J. Plant Develop.
21(2014): 153–160

DIVERSITY AND ECOLOGICAL DETERMINANTS OF DEAD WOOD FUNGI IN TREE NATURAL RESERVES OF BROAD LEAVED FORESTS FROM SUCEAVA COUNTY

Ciprian BÎRSAN*[1], Cătălin TĂNASE[2], Constantin MARDARI[1], Ana COJOCARIU[1]

Abstract: Dead wood fungi have a major importance for forests biodiversity as they produce wood degradation in forest habitats. In this paper are presented some aspects related to the diversity of dead wood fungi in tree deciduous forest types from tree natural reserves (Crujana, Dragomirna and Zamostea) from Suceava County and the effect of some ecological factors (host tree, diameter and decomposition degree of the dead wood and some microclimatic characteristics of sites) on their occurrence and diversity. Investigations carried out in 2013 resulted in the identification of 44 lignicolous fungi species. Analysis of similarities between lingnicolous fungi species from the investigated natural reserves (by hierarchical clustering) shows a separation of three fungi groups, depending on the host-trees species. The effect of the tree host species was highlighted also by detrended correspondence analysis, which, in addition presented the existence of an altitudinal gradient and a weaker effect of site conditions (slope and aspect) and microclimatic variables (solar radiation) on dead wood fungi occurrence. The effect of diameter and decomposition degree of fallen trunks and branches on dead wood fungi species was investigated using the redundancy analysis showing that wood debris with large surfaces are more easily colonized by the fungi species developing large sporocarps compared to small branches with low diameters colonized only by few or a single fungus species.

Keywords: forest, lignicolous fungi, wood debris, Detrended Correspondence Analysis (DCA), Redundancy Analysis (RDA)

Introduction

Dead wood fungi have a main role in the maintaining of ecosystems health, nutrient cycles, and, consequently, a major importance for forests biodiversity. Lignicolous fungi are, together with insects, the main agents of wood degradation in forest habitats [MÜLLER & al. 2007]. They are the main decomposing agents of the dead vegetal material as wood or litter. Dead wood quantities are lower in forests where the intensive silvicultural interventions are made by humans than in old growth forests and natural reserves where human interventions are minimized [KIRBY & al. 1998]. Host-tree species, wood debris size, microclimate conditions, decomposition degree and initial position of dead wood from tree are the variable keys influencing the fungi species composition [JACOB & MORTEN 2004; KÜFFER & SENN-IRLET, 2005]. The main task of this study was to investigate the dead wood fungi diversity in tree deciduous forest types from tree natural reserves from Suceava County and the effect of some ecological determinants (host tree, diameter and decomposition degree of the dead wood and some microclimatic characteristics of sites) on their diversity.

[1] "Alexandru Ioan Cuza" University of Iași, "Anastasie Fătu" Botanical Garden, Dumbrava Roșie, 7-9, Iași – Romania
[2] "Alexandru Ioan Cuza" University of Iași – Faculty of Biology, Carol I, 20A, 700505, Iași – Romania
* Corresponding author. E-mail: ciprian.birsan@uaic.ro

The natural reserve from Dragomirna is represented by a natural arboretum of *Fagus sylvatica* (130 years old) with the main habitat type, 91V0, Dacian beech forests (*Symphyto-Fagion*). In Crujana forest (*Quercetum*) the natural arboretum is constituted of a mix of deciduous species, with oak species (*Quercus robur*) as dominant tree species, similar to the oak forests from Central Europe; the main habitat type is 9160, Sub-Atlantic and medio-European oak or oak-hornbeam forests of *Carpinion betuli* [SÂRBU & al. 2007]. Zamostea Forest is a natural reserve represented by mixed communities of *Quercus robur*, *Fraxinus* sp., *Salix* sp. and *Populus* sp. It represents an area of riverine forest with more lignicolous species compared to the above mentioned natural reserves (Tab. 1) [BLEAHU & al. 2006]. The main habitat type in this site is 91F0-Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia* along the great rivers (*Ulmenion minoris*) [GAFTA & MOUNTFORD, 2008].

