# MUSHROOMS in the Garden



HELLMUT STEINECK

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second revised and enlarged edition

24 color photographs
45 black and white photographs
12 line drawings

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# Translators' note

We are glad to share this delightful book with English-speaking readers. This book is unusual in emphasizing growing mushrooms out of doors, not only as additions to the vegetable garden, but as decorative and unusual enhancements to the ornamental garden as well. Thus, the author does not just concern himself with the commonly (and not so commonly) eaten mushrooms, but with those which are particularly beautiful, striking, or unusual-looking and which can be used by the gardener to help achieve a desired effect, such as a bit of shady forest or a meadow with fairy rings.

Many of the species which Herr Steineck discusses occur not only in Europe, but in North America also. Furthermore, the methods of cultivation which he describes would be generally applicable to many other species of the genera he discusses. His methods thus provide guides and suggestions for how to grow desirable local species.

Common names follow general usage in English; where these are unavailable we have used the Latin names.

This book is not intended to be used to identify mushrooms. Neither the author, translators, nor the American nor German publishers can be responsible for any ill effects suffered by mushroom eaters. We urge our readers to be certain of their identifications and to eat sparingly of species new to them until they know that they are not sensitive.

May the ideas and enthusiasm of the author stimulate a wider interest in cultivating fungi. Culturing fungi need not require special tools and complex techniques. Herr Steineck's methods for back-yard culturing are straightforward and easy for gardeners, and we hope that this book may excite you to grow your own mushrooms for food and as ornamentals.

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# Foreword

During my many years of acting as advisor on *Agaricus* cultivation for the Department of Agriculture of the Rheinland I was very intensively involved with the commercial cultivation of mushrooms. Thus it was not pure chance that I endeavored, after this activity ended, to discover ways of culturing many species of mushrooms, and that study of mushrooms became my leisure activity.

In my garden I have tried to create for these oddities of the plant world growing conditions like those occurring in nature in meadows and fields, in gardens and forests. This required detailed observation during walks and hikes to unearth the preferences of individual species of mushrooms for particular habitats, so that I could provide the same requirements in the garden. It was just as important to use only the very simple methods usually available to the gardener who wishes to culture mushroom mycelium and spawn to use in establishing mushrooms in the garden.

All this led to numerous visits by gardening enthusiasts who were interested in cultivating mushrooms in their gardens, and to more and more inquiries and conversations about how to do this.

Thus I was eventually persuaded to write down my experience in this field, to show all mushroom enthusiasts how they too can make mushrooms grow in their own gardens. After a brief glimpse into the life of mushrooms, I have attempted to compile a selection of species suitable for the garden, with information on their natural habitats and potential for cultivation, and to describe in detail the cultural potential for the most important species. I hope that this opens up a new interesting area of activity for the garden lover.

I must especially thank Mr. Roland Ulmer for showing spontaneous interest in the topic and for committing himself in word and deed to realizing the idea.

Leichlingen

Hellmut Steineck

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# History and biology

## Fungi

When we speak of fungi we probably think of *Boletus edulis*, chanterelles, the common cultivated mushroom, and their delicious relatives which are collected in forest and field or raised in old mine tunnels or special climate-controlled culture houses. Perhaps we will also think of molds, which under certain circumstances make bread unpalatable and destroy valuable foodstuffs, but on the other hand are responsible for delicious blue cheeses. We could not drink a glass of beer or wine if there were no yeast fungi; we also need them to be able to bake good bread and delicate sweet rolls. Harmful species of fungi attack wine, fruits, vegetables, and agricultural crops and cause considerable losses. Even people are attacked by fungi, such as those causing athlete's foot and aspergillosis. Yet fungi can also help in our struggle against animal pests, when for example they attack house flies in the fall, kill caterpillars in vegetable gardens in summer and fall, or destroy caterpillars during massive outbreaks of these pests in forests. Fungi are therefore in part dangerous pathogens, but also furnish medicines against diseases. They are indispensible for life, since without them the nutrient cycle in nature would not be possible; the transformation of organic substances, the provision of forest trees with nutrients, the alteration of numerous compounds in the soil are their work.

The number of species of fungi is estimated to be more than 100,000, of which about 30,000 occur in Europe, with about 3000 species of the larger fungi. However, only a few dozen species will be considered in this book, namely those which are suitable for the garden and which, as we will learn, can offer much delight.

