Macromycete of recreational plantations of the city of Voronezh (Russia): species diversity, distribution and environmental significance

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Abstract. Macromycete are an integral component of the forest biogeocoenosis. They play an important role in ecosystem functioning. Being the most important heterotrophic element, macromycete take an active part in mineralization and humification processes. 56 species of macromycete, belonging to 17 families, are identified in the recreational plantations of Voronezh city. Most of these families belong to the order Agaricales. Mycorhiza-formers, litter and humus saprotrophic, xylotrophic and coprotrophic species are noted among the trophic groups of fungi. The greatest species diversity characterizes mycorhiza-forming agents and xylotrophic forms. Single coprotrophic and humus saprotrophic forms can be seen. Litter saprotrophic species occupy an intermediate position. In recreational plantations, about 38% of mushroom species are edible, 25% are conditionally edible species, and 37% are inedible and poisonous species. Moreover, most macromycete grow solitary or in small groups. The most significant functions of macromycete in the conditions of recreational plantations are their ability to form mycorhiza, which is important for the growth and development of the main forest-forming species (oak and pine); participation of saprotrophic mycobiota in the circulation of substances, as well as the nutritional value of certain types of macromycete.

1. Introduction

The integral component of forest biogeocoenosis is fungi, which play an important role in the functioning of ecosystems. Macromycete include mushrooms with large fruit bodies of various shapes that are available for observation with the naked eye. They have very close link with each other and with other organisms making forest biocoenosis. Among other things, fungi are inherent in regulatory functions, as they have a significant impact on the biodiversity of other groups of organisms [1, 2].

Currently, representatives of mycobiota are undergoing extensive research. In recent years, the attention of researchers in many countries has been directed toward studying the possibility of fungi using as a source of biologically active and medicinal substances. A special place is occupied by *Ganoderma lucidum* (Fr.) Karst, *Lentinus edodes* (Berk.) Sing and *Cordyceps sinensis* (Berk.) Sacc., used for medicinal purposes in traditional medicine of the East for more than two thousand years. Several authors indicate the presence of biologically active substances and healing properties of...
macromycete [3-6]. The information about biologically active substances and medicinal properties of macromycete is necessary for understanding of diverse importance of these organisms.

The problems of anthropogenic transformation of mycobiota in recreational plantations are considered in the works of N. N. Gavritskova, V. A. Mukhin and other authors [7,8]. The authors report that increased recreational load on forest communities is reflected in ecological-trophic structure and species abundance of macromycete. In the most cases, an increase in recreational exposure leads to a decrease in the abundance of fungi species. At the same time, participation of xylotrophic species in mycocoenosis increases and the number of mycorhiza-formers decreases.

I. V. Gordeeva [9] suggests using cap mushrooms as test objects for qualitative bioindication (delimiting polluted and unpolluted territories).

Macromycete are the most important heterotrophic link in forest biogeocoenosis. They actively participate in that part of biological circulation of substances, which is associated with mineralization and humification processes. Therefore, the study of macromycete complex in biogeocoenosis and the problems of mycobiota inventory are among the priority tasks of forest ecology.

The present studies of macromycete were conducted as a part of comprehensive environmental survey of the recreational areas in Voronezh city (figure 1).

![Figure 1. Plan of the research area.](image)

The first necessary step towards global research of mycobiota, especially macromycete, is to establish their species composition in plant communities. This fact explains the relevance of the present studies.

The aim of the research was to determine the species composition, identify distribution features and assess the significance of macromycete in recreational plantations of Voronezh city - vegetable communities used for mass rest of the citizens and other purposes which are not connected with production activity. As objects for experiments, plantations in the city of Voronezh, the most visited by residents for short-term rest (recreation) were chosen. For these plantations such research is conducted for the first time. It is impossible to compare results with other sources since the novelty of the research. For the first time for the area the list of mushrooms-macromycete is given, their distribution is assessed, environmental importance is shown in this work.
2. Methodology

The study of plantations was conducted using standard techniques of forestry, taxation, environmental, botanical and soil research. The species composition of macromycete was determined during the route test survey. Identification of species was carried out according to the determinant handbooks and monographs [10,11]. The distribution and abundance of fungi were determined on sample plots using Haas and Moser scales [12]. Basidioma (fruit bodies) distributions were noted using 5-point Gaas scale: 1 – single specimens; 2 – small groups (2-3 items); 3 – large groups (10-20 items); 4 – rows; 5 – rings . The abundance of species was determined by the modified Moser scale: + - one fruit body; from 1 to 2-5 fruit bodies; from 2 to 6-50 fruit bodies; from 3 to 51-100 fruit bodies; 101-500 fruit bodies; 501 and more fruit bodies.

