Agaricus species from Greece

Stephanos Diamandis* & Charikleia Perlerou

NAGREF–Forest Research Institute, 570 06 Vassilika, Thessaloniki, Greece

Received 11 January 2008 / Accepted 17 March 2008

Abstract. The genus *Agaricus* includes saprotrophic species occurring in a variety of ecosystems. Most of them, however, are confined to grasslands. Forty one taxa have been recorded in Greece to date. Some species, although heavily picked for their gastronomic value, seem to appear in abundance while others, which are inedible, seem to be infrequent or rare. As in recent years grass and pasturelands in Greece have been included in "improvement programmes" and subjected to the use of fertilizers, there is concern about the disturbance caused to the habitats of the *Agaricus* species and consequent changes in the fungal biodiversity. It is obvious that further research on the ecology and particularly the factors governing the fruiting and spreading of *Agaricus* species is necessary before any concrete conclusions are reached and any conservation measures are imposed.

Key words: *Agaricus,* conservation, frequency, fungal biodiversity, Greece

Introduction

The genus *Agaricus* L. includes a fair number of saprotrophic species occurring in a variety of ecosystems. Ninety species have been recorded in Europe (Cappelli 1984; Bas 1991), but estimates for the worldwide distribution are likely to exceed 200. Historically, all of the species producing gilled mushrooms were classified in a massive genus, *Agaricus.* In the 19th century, Elias Fries divided *Agaricus* into a number of smaller genera based on easily ascertainable features such as attachment of the gills, texture of the stalk, presence or absence of a veil, and colour of the spores (Arora 1986).

From both the economic and gastronomic points of view, the genus *Agaricus* is definitely the most important group of gilled mushrooms because it includes the widely cultivated species *A. bisporus* and its varieties and cultivars. It also includes a number of delicious collectables which are not easy to recognize in the field. Even though several species are favourites for many mushroom pickers, the genus *Agaricus* is also characterized by some confusingly polymorphic species (variable size, shape, colour, etc.), which make their identification a difficult task. Fortunately, no member of the genus is deadly poisonous, but some species cause mild to severe vomiting and diarrhea in most people. A few people are not able to consume any of the edible *Agaricus* species including the cultivated *Agaricus bisporus* because they experience vomiting and diarrhea.

Four characteristics are considered to be the most important for identification of the *Agaricus* species: the staining reaction, the odour, the veil characteristics and the spore size. Unfortunately, again, all of the above characteristics, with the exception of spore size, may be influenced or altered by the environment. Specimens growing in the open, for instance, may be coloured differently when compared to other specimens which grow in shady places. Similarly, dry or old specimens manifest their staining reaction and odour more slowly or subtly than young, fresh individuals, while soggy specimens may not display their normal odour and staining reactions at all. It is obvious that the habitat and the environmental conditions should always be taken into consideration when attempting to identify unfamiliar *Agaricus* species (Arora 1986).

Some *Agaricus* species are notable for their beauty and elegance while others are large and fleshy. They can be found in urban and suburban habitats such as gardens and parks, cemeteries and roadsides, along grassy trails and on compost piles. They also grow in rural areas such as forests and pastures where they fruit in large quantities.

*Corresponding author: e-mail: diamandi@fri.gr

The *Agaricus* species in Greece fruit in late spring and from late summer through autumn whenever the conditions are favourable, moist and mild. Most species, however, can be found right after the first late summer or autumn rains while the temperatures are still high. A few species fruit even in December and January in lowland areas and during years with mild winters.

The objective of the present work was to report all the species of the genus *Agaricus* recorded in Greece to date along with details in regard to their frequency, habitat, fruiting time, edibility and first reporting author/s.

Recorded species

Forty one taxa have been recorded in the genus *Agaricus* in Greece to date. Frequency information is based on long collecting experience and database citations. The taxa are arranged here in alphabetical order.

Agaricus abruptibulbus *sensu auct. eur.*
Rare, it was found in Greek fir (*Abies cephalonica* Loudon) forests. Its carpophores appear in late summer and autumn. Edible. Reported by Pantidou (1980).

