

AFFORESTATIONS AND SUCCESSIONAL PROCESSES. A VIEW THROUGH THE STRUCTURE OF INVERTEBRATE POPULATIONS

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Abstract. Afforestation is a remedial strategy that follows the pattern of natural forest ecosystems, which still are one of the most damaged ecological structures over time. The effectiveness of afforestations at local / regional scale and time scale at which successional phenomena can be observed in these ecological structures and how similar become in time to the structure and functions of natural forest ecosystems, still are of high interest for the scientists and not only. We have chosen for a preliminary study, ten forest plantations situated in the Criș and Mureș river basins (West Romania) grouped into two categories: four-year-old plantations and ten-year-old plantations. Was studied epigeic invertebrate fauna collected both qualitatively and quantitatively. It was followed the taxonomic composition of invertebrate communities, there were calculated the major structural indices of the zoocoenoses and linear correlation coefficient (r) for groups of predators and their potential food. The degree of taxonomic similarity was calculated using the Sørensen index of similarity and it was established the significance level between the existent differences using the Mann-Whitney test. There were noticed significant and highly significant differences between the plantations both in the same age group and of different ages. There are also differences in the way the predators consume the food and also, the strength of the trophic connections between predators and prey.

Keywords: Epigeic invertebrates, forest plantations, structural characteristics, forest age.

Rezumat. Împăduririle și procesele succesionale. O vedere prin structura populațiilor de nevertebrate. Împăduririle reprezintă strategii de remediere care au ca model ecosistemele forestiere naturale și care au fost și încă reprezintă una dintre cele mai vătămate structuri ecologice de-a lungul timpului. Eficiența împăduririlor la nivel local sau/și regional, scala de timp la care pot fi observate fenomenele succesionale în aceste structuri ecologice și cât de similare ecosistemelor forestiere naturale devin în timp, ca structură și funcții, reprezintă încă un domeniu larg de interes. Am ales, ca studiu preliminar, zece plantații de pădure din bazinele Crișului și Mureșului (Vestul României) grupate în două categorii: plantații de 4 ani și plantații de 10 ani. A fost studiată fauna de nevertebrate epigeice colectată atât sub aspect calitativ cât și cantitativ. A fost urmărită compoziția taxonomică a comunităților de nevertebrate, principalii indici structurali ai zoocenozelor și s-a calculat coeficientul de corelație liniară (r) pentru grupe de prădători și potențiala hrană. Gradul de similaritate taxonomică a fost calculat utilizând indicii de similaritate Sørensen iar existența diferențelor și gradul de semnificație al acestora au fost stabilite utilizând testul Mann-Whitney. S-au remarcat diferențe semnificative și înalt semnificative atât între plantații din aceeași categorie de vârstă cât și între plantații de vârste diferite. De asemenea, s-au observat diferențe între modurile de accesare a hranei de către prădători precum și în ceea ce privește tăria legăturilor trofice dintre aceștia și pradă.

Cuvinte cheie: nevertebrate epigeice, plantații de pădure, succesiune ecologică, vârsta pădurii.

INTRODUCTION

One of the toughest human interventions on nature was and still is deforestation. In the last hundred years, large areas of forest have been cleared or fragmented. Given the importance of forests in the ecosphere, both in structural and in functional terms, in recent decades, interest has been granted to the reforestation process.

The reforestation rate and size vary from country to country, given that it is a complex and costly process. In Romania, such initiatives are put in practice especially in lowland areas where valuable forests (century-old) were transformed into farmlands, decades ago.

The aim of the study was to identify the structural characteristics of epigeic invertebrate populations from forest plantations in order to obtain preliminary information on ecological succession and next, with additional data from further studies, information about the effectiveness of local afforestation strategies (CRISTEA et al., 2004).

