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FUNCTIONAL ANALYSIS OF COLEOPTERA (INSECTA: COLEOPTERA) WITHIN CONSORTIA OF THE MOST COMMON XYLOTROPHIC BASIDIOMYCETES (FUNGI: BASIDIOMYCOTA) IN SARATOV REGION

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Abstract. Functional groups of connections between mycetophilous coleopterans and xylotrophic basidiomycetes were analyzed, and a heteroconcentric model of the four most common fungi was constructed to determine the structure of mycoconsortium in the Saratov region. Material collection was carried out from 2017 to 2023 in the Gagarinsky, Khvalynsky, Engels, Bazar-Karabulak, Krasnoarmeysky, Tatischevsky, Soviet, Marxovsky, and Soviet districts of the Saratov region. In the course of studying the mycoconsortia of 27 species of xylotrophic basidiomycetes (Polyporales, Agaricales, Hymenochaetales) in the Saratov region, 7 types and 12 functional series of 103 species of beetles from 23 families were identified within 3 groups of consortial connections. The functional spectrum includes topical, trophic, and fensive connections. The topical series encompasses episubstratal-stational and endosubstratal-stational connections. The trophic series includes 5 types of connections (biotrophic, saprotrophic, mixotrophic, necrotrophic, and predatory) and 9 functional series. In the heteroconcentric model, ensembles that include the most comprehensive and distinct groups of connections (topical, biotrophic, saprotrophic, mixotrophic, and fensive) were identified.

Keywords: mycetophilous coleopterans, fungi, fauna, heteroconcentric model, Saratov region

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ФУНКЦИОНАЛЬНЫЙ АНАЛИЗ ЖЕСТКОКРЫЛЫХ (INSECTA: COLEOPTERA) В СОСТАВЕ КОНСОРЦИЙ НАИБОЛЕЕ РАСПРОСТРАНЕННЫХ КСИЛОТРОФНЫХ БАЗИДИОМИЦЕТОВ (FUNGI: BASIDIOMYCOTA) САРАТОВСКОЙ ОБЛАСТИ

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Аннотация. Проанализированы функциональные группы связей мицетофильных жесткокрылых с ксилотрофными базидиомицетами, и построена гетероконцентровая модель 4 наиболее распространенных грибов, позволяющая определить структуру микоконсорций Саратовской области. Сбор материала проводился в период с 2017 по 2023 г. в Гагаринском, Хвалынском, Энгельсском, Базарно-Карабулакском, Красноармейском, Татищевском, Советском, Марксовском и Советском районах Саратовской области. В ходе исследования микоконсорций 27 видов ксилотрофных базидиомицетов (Polyporales, Agaricales, Hymenochaetales) Саратовской области в 3 группах консортивных связей выделено 7 типов и 12 функциональных рядов 103 видов жесткокрылых из 23 семейств. Функциональный спектр содержит топические, трофические и фензивные связи. Топический ряд представлен эписубстратно-стациальными и эндосубстратно-стациальными связями. Трофический включает 5 типов связей (биотрофические, сапротрофические, миксотрофические, некротрофические и хищничество) и 9 функциональных рядов. В гетероконцентровой модели выделены концерны, включающие наиболее полные и обособленные группы связей (топические, биотрофические, сапротрофические, миксотрофические и фензивные).

Ключевые слова: мицетофильные жесткокрылые, грибы, фауна, гетероконцентровая модель, Саратовская область

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Introduction

Any system represents a complex of interacting elements possessing a structure – a set of ways in which they are connected. In the consortium of xylotrophic fungi, diverse interactions arise with beetles, which can manifest in the dependency of the beetle on the fungus as well as the fungus on the beetle [1].

Consortial connections play an important role in the structure of consortium, determining the type of interaction between the consorts and their determinants. The structure of consortium is characterized by the presence of topical and trophic connections, which are the main components in forming the system, while other connections can be considered secondary [2]. In the mycoconsortium, where xylotrophic basidial fungi of the Saratov region act as determinants, three groups of beetles were identified: topoconsorts, trophoconsorts, and fensive consorts.

