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CHARACTERISTICS OF EPIGEIC INVERTEBRATES OF SOME NATURAL FORESTS AND PLANTATIONS FROM THE WESTERN PLAIN (ROMANIA)

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Abstract

The aim of this paper is to highlight some interspecific relationships existing in epigeic invertebrate communities in natural forest ecosystems and plantations in the Western Romanian Plain. Nine sites were studied: 2 natural forests and 7 plantations. The material was collected with Barber traps during the summer season. The fauna was identified at the higher level of the species and Coleoptera: Carabidae - at species level, using specific identification keys. The following aspects were analysed: taxonomic composition, status of the taxa in the local coenoses from the point of view of their constancy classes in the samples, as well as the linear correlation coefficient (r) between the predatory taxa but also between the predators and their food sources. The results of this study highlight the importance of the coenotic heterogeneity in ensuring complex and long-lasting interspecific relationships along the path of ecological succession, resulting in a quality supply of environmental services provided by forests.

Key words: *forests, invertebrates, plantations, populations' structure, Western Plain.*

INTRODUCTION

Deforestation is one of the most dramatic human interventions on the biosphere, with huge consequences on its structure and functions (Palaghianu & Dutca, 2017). In the last decades, with the increase of the climatic changes (and not only), an attempt was made in Romania to compensate the reduction of forest ecosystems by afforestation (Feurdean, 2010; Chivulescu et al., 2021; Munteanu et al., 2016), half of the forest plantations having industrial purposes (Boháč et al., 2007; Stephens & Wagner, 2007). Afforestation is only 8% of the forested surface of Europe (Oxbrough et al., 2010), but it represents an important resource in some countries (even reaching over 70% of their total forested area), used in economic purpose (timber) and also, recreational end ecological (carbon storage) (Budău et al., 2023).

In Romania the natural and plantation forests were subjected to many studies regarding: characterization of the natural (Poole et al., 2003; Neblea et al., 2020) and invasive (Vítková et al., 2020; Ciuvăț et al., 2022) plant species, the native (Varvara & Coldea, 1984; Varvara & Pisică, 1993; Varvara, 1985; 2004; 2005; Cicort-Lucaciu et al., 2020; Ciornei et al., 2020; Prunar et al., 2022; David et al, 2023), and invasive (Olenici et al., 2022) invertebrates species, the forests dynamic (Tudoran et al., 2021) and conservation (Turcu et al., 2016; Albulescu et al., 2022), ecology (Falcă et al., 2000; 2004a; 2004b; 2005a; 2005b; Forio et al., 2020; Hamřík et al., 2023). There are a few subjects focused on afforestation (Burdon et al., 2020; Pérez et al., 2021; Szigeti et al, 2022; Ho et al., 2023).

Invertebrates are important components in all types of ecosystems, due to their role in the integrative trophic networks (Kosewska et al., 2023). In forests, the epigeic invertebrates are present from soil to supraepigeic level as detritivores, phytophagous, predators and, in the meantime are food source for superior trophic level of each of them (Oxbrough et al., 2010; Noreika et al., 2020; Mitchell et al., 2023).

Studying the structural characteristics of the epigeic invertebrates using higher taxa/suprataxa (superior to species level) is not an uncommon practice (Biaggini et al., 2007; Gerlach et al., 2013). However, some invertebrates are special due to their ability to reflect most changes (of natural or anthropogenic origin) in the habitats, through structural variations of their communities, for instance bioidicators such as myriapods, spiders, ants, some of the Coleoptera (i.e. Staphylinidae and Carabidae) (Folgarait, 1998; Rainio & Niemelä, 2003; Pearce & Venier, 2006; Perry & Herms, 2019; Kosewska et al., 2023).

In this study we aimed to find and highlight those structural peculiarities of communities of epigeic invertebrates that make the difference between plantations of different ages and which also, it reports them more structurally and functionally close to mature forests. The comparisons with epigeic invertebrate populations inhabiting adjacent natural forests help to outline ideas related to ecological stage of the forest plantations in the successional ecological context.