A. albertii Bon
Frequent, it was recorded in large numbers in Macedonia (N Greece) and Thessaly (C Greece). It fruits from late April to November. Edible, good. Reported by Konstantinides (2004).

A. arvensis Schaeff. (*A. cretaceus sensu* Ricken, Pilát, non Fr.)
Common, it was recorded in a variety of habitats such as grassy places, pastures, forest edges (*Fagus sylvatica* L., *Castanea sativa* Mill.) on rich or manured soil. Its carpophores appear from April to November. Edible, excellent. Reported by Landerer (1858 – in Pantidou 1973). It can be separated from the poisonous *A. xanthodermus* Genev. by the base of its stem which does not turn yellow immediately after rubbing.

A. augustus Fr. (*A. perrarus* Schulzer)
Infrequent, it was found in hardwood and coniferous forests (*Abies borisii-regis* Mattf., *Quercus frainetto* Ten., *Fagus sylvatica*). It fruits more often gregariously or in groups from August to October. Edible and good. Reported by Diamandis & Perlerou (1990). Important morphological features are its almond extract odour, yellow-staining cap with brown fibrils or scales, prominent ring, brown spores and shaggy stem at young age.

A. benesii (Pilát) Singer
Infrequent, it occurs in broadleaved and more rarely in coniferous forests. It fruits in late summer and autumn. Edible. Reported by Konstantinides (2006).

A. bernardii (Quél.) Sacc.
Frequent, it grows in saline pastureland along the coast, along roads that are salted in winter against ice and also around sheep folds where shepherds set salt feeders. It fruits in spring and autumn. Edible. Reported by Maire & Politis (1940 – in Pantidou 1973). It resembles its close relative *A. bitorquis* (Quél.) Sacc. but differs in staining reddish when cut and it is more apt to have a warty or scaly cap (Arora 1986).

A. bisporus (J.E. Lange) Imbach
Thought to be rare, however, it is now considered frequent. Carpophores were found mainly under cypress on bare soil and less often on sheep dung heaps. It fruits in spring and in September–October. Edible. Reported by Callac *et al.* (2000).

A. bitorquis (Quél.) Sacc. (*A. edulis* (Vittad.) Konrad & Maubl.)
Infrequent, it was recorded under *Eucalyptus* spp. along country roads and paths and also in parks on sandy, dry soil. Carpophores appear in April–May and again from August to October. Edible and very good. Reported by Athanasiou & Theochari (2001). Features which distinguish this species from other *Agaricus* spp. are the band like or sheathing ring usually with two free limbs, its solid stem and firm texture, the flesh that does not stain yellow or red and the lack of anise or phenol odour.

A. bresadolanus Bohus
Frequent, it was recorded in manured pastures, around manure piles and occasionally under broadleaved trees (in particular poplar, black locust, oak) and conifers. Carpophores appear from April to November. Edibility confusing. Some authors consider it as edible and good and others as toxic. Reported by Konstantinides (2004).

A. campestris L. : Fr.
Probably the most common of all. It grows in pastures. Although heavily picked, it can be found in abundance from April to November. Edible and good. Reported by Landerer (1858 – in Pantidou 1973).

A. campestris var. ***squamulosus*** (Rea) Pilát
Infrequent, it occurs in mountain pastures from May to September. Edible and good. Reported by Diamandis (1985).

A. comtulus Fr.
Rare, it is found in pastures, at the edge of country roads and always among grass and other vegetation. Carpophores appear solitary or in small groups in autumn. Not edible. Reported by Maire & Politis (1940 – in Pantidou 1973).

A. cupreobrunneus (Jul. Schäff. & Steer ex F.H. Møller) Pilát (*Psalliota cupreo-brunnea* Jul. Schäff. & Steer ex F.H. Møller)
Infrequent, it was found in old wheat fields. It fruits from April to November. Edible. Reported by Perlerou & Diamandis (2000).

A. dulcidulus Schulzer
Frequent, it occurs in coniferous and mixed forests in the needle litter. It produces its carpophores singly or in small groups in late summer and autumn. Edible. Reported by Konstantinides (2004).

A. fuscofibrillosus (F.H. Møller) Pilát
Rare, it grows in forests on rich, calcareous soil. Carpophores can be found in small groups or singly from August to October. Edible. Reported by Konstantinides (2004).

