PERIODICUM BIOLOGORUM
VOL. 111, No 4, 397–403, 2009

UDC 57:61
CODEN PDBIAD
ISSN 0031-5362

Original scientific paper

Lignicolous fungi on Pedunculate oak in lowland forests of Central Croatia

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Key words: Ascomycota, Basidiomycota, Quercus robur, wood decay

Received July 8, 2009.

Abstract

Background and Purpose: *Dead wood is one of the most important factors for biodiversity in forests. Lignicolous fungi are key players; they are responsible for primary decomposition and they play important role in nutrient cycles. Pedunculate oak forests in Croatia are one of the most significant sources of organic material and mineral elements which provide habitat, nutrition or food to a variety of organisms of which some play an important role in its decomposition and mineralization. The purpose of our study was to reveal the species spectrum of lignicolous fungi on Pedunculate oak in lowland forests of Central Croatia.*

Materials and Methods: *During the three-year research period (2002–2004), fruit bodies of lignicolous fungi were collected on living standing trees, fallen logs, stumps, timber assortments in the forest and on log yards, and fallen dead branches on Pedunculate oak in Pokupski bazen and Lonjsko polje in Central Croatia. Identification based on upon their macroscopic and microscopic characteristics, using standard binocular and light microscope.*

Results and Conclusions: *A total of 72 species of lignicolous fungi on Pedunculate oak in lowland forests of Central Croatia were identified during the research. One species from Croatian Red list of fungi was identified:* Hapalopilus croceus. *A certain number of species found during this research can be considered as harmful lignicolous fungi in managed Pedunculate oak forests attacking standing trees, causing heartrot at the stem, stem base or root. Because of geographical diversity, Croatian forests have high biodiversitiy potential for lignicolous fungi.*

INTRODUCTION

Lignicolous fungi are described as fungi which develop on living or dead wood (*1*). The majority of species belong to the phylum *Basidiomycota (2)*. Lignicolous fungi are essential for the functioning of forest ecosystems. Wood decomposition is an important process in nutrient recycling, soil formation and the carbon budget of forest ecosystems (*3*).

Lignicolous fungi are responsible for primary decomposition and they play an important role in nutrient cycles. They are necessary from the initial stages of wood decay to the complete disintegration of wood residues and it is estimated that about 50% of forest macrofungi are wood-decomposing (*3*). Different types of dead wood (roots, branches and logs) and their stage of decomposition provide a wide range of niches and permit a high diversity of wood-inhabiting fungi (*4*).

The biodegradation of cellulose and lignified cellulose reaches high levels and is responsible for the return of hundreds of billions of tons of CO2 annually to the atmosphere and is a major biological component of the terrestrial Carbon Cycle *(5)*. Decaying wood is a short-term sink but a long-term source of organic matter and nutrients, a habitat of awide array of organisms and after humification it is an important component of forest soil. The massive fungal component is based largely on the role of fungi in two major biological systems: 1. as decay organisms of plant debris; 2. as mycorrhizal partners with trees and other plants *(6)*.

Pedunculate oak (*Quercus robur* L.) forests are the most valuable forests in Croatia. Aside from their economic value (wood income) and other beneficial values as forest ecosystems, they are the most significant sources of organic material and mineral elements which provide habitat, nutrition or food to a variety of organisms of which some play an important role in its decomposition and mineralization. A few reports on lignicolous fungi in forests in Croatia can be found in literature *(2, 7–11)* and also several that describe lignicolous fungi in similar European vegetational regions *(12–22)*.

As modern forestry needs to retain appropriate levels of deadwood (*23, 24*), a systematic approach in inventory of lignicolous fungi is necessary. The purpose of our study was to reveal the species spectrum of lignicolous fungi on Pedunculate oak in lowland forests of Central Croatia.