The ten forest plantations we studied are located in the Criș and Mureș basins, on different soil types, most of them, former cultivated lands. The forest plantations studied are grouped in two categories, according to their age:

1. Four-year-old plantations: Uivar - on Timișul Vechi, Sânmartin - on Timișul Vechi (two plantations, one of oak and another of ash), Cermei (on Teuzului lowland, the Crișul Repede basin);
2. Ten-year-old plantations: Adea-Mișca - on the right side of the Crișul Alb (2 plantations – Adea 1 and Adea 2); Secusigiu, in the Mureș basin (three plantations) and Somoș, on the right side of the Crișul Alb. Plantations differ both in woody species composition used for afforestation, but also in the existing soil type and hence, microclimate.

MATERIAL AND METHODS

For sampling the invertebrates we used the Barber traps method. In each forest plantation, there were installed ten Barber traps filled with a mixture of 4% formalin solution and ethylene glycol (1:1 vol.). The traps were installed at five meters distance each other and the sampling period was 20 June-20 July 2011.

We studied for the epigeic invertebrate groups (identified at a level superior to species) the absolute and relative numerical abundance, the numerical density, the structure of dominance, the classes of constancy, standard deviation, dispersion, distribution and the coefficient of linear correlation (r) for predators and their potential prey.

For the statistical analysis we used PAST programme (HAMMER et al., 2001). The Shapiro-Wilk test was used to verify the data distribution (ZAMFIRESCU & ZAMFIRESCU, 2008). If $p < 0.05$, the data are non-normal distributed (HAMMER et al., 2001). The log-transformation ($x+1$) was used to improve the normality and homoscedasticity of data set (McCUNE et al., 2002). As a result of log-transformation, we noticed a non-normal distribution of data, a reason to use the non-parametric test of Mann-Whitney, to test the dissimilarities between the studied sites (HAMMER et al., 2001).

RESULTS AND DISCUSSIONS

The number of superior taxa found in the two groups of forest plantations is very close: 13 (Uivar) - 18 (Sânmartin flooded) taxa in the four-year-old plantations and of 14 (Adea 2) - 19 (Secusigiu 2) taxa in the ten-year-old plantations respectively. The average values of the numerical densities ranged between 165 and 396.12 ind/s.u. in the four-year-old plantations and between 24.44 and 255.9 ind/s.u. in the ten-year-old plantations. The relative numerical abundances of the invertebrate groups determined various structures of the numerical dominance in the local invertebrate communities. Thus, it has been observed that in the younger plantations, the eudominant and dominant invertebrate groups represent 28.58-84.61% of the total epigeic invertebrates, while in the older plantations, these groups are 5.88-53.33% of the total (Tables 1-2).

Table 1. Structural characteristics of the invertebrate communities from the four-year-old plantations.

		UIVAR		SÂNMARTIN OAK		SÂNMARTIN ASH		SÂNMARTIN FLOODED		CERMEI	
Number of supraspecific taxa		18		14		16		13		14	
No. ind./ s.u.		396.12		325		295		165		183.43	
STRUCTURE (% taxa)											
Eudominant	Euconstant	16.67	55.55	28.57	71.44	12.5	62.5	84.61	38.47	7.14	7.14
Dominant	Constant	27.77	5.56	7.15	14.28	25	6.25	0	23.07	21.44	0
Subdominant	Rel. constant	5.56	16.67	21.43	0	25	6.25	0	15.39	28.57	7.14
Recedent	Accessory	5.56	0	14.28	14.28	12.5	25	15.39	0	28.57	0
Subrecedent	Accidental	44.44	22.22	28.57	0	25	0	0	23.07	14.28	85.72
No. of Coleoptera families		14		11		11		7		4	

The groups of the numerically dominant invertebrates in the four-year-old plantations are usually the springtails, ants and mites, while in the ten-year-old plantations, dominant are mites; springtails, Diptera and Isopoda had a fluctuating status. Regarding the constancy classes of the invertebrate groups, we found Acarina, Araneae, Coleoptera, Diptera, Heteroptera and Hemiptera as euconstant / constant groups in the younger plantations (Fig. 1).