A. gennadii (Chatin & Boud.) P.D. Orton
Rare, it is found in a wide range of habitats such as pastures, parks, along country roads, in greenhouses and even at the edges of coniferous forests on sandy soils. It fruits from April to October. Edible. Reported by Konstantinides (2004).

A. haemorrhoidarius Schulzer
Rare, it was recorded in grassy places in coppice oak forest. It fruits in the autumn. Reported by Pantidou (1973).

A. impudicus (Rea) Pilát
Rare, it was recorded only in one location. It usually grows along trails, in forests, preferably on sandy soil. Carpophores grow in late summer and in autumn. Edible. Reported by Konstantinides (2006).

A. koelerionensis (Bon) Bon
Rare, it was recorded in grassland near the coastline. Edible but not particularly good. Recorded by Diamandis (2008).

A. langei (F.H. Møller) F.H. Møller (*A. haemorrhoidarius sensu auct.* J.E. Lange, Pilát)
Infrequent in Greece, it grows in coniferous forests, especially fir (*Abies borisii-regis*) forests. Carpophores found in small groups in late summer to October. Edible and good. Reported by Konstantinides (2004).

A. lanipes (F.H. Møller & Jul. Schäff.) Hlaváček
Rare, it was collected only in one location. It grows in forests, parks and river banks on sandy soils. Carpophores appear from August to November in groups. Edible, but it is recommended not to pick it because of its rarity. Reported by Konstantinides (2006).

A. litoralis (Wakef. & A. Pearson) Pilát
Infrequent, it can be found in pastures, roadsides and along the coast on sandy soil. It often fruits in groups from April to November. Edible and good. Reported by Konstantinides (2004).

A. luteomaculatus (F.H. Møller) F.H. Møller
Rare, it occurs in Greek fir (*Abies cephalonica*) forests. Its carpophores appear in late summer to mid-autumn. Not edible. Reported by Pantidou (1973).

A. macrocarpus (F.H. Møller) F.H. Møller
Locally common, it was collected in black pine (*Pinus nigra*) and Greek fir forests. Differs from *A. abruptibulbus* Peck. in its cheilocystidia which have papillate apex. Reported by Zervakis *et al.* (2002a).

A. macrosporus (Jul. Schäff. & F.H. Møller) Pilát (*Psalliota arvensis* subsp. *macrospora* Jul. Schäff. & F.H. Møller)
Infrequent, it was found in grassy places, in chestnut forests and, less often, in pastures. It fruits in the autumn. Edible. Reported by Diamandis & Perlerou (2002).

A. mediofuscus (F.H. Møller) Pilát
Rare, it was found in alpine pastures in October. Reported by Dimou *et al.* (2002).

A. moelleri Wasser (*A. praeclaresquamosus* var. *terricolor* (F.H. Møller) Bon & Cappelli)
Infrequent, it occurs in pastures, shrubland, parks and forest edges. Carpophores appear in groups in spring and again in the autumn. Poisonous, it may cause gastric upsets. Reported by Konstantinides (2004).

A. niveolutescens Huijsman
Rare, it grows in hardwood forests and especially beech, in grassy places and along country roads and paths on calcareous soils. Carpophores appear solitary or gregarious in autumn to early winter. Not edible. Reported by Athanasiou & Theochari (2001).

A. nivescens (F.H. Møller) F.H. Møller
Rare, it was recorded in Greek fir (*Abies cephalonica*) forests. Edible. It was reported by Pantidou (1973). Closely related to *A. arvensis,* it differs in its more globose and pure white or slightly yellowing cap, its longer remaining whitish gills and shorter spores.

A. pampeanus Speg.
Rare, it is found in pastures and fields on rich, basic soils. It fruits in small groups or solitary in late summer and autumn. Edible. Reported by Athanasiou & Theochari (2001). It belongs to the wider group of *A. campestris,* differing from other forms by the size of its spores which are much longer, up to 10.8 µm.

A. porphyrizon P.D. Orton (*A. purpurascens* (Cooke) Pilát, non Fr.)
Infrequent, in broadleaved forests, parks and gardens on rich, sandy soil, in warm places. It fruits solitary or in small groups in late summer and autumn. Edible. Reporded by Polemis (1998).

