Influence of environmental conditions on plants in different climatic zones

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Abstract. Due to global shifts in climate, studies in contrasting conditions of two natural and climatic zones are of particular interest: (1) subzone of mixed and broad-leaved forests, (2) south-steppe subzone. In the period 2019-2020, 308 plant species from 56 families were surveyed. Phytopathogens damage plants, and therefore increase the loss of quality of plant materials. The frequency of occurrence of mycoses in autumn is 2-14 times higher than in spring-summer observations. The activity of phytopathogenic fungi of the genera of Fusarium (the causative agent of fusarium), Puccinia (rust), Phoma (phomosis), Rhizoctonia (scab), Verticillium (tracheomycotic or vascular wilting) increases. Differences in dominant micromycetes from the point of view of geography were determined: zone 1 (forest) - Alternaria spp., Chaetomium spp., Fusarium spp., F.avenaceum (Fr.) Sacc., F.solani (Mart.) Sacc., Heterosporium iridis (Fautrey & Roum.) JE Jacques, Phoma spp., Stemphylium spp., Verticillium spp.; zone 2 (steppe) - Alternaria spp., Botrytis spp., Cladosporium spp., Fusarium avenaceum, Fusarium spp., Peronospora spp., Phoma spp., Pullularia spp., Septoria spp. Screening of pesticides (biological fungicides) showed the effectiveness of preparations based on Pseudomonas fluorescens, Bacillus subtilis or Streptomyces griseus in limiting the growth of the mycelium of phytopathogenic fungi.

1. Introduction

The increase in industrial production of plant raw material for food and light industries is of high relevance [1, 2]. Expansion of the areas and set of species for cultivation in places other than their natural habitats can be successful provided that the introduction is correct, taking into account the ecology of the plant and the conditions of acclimatization, including on the basis of knowledge about the consortia of plants and components of the agrocenosis - spatial (topical) and food (trophic) relationships [3, 4].

Knowledge base on ecology and agrotechnology of growing plants (geographical conditions of their growth, structural and species composition of the mushroom complex, etc.) should be constantly updated to improve solutions for the control of potential sources of diseases and pests in the planting of plants [5]. Therefore, phytomonitoring is important: complex diagnostics of the state of plants, control of factors affecting their growth, development and productivity.

2. Materials and methods

The basis of the phytomonitoring data was formed by the materials of long-term observations of the
state of collection plantings of plants (2019-2020) at the following observation points: The Main Botanical Garden named after N.V. Titov Russian Academy of Sciences (MBG) (55°50'39.21"N 37°37'15.79" E), the arboretum of the All-Russian Research Institute of Phytopathology (ARIP) (55°37'25.85"N 36°59'13.52" E), botanical garden of the All-Russian Research Institute of Medicinal and Aromatic Plants (M_ARIMAP) (55°33'54.45"N 37°35'41.82" E) and the Botanical Garden of the North Caucasian Branch of the All-Russian Research Institute of Medicinal and Aromatic Plants NCB_ARIMAP (45°8'27.95"C 39°25'23.65" B). Route surveys were made in spring and autumn in two natural and climatic zones: (1) forest - a subzone of mixed and broad-leaved forests, (2) steppe - south-steppe subzone. A list of 308 species of plants from 56 families was compiled.

Weather conditions for the growing season 2019-2020 were favorable for the viability of MPs from different families. In terms of the average air temperature for the growing season in the years of observation (2019/2020), the differences are not significant: M_ARIMAP - 12.4 / 12.0°C, NCB_ARIMAP - 18.2 / 17.6°C, MBG - 12.8 / 12.3°C and ARIP - 12.5 / 11.8°C. Geographic contrasting differences, incl. between zone 1 and zone 2, observed for the amount of precipitation during the growing season during the observation years (2019/2020): M_ARIMAP - 434/375 mm, NCB_ARIMAP - 443/210 mm, MBG - 323/585 mm and ARIP - 396 / 518 mm.

The assessment of the degree of damage to the leaf surface by spots was carried out according to the scale of accounting for diseases: 0 points - visually healthy of plants; 1 - slightly damage of plants (1-10% of an organ or plant); 2 - medium damage of plant (10-50%, severely affected organs are not found); 3 - severe damage of plant (25-50%, some organs or plants are severely affected); 4 – plant death (more than 50%). The structure of the isolated microbial complexes was characterized on the basis of the frequency of occurrence of species in percent. In the studies, the level of damage to plants from various causes was determined - weather conditions and phytopathogenic agents.