Materials and methods

Materials were collected from 2017 to 2023 in the Gagarinsky, Khvalynsky, Engels, Bazar-Karabulak, Krasnoarmeysky, Tatischevsky, Soviet, Marxovsky, and Soviet districts of the Saratov region. Various methods were used for material collection: manual collection, flotation method, and traps. Initially, open-living beetle species and inhabitants of the mycelial layer were collected from the fruiting body on the substrate. Fungi were identified according to modern literature [3–6]. The heteroconcentric model of the consortium was created in the Adobe Photoshop CC 2019 program.

Results and discussion

In the course of studying the mycoconsortia of 27 species of xylotrophic basidiomycetes (Polyporales, Agaricales, Hymenochaetales) from the Saratov region, 7 types and 12 functional sequences of 103 beetle species from 23 families were identified within 3 groups of consortial connections. The detailed composition of beetle species associated with basidiomycetes in the Saratov region is presented in a number of articles by the authors [7–12].

Table 1

Classification of consortial connections in mycoconsortium of xylotrophic basidiomycetes of the Saratov region

Group of connections	Type of connections	Functional rows
topical	substrate-stational	endosubstrate-stational
		epiendosubstrate-stational
trophic	biotrophic	obligate mycetobiophagy
		facultative mycetobiophagy
	sapro-trophic	obligate mycetosaprofagy
		facultative mycetosaprofagy
	mixotropic	obligate mycetomixofagy
		facultative mycetomixofagy
	predation	obligate predation
		facultative predation
	necrophagic	sapronecrophagy
fensive	fensive	fensive

The functional spectrum contains topical, trophic, and phensic relationships. The topical sequence is represented by episubstrate-stational and endosubstrate-stational connections. Endosubstrate-stational connections are formed by some beetles at the larval stage (Erotilidae: *Dacne bipustulata* (Thunberg, 1781), *Dacne pontica* (Bedel, 1868); Tenebrionidae: *Diaperis boleti* (Linnaeus, 1758), *Eledona agricola* (Herbst, 1783); Mycetophagidae: *Mycetophagus quadripustulatus* (Linnaeus, 1760), *Mycetophagus piceus* (Fabricius, 1777); Staphylinidae: *Atheta crassicornis* (Fabricius, 1792), *Gyrophaena affinis* Mannerheim, 1830, *Gyrophaena bihamata* C.G. Thomson, 1867, *Gyrophaena manca* Erichson, 1839, *Scaphisoma boleti* (Panzer, 1793), *Lordithon thoracicus* (Fabricius, 1777)). One of the beetle families most closely associated with development in the fruiting bodies of xylotrophic fungi is the wood-boring beetles – Ciidae. The distribution of Ciidae species is significantly determined by the hardness and structure of the fruiting bodies they inhabit [13–15].

The trophic sequence includes 5 types of relationships (biotrophic, saprotrophic, mixotrophic, necrotrophic, and predation) and 9 functional sequences. Priority is given to saprophagous connections, with 59 species of consorts (*Gyrophaena sp., Atheta sp., Lordithon sp., Scaphisoma sp., Sepedophilus sp*. (Staphylinidae), *Cyllodes sp.* (Nitidulidae), *Dacne sp., Triplax sp.* (Erotilidae), *Arthrolips sp.* (Corylophidae), *Mycetophagus sp.* (Mycetophagidae), *Cis sp., Ennearthron sp., Ropalodontus sp.* (Ciidae), *Diaperis sp., Eledona sp., Pentaphyllus sp*. (Tenebrionidae), *Cerylon sp.* (Cerylonidae)).

Necrotrophic (*Nicrophorus vespilloides* Herbst, 1783 (Silphidae)) and biotrophic sequences (*Tachyporus solutus* Erichson, 1839, *Oxyporus rufus* (Linnaeus, 1758) (Staphylinidae), *Prionychus ater* (Fabricius, 1775) (Tenebrionidae)) are represented by a minimal number. Fensive functional sequences in mycoconsortium are few and are characterized by beetle species that use the fruiting bodies for shelter and protection from enemies (*Ampedus pomorum* (Herbst, 1784) (Elateridae)) [16].