A. porphyrocephalus F.H. Møller
Rare, it was recorded only once. It grows in rich, manured pastures. Its carpophores appear in the autumn. Edible and good. It was reported by Konstantinides (2006).

A. praeclaresquamosus (F.H. Møller) Bon & Capelli (*A. placomyces* Peck)
Infrequent, it grows in forests, parks and shrubland. Carpophores appear in autumn. Toxic, it may cause gastric upsets. *A. placomyces* was reported by Diamandis (1985).

A. romagnesii Wasser (*A. radicatus* (Vittad.) Romagn.)
Rare, it was collected only once in *Quercus frainetto* forests. Inedible. Reported by Zervakis *et al.* (2002b).

A. semotus Fr. (*A. rubellus* (Gill.) Sacc.)
Rare, it was collected once under *Quercus frainetto.* Inedible. Reported by Zervakis *et al.* (2002b).

A. sylvaticus Schäff. (*Psalliota sanguinaria* (P. Karst.) J.E. Lange)
Frequent, it was recorded in coniferous (*Pinus radiata* D. Don, *P. pinea* L., *Abies cephalonica, A. borisii-regis, Picea abies* (L.) Karst.) and also in hardwood forests (*Quersus frainetto, Castanea sativa, Fagus sylvatica*). It fruits from August to October. Edible. Reported by Landerer (1858 – in Pantidou 1973).

A. sylvicola (Vittad.) Lév. (*Psalliota sylvicola* (Vittad.) Richon & Roze)
Common, it occurs in coniferous and broadleaved forests. It was found under *Cedrus libani* A. Rich., *C. deodara* (D. Don) G. Don, *Pinus halepensis* Mill., *P. brutia* Ten., *Cupressus sempervirens* L., *Abies borisii-regis, Quercus*

frainetto, Fagus sylvatica. Carpophores appear solitary or in clusters in the autumn and even mid-winter. Reported by Maire & Politis (1940 – in Pantidou 1973). It rather resembles *A. arvensis,* but is often more erect and less robust, has smaller spores and grows on bare soil.

A. subfloccosus (J.E. Lange) Pilát

Rare, it was recorded in fir (*Abies cephalonica*) forest among needle litter. It fruits solitary to gregarious in the autumn. Edible. Reported by Pantidou (1980).

A. xanthodermus Genev.

Frequent, it is frequently found in grasslands, parks and forest openings. Its carpophores may appear from April to November every time there is enough moisture. It causes gastric upsets. Reported by Maire & Politis (1940 – in Pantidou 1973).

A. xanthodermus var. ***griseus*** (A. Pearson) Bon & Cappelli

Frequent, it occurs in grassy openings of hardwood forests, pastures and gardens. It fruits in groups in spring and autumn. Toxic. It causes gastric upsets. Reported by Konstantinides (2004).

A. xanthodermus var. ***lepiotoides*** Maire

Frequent, it occurs in grassy openings of hardwood forests, pastures and gardens. It often fruits in small groups from April to October. It causes gastric upsets. Reported by Konstantinides (2004).

Discussion

Despite the fact that carpophores of the genus *Agaricus* are considered as favorite among mushroom pickers, this is not an easy group of macromycetes to identify. Furthermore, even though there are no members of the group causing fatal poisoning, a few can cause really unpleasant gastric disorders for many people. It appears that the phenol-smelling species are responsible for the poisoning in the majority of people who are sensitive to eating them. Their smell may not be evident in the field, however, it becomes more pronounced when they are cooked.

The cultivated mushroom *A. bisporus* is definitely the most well known, however, it is considered as mediocre from the culinary point of view. *A. campestris* is a popular species too, but the very best to eat are *A. augustus, A. arvensis, A. bernardii* and *A. bitorquis* which, in fact, are not very popular.