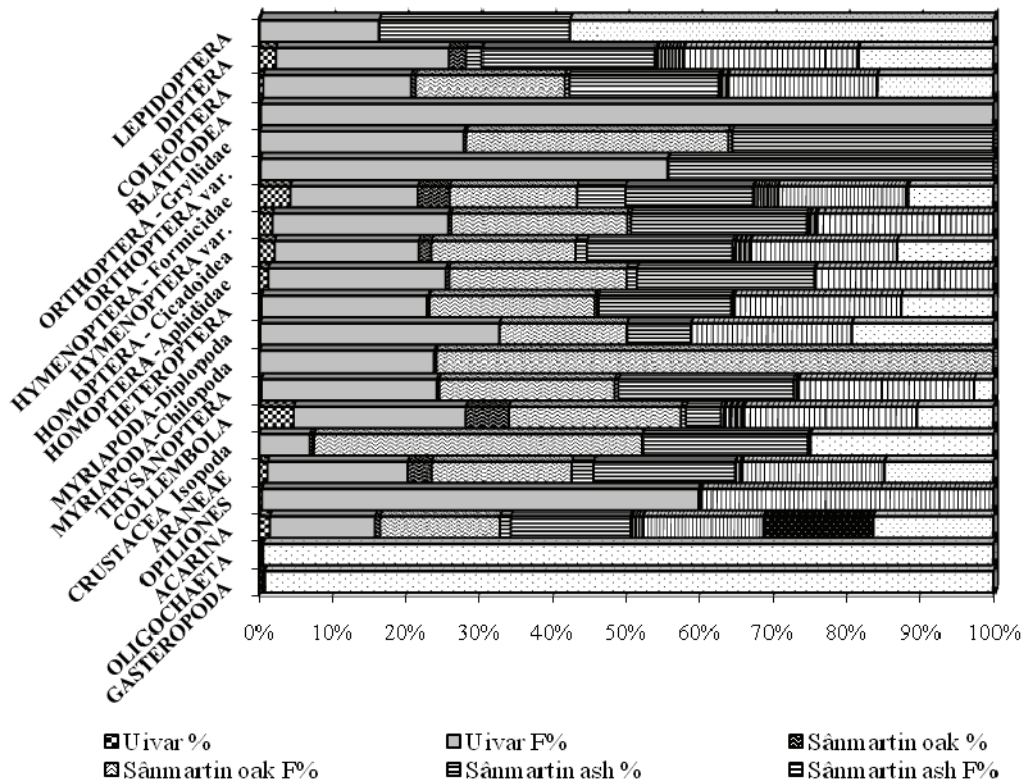


Figure 1. The numerical relative abundances (%) and frequencies (F%) of epigeic invertebrate groups from four-year-old plantations.

There are no great differences in this respect in the ten-year-old plantations, but the fact that the higher number of euconstant / and constant groups (we find Hymenoptera, Gryllidae, Isopoda, gastropods in addition to the structure of the four-year-old plantations) and a different situation in the forest plantation of Secusigiu 1, where the groups of invertebrates have at most relatively constant character (Fig. 2).

The beetle fauna is represented by a varying number of families in the studied sites. The common element for the beetle fauna from the two plantations categories is that beetle families have the general status of sub-dominant groups (numerically).

Table 2. Structural characteristics of the invertebrate communities from the ten-year-old plantations.