## The history of mushroom cultivation

The use of mushrooms as food can be traced back to the Stone Age. References to the value of edible fungi and the danger of poisonous ones are to be found in the surviving literature as far back as about 500 B.C. Attempts to cultivate them are first mentioned at the beginning of our era and concern at first only

*Agaricus*, truffles, *Boletus edulis*, and mushrooms living on wood. In the last 100 years the number of attempts at cultivation have continually increased as knowledge about the mode of life of mushrooms has become more complete and better technical means for growing them have constantly become available. In addition, the yield of wild mushrooms has decreased from year to year because living conditions for them have become more and more unfavorable, and collecting them has required great expenditure of time. Their prices have risen more than those of cultivated mushrooms because of the rising cost of labor.

Cultivating attempts have gone in two directions. At first mainly those places which corresponded to the conditions in their natural habitats were tried as possibilities for growing mushrooms, but more recently people have developed methods of cultivation on suitable nutrient substrates in special culture rooms. Cultivating attempts have been carried out with about 30 species of mushrooms. Up to now, except for the common cultivated mushroom (*Agaricus bisporus*), large-scale commercial cultivation has occurred only in Asia, where the shiitake (*Lentinus edodes*), the paddy straw mushroom (*Volvariella volvacea*) the velvet shank (*Flammulina velutipes*), and the jew's ear (*Auricularia auricula-judae*) are cultivated. Recently *Agaricus bitorquis*, some species of

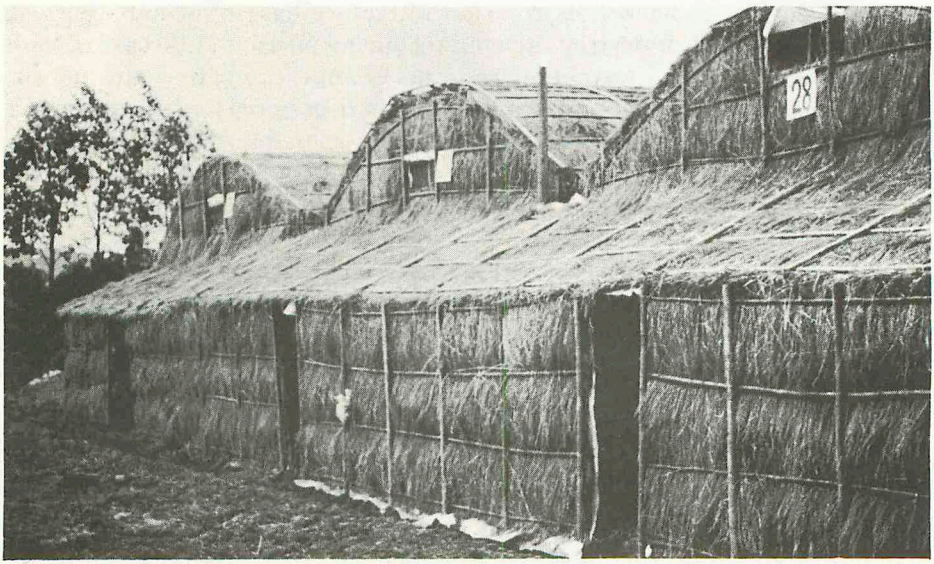



*Fig. 1. Houses for culturing mushrooms in Taiwan*

*Pleurotus*, and *Kuehneromyces mutabilis* have also been cultivated in Europe in rather large numbers. The semicultivation of truffles under oaks, as is customary in southern France and Italy, should also be mentioned. In additon to the mushrooms named, species of *Stropharia*, *Coprinus*, *Pholiota*, and *Helvella* are cultivated commercially, while species of *Tricholoma*, *Clitocybe*, *Lepiota*, *Marasmius*, as well as *Hypholoma* (*Nematoloma*) *capnoides* and *Flammulina velutipes*, are grown on a more amateur scale in park grounds and gardens. For decades people have endeavored to discover how to grow the valuable *Boletus edulis* and the popular chanterelle, but only in recent years have we made any progress toward this goal. It looks as though in the years ahead we could expect the discovery of methods of cultivating many other species of mushrooms, making a truly multifaceted cultivation of mushrooms in one's own garden possible.