The ratio of the number of species and types of consortium connections in different beetle families is presented in Table 2.

Table 2

Types of consortial connections in various families of consortia

Families	Number of species	Types of connections						
		CS	**BT**	**ST**	**MT**	**P**	**N**	**F**
Carabidae	5	+	–	–	+	+	–	–
Histeridae	2	+	–	–	–	+	–	–
Leiodidae	3	+	–	+	–	–	–	–
Silphidae	1	+	–	–	–	–	+	–
Staphylinidae	37	+	+	+	+	+	–	–
Elateridae	1	+	–	–	+	+	–	+
Dermestidae	1	+	–	–	–	–	+	–
Anobiidae	1	+	–	+	–	–	–	–
Nitidulidae	4	+	–	+	–	–	–	–
Monotomidae	1	+	–	+	–	–	–	–
Cryptophagidae	1	+	–	–	+	–	–	–
Erotylidae	6	+	+	+	+	–	–	–
Laemophloeidae	1	+	–	+	–	–	–	–
Corylophidae	4	+	–	+	–	–	–	–
Coccinellidae	1	+	–	–	+	+	–	–
Alexiidae	1	+	–	+	–	–	–	–
Latridiidae	3	+	–	+	+	–	–	–
Bothrideridae	1	+	–	+	–	–	–	–
Cerylonidae	1	+	–	+	+	–	–	–
Mycetophagidae	6	+	–	+	+	–	–	–
Ciidae	10	+	–	–	+	–	–	–
Zopheridae	1	+	–	+	–	+	–	–
Tenebrionidae	11	+	+	+	+	+	–	+
Всего:	**103**							

Designations of types of connections: CS – substrate-stational, BT – biotrophic, ST – saprotrophic, MT – mixotrophic, P – predation, N – necrotrophic, F – phenic.

Among the analyzed families of Coleoptera, the leading place in terms of the number of types of relationships belongs to the families Tenebrionidae, Staphylinidae, and Erotylidae. Tenebrionidae have 7 types of relationships and 8 functional sequences: substratic-stational (endosubstratic-stational, episubstratic-stational), biotrophic (facultative mycetobiotrophy), saprotrophic (obligate mycetosaprophagy, facultative myceto-saprophagy), mixotrophic (obligate myceto-saprophagy), fensive, and predation (obligate predation). Staphylinidae have 6 types of relationships and 8 functional sequences: substratic-stational (endosubstratic-stational, episubstratic-stational), biotrophic (facultative mycetobiotrophy), saprotrophic (obligate myceto-saprophagy, facultative myceto-saprophagy), mixotrophic (obligate myceto-saprophagy, facultative myceto-mixophagy), and predation (obligate predation). Erotylidae have 5 types of relationships and 5 functional sequences: substratic-stational (endosubstratic-stational, episubstratic-stational), biotrophic (facultative mycetobiotrophy), saprotrophic (obligate myceto-saprophagy), and mixotrophic (obligate myceto-saprophagy). The other families of Coleoptera include 2–4 types of consort relationships.

As a new approach to studying consorts, a heterocentric model can be applied, which allows for a more visually representative structure of consorts. In this model, each centre is represented as a circle with a determinant (a basidiomycete) located in the center. Within the circle, consorts – coleopteran insects that are found in this center – are placed. All centers of the consortium are united through the determinant, which in the model is depicted as a central rod passing through all the centers [2]. This model was constructed based on the types of consortium relationships and makes it possible to visually represent the interactions between the xyotrophic fungi of 4 species of basidiomycetes: *Cerioporus squamosus* (Huds.), *Laetiporus sulphureus* (Bull.), *Trichaptum biforme* (Fr.), *Fomes fomentarius* (L.), and coleopteran insects (Fig. 1).