		ADEA 1		ADEA 2		SECUSIGIU 1		SECUSIGIU 2		SECUSIGIU 3		SOMOȘ	
No. of supraspecific taxa		17		14		15		19		17		17	
No. ind./s.u.		32.19		24.44		36.8		255.9		45.5		96.44	
STRUCTURE (% taxa)													
Eudominant	Euconstant	5.88	5.88	7.14	0	33.33	6.67	15.79	5.26	23.53	0	5.88	0
Dominant	Constant	0	23.53	0	0	20	33.33	10.53	36.84	0	23.53	0	11.76
Subdominant	Rel. constant	11.76	29.42	0	7.14	26.67	33.33	15.79	15.79	47.06	47.06	5.88	5.88
Recedent	Accessory	29.42	5.88	7.14	50	6.67	13.33	5.26	26.32	11.76	5.88	82.36	29.42
Subrecedent	Accidental	52.94	35.29	85.72	42.86	13.33	13.33	52.63	15.79	17.65	23.53	5.88	52.94
No. of Coleoptera families		3		4		9		12		8		8	

VEHVILÄINEN et al. (2008) noticed higher abundances of predators in monocultures than in mixed plantations. A similar situation we observed in the Sânmartin monocultures (oak and ash).

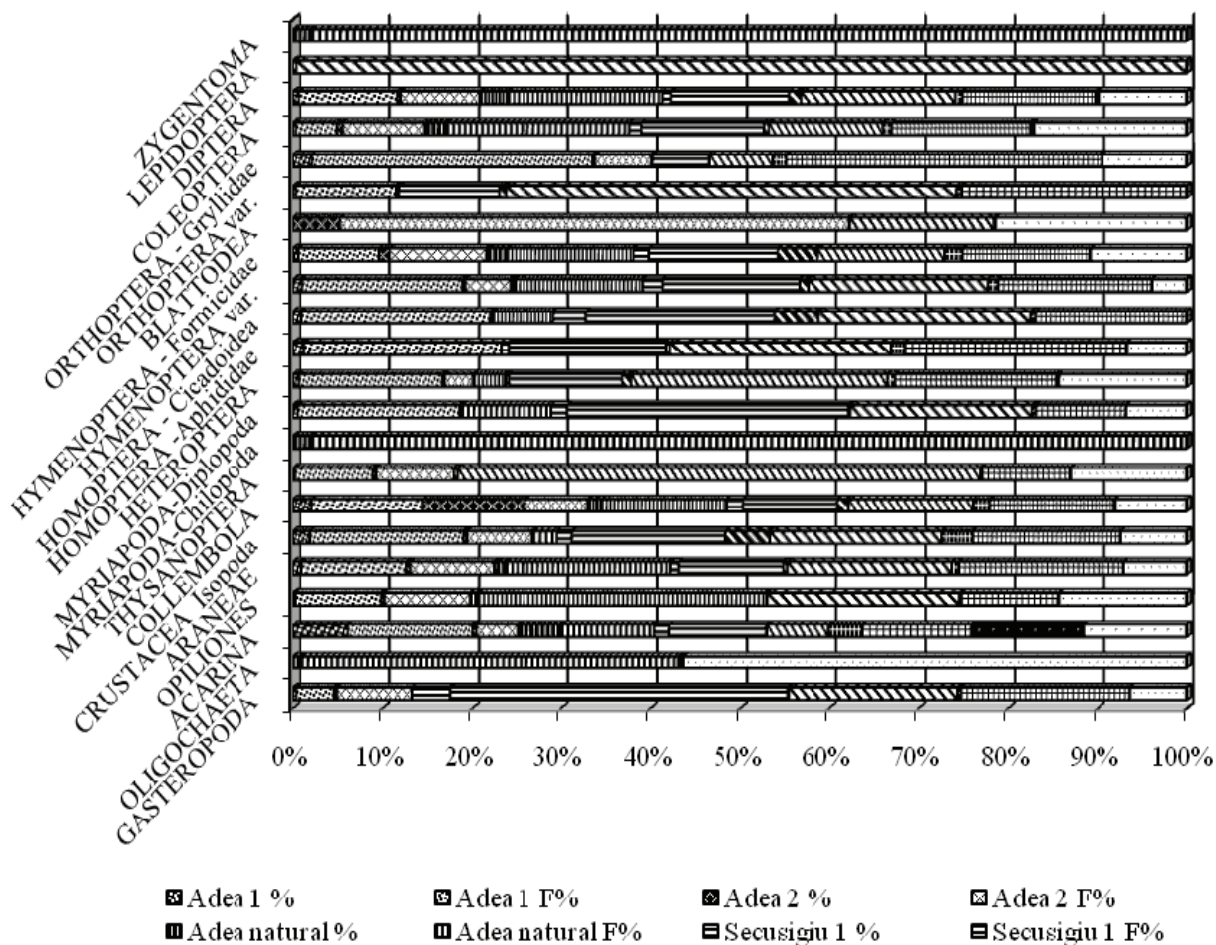


Figure 2. The numerical relative abundances (%) and frequencies (F%) of epigeic invertebrate groups from the ten-year-old plantations.

Table 3. The degree of similarity (Sørensen index of similarity) between the invertebrate communities inhabiting the studied forest plantations.

	Adea 1	Adea 2	Adea natural	Somoş	Secusigiu 1	Secusigiu 2	Secusigiu 3	Cermei	Uivar	Sânmartin flooded	Sânmartin oak	Sânmartin ash
Adea 1	-											
Adea 2	77.77	-										
Adea natural	43.48	54.54	-									
Somoş	76.19	70	56	-								
Secusigiu 1	82.05	64.86	59.57	68.08	-							
Secusigiu 2	68.08	66.66	64.28	65.45	83.33	-						
Secusigiu 3	88.37	78.05	62.74	74.51	86.36	84.61	-					
Cermei	74.28	78.78	78.78	65.11	72.22	63.63	65	-				
Uivar	75.55	79.07	64.15	60.38	78.26	59.26	80	61.9	-			
Sânmartin flooded	75.67	80	62.22	57.77	73.68	73.91	61.54	70.58	77.27	-		
Sânmartin oak	76.19	75	68	64	74.42	64.15	76.59	71.79	81.63	73.71	-	
Sânmartin ash	76.19	80	64	64	83.72	82.35	80.85	71.79	77.55	82.93	86.95	-