Tab. 1. Important geographical features of the three natural reserves of broad leaved forests

Crt. No.	Name	Area (ha)	Altitude (m)	Main forest types	Geographical coordinates
1.	Crujana Reserve (Quercetum)	39.4	370-393	*Quercus robur* dominant	47^0 45' N 26^0 11' E
2.	Dragomirna Reserve (Beech-trees)	134.8	380-450	*Fagus sylvatica* dominant	47^0 45' N 26^0 12' E
3.	Zamostea Reserve	107.6	290	*Quercus robur*, *Fraxinus excelsior*, *Populus* sp., *Salix* sp.	47^0 52' N 26^0 15' E

Materials and methods

Diversity of lignicolous fungi was analyzed in three natural reserves of broad leaved forests from Suceava County: Crujana, Dragomirna and Zamostea (Fig. 1). Samples were collected in 63 randomly chosen points (21 in each natural reserve) on square shaped areas of 100 m^2 each. Investigations were made from April to October 2013. For each sample, geographical coordinates and altitude were recorded using a geographic positioning device (GPS II Plus Garmin Ltd.). All remnants of dead wood which had at least one sporocarp have been registered. For all dead wood debris we noticed: diameter, length, decomposition degree and host tree species. Sporocarps of unidentified species were investigated through laboratory specific methods based on micro-morphological and macro-morphological characters according to identification keys and reference guides [BERNICCHIA, 2005; BREITENBACH & KRÄNZLIN, 1986; JÜLICH & STALPERS, 1980; JÜLICH, 1989; SĂLĂGEANU & SĂLĂGEANU, 1985; TĂNASE & al. 2009]. Estimation of wood's decomposition degree was semi-quantitatively and subjectively done using a knife [RENDVALL, 1995]. Analysis of similarities among lignicolous fungi species was realized using the Sorensen index (presence-absence data) in a hierarchical clustering procedure using the UPGMA algorithm. Detrended Correspondence Analysis (DCA) has been realized in order to distinguish the main gradients in lignicolous species composition and to characterize them from an ecological perspective. Detrending by segments and non-weighted average values of altitudes, heat load and potential annual incidence radiation [McCUNE & KEON, 2002] for each plot were used (as passive projected variables). Redundancy analysis was used in order to observe the influence of the diameter and decomposition degree of the dead wood on fungi species. The hierarchical agglomerative clustering has been realized using the GINKGO software [DE CÁCERES & al. 2003]. DCA and RDA have been realized in CANOCO 4.5 [TER BRAAK & ŠMILAUER, 2002].

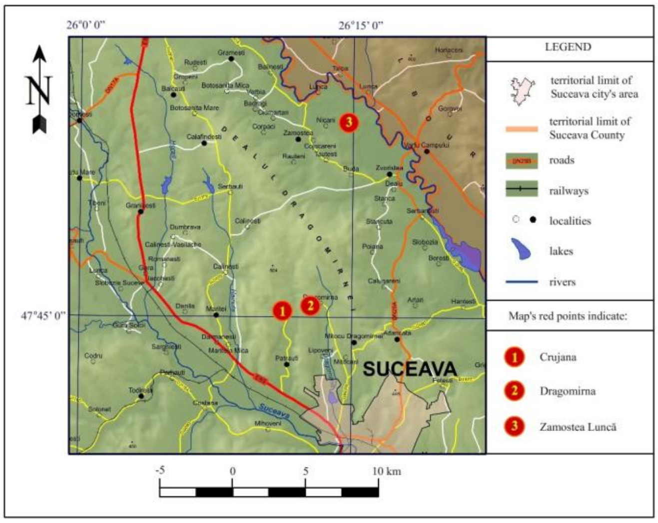

Fig. 1. Geographical positions of investigated Forests Reservations

Results and discussion

Investigations have been realized in the mentioned areas where we collect 486 samples belonging to 44 lignicolous fungi species (Tab. 2) with an average of 11 species per plot. *Trametes* and *Xylaria* were the most species rich genera, each with three species. Depending on their nutrition mode the fungi species belong to three categories: lignicolous saprophyte (28 species), lignicolous sapro-parasite (12 species) and parasite (4 species). The amount of dead wood, one of the important features of the maintaining of a high diversity of lignicolous macrofungi, varied among the sites (plots). The more dead wood was present, the greater diversity of species was registered, because of higher colonization probability.