MATERIALS AND METHODS

In Western Romanian Plain, into Criș and Mureș river basins, there have been established nine study sites consisting in: three plantations (Uivar, Cermei and Sânmartin) each of them being four years old (hereinafter referred to as "young plantations" and abbreviated U, C and S), four plantations (Adea 1, Adea 2, Secusigiu 1 and Secusigiu 2) each of them being 8-10 years old (hereinafter referred to as "old plantations" and abbreviated A1, A2, S1 and S2), and two natural forests (Adea close to Adea plantations - abbreviated A.n.f. and Sânmartin in the vicinity of Sânmartin ash plantation - abbreviated S.n.f). All plantations differ through the woody species composition, microclimate, and various soil types. 60% from planted species are represented by pedunculate oak (*Quercus robur*), followed by Turkey/Austrian oak (*Q. cerris*) and ash (*Fraxinus excelsior*). In the depression areas the plantations are dominated by poplar (*Populus* sp.), ash and honey locusts (*Gleditsia triacanthos*).

The herbaceous vegetation forms grasslands with mezzophilous and mezzo-hygrophilous plant species and cultivated fields due to various geomorphological aspects at local and regional level. The process of reconstruction the forestry ecosystems was quite incipient in 2012 even the age of the plantations were 4-10 years old demonstrating the fact that the afforestation begun in 2003 and ongoing is working well but slowly in time (Crăciunescu, 2014). We present the study conducted during the summer season (June-August) of 2012 as a contribution at the better understanding of interspecific relationships existing in epigeic invertebrate communities in natural forest ecosystems and plantations, an important subject at national but also at international level. We are aware of the fact that in the interval of 10-12 years, some changes appeared regarding the numerical dominance, structure and constancy classes in epigeic invertebrate taxa and also the dimension of similarities between the invertebrate communities in the nine investigated sites. But our purpose is that our data to be a starting point for similar researches in the areas studied in 2012 or in other areas to highlight long-term structural and functional changes due to anthropogenic impact, climate change and knowledge based restoration of affected areas.

The epigeic invertebrate fauna was collected using Barber traps filled with a mixture (1:1 vol.) of formalin 4% and ethylene glycol. In each site ten Barber traps were installed, at approximately twenty meters from the forest/plantation edge and five meters distance between traps.

The invertebrates were identified supratAxa (superior to species level) using the specific identification keys. The Coleoptera were identified at the Family level. Among the Coleoptera, the ground beetles (Coleoptera: Carabidae) were identified at species level, because data at species level on the structure characteristics and interspecific relationships brings more accuracy regarding aspects related to successional stages of plantations and the conclusions of this study.

The data on epigeic invertebrates offered qualitative and quantitative information on the communities inhabiting both plantations and natural forests: the taxonomic composition, the species richness and specific diversity, the numerical relative abundances and the structure of the numerical dominance, and also the classes of constancy of taxa in the integrative coenoses. We also studied the degree of similarity of the invertebrate communities using the Mann -Whitney test for the degree of statistical significance of these similarities.

To obtain more relevance of the previous information, we calculated the linear regression index (r) for predator taxa and taxa being their potential prey, as well as for pairs of predator taxa known to be in potential competition in habitats.

The correspondence analysis (CA), and Bray-Curtis index of similarity were calculated using the statistical soft PAST (Legendre & Legendre, 1998; Hammer et al., 2001).

The one-way ANOVA test indicates that the differences between investigated ecosystems are significant: F = 3.148; df = 21; $p<0.05$.

For the Table 1 and 2 the abbreviations are as follows: Numerical dominance: ED - eudominant, D - dominant, SD - subdominant, RCD - recedent, SRCD - subrecedent. Tischler constancy classes: ECT - euconstant, CT - constant, rel. CT - relativ constant, ACS - accessory, ACD - accidental.

RESULTS AND DISCUSSIONS

The number of suprataxa (superior taxa) varies between 13 and 19 in the plantations of 4 years old and between 14 and 19 in the plantations of 8-10 years old respectively (Tables 1 and 2).

The taxonomical composition of epigeic invertebrate communities of the nine sites (without detailed identification of Coleoptera families) is almost identical. Although, the numerical abundances of the superior taxa from the studied communities determine different structure of their numerical dominances, also the frequencies, respective constancy's classes in with the taxa of epigenic invertebrates are framed.