Naturally occurring hydrazines, such as agaritine, are found in edible mushrooms. According to Schulzová *et al.* (2002) the content of agaritine in cultivated *A. bitorquis* varied from 165 to 457 mg $kg^{(-1)}$ on average being 272 ± 69 mg $kg^{(-1)}$, while in *A. bisporus* it was detected at the level of 228.2 mg $kg^{(-1)}$ (Hashida *et al.* 1990). As agaritine and its putative metabolites are suspected for mutagenic and carcinogenic potential in mammalian cells, more research should be focused on its effects to human cells because of the increasing consumption of cultivated *Agaricus* mushrooms. Such concern, of course, should not discourage the public from consuming mushrooms, as it has been proven that low molecular weight antitumor and antimetastatic substances were also isolated from *A. blazei* and other *Agaricus* species (Kimura 2005).

Work carried out in Greece by Theochari *et al.* (2003) towards finding carpophores in the field of autochthonous mycelium of *A. bisporus* revealed some very interesting results. The fungus was recorded repeatedly in quite a few places in Greece on sheep manure piles and under cypress (*Cupressus sempervirens*). In the former habitat, carpophores appeared from early autumn until late spring because of its fast soaking with water after the first rains while on the latter, they emerged later in winter until early spring because of slower hydration of the cypress litter and faster drying out in spring. One out of 117 isolations of the fungus was a 4-haploid-basidiospore isolation, a rare and valuable event as such haploid spores are unique for breeding and can produce new genetic material for the mushroom cultivation industry. Furthermore, one more isolate was obtained from original mycelium collected from cypress litter under natural cypress in Crete. Such an isolate can be considered as particularly important for evaluation and preservation of the biodiversity.

The genus *Agaricus* is thought to be mainly distributed in the tropics and subtropics. It would be expected that Greece, at the southern end of the Balkan Peninsula, would host more species than other parts of Europe. Forty one taxa (39 species and 2 varieties) are reported here but more intensive surveys should be carried out, especially in Peloponnese, Crete and the southern Aegean islands, for that purpose. Similarly in Turkey, 37 taxa (33 species and 4 varieties) have been recorded so far, a number which can be substantially increased (Sesli & Denchev 2005). Recently, Lacheva (2006) reported 31 new taxa in Bulgaria bringing the total number of *Agaricus* taxa in this neighboring country to 59 (50 species and 9 varieties).

The information cited here on the frequency and abundance of the recorded species also needs some critical comments. Popular species among mushroom pickers such as *A. albertii, A. arvensis, A. campestris, A. macrosporus* and *A. sylvicola,* which are heavily collected every season, tend to fruit in abundance. Although systematic surveys on permanent plots have not been carried out, it seems that mushroom pickers have not experienced any noticeable reduction in their collections. On the contrary, other species which are confined to grasslands and are considered as rare and infrequent, although not picked at all or only occasionally because their edibility is confusing or not established, seem not to be able to extend their range or to increase their numbers. It is widely accepted that natural grasslands typically have an associated mycota (Spooner & Roberts 2005). In recent years grass and pasturelands in Greece have been included in "improvement programmes" by using fertilizers spread from the air. It is established that fertilizers destroy the natural mycota of grasslands, replacing waxcaps (*Hygrocybe* species and other fungi with commonplace nitrophilic species of the genera *Panaeolus, Coprinus, Psilocybe* and *Stropharia* (Spooner & Roberts 2005). The effects of such programmes

on biodiversity and particularly on fungal biodiversity have not been thoroughly considered before application, and even worse, the programmes have not been monitored or evaluated in depth after application.

It is obvious that research on the ecology and particularly the factors governing the fruiting and spreading of *Agaricus* species is necessary before any concrete conclusions are reached and any conservation measures are imposed.

References

Arora, D. 1986. Mushrooms demystified. Ten Speed Press, Berkeley.

Athanasiou, Z. & Theochari, I. 2001. Compléments á l'inventaire des *Basidiomycétes* de Gréce. – Mycotaxon **79**: 401-415.

Bas, C. 1991. A short introduction to the ecology, taxonomy and nomenclature of the genus *Agaricus.* – In: L.J.L.D. van Griensven [ed.]. Genetics and breeding of *Agaricus,* pp. 21-24. Pudoc, Wageningen.