3. Results and discussion

The plantations, in which the research was conducted, are characterized by the following indicators. Species composition: 5P3B2A + As. Pine - 60 years old; birch, oak and aspen - 40 years. Density is 0.6; bonitet II. Medium-sized undergrowth consists of Scots pine (Pinus sylvestris L.), European white birch (Betula pendula Roth.), Aspen (Populus tremula L.), English oak (Quercus robur L.), and Norway maple (Acer platanoides L.). The underbrush is found in clumps: English field maple (Acer campestre L.), Tatar maple (Acer tataricum L.), dogwood (Swida sanguinea L.), brickberry (Cotoneaster lucidus Schlecht), mountain ash (Sorbus aucuparia L.), European bird cherry (Padus avium Mill.) and blackberry (Rubus caesius L.). The ground cover consists of blood-red geranium (Geranium sanguineum L.), greater celandine (Chelidonium majus L.), wild strawberries (Fragaria vesca L.), and shorthear (Calamagrostis epigejos (L.) Roth), purple small-reed (Calamagrostis canesc L.), leafy spurge (Euphorbia esula L.), meadow bluegrass (Poa pratensis L.), meadow fescue (Festuca pratensis Huds), and rasp-grass (Carex pilosa Scop). The degree of coverage is 65%. The type of forest is grass pine forest; the type of forest conditions is B2 (fresh subor). The relief is weakly sloping with sod-forest humus medium-sized pseudo fiber sandy soil. The species composition of macromycete, as well as, their characteristics are given in the table 1.

Table 1. Macromycete of recreational plantations.