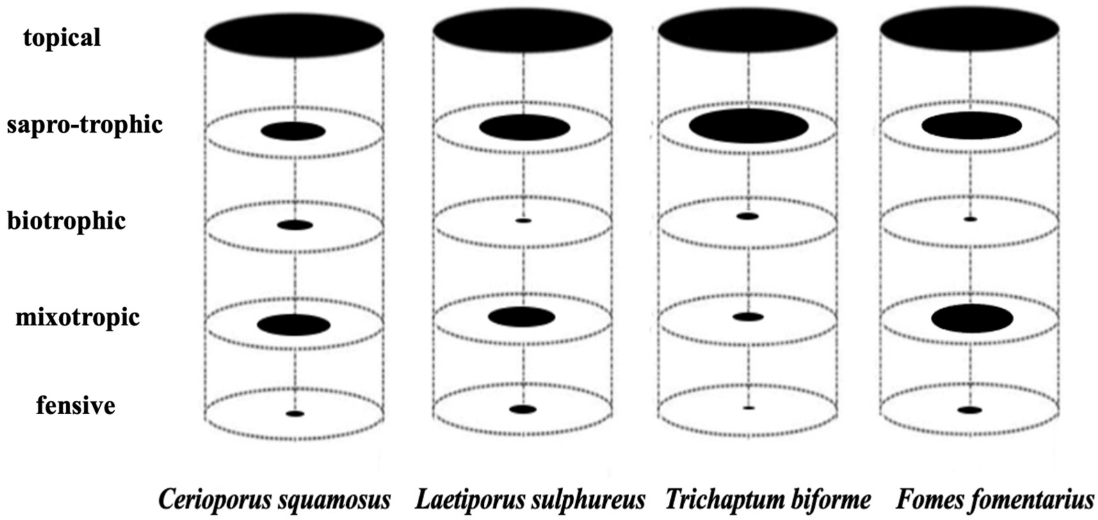

Fig. 1. Heteroconcentric Model of Mycoconsortia of Xylotrophic Basidiomycete Fungi in the Saratov Region

The models of all four species have a similar structure. The dominating concentric zones are topical and trophic. The dominance of these types of relationships indicates their system-forming role in the mycoconsortium.

In the three trophic types of relationships, saprotrophics (*L. sulphureus* (52 %), *T. biforme* (69 %), *F. fomentarius* (43 %)) were the most widespread. The composition of beetle mycetobionts inhabiting the fruit bodies of fungi significantly depends on the age, condition, and position on the substrate of these bodies, as well as on weather and microclimatic conditions, the degree of insect damage, and other factors. Young fruit bodies are rarely populated by beetles, and their presence is low, which can be determined by the size of the biotrophic concentric zones. During this period, the most frequently encountered beetle mycetophagous species are from the Staphylinidae family. Fruit bodies that have completed growth and sporulation become dry, loose, and hard due to the formation of a dimitic hyphae system [5]. In the consortia of *C. squamosus*, mixotrophs represent the largest group (53 %) due to the universal structure and consistency of young and old fruit bodies, as well as their rapid decay. The number of predator species associated with xylotrophic basidiomycete fungi through fensive relationships is approximately the same, which can be explained by the independence of this beetle group from the type of fungus and its structure, as they are attracted by other insects and larvae [17].

Conclusion

During the functional analysis of mycoconsortium, we identified 7 types of relationships between xylotrophic basidiomycete fungi (27 species) and beetles (103 species) in the Saratov region. We noted substrate-stationary, saprotrophic, biotrophic, mixotrophic, necrophagous, predation, and fensive types of relationships, and 12 functional sequences. Saprotrophs, biotrophs, and mixotrophs represent distinct groups and based on them, concentric zones were identified in the heteroconcentric model of the 4 most common species of basidiomycetes in the Saratov region.

The information obtained from our study can serve as a basis for further analysis of the functional sequences of beetles in the consortia of xylotrophic basidiomycete fungi in the Saratov region.

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