MATERIALS AND METHODS

During the three-year research period (2002–2004), fruit bodies of lignicolous fungi were collected on living standing trees, logs, stumps, timber assortments in the forest and on log yards, and fallen dead branches on Pedunculate oak in lowland forests of Central Croatia. The research was carried out in two localities at Pokupski bazen: Jastrebarski lugovi (JL) (within the phytocoenosis *Carpino betuli – Quercetum roboris* /Anić 1959/ emend. Rauš 1969) on an area of 10 hectares, and Pisarovinski lugovi (PL) (within the phytocoenosis *Genisto elatae – Quercetum roboris* Ht. 1938) on 43 hectares; two localities at Lonjsko polje: Posavske šume (PS) on 28 hectares, and Lonja (LO) on 46 hectares (within the phytocoenosis *Genisto elatae – Quercetum roboris*) (Figure 1). The main difference between these two phytocenoses with Pedunculate oak as a dominant species is flood status. Forests of Pedunculate oak and hornbeam on slightly higher locations (*Carpino betuli – Quercetum roboris*) are not regularly flooded and soils are drier. *Genisto elatae-Quercetum roboris* phytocoenosis are regularly flooded and grow on wetter soils.

The fruit bodies of lignicoulous fungi were collected several times from March to November (Table 1) from Pedunculate oak. The collected fungal fruit bodies were analyzed in the laboratory of Croatian Forest Institute.

Figure 1. *localities of research in lowland forests of Central Croatia (JL – Jastrebarski lugovi; PL – Pisarovinski lugovi; LO – Lonja; PS – Posavske šume)*

Identification was based on their macroscopic and microscopic characteristics, using standard binocular and light microscope. The specimens were identified according to Michael and Hening 1960 *(12)*, Westcoot 1960 *(25)*, Boyce 1961 *(26)*, Jahn 1979 *(18)*; Jülich 1984 *(19)*, Breitenbach and Kränzlin 1986 *(27)*; Ryvarden and Gilbertson 1993 *(21)*, Hartmann *et al*. 1995 *(28)*, Butin 1996 *(29),* Keizer 1996 *(30)*, Tomiczek *et al*. 2000 *(31)* and Dähncke 2001 *(32)*.

RESULTS

A total of 72 species of lignicolous fungi on Pedunculate oak in lowland forests of Central Croatia were identified during the study. The classification of species according to Hibbett *et al*. 2007 (*33*) and Index Fungorum (34) is given below:

Kingdom **Fungi**

Phylum **Ascomycota**

Class **Leotiomycetes**
Subclass **Leotiomycetidae**
Order **Helotiales**
Family **Incertae sedis**
Hymenoscyphus fructigenus (Bull.) Fr. (1821)

Class **Sordariomycetes**
Subclass **Xylariomycetidae**
Order **Xylariales**
Family **Xylariaceae** Tul. & C. Tul. (1861)
Daldinia concentrica (Bolton) Ces. & De Not. (1863)
Hypoxylon fragiforme (Pers.) J. Kickx f. (1835)

TABLE 1

Lignicolous fungi collected on Pedunculate oak in central Croatian lowland forests.