For instrumental analysis (microbiological, physicochemical studies), soil and plant samples were taken in the spring and autumn of 2019-2020 in compliance with sterility. For analyzes, mixed samples were used, obtained from 5 point (individual) samples from each collection site. Repetition - three times. Selected samples were analyzed by traditional methods adopted in microbiology (humidity chamber, inoculation on nutrient media) and soil science. Identification of the isolated species was carried out according to modern keys for fungi [6-8]. Terminology is shown in accordance with Index Fungorum (http://www.indexfungorum.org).

Were isolated strains of micromycetes - plant pathogens, for which a series of tests (screening) of the effectiveness of fungicidal preparations was carried out. The experimental scheme included the following options: K - control (filter soaked in distilled water), Dr - recommended (registered) dose of the pesticide; ½-fold dose (½ D) - minimum concentration; double dose (2xD) is the maximum concentration of the pesticide. In testing the effect of inhibiting the growth of fungal phytopathogens, the following pesticide were used: binoram at the recommended dose of 7.5 mg / l (B - active principle of the \textit{Pseudomonas fluorescens} strain); phytosporin at a dose of 30 mg / l (Fs - \textit{Bacillus subtilis} 26 D); phytolavin at a dose of 2.0 mg / l (Fl - a.i. phytobacteriomycin produced by \textit{Streptomyces griseus}) and, as a reference standard, a chemical fungicide - maxim at a dose of 0.1 mg / l (M - a.i. fludioxonil).

The obtained experimental data were analyzed using Microsoft Excel (2013). For data processing, a two-way analysis of variance at 95% probability level (Pu) was used.

3. The study of the populations of plants for resistance to fungal diseases

The phytocenosis of the collection plantings of plants was diverse and included representatives of different families – \textit{Amaryllidaceae}, \textit{Asteraceae}, \textit{Caryophyllaceae}, \textit{Polygonaceae}, \textit{Caprifoliaceae}, \textit{Hypericaceae}, \textit{Iridaceae}, \textit{Campanulaceae}, \textit{Ranunculaceae}, \textit{Norice}, \textit{Solanaeace}, \textit{Primulaceae}, \textit{Plantaginaceae}, \textit{Polemoniaceae}, \textit{Crassulaceae}, \textit{Lamiaceae}, etc. On the territory of ARIMAP, \textit{Asteraceae} (14%), \textit{Lamiaceae} (9%) and \textit{Fabaceae} (9%) dominated; MBG – \textit{Lamiaceae} (20%), \textit{Asteraceae} (13%), \textit{Caryophyllaceae} (12%), \textit{Ranunculaceae} (9%); ARIP - \textit{Lamiaceae} (27%) and \textit{Rosaceae} (11%), other families were represented by less than 5%.
To compare the geographical features of MP growth in collection plantings and the development of diseases, the species present in all survey points were identified. A set of eight plants belonging to seven families has been obtained: Saxifragaceae, Asteraceae, Caprifoliaceae, Iridaceae, Fabaceae, Ranunculaceae (Table 1). The maximum lesion score was observed in the forest zone on the following plants: Galega officinalis L., Bergenia crassifolia (L.) Fritsch, Hypericum perforatum L., Echinacea purpurea (L.) Moench; in the steppe zone - Inula heleneum L., Helleborus caucasicus A. Braun, Achillea millefolium L. For plants with a wide range of habitats or cosmopolitans - Achillea millefolium and Hypericum perforatum are characterized by a wide range of ecological tolerance. They are able to exist in various habitats. The resistance of cosmopolitan plants to damage by phytopathogens was established: according to the degree of damage by fungal agents, it was medium (2 points), and in terms of distribution, it was low (less than 20%).

Reconnaissance surveys established general symptoms of damage in the collection plantings of plants: necrotic spots on leaves, chlorosis and marginal necrosis, discoloration of leaves and shoots, drying and wilting of individual leaves and shoots, etc. On average, for a sample of 65 species (zone 1) and 56 species (zone 2) the degree of damage to the leaf surface by spots in different years of phytomonitoring corresponded to 1 point or weak damage less than 10%.

The appearance of spots on the leaves can be non-infectious and infectious. The fertility conditions of the collection plots are typical for natural zones - soddy-podzolic soil (zone 1) and ordinary chernozem (zone 2). In general, at all observation points, the agrophone or growth conditions were assessed as satisfactory. The organic carbon content averaged 0.9-1.6% in zone 1 and 1.7-2.9% in zone 2; \( \text{pH_{water}} \) was closer to the conditions of agroeconomics: in zone 1, 7.10-7.45, zone 2 - above 7.65. Differences in the content of macroelements have been determined - supply: average nitrogen (above 50 mg / kg) at all observation points; for phosphorus, average for MBG and ARIP, very high and high - M_ARIMAP and NCB_ARIMAP (above 150 mg / kg); for potassium - high and very high at all monitoring points (above 170 mg / kg).