| #  | Macromycete species                              | Trophic group* | Category by edibility ** | Abundance (Moser scale), points | Gaas distribution, point |
|----|--------------------------------------------------|----------------|--------------------------|--------------------------------|--------------------------|
| 1  | Mushroom (Agaricus sylvaticus Schaeff.)          | Hs             | E                        | 1                              | +                        |
| 2  | Wood mushroom (Agaricus sylvicola (Vitt.) Sacc)  | Hs             | Ce                       | 1                              | +                        |
| 3  | Chestnut dapperling (Lepiota castanea Quel.)     | Hs             | P                        | 1                              | 1                        |
| 4  | Common ink cap (Coprinus atramentharit Fr.)     | Cop            | Ce                       | 2                              | +                        |
| 5  | False death cap mushroom (Amanita citrina Pers.)| Mf             | In                       | 1                              | 1                        |
| 6  | Fly agaric (Amanita muscaria (L.) Lam.)          | Mf             | P                        | 1                              | 1                        |
| 7  | Panther cap (Amanita pantherina (DC) Krombh)    | Mf             | P                        | 1                              | 1                        |
| 8  | Death angel (Amanita phalloides (Vaill. ex Fr.) Link.) | Mf         | P                        | 2                              | 1                        |
| #  | Macromycete species                                      | Trophic group* | Category by edibility ** | Abundance (Moser scale), points | Gaas distribution, point |
|----|----------------------------------------------------------|----------------|--------------------------|------------------------------|--------------------------|
| 9  | Honey mushroom (*Armillariella mellea* (Vahl) P. Kumm)   | Xs             | E                        | 3                           | 1                        |
| 10 | Sulfur-tuft (*Hupholoma fasciculare* (Huds.) P. Kumm)   | Xs             | P                        | 3                           | +                        |
| 11 | Cep (*Boletus edulis* Bull.)                             | Mf             | E                        | 1                           | 1                        |
| 12 | Underoak mushroom (*Boletus luridus* Schaeff.)           | Mf             | E                        | 1                           | +                        |
| 13 | Red-cracked boletus (*Xerocomus chrysenteron* (Bull.)    | Mf             | E                        | 2                           | 1                        |
| 14 | Pinwheel mushroom (*Marasmius rotula* (Scop.) Fr.)       | Xs             | In                       | 1                           | +                        |
| 15 | Leaden entoloma (*Entoloma sinuatum* Bull. ex Pers.)     | Mf             | P                        | 2                           | +                        |
| 16 | Oyster cap (*Pleurotus ostreatus* (Jacq.) P. Kumm.)      | Xs             | E                        | 2                           | 1                        |
| 17 | Psathyrella candolleana (*Psathyrella candolleana* (Fr.) Maire) | Xs             | In                       | 2                           | 1                        |
| 18 | Fairy cakes (*Hebeloma crustuliniforme* (Bull.) Quel.)    | Mf             | P                        | 1                           | 1                        |
| 19 | Beefsteak polypore (*Fistulina hepatica* (Schaeff.) With.) | Xs             | E                        | 1                           | +                        |
| 20 | Webcap (*Cortinarius triumphans* Fr.)                    | Mf             | P                        | 2                           | 1                        |
| 21 | Trooping funnel (*Clitocybe infundibuliformis* (Schaeff.) Quel.) | Ls             | E                        | 2                           | 2                        |
| 22 | Cloud funnel (*Clitocybe nebularis* (Batsch) P. Kumm.)   | Ls             | Ce                       | 2                           | 2                        |
| 23 | Aniseed toadstool (*Clitocybe odora* (Bull.) P. Kumm.)   | Ls             | E                        | 2                           | 1                        |
| 24 | Giant leucopax (*Leucopaxillus giganteus* (Sowerby) Singer) | Ls             | E                        | 1                           | 1                        |
| 25 | Collybia (*Collybia confluens* Pers.)                    | Ls             | In                       | 2                           | +                        |
| 26 | Gymnopus dryophilus (*Collybia dryophila* (Bull.) P. Kumm) | Ls             | Ce                       | 2                           | +                        |
| 27 | Wood woolly-foot (*Gymnopus peronatus* (Bolt.: Fr.) P. Kumm) | Ls             | In                       | 2                           | +                        |
| 28 | Wood blevit (*Lepista nuda* (Bull.))                     | Mf             | Ce                       | 1                           | 1                        |
| #  | Macromyete species                                      | Trophic group | Category by edibility | Abundance (Moser scale), points | Gaas distribution, point |
|----|--------------------------------------------------------|---------------|-----------------------|---------------------------------|--------------------------|
| 29 | Grooved cavalier mushroom (Melanoleuca grammopodia)    | Xs            | E                     | 1                               | 1                        |
| 30 | Common bonnet (Mycena galericulata)                     | Xs            | Ce                    | 1                               | 1                        |
| 31 | Clustered bonnet (Mycena inclinata)                     | Xs            | Ce                    | 1                               | 1                        |
| 32 | Grooved bonnet (Mycena polygramma)                      | Xs            | Ce                    | 1 +                             |                          |
| 33 | Lilac bonnet (Mycena pura)                              | Ls            | Ce                    | 1 +                             |                          |
| 34 | Waxy laccaria (Laccaria laccata)                        | Mf            | E                     | 1 +                             |                          |
| 35 | Gas Agaric (Tricholoma sulphureum)                       | Mf            | P                     | 2                               | 1                        |
| 36 | Sooty head (Tricholoma portentosum)                     | Mf            | E                     | 2 +                             |                          |
| 37 | Red hot milk cap (Lactarius rufus)                      | Mf            | E                     | 2                               | 2                        |
| 38 | Yellow swamp russula (Russula claroflava)               | Mf            | E                     | 1                               | 1                        |
| 39 | Copper brittlegill (Russula decolorans)                 | Mf            | E                     | 1                               | 1                        |
| 40 | Vomitig russula (Russula emetica)                       | Mf            | Ce                    | 1 +                             |                          |
| 41 | Milk-white brittlegill (Russula delica)                 | Mf            | E                     | 1 +                             |                          |
| 42 | Rosy russula (Russula rosea)                            | Mf            | Ce                    | 1 +                             |                          |
| 43 | R. pectinata (Russula pectinata)                        | Mf            | E                     | 2                               | 1                        |
| 44 | Bloody brittlegill (Russula sanguinea)                  | Mf            | Ce                    | 1                               | 1                        |
| 45 | Bare-toothed russula (Russula vesca)                    | Mf            | E                     | 2                               | 1                        |
| 46 | Crab brittlegill (Russula xerampelina)                  | Mf            | E                     | 1 +                             |                          |
| 47 | Blancaccio (Lactarius piperatus)                        | Mf            | E                     | 1                               | 1                        |
| 48 | Hairy bracket (Trametes hirsuta)                        | Xs            | In                    | 1                               | 1                        |
| 49 | Tinder fungus (Fomes fomentarius)                       | Xs            | In                    | 1                               | 1                        |
| 50 | Sulphur polypore (Laetiporus sulphureus)                 | Xs            | Ce                    | 1                               | 1                        |
| 51 | Dryad's saddle (Polyporus squamosus)                    | Xs            | Ce                    | 1 +                             |                          |
| 52 | Birch bracket (Piptoporus betulinus)                    | Xs            | In                    | 1                               | 2                        |
Macromycete species & Trophic group* & Category by edibility ** & Abundance (Moser scale), points & Gaas distribution, point
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53 Maze-gill fungus (*Daedalea quercina* (L.) Pers.) & Xs & In & 1 & 1
54 Red belt conk (*Fomitopsis pinicola* (Sw.) P. Karst.) & Xs & In & 1 & +
55 Willow bracket (*Phellinus igniarius* (L.) Quel.) & Xs & In & 1 & +
56 Oak bracket (*Phellinus robustus* (P. Karst.) Bourdot & Galzin) & Xs & In & 1 & 1