Species	Month and year of collection		
	2002	2003	2004
Abortiporus biennis	–	7, 9	7, 9
Armillaria gallica	–	–	9
Armillaria mellea	–	–	9
Armillaria tabescens	–	–	9
Bjerkandera adusta	5, 9	5, 7, 9, 10	5, 9
Bjerkandera fumosa	–	7, 10	–
Byssomerulius corium	–	–	9
Coprinus disseminatus	–	10	–
Coriolopsis gallica	–	–	9
Crepidotus calolepis	–	–	9
Crepidotus crocophyllus	–	10	–
Crepidotus mollis	–	–	9
Cyathus striatus	–	10	9
Daedalea quercina	5, 6	5, 6, 7	5, 6, 7, 9
Daedaleopsis confragosa	5, 6, 7, 11	5, 6, 7, 9, 11	6, 9
Daldinia concentrica	–	10	9
Fistulina hepatica	6, 9	6, 9	6, 9
Flammulina velutipes	–	10	9
Fomes fomentarius	3, 5, 6, 8, 9, 10, 11	3, 5, 6, 7, 8, 9, 10, 11	3, 5, 6, 7, 9, 10, 11
Ganoderma applanatum	–	3, 5, 9, 10	9
Ganoderma lucidum	–	7, 9, 10	7, 9
Ganoderma resinaceum	–	7, 9	7,9
Grifola frondosa	9	–	–
Hapalopilus croceus	–	–	6
Hymenochaete rubiginosa	6, 9	6, 10	6, 9
Hymenoscyphus fructigenus	–	–	9
Hyphodontia quercina	–	10	–
Hypholoma fasciculare	–	10	–
Hypholoma fasciculare var. *pusillum*	–	10	–
Hypholoma sublateritium	–	10	–
Hypochnicium geogenium	–	–	9
Hypoxylon fragiforme	6	6, 10	9
Inonotus dryadeus	6	6, 9	6, 9
Kuehneromyces mutabilis	–	–	9
Laetiporus sulphureus	5, 9	–	9
Lenzites betulina	9	7, 11	9
Loweomyces fractipes	–	–	9
Meripilus giganteus	–	7	–
Merulius tremellosus	9, 10	9, 10	9, 10
Mycena erubescens	–	10	–
Mycena galericulata	–	10	–
Mycena tintinnabulum	–	10	–
Oudemansiella mucida	–	10	–
Oxyporus corticola	–	5	–
Peniophora nuda	–	10	–
Peniophora quercina	5, 6	5	6
Phellinus ferruginosus	–	11	–
Phellinus robustus	3, 5, 6, 7, 8, 9, 10, 11	3, 5, 6, 7, 8, 9, 10, 11	3, 5, 6, 7, 8, 9, 10, 11
Phlebia radiata	–	11	9
Pluteus cervinus var. *cervinus*	–	10	–
Polyporus badius	–	–	9
Postia tephroleuca	–	–	9
Pseudoclitocybe cyathiformis	–	10	–
Radulomyces confluens	–	–	9
Radulomyces molaris	–	10	–
Schizophyllum commune	3, 5, 6, 7, 9, 10	3, 5, 6, 7, 8, 9, 10, 11	3, 6, 7, 9, 10
Schizopora paradoxa	–	–	10
Scopuloides rimosa	–	–	10
Steccherinum ochraceum	–	10	–
Stereum gausapatum	–	10	–
Stereum hirsutum	3, 5, 6, 8, 9, 10	3, 5, 6, 7, 8, 9, 10	3, 5, 6, 8, 9, 10
Stereum rameale	–	9, 10	9, 10
Stereum subtomentosum	10	–	–
Trametes gibbosa	–	7, 8, 10	9
Trametes hirsuta	–	–	9
Trametes pubescens	–	5, 6, 9	5, 9
Trametes trogii	–	10	–
Trametes versicolor	3, 5, 6, 7, 9, 10	3, 5, 6, 7, 8, 9, 10	3, 5, 6, 7, 9
Tyromyces chioneus	–	–	9
Tyromyces subcaesius	–	–	9
Veluticeps fimbriata	–	–	9, 10

TABLE 2

Locations, substratum and parasitic status of lignicolous fungi on Pedunculate oak in central Croatian lowland forests.