In all plantations it is noted that the taxa considered (eu) dominants vary in proportion apparently randomized. As persistence in habitat, we have a fairly small proportion of (eu)constant taxa in young plantations (e.g. mites, dipterans, spiders, Heteroptera, beetle and Hemiptera). In the old plantations, in the same category of taxa (eu)constants, are also present isopods, Gryllidae and gastropods (Purice & Cioboiu, 2014).

The Coleoptera are subdominant numerically in all plantations. The beetle fauna varies as families' composition and more, as carabid species (Coleoptera: Carabidae).

Table 1. The epigeic invertebrate taxa in the numerical dominance structure and constancy classes, as proportion (%) from the total number of supraspecific / superior taxa/ site in the young plantations and adjacent natural forest

Statistical classes	C	U	S	S.n.f.
ED	7.14	16.67	12.5	28.57
D	21.44	27.77	25	7.15
SD	28.57	5.56	25	21.43
RCD	28.57	5.56	12.5	14.28
SRCD	14.28	44.44	25	28.57
ECT	7.14	55.55	62.5	71.44
CT	0	5.56	6.25	14.28
rel. CT	7.14	16.67	6.25	0
ACS	0	0	25	14.28
ACD	85.72	22.22	0	0

Table 2. The epigeic invertebrate taxa in the numerical dominance structure and constancy classes, as proportion (%) from the total number of supraspecific / superior taxa/ site in the old plantation and adjacent natural forest

Statistical classes	A 1	A 2	A.n.f.	S 1	S 2
ED	5.88	7.14	26.67	33.33	15.79
D	0	0	13.33	20	10.53
SD	11.76	0	0	26.67	15.79
RCD	29.42	7.14	0	6.67	5.26
SRCD	52.94	85.72	60	13.33	52.63
ECT	5.88	0	6.67	6.67	5.26
CT	23.53	0	33.33	33.33	36.84
rel. CT	29.42	7.14	6.67	33.33	15.79
ACS	5.88	50	6.67	13.33	26.32
ACD	35.29	42.86	46.66	13.33	15.79

We found between 4 and 11 families of Coleoptera in young plantations and also 11 families in the natural forest of Sânmartin. Staphylinidae vary in frequency between 60% and 80%, as well as Carabidae which is represented by 6 species, all of them being accidental in the area. The presence of Coleoptera families in old plantations varies between 3 and 12, while in the adjacent natural forest (Adea) we found 11 families. Members of Family Staphilinidae are present in all old plantations, with a frequency ranging between 11.11% (Adea 1) and 62.5% (Secusigiu 2), while members of Family Carabidae (represented by 5 species) has a frequency of 11.11% - 50% (Table 3). These results are quite contradictory. Coleman (2004) emphasized that there are changes in the Carabidae communities inhabiting young forest plantations. On the other hand, Oxbrough et al. (2010) mention that in advanced successional stages a more specialized populations of invertebrates are present, associated with a relative high number of indicator species (as are Carabidae). We also tested the degree of similarities of epigeic invertebrate communities by Bray-Curtis test.

The clear grouping of the sites in three clusters can be observed, based on the similarity in numerical abundances of the superior taxa in epigeic invertebrate communities, as follows: Cermei invertebrate community is detached by the other sites as similarity of the invertebrate community, maybe because here only 4 families of Coleoptera are present (Elateridae with 44.44% frequency in samples and the rest of three families - only 11.11% frequency) (Figure 1).

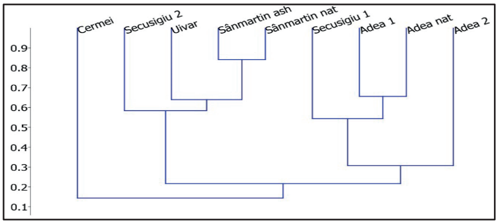

Figure 1. The degree of similarity between epigeic invertebrate communities (according to Bray-Curtis index of similarity, based on numerical abundances of invertebrates)

The second cluster consists in Secusigiu 2 (old plantation), Uivar and Sânmartin ash (young plantations) together with Sânmartin natural forest. The last two sites are very similar regarding invertebrate communities.