We measured the degree of similarity between the forest plantations, from the point of view of taxonomical composition of invertebrate populations. The values of Sørensen index (Table 3) show generally a similarity above 60%, except for the invertebrate population from the natural forest of Adea and two forest plantations (Adea 1 and Somoş). How significant these differences are, is measured by Mann-Whitney test (Table 4). Thus, even if the degree of similarity is high between four-year-old plantations, did not appear to be statistically significant.

POOLE et al. (2003) noticed that the median number of carabid species per trap was significantly greater at the mature sites than at the regenerating sites. The mature site also had a significantly greater median diversity/pitfall trap than the regenerating site. In addition, there was a 70% similarity (Sorensen index) in ground beetle composition between the sites. Related to these findings, we could say that the average numerical density and ground beetles diversity are quite similar with the situation described by POOLE et al. (2003).

Table 4. The signification level (values of p) for the dissimilarities in taxonomical composition of the forest plantations, according to Mann-Whitney test; the blank spaces indicate no significant differences.

	Adea 1	Adea 2	Adea natural	Somoş	Secusigiu 1	Secusigiu 2	Secusigiu 3	Cermei	Uivar	Sânmartin flooded	Sânmartin oak	Sânmartin ash
Adea 1				0.00009		0.0144			0.0083			0.0405
Adea 2				0.0002		0.0263		0.0019	0.024			
Adea natural				0.0006		0.0416		0.0093	0.0084			
Somoş					0.0003		0.0001			0.0001	0.00456	
Secusigiu 1						0.0093		0.0043	0.0027			0.0364
Secusigiu 2							0.0135		0.0078	0.0119		
Secusigiu 3												
Cermei												
Uivar												
Sânmartin flooded								0.0027	0.0022			0.0338
Sânmartin oak												
Sânmartin ash												

Among the four-year-old plantations, Cermei, where there are present both spiders and predator carabid species, mites and Collembola are epigeic invertebrates consumed by spider; these resources appear to be sufficient for spiders. The ground beetles have not correlations with food resource, and therefore the correlation coefficient for the interaction spiders-ground beetles indicates a ratio of the competition (Table 5).