Species	Harmful	Location	Found on/ substratum
Abortiporus biennis	×	JL, LO, PL	soil next to the living tree, log, branch
		JL, PL	decayed stump
		JL	log
		PL	branch
Armillaria gallica	×	JL	log
Armillaria mellea	×	JL	log
Armillaria tabescens	×	JL	log
Bjerkandera adusta	×	JL, LO, PL	decayed wood
		JL, LO	branch on the ground
		JL	log
		LO	dieback tree
Bjerkandera fumosa	–	LO	decayed wood, branch on the ground, dieback tree
Byssomerulius corium	–	JL	branch on the ground
Coprinus disseminatus	–	JL	branch on the ground
Coriolopsis gallica	×	LO	log
Crepidotus calolepis	–	LO	branch on the ground
Crepidotus crocophyllus	–	JL	branch on the ground
Crepidotus mollis	–	LO	branch on the ground
Cyathus striatus	–	JL	branch on the ground
		LO	trunk
Daedalea quercina	×	JL, LO	log
		PS; LO	branch on the ground
Daedaleopsis confragosa	×	JL, PL, LO	dieback tree
		JL, PL, LO	branch on the ground
Daldinia concentrica	–	JL, LO	log
Fistulina hepatica	×	PL, JL	fresh stump
		PL	wound on a living tree
Flammulina velutipes	–	JL, LO	log
Fomes fomentarius	×	JL, PO, PS	trunk of a living tree
		JL, PL, LO, PS	trunk of a dieback tree, log
Ganoderma applanatum	×	LO	base of a decayed tree, dieback tree, stump of a broken tree, base of a living tree
Ganoderma lucidum	×	LO	decayed stump, base of a living tree, log
Ganoderma resinaceum	×	LO	base of a dieback tree
Grifola frondosa	×	JL	base of a living tree
Hapalopilus croceus	–	LO	decayed wood
Hymenochaete rubiginosa	×	JL, PL, PS, LO	log
		JL	stump
Hymenoscyphus fructigenus	–	LO	branch on the ground
Hyphodontia quercina	–	JL	branch on the ground
Hypholoma fasciculare	–	JL	log
Hypholoma fasciculare var. *pusillum*	–	JL	log
Hypholoma sublateritium	–	JL	log
Hypochnicium geogenium	–	LO	branch on the ground
Hypoxylon fragiforme	–	JL, PL, PS, LO	log
Inonotus dryadeus	×	JL, LO	decayed stump
		JL	base of a living tree
Kuehneromyces mutabilis	–	JL, LO	log
Laetiporus sulphureus	×	PL, LO	decayed stump
		Jl	fresh stump
Lenzites betulina	×	PL, LO	branch on the ground
		Pl	stump
		LO	log
Loweomyces fractipes	–	LO	branch on the ground
Meripilus giganteus	×	LO	broken tree
Merulius tremellosus	–	JL, PL, LO	branch on the ground
		LO, PS	stump
		JL	log
Mycena erubescens	–	LO	branch on the ground
Mycena galericulata	–	JL	branch on the ground
Mycena tintinnabulum	–	LO	branch on the ground
Oudemansiella mucida	–	LO	log
Oxyporus corticola	–	LO	branch on the ground
Peniophora nuda	–	LO	branch on the ground
Peniophora quercina	–	PL, PS, JL, LO	branch on the ground
Phellinus ferruginosus	×	LO	log

Phylum **Basidiomycota**

Class **Agaricomycetes**
Subclass **Agaricomycetidae**
Order **Agaricales**
Family **Agaricaceae** Chevall. (1826)
Coprinus disseminatus (Pers.) Gray (1821)
Cyathus striatus (Huds.) Willd. (1787)
Family **Fistulinaceae** Lotsy (1907)
Fistulina hepatica (Schaeff.) With. (1792)
Family **Inocybaceae** Jülich (1982)
Crepidotus calolepis (Fr.) P. Karst. (1879)
Crepidotus crocophyllus Berk.
Crepidotus mollis (Schaeff.) Staude (1857)
Family **Mycenaceae** Roze (1876)
Mycena erubescens Höhn. (1913)
Mycena galericulata (Scop.) Gray (1821)
Mycena tintinnabulum (Batsch) Quél. (1872)
Family **Physalacriaceae** Corner (1970)
Armillaria gallica Marxm. et Romagn. (1987)
Armillaria mellea (Vahl) P. Kumm. (1871)
Armillaria tabescens (Scop.) Emel (1921)
Flammulina velutipes (Curtis) Singer (1951)
Oudemansiella mucida (Schrad.) Höhn. (1910)
Family **Pluteaceae** Kotl. & Pouzar (1972)
Pluteus cervinus var. *cervinus* P. Kumm. (1871)
Family **Pterulaceae** Corner (1970)
Radulomyces confluens (Fr.) M.P. Christ. (1960)
Radulomyces molaris (Chaillet ex Fr.) M.P. Christ. (1960)
Family **Schizophyllaceae** Quél. (1888)
Schizophyllum commune Fr. (1815)
Family **Strophariaceae** Singer & A.H. Sm. (1946)
Hypholoma fasciculare (Huds.) P. Kumm. (1871)
Hypholoma fasciculare var. *pusillum* J. E. Lange (1923)
Hypholoma sublateritium (Schaeff.) Quél. (1873)
Kuehneromyces mutabilis (Schaeff.) Singer & A.H. Sm. (1946)
Family **Tricholomataceae** R. Heim ex Pouzar (1983)
Pseudoclitocybe cyathiformis (Bull.) Singer (1956)

Subclass **Incertae sedis**
Order **Gloeophyllales**
Family **Gloeophyllaceae** Jülich (1982)
Veluticeps fimbriata (Ellis & Everh.) Nakasone (1990)