Weather conditions for the growing season 2019-2020 were favorable for the development of causative agents of fungal diseases. At different points of observation in the structural-species composition of the fungal complex of the rhizosphere (soil affected by plant roots) and rhizoplena (plant root surfaces) micromycetes (by genera) were determined:

- **zone 1 (forest)** - Acremonium, Alternaria, Aspergillus, Cladosporium, Clonostachys, Colletotrichum, Cunninghamamella, Fusarium, Mucor, Penicillium, Phoma, Phytophthora, Pythium, Rhizoctonia, Rhizopus, Trichoderma; singularly found - Bis fusarium, Cephalotrichum, Coniothyrium, Dinemasporium, Erysiphe, Eupenicillium, Gongronella, Heterosporium, Marssonina, Nigrospora, Oidium, Pestalotia, Phylllosticta, Protomonocys, Ramularia, Septoria, Sperellilophithecies;
- **zone 2 (steppe)** - Absidia, Acremonium, Actinomucor, Alternaria, Aspergillus, Bipolaris, Cladosporium, Clonostachys, Colletotrichum, Cunninghamamella, Curvularia, Fusarium, Gongronella, Mucor, Penicillium, Phoma, Phomopsis, Phytophthora, Pyrothizo, Trichoderma, Verticillium.

According to the results of analysis of variance of long-term data of phytomonitoring, it was proved that the geographical conditions of the location of planting of plants affect the damage to plants by fungal diseases (contribution 34±11%, \( \text{Pα} = 95% \)). The influence of biotic factors (physiology and adaptation of plants in agroeconomics) is not reliable, which is explained by the wide range of ecological tolerance of collection plants that can exist in different habitats.

A comparative analysis of the biodiversity and structure of the fungal complex was carried out for plant species present at all points of the survey. The composition of the fungal community, which includes 29 species, was determined for the studied set of plants. The lowest biodiversity is determined for Ber genia crassifolia (L.) Frits ch, Iris sibirica L., Galega officinalis L. (less than 10 species) and the highest biodiversity for Inula heleneum L., Helleborus caucasicus A. Braun, Echinacea purpurea (L.) Moench (12-18 species). The seasonality of manifestation by the frequency of occurrence of fungi of different genera on collection plants was established. The following genera of dominate in the mushroom complex (the frequency of occurrence is more than 40%):

- **zone 1 (forest)** - Acremonium, Alternaria, Ascochyta, Aspergillus, Clonostachys, Colletotrichum,
Cunninghamella, Mucor, Penicillium, Phytophthora, Pythium, Rhizoctonia, Rhizopus, Talaromyces, Trichoderma, Verticillium; zone 2 (steppe) - Acremonium, Actinomucor, Alternaria, Aspergillus, Colletotrichum, Cunninghamella, Curvularia, Fusarium, Mucor, Phomopsis, Pythium, Rhizoctonia, Rhizopus. In autumn, the fungal complex is represented by micromycetes of the genera (zones 1, 2): Alternaria, Aspergillus, Clonostachys, Cunninghamella, Fusarium, Humicola, Mucor, Paecilomyces, Penicillium, Rhizoctonia, Rhizopus, Talaromyces, Trichoderma.

Differentiation of micromycete species by abundance and/or frequency of occurrence of species allows us to consider them as markers, the presence of which can signal the influence of certain risk factors (or their absence) on plant growth and obtaining quality products, for example, representatives the genera of Cylindrocarpon, Phoma (Fig. 1).

![Figure 1. Composition of the mushroom complex in the agrocenosis of medicinal plants (long-term data): A - random, 1–25%; B - rare, 26-50%; C - frequent, 56–75%; D - predominant or dominant, 76–100% (* in some cases, genera of Cunninghamella, Fusarium, Phytophthora were dominant).](image)

Interesting results were obtained when analyzing changes in the species composition and structure of fungi of the genera of Fusarium, which were isolated from plants of the families Fabaceae, Polygonaceae, Iridaceae, Convallariaceae, Allioideae, Ranunculaceae, Rosaceae, Asparagaceae, Lamiaceae. The maximum frequency of species occurrence above 57% is determined for F.solani; F.graminearum and F.nivale with frequency of species occurrence = 11-20%; F.poae, F.scirpi, F.oxysporum with a species frequency of less than 10%. In the collection plantings of plants growing at all monitoring points, namely Echinacea purpurea (L.) Moench, all species of fungi of the genera of Fusarium were isolated, with the exception of F. nivale, F.poae, in contrast to Galega officinalis L., where only Fusarium solani is abundantly represented and other species have not been identified.