* MF – mycorhiza-formers; Ls – litter saprotrophic forms; Xs – xylotrophic forms; Cop – coprotrophic forms; Hs - humus saprotrophic forms;
**E – edible; Ce – conditionally edible; In – inedible; P – poisonous.

The analysis of the data presented in the table makes it possible to note the following. 56 species of macromycete of fungi belonging to 17 families were found in recreational plantations. Most of these families are included in the order *Agaricales*. At the same time, the greatest species diversity is common for the *Tricholomataceae* (16 species) and the *Russulaceae* (11 species) families.

Among the trophic groups of fungi, mycorhiza-forming, litter and humus saprotrophic, xylotrophic and coprotrophic forms are noted. Mycorhiza formers (25 species) and xylotrophic (19 species) predominate in the coenosis under consideration. The smallest number is typical for coprotrophic – 1 species and humus saprotrophic – 3 species. Litter saprotrophic forms occupy an intermediate position – 8 species. Trophic groups are not equally represented in different families. For example, all the identified species of the *Boletaceae*, *Amanitaceae* and *Russulaceae* families belong to the mycorhiza-forming ones. Humus saprotrophic (3 species) and coprotrophic (1 species) forms are identified in the *Agaricaceae*. The *Tricholomataceae* include representatives of various trophic groups: xylotrophic (4 species), litter saprotrophic (8 species) and mycorhiza-forming species (4 species). All the macromycete are xylodestructors (causative agents of stem rot of trees) in *Hymenochaetales* and *Polyporales* families.

By the categories of edibility, the detected macromycete are distributed as follows: edible – 21 species, conditionally edible – 14 species, inedible – 12 species of fungi and 9 species are poisonous ones. It should be noted that the largest number of species of edible fungi belong to the *Tricholomataceae* (6 species) and the *Russulaceae* (8 species) families. One type of edible fungi is found in the *Strophariaceae*, *Agaricaceae*, *Physalacriaceae*, *Pleurotaceae*, and *Fistulinaceae* families. All the three species of the found mushrooms are edible in the *Boletaceae* family.

Most of macromycete in the recreational plantations grow solitary or in small groups. It is fully consistent with their bioecological features and climatic conditions of the territory.

4. Conclusion

Playing the role of the main regulator of material and energetic processes in the ecosystems, macromycete are involved in the supply of trees, shrubs and herbaceous plants with nutrients and water. Having a highly developed enzymatic apparatus, fungi take part in the destruction of dead organic matter in the form of decay, leaf and ground litter. They determine the existence and vital activity of individual groups of soil and a number of terrestrial animals, microorganisms, protozoa. They are also producers of proteins, enzymes, biologically active substances, and therefore are increasingly being used in agriculture, medicine, and the food industry. At the same time, many species of fungi are pathogenic ones. They cause enormous damage to plantings, causing dangerous plant diseases that cause drying out and destabilization of plantations.
Thus, macromycete (in the studied plantations) perform diverse functions. Saprotrophic species play an important role in the circulation of substances, destroying plant residues and turning them into forms accessible to plants, while cleaning the forest from annual leaf litter.

Mycorrhiza mushrooms play a noticeable positive role. Entering into symbiosis with trees and shrubs, they supply their symbionts with moisture containing nitrogenous and mineral substances dissolved in it. Branched mycelium significantly increases the suction surface of tree and shrub roots, contributing to the growth and development of plants. Mycorhiza is extremely important for such major forest-forming species of our territory as oak and pine.

Talking about macromycete, it is impossible not to mention their nutritional values. 21 species of edible mushrooms grow in this stand, which is of particular importance in recreational forests. 12 species of mushrooms from 21 identified species of edible macromycete are regularly hunted and eaten (according to the surveys of local residents).

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