Order **Hymenochaetales**
Family **Hymenochaetaceae** Imazeki & Toki (1954)
Hymenochaete rubiginosa (Dicks.) Lév. (1846)
Inonotus dryadeus (Pers.) Murrill (1908)
Phellinus ferruginosus (Schrad.) Pat. (1900)
Phellinus robustus (P. Karst.) Bourdot & Galzin (1928)
Family **Schizoporaceae** Jülich (1982)
Hyphodontia quercina (Pers.) J. Erikss. (1958)
Schizopora paradoxa (Schrad.) Donk (1967)

Order **Polyporales**
Family **Fomitopsidaceae** Jülich (1982)
Daedalea quercina (L.) Pers. (1801)
Laetiporus sulphureus (Bull.) Murrill (1920)
Postia tephroleuca (Fr.) Jülich (1982)
Family **Ganodermataceae** Donk (1948)
Ganoderma applanatum (Pers.) Pat. (1887)
Ganoderma lucidum (Curtis) P. Karst. (1881)
Ganoderma resinaceum Boud. (1890)
Family **Meripilaceae** Jülich (1982)
Grifola frondosa (Dicks.) Gray (1821)
Meripilus giganteus (Pers.) P. Karst. (1882)
Family **Meruliaceae** P. Karst. (1881)
Abortiporus biennis (Bull.) Singer (1944)
Bjerkandera adusta (Willd.) P. Karst. (1880)
Bjerkandera fumosa (Pers.) P. Karst. (1880)
Hypochnicium geogenium (Bres.) J. Erikss. (1958)
Loweomyces fractipes (Berk. & M.A. Curtis) Jülich (1982)
Merulius tremellosus Schrad. (1794)
Phlebia radiata Fr. (1821)
Scopuloides rimosa (Cooke) Jülich (1982)
Steccherinum ochraceum (Pers.) Gray (1821)
Family **Phanerochaetaceae** Jülich (1982)
Byssomerulius corium (Pers.) Parmasto (1967)
Family **Polyporaceae** Fr. ex Corda (1839)
Coriolopsis gallica (Fr.) Ryvarden (1973)
Daedaleopsis confragosa (Bolton) J. Schröt. (1888)
Fomes fomentarius (L.) J.J. Kickx (1867)
Hapalopilus croceus (Pers.) Donk (1933)
Lenzites betulina (L.) Fr. (1838)
Oxyporus corticola (Fr.) Ryvarden (1972)
Polyporus badius (Pers.) Schwein. (1832)
Trametes gibbosa (Pers.) Fr. (1838)
Trametes hirsuta (Wulfen) Lloyd (1924)
Trametes pubescens (Schumach.) Pilát (1939)
Trametes trogii Berk. (1850)
Trametes versicolor (L.) Lloyd (1921)
Tyromyces chioneus (Fr.) P. Karst. (1881)
Tyromyces subcaesius A. David (1974)

Order **Russulales**
Family **Peniophoraceae** Lotsy (1907)
Peniophora nuda (Fr.) Bres. (1897)
Peniophora quercina (Pers.) Cooke (1879)
Family **Stereaceae** Pilát (1930)
Stereum gausapatum (Fr.) Fr. (1874)
Stereum hirsutum (Willd.) Pers. (1800)
Stereum rameale (Schwein.) Burt (1920)
Stereum subtomentosum Pouzar (1964)

Data on these fungi are given in Tables 1 and 2, as well as the month and year of collection, location and substratum.