We notice that Uivar, Sânmartin ash and Sânmartin natural forest are similar due to the following taxa: Coleoptera, Opiliones, Orthoptera-Gryllidae, Diptera, Homoptera-Aphididae, Collembola, Thysanoptera, Araneae and Myriapoda - Chilopoda. Secusigiu 1 and Secusigiu 2 are similar due to Isopods, Orthoptera var., Diplopoda, cicads, Hymenoptera var., ants and Hemiptera.

Like the previous, Adea 1 and Cermei are similar because of gastropods, Lepidoptera and Acari, while Adea nat. is a distinct community because of Blattodea, Oligochaeta and Zygentoma. The degree of similarity between epigeic invertebrate communities in the 7 plantations and 2 natural forests, in terms of the numerical abundances of suprataxa, is graphically represented in Figure 2.

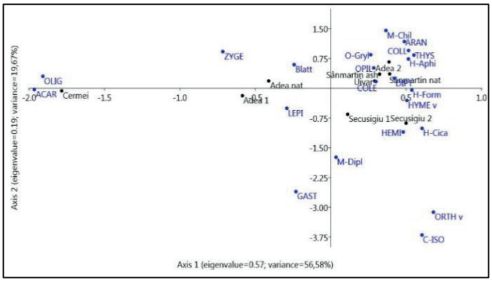

Figure 2. Correspondence analysis (CA) of epigeic invertebrates from all 9 investigated sites (taking into consideration the total numerical abundance/each site)

Legend: GAST (Gasteropoda), OLIG (Oligochaeta), ACAR (Acarina), OPIL (Opiliones), ARAN (Araneae), C-ISO (Crustacea-Isopoda), COLL (Collembola), THYS (Thysanoptera), M-Chil (Myriapoda-Chilopoda), M-Dipl (Myriapoda- Diplopoda), ZYGE (Zygentoma), HEMI (Hemiptera), H-Aphi (Homoptera-Aphididae), H- Cica (Homoptera-Cicadoidea), HYME v (Hymenoptera-var.), H-Form (Hymenoptera-Formicidae), Blatt (Blattodea), ORTH v. (Orthoptera var.), O-Gryl (Orthoptera- Gryllidae), COLE (Coleoptera), DIPT (Diptera), LEPI (Lepidoptera).

The third cluster is composed of the invertebrate communities from Secusigiu 1, Adea 1 and Adea 2 (old plantations) as well as Adea natural forest (Adea nat.). The dimension of these similarities between the invertebrate communities is expressed in Table 3.

Table 3. Matrix of Bray-Curtis index of similarity for the epigeic invertebrates communities of the nine studied sites

	A.n.f.	A 1	A 2	S 1	S 2	C	U	S	S.n.f.
A.n.f.	1	**0.66**	0.26	0.50	0.23	0.23	0.21	0.33	0.31
A 1	**0.66**	1	0.36	**0.58**	0.16	0.21	0.15	0.24	0.23
A 2	0.26	0.36	1	0.31	0.17	0.05	0.12	0.19	0.22
S 1	0.50	**0.58**	0.31	1	0.25	0.16	0.15	0.23	0.27
S 2	0.23	0.16	0.17	0.25	1	0.09	**0.57**	0.61	**0.57**
C	0.23	0.21	0.05	0.16	0.09	1	0.16	0.14	0.12
U	0.21	0.15	0.12	0.15	0.57	0.16	1	**0.65**	0.62
S	0.33	0.24	0.19	0.23	**0.61**	0.14	**0.65**	1	**0.84**
S.n.f.	0.31	0.23	0.22	0.27	**0.57**	0.12	**0.62**	**0.84**	1

In the epigeic invertebrate communities we encounter not only variations in the quantitative aspects of the present taxa, reflected, as we have shown, in different degrees of similarity, but also more or less solid interspecific relationships between taxa. The r linear correlation coefficient was measured between predatory and prey taxa and also, between predatory taxa known to be competitors in forests (Table 4).