At Uivar, the predators are represented by spiders and a few ground beetle species (*Pterostichus atterimus* (Herbst 1784) and *Brachinus crepitans* (Linnaeus 1758)) and Coccinellidae (*Coccinella septempunctata* (Linnaeus 1758), *Psyllobora vigintiduopunctata* (Linnaeus 1758)). The coefficient of correlation shows that springtails are a limited food resource and do not determine a competitive ratio for Coccinellidae neither with spiders, nor with ground beetles.

For other plantations, food resource appears to be abundant, but aphid consumption by spider and carabid causes a competitive trend between the two types of predators ($r = 0.6756$).

In the monocultures of Sânmartin (oak and ash), food resources for predators (spiders, carabids, coccinellids) are the same as in Uivar but they are used in a different way. In the oak plantation, the spiders consume aphids and Diptera, the ground beetles consume cycads (limited resource, $r = -0.8122$) and Coccinellidae feed on springtails, mites and Diptera, the last group being a limited resource for Coccinellidae. These ratios, however, do not determine the competitive relationship between predators. In the ash plantation, the spiders consume mites, aphids and springtails. The latter are also food for ground beetles, together with Diptera and cicadas; the last ones are also consumed successfully by Coccinellidae. This leads to a competitive situation between Araneae and Coccinellidae ($r = -0.537$) and between Araneae and Carabidae ($r = 0.6246$).

Table 5. The coefficient of correlation (r) between predator groups and their potential prey in the invertebrate communities inhabiting four-year-old forest plantations.

	Cernei	Uivar	Sânmartin flooded	Sânmartin oak	Sânmartin ash
Araneae-Collembola	0.5803	0.2871	-1	0.0578	0.7846
Araneae-Acarina	0.6202	0.3135	1	0.2714	-0.4752
Araneae-Diptera	-0.2727	-0.06818	1	0.9114	-0.3803
Araneae-Cicadoidea	0.4062	0.6537	1	0.5471	0.1484
Araneae-Isopoda	0.3486	0	0	0	0.3025
Araneae-Aphididae		0.5401	1	0.8898	0.4947
Araneae-Carabidae		0.6756		0.4662	0.6246
Carabidae-Collembola	0.0273	0.3152		0.1477	0.9704
Carabidae-Acarina	0.1112	0.1897		-0.0425	-0.241
Carabidae-Diptera	-0.0123	0.1366		-0.1719	-0.8031
Carabidae-Cicadoidea	0.2795	0.7026		-0.8122	-0.6127
Carabidae-Isopoda	-0.1627	0		0	-0.0554
Carabidae-Aphididae		0.8833		-0.3044	-0.1941
Carabidae-Coccinellidae		-0.3561	-1	0.1336	-0.3962
Coccinellidae-Collembola		-0.5614	1	0.682	-0.4082
Coccinellidae-Acarina		0.1197	-1	0.7506	0.9076
Coccinellidae-Diptera		0.4052	-1	-0.713	0.7376
Coccinellidae-Aphididae		0.0172	-1	-0.3106	0.2713
Coccinellidae-Cicadoidea				-0.1787	-0.0462
Araneae-Coccinellidae		-0.1368	-1	-0.4374	-0.537

In the ten-year-old plantations, it is remarkable the absence of the ground beetles from Adea plantations. The spiders consume springtails, mites and Diptera, which are a sufficient resource for the needs of these predators. At Somoș, the trophic offer is richer for Araneae and Carabidae; spiders feed on almost all groups of prey, while the ground beetles seem to feed only on Diptera. This situation does not determine a competition for food between predators (Table 6).

The plantations from Secusigiu, the richest sites in food resources for predator invertebrates, offer different situations, both as diet of predators and the food status in the local communities.