Tab. 2. The species and main characteristics of lignicolous fungi recorded in the research plots

Species	Occurrence	Host-tree
1. *Armillaria mellea*	IX XI	Deciduous
2. *Armillaria ostoyae*	IX XI	Deciduous
3. *Auricularia auricula-judae*	I XII	Elder, Beech-tree, Acacia
4. *Bjerkandera adusta*	I XII	Deciduous, Beech-tree
5. *Bulgaria inquinans*	IX XI	Deciduous
6. *Chondrostereum purpureum*	I XII	Deciduous, Beech-tree, Birch-tree, Poplar
7. *Daedalea quercina*	I XII	Oak

8. Daedaleopsis confragosa	VII X	Deciduous
9. Daldinia concentrica	V X	Deciduous, Birch-tree, Beech-tree, Oak
10. Exidia glandulosa	I XII	Oak
11. Fistulina hepatica	VIII X	Deciduous, Oak
12. Fomes fomentarius	I XII	Beech-tree, Birch-tree
13. Fuscoporia ferruginosa	I XII	Beech-tree
14. Ganoderma applanatum	I XII	Deciduous
15. Ganoderma lucidum	I XII	Oak
16. Hyphodontia sambuci	I XII	Deciduous
17. Hypholoma fasciculare	V XI	Deciduous
18. Hypholoma lateritium	VIII XI	Deciduous
19. Hypoxylon fragiforme	I XII	Deciduous, Beech-tree
20. Laetiporus sulphureus	I XII	Deciduous, Willow
21. Lenzites betulina	IV XII	Deciduous, Beech-tree, Oak
22. Meripilus giganteus	VII X	Beech-tree, Oak
23. Merulius tremellosus	IX XII	Beech-tree, Poplar
24. Peniophora quercina	I XII	Oak
25. Phellinus igniarius	I XII	Deciduous, Willow
26. Phlebia radiata	IX XII	Deciduous
27. Pleurotus ostreatus	X XII	Beech-tree, Poplar, Willow
28. Plicaturopsis crispa	IX XII	Beech-tree
29. Pluteus salicinus	VIII X	Willow, Alder, Beech-tree
30. Polyporus arcularius	I XII	Deciduous
31. Pycnoporus cinnabarinus	I XII	Deciduous, Beech-tree, Cherry
32. Sarcoschypha coccinea	II IV	Deciduous, Hornbeam
33. Schizophyllum commune	I XII	Deciduous
34. Stereum hirsutum	I XII	Deciduous
35. Trametes pubescens	VII X	Deciduous
36. Trametes hirsuta	I XII	Beech-tree, Oak
37. Trametes versicolor	I XII	Deciduous
38. Tremella foliacea	I XII	Birch-tree, Beech-tree
39. Tremella mesenterica	I XII	Beech-tree, Oak, Ash
40. Vuilleminia comedens	I XII	Beech-tree
41. Xylaria hypoxylon	I XII	Deciduous
42. Xylaria longipes	I XII	Maple
43. Xylaria polymorpha	I XII	Beech-tree, Oak
44. Xylobolus frustulatus	I XII	Deciduous, Oak

Analysis of similarities between lingnicolous fungi species from the investigated natural reserves shows a separation of three fungi groups as follows (Fig. 2): a group with *Quercus* (in Crujana forest), another group with *Fagus* (in Dragomirna forest) and another group with *Quercus*, *Populus* and *Salix* (in Zamostea forest). This suggests that the installation of lignicolous fungi species depends on the host-trees. Thus, in the *Quercus* stands were identified species as *Daedalea quercina*, *Exidia glandulosa*, *Ganoderma lucidum*, *Peniophora quercina* which differentiate them from the *Fagus* stands where more frequent are *Bjerkandera adusta*, *Fomes fomentarius*, *Fuscoporia ferruginosa*, *Plicaturopsis crispa* or *Vuilleminia comedens*. However, there are also common species for these two forest types: *Meripilus giganteus*, *Trametes hirsuta*, *Tremella foliacea* etc. More similar to the almost pure oak stands from Crujana reserve is the mixed forest with oak, ash and willow or poplar from Zamostea natural reserve. As in this riverine forest the trees layer is more diversified, also the dead wood fungi diversity is more increased compared to the pure oak forest or pure beech forests. The difference could be produced by *Populus*, *Salix* or *Fraxinus* individuals preferring places with higher humidity and presenting a different and more species rich fungi community. This fact is highlighted by the means of a simple linear regression (Fig. 3) showing that diversity (species richness) of dead wood fungi species increases with diversity (species richness) of woody plant species from investigated areas.