Table 4. The r linear correlation coefficient for pairs of taxa in the studied invertebrate communities

Pray-predator relationship	A1	A 2	A.n.f.	S1	S2	C	U	S	S.n.f.
Araneae - predator									
Collembola	0.74	0	0.68	0	-0.58	0.58	0	0.78	0
Acarina	0	0	0	0	0	0.62	0	-0.47	0
Diptera	0	0.58	0.66	-0.56	0.58	0	0	0	0.91
Isopoda	0	0	0	0.73	0	0	0	0	0
Aphididae	0	0	0	0.61	0	0	0.54	0.49	0.88
Carabidae	0	0	0	0	0	0	0.67	0.62	0.46
Coccinellidae	0	0	0	0	0	0	0	-0.43	-0.53
Carabidae - predator									
Collembola	0	0	0	0	0	0	0	0.97	0
Diptera	0	0	0	0	0	0	0	0	-0.83
Aphididae	0	0	0	0.74	0	0	0.88	0	0

The linear correlation coefficient shows how predator taxa use food resources in habitats, as well as potential competition between predators. Although, on average, the number of prey-predator interspecific links is equal in plantations (Verhviläinen et al., 2008), regardless of their age, the food sources used by predators vary from one plantation to another.

For example, in the Adea 1 plantation (A1) the Araneae (spiders) consume Collembola, while in Adea 2 (A2) prefer the Diptera, and in the Adea natural forest (A.n.f.) both resources are consumed. In Secusigiu 1 (S1), the spiders access three food sources, of which, Diptera appear to be limited source (r negative) while aphids are consumed here also by carabids, even to a greater extent. However, between these two predators (carabids and spiders) the competition is not installed. In Secusigiu 2 (S2) Collembola appears to be a limited food resource for Araneae.

In young plantations, competition among predators for food is better noted. This is the situation in Uivar (U) where the carabids consume aphids more than the spiders do and both predators are competing (Table 4). The same situation is presented in Sanmartin Ash (S) for Collembola.

A special situation is in the natural forest of Sanmartin (S.n.f) where the Diptera are consumed by both spiders and carabids, but for carabids the diptera are limited source of food. However, it appears that the spiders compete with Coccinellidae for aphids.

Oxbrough et al. (2010) mentioned that previous studies on carabids in plantations had conflicting results: either high specific richness in the early stages, or, on the contrary, in the advanced stages, or, only minor changes during the ecological succession. The biodiversity-enhancing effects of the vegetation on soil mesofauna (Szigeti et al., 2022) and invertebrates (Chiriac et al., 2020) are documented in recent years, reflecting the importance of habitat and plant species variability. It remains poorly known the impacts of tree diversity on soil fauna (David et al., 2023).

CONCLUSIONS

The studied plantations, as well as the natural forests, prove a relatively high structural heterogeneity, although they have very similar taxonomic composition of epigeic invertebrate communities.

This structural heterogeneity is due both directly and indirectly to the way in which vegetation change. This, over time, after the initial planting moment, develops differently in the sites, even when the initial afforestation formulas are similar, and, because local abiotic factors are involved in the influence of the development of plant communities in a certain way and rhythm. Hence, the emergence and development/persistence of a series of local abiotic and biotic features, generating changes as a domino effect both horizontally and vertically. We are talking about the litter layer generated by the planted species as well as their canopy that varies in their developmental stages. All this determines the existence of different local microclimatic peculiarities, which limit or favour the installation and persistence in these habitats of the other coenotic components (consumers).

It is a great difference between plantations and natural forests in relation to the period necessary to reach maturity (ecological succession), viewed through the prism of epigeic invertebrates and not only. We refer, for example, to the number of predatory taxa and their status as constancy in the habitat. It is worth mentioning that for example, carbides have the status of accidental in all plantations. In addition, the small number of existing predator-predator interspecific links also proves that plantation dynamics are not exactly favourable to predators at that time of study.

The short period of time allocated to this study has prevented us from obtaining a more complex data set, so the results presented are practical, a characterization of the structure of communities of epigeic invertebrates in that short segment of time, especially in relation to the entire successive period they will go through.

That is why we think that it is by far necessary to continue the studies in these plantations, with a complex protocol, in order to obtain more consistent data greatly necessary, at least in Romania, on this segment of research.

We present the study conducted during the summer season (June-August) of 2012 as a contribution at the better understanding of interspecific relationships existing in epigeic invertebrate communities in natural forest ecosystems and plantations, an important subject at national but also at international level. Also, the data we produces 11 years ago we would like to be a starting point for highlighting long-term structural and functional changes of the studied areas or other similar.

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