Callac, P., Imbernon, M., Guinberteau, J., Pirobe, L., Granit, S., Olivier, J.-M. & Theochari, I. 2000. Discovery of a wild Mediterranean population of *Agaricus bisporus,* and its usefulness for breeding work. – In: L.J.L.D. van Griensven [ed.]. Science and cultivation of edible fungi, pp. 245-252. Balkema, Rotterdam.

Capelli, A. 1984. *Agaricus* L. : Fr. ss. Karsten (*Psalliota* Fr.). Fungi Europaei. Vol. **1**. Saronno.

Diamandis, S. 1985. [Recording the Greek mycoflora] – Forest Research **2**(6): 101-118. (In Greek)

Diamandis, S. 2008. Mushrooms and toadstools of Greece. 2nd edn. Ion Publ., Athens. In press.

Diamandis, S. & Perlerou, C. 1990. [New records of higher *Basidiomycetes* and *Ascomycetes* in Greece]. – Scientific Annals, Department Forestry & Natural Environment, Aristotele Univ. Thessaloniki, **150**(2): 291-303. (In Greek)

Diamandis, S. & Perlerou, C. 2002. [Macromycetes in the Greek grasslands]. – In: Platis & Papachristou [eds.]. 3rd Panhellenic Rangelands Congress, Karpenisi, 2002. Pp. 215-221. Greek Pasture and Range Society, Thessaloniki. (In Greek)

Hashida, C., Hayashi, K., Jie, L., Haga, S., Sakurai, M. & Shimizu, H. 1990. Quantities of agaritine in mushrooms (*Agaricus bisporus*) and the carcinogenicity of mushroom methanol extracts on the mouse bladder epithelium. – Nippon Koshu Eisei Zasshi **37**(6): 400-405.

Kimura, Y. 2005. New anticancer agents: *in vitro* and *in vivo* evaluation of the antitumor and antimetastatic actions of various compounds isolated from medicinal plants. – In Vivo **19**(1): 37-60.

Konstantinides, G. 2004. [Mushrooms, a field guide]. Zarzonis Publ. Co, Thessaloniki. (In Greek)

Konstantinides, G. [ed.] 2006. [1000 Mushrooms and toadstools of W. Macedonia]. Mycological Society of W. Macedonia (MSWM), Kastoria. (In Greek)

Lacheva, M. 2006. [Genus *Agaricus* L. : Fr. emend. P. Karst. (Mushroom) in Bulgaria – taxonomy, ecology, chorology and economical importance]. PhD thesis. Agricultural University, Plovdiv. (In Bulgarian)

Pantidou, M. 1973. Fungus-host index for Greece. Benaki Phytopath. Institute, Athens.

Pantidou, M. 1980. Macrofungi in forests of *Abies cephalonica.* – Nova Hedwigia **32**: 709-723.

Perlerou, C. & Diamandis, S. 2000. [New records of Greek macromycetes]. – Forest Research **13**: 51-57. (In Greek)

Polemis, E. 1998. [Mushrooms of Andros]. Diploma thesis. Agricultural University, Athens. (In Greek)

Schulzová, V., Hajšlová, J., Peroutka, R., Gry, J. & Andersson, H.C. 2002. Influence of storage and household processing on the agaritine content of the cultivated *Agaricus* mushroom. – Food Additive & Contaminants **19**(9): 853-862.

Sesli, E. & Denchev, C.M. 2005. Checklists of the myxomycetes and macromycetes in Turkey. – Mycologia Balcanica **2**: 119-160.

Spooner, B. & Roberts, P. 2005. Fungi. Harper Collins Publ., London.

Theochari, I., Callac, P., Athanasiou, Z., Nikolaou, A. & Guinberteau, J. 2003. [Inventory of *Agaricus bisporus* in Greece]. – Forest Research **16**: 11-16. (In Greek)

Zervakis, G., Dimou, D.M., Polemis, E. & Karadelev, M. 2002a. Mycodiversity studies in selected ecosystems of Greece: 2. Macrofungi associated with conifers in the Taygetos mountain (Peloponnese). – Mycotaxon **83**: 97-126.

Zervakis, G.I., Polemis, E. & Dimou, D.M. 2002b. Mycodiversity studies in selected ecosystems of Greece: 3. Macrofungi recorded in *Quercus* forests from Southern Peloponnese. – Mycotaxon **84**: 141-162.