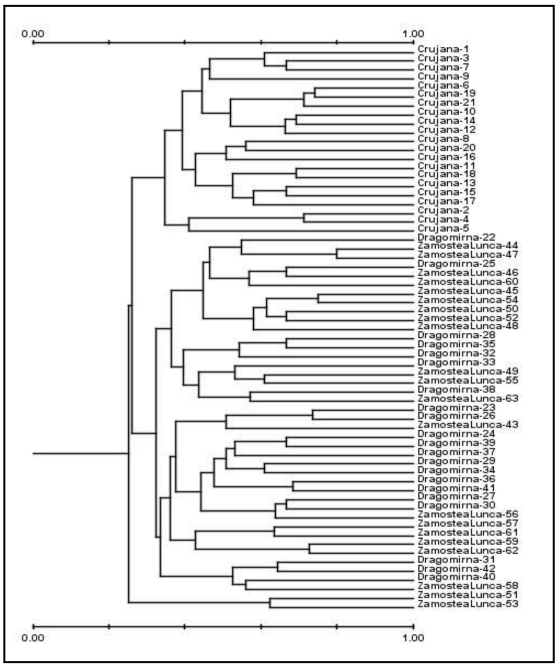

Fig. 2. Dendrogram generated by the hierarchical clustering presenting lignicolous fungi similarities among sites

Through Detrended Correspondence Analysis (DCA) (Fig. 4) three groups were also separated: the first group located at the right, in the lower region of the ordinogram includes the dead wood fungi from the *Fagus sylvatica* forest (Dragomirna), the second one also from the right part but in the upper part of the ordinogram include the dead wood fungi from the mixed forest of *Quercus robur* and other more hygrophilous trees species (Zamostea) and the third one includes dead wood fungi from the *Quercus robur* forest (Crujana). The first DCA axis is weakly negative correlated with heat load and PADI and explains only 5.9% of species-environment relation. The second axis is more strongly correlated with altitude and explains 37.6% of species-environment relation, indicating that the second axis is the most important one and the existence of a altitudinal gradient, from relatively low altitudes forests to higher altitude forests, suggesting that altitude represent the main factor with significant influence on the dead wood fungi composition in the investigated vegetal communities. Only secondarily, the dead wood fungi composition is influenced by the heat and incidence solar radiation indicating that variation in dead wood species among stands might be related to variation in local microclimate conditions. As between investigated stands there are no significant differences regarding heat load (slopes and aspects) and solar radiation, these ecological factors have not a strong significant effect on dead wood fungi species occurrence. DCA could be also interpreted in terms of dead wood fungi affinity for host-trees. Thus, left group include species preferring oak wood (*Quercus robur*-dominant tree in Crujana forest): *Daedalea quercina*, *Ganoderma lucidum*, *Exidia glandulosa* and *Peniophora quercina*. The second group includes species showing a high affinity for beech wood (*Fagus sylvatica*-dominant tree in Dragomirna forest): *Pleurotus ostreatus*, *Fomes fomentarius*, *Plicaturopsis crispa* and *Vuilleminia comedens*. The third group includes species besides oak, also willow and poplar wood: *Pluteus salicinus*, *Phellinus igniarius* and *Laetiporus sulphureus*.

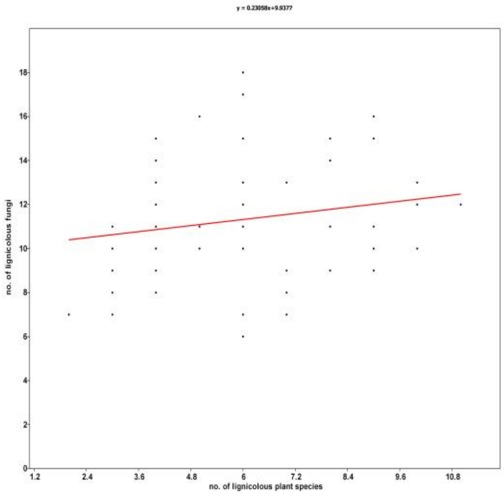

Fig. 3. Linear regression expressing the variation of fungi species richness as a function of lignicolous species richness