The results of a series of tests (screening) of biological preparations to curb (limit) the growth of phytopathogenic fungi isolated from the leaves and roots of MP collection plantings (botanical gardens) are presented in Table 1. The chemical fungicide maxam against the pathogen of leaf spots micromycete Alternaria sp. has shown high efficiency in all tested doses. (ecrisotroph), mold fungus Penicillium sp. (saprotroph, biodestructor), and a slowly growing phytopathogen, the causative agent of root rot - Pythium sp. (saprotroph). In terms of the effect of biological preparations on the growth of fungal mycelium, the best result was observed in the variant with the use of binoram in the recommended dose against fungi of the genera of Alternaria and Pythium, phytolavin - Pythium and, to a lesser extent, Alternaria. No significant fungicidal effect of phytosporin has been established in tests.
Table 1. Screening of fungicides against fungal diseases of plants

| Phytopathogen (zone of origin) | Option | ½ D | Dr | 2x D |
|-------------------------------|--------|-----|----|------|
| Alternaria sp. (forest)       | B      | y   | y  | y    |
|                               | Fs     | 0   | 0  | 0    |
|                               | Fl     | 0   | y  | y    |
|                               | M      | x   | x  | x    |
| Penicillium sp. (forest)      | B      | 0   | 0  | 0    |
|                               | Fs     | 0   | 0  | 0    |
|                               | Fl     | 0   | 0  | 0    |
|                               | M      | x   | x  | x    |
| Pythium sp. (steppe)          | B      | 0   | y  | y    |
|                               | Fs     | 0   | 0  | y    |
|                               | Fl     | y   | y  | y    |
|                               | M      | y   | y  | y    |

Note: according to the degree of the effect of pesticides on the growth of fungal mycelium, they were differentiated: strong effect of the drug (x) - the mycelium of the fungus approaches the filter with the drug, but does not overgrow it; middle (y) - the mycelium comes close to the filter and partially overgrows it; no effect (0) - the fungus mycelium completely overgrows the filter.

4. Conclusion

An extensive material of long-term monitoring has been accumulated and systematized (annually, twice a season) of collection plantings of ornamental and medicinal plants from 56 families with a total number of 308 species. Due to global shifts in climate and changes in society, studies in contrasting conditions of two natural and climatic zones are of particular interest: (1) forest - a subzone of mixed and broad-leaved forests, (2) steppe - south-steppe subzone.

Based on the results of visual diagnostics on the territory of the MBG im. N.V. Tsitsin RAS (Moscow), ARIMAP (Moscow), the North Caucasus branch of ARIMAP (Krasnodar Territory) and the ARIP arboretum (Moscow region), most of the plants are classified as healthy and weakly affected, which suggests their adaptability to environmental conditions. The techniques for caring for collection plants created an agronomic background of a satisfying environment in terms of the level of reaction, provision with nitrogen, phosphorus, potassium and organic matter content.

The seasonality of growth and occurrence of micromycetes on shoots and leaves has been established. In the autumn count, in comparison with the spring, the abundance of micromycetes increased by 2-14 times, incl. phytopathogenic fungi of the genera of Fusarium (the causative agent of fusarium), Puccinia (rust), Phoma (phomosis), Rhizoctonia (scab), Verticillium (tracheomycotic or vascular wilting).

Differences in the dominant micromycetes from the point of view of the geography of the survey points were determined: zone 1 (forest) - Alternaria spp., Chaetomium spp., Fusarium avenaceum (Fr.) Sacc., Fusarium solani (Mart.) Sacc., Fusarium spp., Heterosporium iridis (Fautrey & Roum.) JE Jacques, Phoma spp., Stemphylium spp., Verticillium spp.; zone 2 (steppe) - Alternaria spp., Botrytis spp., Cladosporium spp., Fusarium avenaceum, Fusarium spp., Peronospora spp., Phoma spp., Pullularia spp., Septoria spp.

In the collections of botanical gardens, species with an average degree (2-3 points) of lesions by leaf spots were identified as disease-sensitive populations of plants: Eleutherococcus senticosus (Rupr.) Maxim., Leonurus quinquelobatus Gilib., Melissa officinalis L., Valeriana simplicifolia (Rchb.) Kabath, Origianum vulgare L., Mentha × piperita L., Hyssopus officinalis L., Stachys byzantina K. Koch, Cichorium intybus L., Scutellaria baicalensis Georgi.
Screening of pesticides (biological fungicides) for limiting the growth of phytopathogens showed the effectiveness of the use: *Pseudomonas fluorescens* and phytobacteriomycin (synthesis of *Streptomyces griseus*) against the growth of fungi of *Alternaria* sp. and *Pythium* sp.; *Bacillus subtilis* - against *Pythium* sp.

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