At Secusigiu 1, among the invertebrates consumed by spiders, only Diptera seems to be a limited resource ($r = -0.5647$) and aphids are food both for spiders and ground beetles. At Secusigiu 2, although the ground beetles are present, do not appear to access very much the trophic offer (perhaps due to a tendency to use the Isopoda), while Araneae feed on cycads, Diptera, as well as on smaller invertebrates (mites and springtails), which, however, appear to be limited resources.

At Secusigiu 3, the way predators use the food resource differ from the previous situations. The ground beetles use the most part of the food resources, while Araneae are limited in the consumption of Diptera and cycads. This situation does not determine a competitive ratio between predators.

Table 6. The coefficient of correlation (r) between predator groups and their potential prey in the invertebrate communities inhabiting forest plantations of ten years old.

	Adea 1	Adea 2	Adea natural	Somoș	Secusigiu 1	Secusigiu 2	Secusigiu 3
Araneae-Collembola	0.7429	-0.2769	0.6823	0.9185	-0.3546	-0.5845	-0.3731
Araneae-Diptera	0.3437	0.5803	0.6659	0.5792	-0.5647	0.5823	0.504
Araneae-Aphididae	0.163			0.6324	0.6139	-0.3883	0.4818
Araneae-Cicadoidea	0.3984		0.2812		0.4593	0.7944	-0.5735
Araneae-Isopoda	0.2269	-0.052		-0.4629	0.7302	0.3605	-0.2112
Araneae-Acarina	0.8143	0.5072	0.6489	0.8608	0.6146	-0.7146	-0.1357
Carabidae-Collembola			0.2289	0	-0.3115	0.1571	0.7497
Carabidae-Diptera			-0.0471	0.0819	0.2932	-0.077	0.2349
Carabidae-Cicadoidea			0.1452		0.8768	-0.188	0.7698

Carabidae-Acarina			0.3935	0.2466	-0.1	0.2517	0.6834
Carabidae-Isopoda				0.2182	0.0537	-0.4035	0.9358
Carabidae-Aphididae				0.4472	0.746	0.1135	0.2964
Araneae-Carabidae			0.3227	0	0.3575	0.2998	-0.3973

CONCLUSIONS

The epigeic invertebrates communities of all studied sites have a high degree of taxonomic richness and are quite similar as taxonomic composition. The differences between them are given by the structure of the communities (numerical dominance structure, constancy, dispersion, proportion of predators and predators status in community structure and food webs).

The differences noticed between the studied sites are not given directly by the trees age or trees formulas used at the beginning of the plantation process (as BOHÁČ et al. mentioned in 2007 in their study), trees composition is proved not having a direct influence on epigeic invertebrates), but indirectly, by the local microclimatic characteristics determined by trees.

The common elements for all studied plantations are the structure quite simple and unstable, due to proportions of constant invertebrate groups, and especially the predators situation: a low diversity and except Araneae – with an accidental presence in the local communities.

COLEMAN (2004) found that the carabid communities change across a successional gradient during the early stages of woodland development. Carabid beetle species richness and diversity tended to increase with time after planting. In case of the plantations we studied, the ground beetles have accidental status in local communities, so, we assume that the difference in age is not large enough to determine the predator ground beetle species to have a constant presence in older plantations.

Although we examined how predators access the food, we believe that this data set is insufficient to conclude that invertebrate communities have food webs with strong connections between predators and prey, due to predators status in local communities, as we mentioned above. These data are a short description of state of fact at local scale, in that sampling period.

For a more complex and accurate description of invertebrate communities structure, further studies are needed, with a sampling protocol to be conducted on broader period of time, comprising also the study of abiotic parameters.

ACKNOWLEDGEMENTS

We express our thanks and gratitude to Dr. Ioana Vicol for her valuable help in statistical analysis of data.

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Received: March 30, 2014

Accepted: June 25, 2014