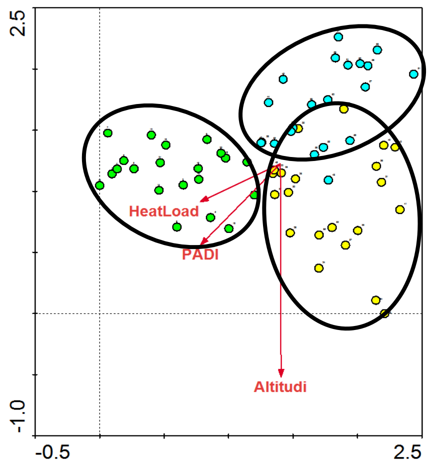

Fig. 4. DCA ordination diagram of the 63 samples using heat load index, potential anual direct radiation index and altitude as passive variables first two axes presented. Eigenvalues: 1st axis: 0.350, 2nd axis: 0.201, total inertia: 2.750.

Redundancy Analysis (RDA) (Fig. 5) suggests that diameter and decomposition degree of fallen trunks and branches have a significant importance for lignicolous fungi species. Thus, wood debris with large surfaces are more easily colonized by the fungi species (interspecific competition is avoided) developing large sporocarps (*Fomes fomentarius*, *Laetiporus sulphureus*, *Ganoderma applanatum*, etc.), as compared to small branches with low diameters, which allow only few or a single fungus species to colonize during a particular time (*Picnoporus cynnabarinus*, *Exidia glandulosa*, *Plicaturopsis crispa*, etc.). From another perspective, the monocentric species (which have only one starting point in growth) typically requires more substrate relative to their size than polycentric species. Thus, polycentric species have a physiological and competition advantage on monocentric species. Therefore, presence of these species can be determined not only by the diameter and volume of the substrate itself, but also by the great ability to grow on such a substrate. Besides diameter, the decomposition degree is a determinant factor for the fungus species which can be observed at a certain stage of wood decomposition. Thus, for the incipient stages of wood decomposition *Bjerkandera adusta*, *Chondrostereum purpureum* can be observed; for increased decomposition degrees *Hypoxylon fragiforme* and *Peniophora quercina* are more frequent in the investigated forests.

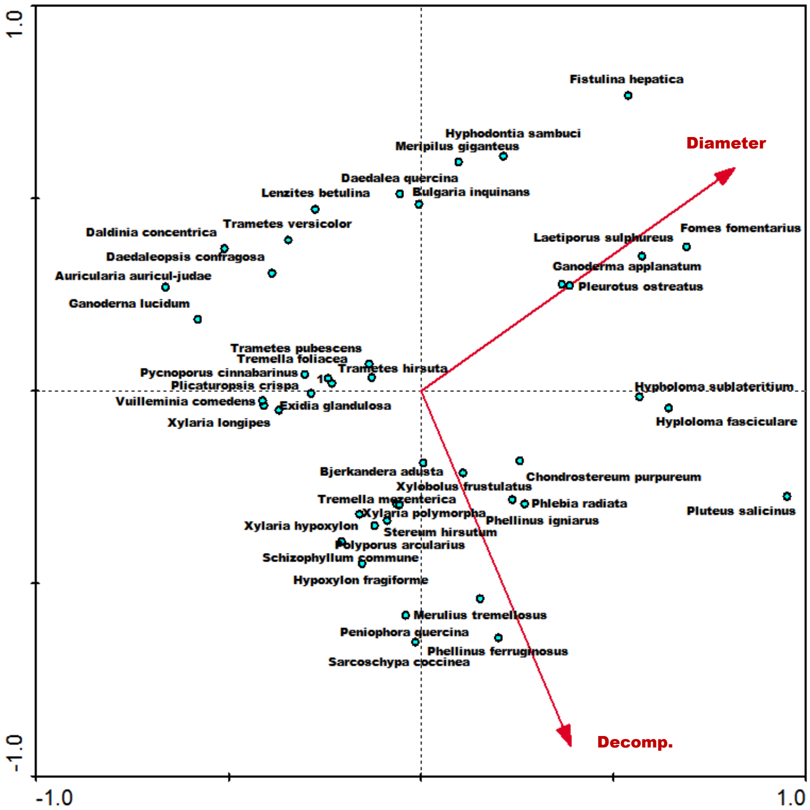

Fig. 5. RDA biplot of axes 1 and 2 with fungal species (44 species) constrained by two explanatory variables (diameter and decomposition degree)

Conclusions

Investigations carried out in tree deciduous forest types from tree natural reserves (Crujana, Dragomirna and Zamostea) from Suceava had as result the identification of 44 lignicolous fungi species. The diversity of lignicolous plant species (linear relationship between their diversity and dead wood fungi species diversity) and the host tree species have significant influence on the dead wood fungi species composition in the investigated areas. Also, the decomposition degree and dimensions of wood debris make clear distinctions among the fungal species which colonize the dead wood of different sizes and different decomposition stages.