TABLE 2
continued

Species	Harmful	Location	Found on/ substratum
Phellinus robustus	×	PL, PS, JL, LO	trunk of a living tree
Phlebia radiata	×	LO	stump, log
Pluteus cervinus var. *cervinus*	–	JL	log
Polyporus badius	–	JL	branch on the ground
Postia tephroleuca	–	JL	branch on the ground
Pseudoclitocybe cyathiformis	–	JL	branch on the ground
Radulomyces confluens	–	JL	branch on the ground
Radulomyces molaris	–	JL	branch on the ground
Schizophyllum commune	×	JL, PL, LO, PS	branch on the ground
		LO, PS	decayed wood
		JL, PL, LO, PS	log
		LO	branch of a fallen tree
Schizopora paradoxa	–	JL	branch on the ground
Scopuloides rimosa	–	JL	branch on the ground
Steccherinum ochraceum	×	LO	log
Stereum gausapatum	×	LO	log
		JL	branch on the ground
Stereum hirsutum	×	JL, PL, LO, PS	branch on the ground
		Pl, PS	log
		LO, PS	branch of a cut tree
		JL, PL	branch on a fallen tree
		JL	wound on a living tree
Stereum hirsutum	×	JL, PL, LO, PS	branch on the ground
		Pl, PS	log
		LO, PS	branch of a cut tree
		JL, PL	branch on a fallen tree
		JL	wound on a living tree
Stereum rameale	×	JL, LO	branch on the ground
Stereum subtomentosum	×	JL	log
Trametes gibbosa	×	PL, JL, LO	decayed stump
Trametes hirsuta	–	JL	branch on the ground
Trametes pubescens	–	LO, PL	branch on the ground
Trametes trogii	×	LO	log
Trametes versicolor	×	JL, PL, LO, PS	branch on the ground
		JL, PL, LO, PS	log
		PL, LO	decayed wood
		JL, LO, PS	branch of a cut tree
Tyromyces chioneus	–	JL	branch on the ground
Tyromyces subcaesius	×	JL	branch on the ground
Veluticeps fimbriata	–	JL	branch on the ground

Abbreviations: JL – Jastrebarski lugovi; PL – Pisarovinski lugovi; PS – Posavske šume; LO – Lonja

DISCUSSION

Lignicolous fungi play a major role in deadwoodology, the ecology of deadwood in forests *(3, 35)*. The species – richness of lignicolous fungi increases with the amount of substrate *(3)*. For the conservation of their biodiversity, as well as for forest biodiversity, productivity and ecological processes, it is vital to retain the appropriate quantities of standing and fallen dead wood in managed forests.

Pedunculate oak in Croatia occurs in forest communities that have well developed tree canopy and undestorey with various tree and shrub species, which provides for a wide variety of conditions for development of lignicolous fungi.

Past studies of these fungi were carried out in the complex of large-scale researches of macromycetes in oak forests *(10, 36, 37)*. Results of this study showed that Pedunculate oak forests in Central Croatia support a rich and diverse mycological complex of lignicolous fungi.

Red Lists for macrofungi exist for most European countries, fourteen countries have fungi protected by law; from 4 species (UK) to 314 species (Croatia) (*4*). In Bavaria, 25% of wood-decay fungi species have been are assessed as threatened *(38)*, in Sweden 20% of 670 native *Aphyllophorales* are endangered *(39)* and nearly 40% of 2120 red-listed organisms related to forest and woodland habitats are saproxylic out of which one fourth are fungi *(40)*. During this study one species from Croatian Red list of fungi was identified: *Hapalopilus croceus* was found on June 24, 2005 in Lonjsko polje.

The Natura 2000 conservation programme of the European Union based on the Habitat Directive is highly successful for animals and plants. Natura 2000 does not officially include fungi as it is mainly based on habitats of invertebrates, mosses, vertebrates and vascular plants in-

cluded in the Bern Convention. Nevertheless, national implementation of the programme has included fungi in at least three countries. In Croatia, 52 important localities for fungi have been selected within the Natura 2000 programme.

Seventy-two species were found and 32 species can be considered as harmful lignicolous fungi in managed Pedunculate oak forests in central Croatia attacking standing trees, causing heartrot at the stem, stem base or root (Table 2). Attacked trees lose technical value and are vulnerable to breaks. Some of the species found are the fungi that attack the produced assortments that predominantly colonize fallen branches and slash, but may also inflict damage on technical timber in favorable conditions *(41)*.

Because of geographical diversity and natural quality, Croatian forests have high biodiversitiy potential (260 native tree species and 4500 native plant species) for lignicolous fungi. Results of this research show cosiderable richness of the species of lignicolous fungi in Pedunculate oak forests of central Croatia. Future scientific research should complete the list of lignicolous fungi in all Peduculate oak and other forest phytocoenoses.

Acknowledgements: *Many thanks to Gabrielle Kovacs from the Austrian Mycological Society for cooperation, advice, literature and identification of lignicolous fungi. Many thanks also to Erhard Halmschlager (Institute of Forest Entomology, Forest Pathology and Forest Protection, BOKU University, Vienna, Austria) for permitting us to use his laboratory facilities and library.*

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