings. Eriophyidae and Cecidomyiidae were more numerous on plants of this family.

The taxonomic composition of phytopathogens is represented by 35 species (Table 4). The trunks and the assimilation apparatus are most vulnerable to the action of pathogens. The most common pathogens are Nectria cinnabarina (on woody plants of the Ulmus family complex); Microsphaera albitoides (on species of the Quercus); Pholiota squarrosa, Drepanopeziza populorum and D. punctiformis (on Populus); Agrobacterium tumefaciens (on Acer).

### Table 3. Diversity of main woody plants faunistic communities.

| Woody plants generic complexes | S      | N      | Ecological indices | t      | t_c | t_p |
|--------------------------------|--------|--------|--------------------|--------|-----|-----|
| Acer                           | 23     | 2522 ± 0.01 | 0.46 | 0.97 |     |
| Quercus                        | 160    | 5925 ± 2.37 | 2.13 | 3.08 |     |
| Populus                        | 36     | 2500 ± 1.28 | 0.72 | 1.04 | 3.98 | 2.306|
| Robinia                        | 61     | 1950 ± 0.40 | 1.38 | 2.47 |     |
| Ulmus                          | 145    | 4910 ± 1.95 | 2.07 | 2.82 |     |

Note: S is the number of species; N is the number of individuals; D_M is the diversity spectrum of Menchik; H is Shannon distribution uniformity measure; t is Student's criterion; t_c is the critical value of the t-criterion.

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### Table 4. Taxonomic composition of woody plants phytopathogenic organisms.

| Generic complex | Fungal nature and species | Localization | Occurrence |
|-----------------|---------------------------|--------------|------------|
| Acer            | Agrobacterium tumefaciens (Smith & Townsend) | trunk        | ++++       |
|                 | Neonecricta coccinea (Pers.) Rossman & Samuels | branches      | +++        |
|                 | Cerrena unicolor (Bull.) Murrill | trunk        | ++         |
|                 | Volvariella bombycina (Schaeff.) Singer | trunk        | ++         |
|                 | Verticillium dahlia Kleb. | trunk        | +++        |
|                 | Ganoderma adspersum (Schulzer) Donk | trunk        | ++         |
|                 | Oxyporus populinus (Fr.) Donk | trunk        | +++        |
| Quercus         | Ophiostoma roboris (Georgescu & Teodoru) Potl. | tree trachea | +          |
|                 | Ceratocystis kubanicum (Sez.-Par.) | tree trachea | +++        |
|                 | Microsphaera albitoides Griffon & Maubl., Bull. | foliage      | +++        |
### Generic complex

**Fungal nature and species** | **Localization** | **Occurrence**
---|---|---
Colpoma quercinum (Pers.) Wetllr. | branches | +
Nummularia bulliardii Tul. | branches | +
Vuilleminia comedens Maire | branches | +
Septoria quercina Desm. | foliage | +

### Populus

**Fungal nature and species** | **Localization** | **Occurrence**
---|---|---
Drepanopeziza populorum (Desm.) Höhn. | foliage | ++++
D. punctiformis Gremmen | foliage | ++++
Melampsora laricis-populina Kleb. | foliage | +++
Mycosphaerella populi (Auersw) J. Schröt. | foliage | +++
Taphrina populina (Fr.) Fr. | foliage | +++
Pholiota squarrosa (Vahl.) P. Kumm. | trunk | ++++

### Robinia

**Fungal nature and species** | **Localization** | **Occurrence**
---|---|---
Phyllactinia fraxini (DC.) Fuss | foliage | ++
Fusarium spp. | branches, foliage | +++
Phomopsis oncostoma (Thüm.) Höhn. | branches, foliage | +++
Erysiphe palczewskii (Jacz.) U. Braun & S. Takam. | foliage | +++
Camarosporium robiniae (Westend.) Sacc. | branches | +++
Diplodia gleditschiae Pass | branches | +

### Ulmus

**Fungal nature and species** | **Localization** | **Occurrence**
---|---|---
Ophiostoma ulmi (Buisman) Nannf. | tree trunk | ++
Dothidea ulmi (C.-J. Duval) Fr. | foliage | +
Nectria cinnabarina (Tode) Fr. | branches | ++++
Septogloeum ulmicolum El. et Ohl. | foliage | +

**Note:** ++++ - often; +++ - rarely; ++ - single; + - sporadically.

### 4. Conclusion

The algorithm was developed for assessing the plantations sanitary state in dry steppe and semi-desert ecosystems, taking into account the peculiarities of forest reclamation complexes for various purposes. The analysis of the forest pathological situation indicates the main tree species unfavorable sanitary state, which is due to the action of the pathological factors complex, including the destructive activity of harmful organisms.

Maintaining the sustainability and increasing the different types/ecological categories plantings viability requires the development of the preventive, sanitary and recreational measures system based on forest pathological monitoring data.

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