References

BERNICCHIA A. 2005. *Polyporaceae s.l.* Fungi Europaei 10. Edizioni Candusso, Alassio, 808 pp.

BLEAHU M., DONE A. & DONE T. 2006. *Arii naturale protejate din Bucovina*. Edit. Terra Design Gura Humorului.

BREITENBACH J. & KRÄNZLIN F. 1986. T. **2**. *Heterobasidiomycetes, Aphyllophorales, Gasteromycetes*. Lucerne: Ed. Mykologia, Suisse: 412 pp.

DE CÁCERES M., FONT X., GARCIA R. & OLIVA F. 2003. *VEGANA, un paquette des programas para la gestión y análisis de datos ecológicos*. VII Congreso Nacional de la Asociación Española de Ecologia Terrestre: 1484-1497.

GAFTA D. & MOUNTFORD O. (eds.). 2008. *Manual de interpretare a habitatelor Natura 2000 din România*. Cluj-Napoca: Edit. Risoprint: 101 pp.

JACOB H. & MORTEN C. 2004. Wood-inhabiting macrofungi in Danish beech-forests – conflicting diversity patterns and their implications in a conservation perspective. *Biological Conservation.* **122**(2005): 633-642.

JÜLICH W. & STALPERS J. A. 1980. *The resupinate non-poroide Aphyllophorales of the temperate northern hemisphere*, North-Holland Publishing Company, Amsterdam, Oxford, New York, 335 pp.

JÜLICH W. 1989. *Guida alla determinazione dei funghi*. *Aphyllophorales, Heterobasidiomycetes, Gasteromycetes*, Vol. 2, Saturnia, Italy: 597 pp.

KIRBY K. J., REID C. M., THOMAS R. C. & GOLDSMITH F. B. 1998. Preliminary estimates of fallen dead wood and standing dead trees in managed and unmanaged forests in Britain. *J. Appl. Ecol.* **35**: 148-155.

KÜFFER N. & SENN-IRLET B. 2005. Diversity and ecology of wood-inhabiting aphyllophoroid basidiomycetes on fallen woody debris in various forest types in Switzerland. *Mycological Progress.* **4**(1): 77-86.

McCUNE B. & KEON D. 2002. Equations for potential annual direct incident radiation and heat load. *Journal of vegetation science*. **13**: 603-606.

MÜLLER J., HOTHORN T. & PRETZSCH H. 2007. Long-term effects of logging intensity on structures, birds, saproxylic beetles and wood-inhabiting fungi in stands of European beech *Fagus sylvatica* L., *Forest Ecology and Management.* **242**(2-3): 297–305.

RENDVALL P. 1995. Community structure and dynamics of wood-rotting basidiomycetes on decomposing conifer trunks in northern Finland. *Karstenia*, **35**: 1-51.

SĂLĂGEANU G. & SĂLĂGEANU A. 1985. *Determinator pentru recunoaşterea ciupercilor comestibile şi otrăvitoare din România*. Bucureşti: Edit. Ceres, 330 pp.

SÂRBU A. (ed.). 2007. *Arii speciale pentru protecţia şi conservarea plantelor în România*, Bucureşti: Edit. Victor B Victor, 396 pp.

SMITH S. E. & READ D. J. 1997. *Mycorrhyzal symbiosis*. 2nd Edition. San Diego: 605 pp.

TĂNASE C., BÎRSAN C., CHINAN V. & COJOCARIU A. 2009. *Macromicete din Romania*, Edit. Univ. Al. I. Cuza Iaşi: 537 pp.

TER BRAAK C. J. F. & ŠMILAUER P. 2002. CANOCO reference manual and CanoDraw for Windows user's guide. Software for Canonical Community Ordination (version 4.5) – Microcomputer Power, Ithaca.

Received: 31 October 2014 / *Revised*: 26 November 2014 / *Accepted*: 8 December 2014