## The life of fungi

### Origin

As long ago as antiquity people tried to fathom the origin and growth of mushrooms, but with little success. They found that mushrooms did not possess leaves, flowers , and fruits like other plants and believed that they arose from unknown juices occuring in the ground. Even in the Middle Ages people still assumed that they were formed out of the moisture in the soil during rains and thunderstorms. Superstitious people asserted that witches and devils made mushrooms grow, or said that one of the saints would ride through the forests and sow mushroom seeds. People did not come closer to the true nature of mushrooms until the 18th century, although it was still debated whether they should be considered plants or animals. This was probably connected with the fact that people formerly believed in animal-plants, which were animals for a part of their lives and later changed into plants, and used these strange beings as medicines. In reality they were dealing with insect larvae which had been attacked and killed by fungi and out of whose dead bodies the fruiting bodies of the fungi later emerged. In the 19th century people first understood the life history of fungi and arranged them taxonomically. For a long time it was not clear if fungi should be considered to be a distinct group of living organisms which were to be put between animals and plants, since fungi depend on the availability of organic substances for their nourishment and are closer in many respects to animals than to plants.

The evolutionary origin of fungi is also not entirely clear even today, since there are no fossil fungi from the Paleozoic era. It is assumed that they originally arose from unicellular algae (flagellates) living in the sea. As the land emerged, forms developed which nourished themselves on dead organisms and therefore no longer needed chlorophyll, which is necessary for assimilation. Thus the first fungi, just like the first animals, probably arose from colorless flagellates, while the forerunners of today's higher plants probably arose from green flagellates and the diatoms and brown algae from brown flagellates. Whether the higher fungi also descended from colorless flagellates is not clear. The former assumption that they did not arise until later, from green or red algae, is now considered unlikely.

## Systematics

In order to attain an understandable arrangement of the plant kingdom, a taxonomic system was constructed which conforms to the evolution of plant life since its beginning.

Lower plants (thallophytes) do not have any defined organs: they include:

1. schizophytes (bacteria and bluegreen algae)
2. algae
3. fungi (fungi and lichens)
4. mosses

Higher plants (cormophytes) consist of roots, stems, and leaves: they include:

5. vascular cryptogams (ferns, horsetails, club mosses)
6. seed plants (gymnosperms, angiosperms—flowering plants)

In the systematics of Müller and Loeffler (1971) and Weberling and Schwantes (1972) the fungi (Mycobionta) are divided into:

1. slime molds (Myxomycota)
2. true fungi (Eumycota)
   a. lower fungi, Phycomycetes
   b. Ascomycetes, } collectively called
   c. Basidiomycetes, } higher fungi.

Our edible fungi belong to the Ascomycetes and Basidiomycetes. We name the Basidiomycetes according to the structure of their fruiting bodies.

The **gilled fungi** consist of a cap and stalk; the stalk may be missing in laterally attached fruiting bodies. The spores are bore on the gill-like lamellae on the underside of the cap. To this group belong most of the edible fungi, such as *Agaricus, Stropharia, Lepiota, Tricholoma, Marasmius, Collybia, Pleurotus.*

The **boletes** have a spongy layer composed of tubes on the underside of the

cap. The spores are formed in the tubes. To this group belong the delicious *Boletus edulis, Boletus badius, Leccinum scabrum.*

The **polypores** generally do not have a stalk. The layer of pores on the underside of the cap is usually fused tightly with the flesh of the cap. The majority of these species is not edible; only a few soft-fleshed species, such as the sulfur polypore, are good to eat when young.

The **toothed fungi** have a cap and stalk. Soft points, on which the spores develop, project from the underside of the cap. *Sarcodon imbricatum* and *Hydnum repandum* belong here.

In **chanterelles and their allies** the stalk merges with the cap. On the underside of the cap are low thick lamella-like ridges on which the spores form.

The **coral fungi** have coral-like fruiting bodies, on whose branches the spores arise. All species are to be eaten with care, including *Sparassis crispa* and *Clavulina.*

**Puffballs and their allies** form their spores within the usually spherical to flask-like fruiting bodies which release the dustlike spores generally through a pore. *Lycoperdon perlatum* and *Bovista plumbea* belong here.

## Nutrition

Almost all plants are autotrophic, that is, from inorganic substances they themselves make the substances necessary for the structure of their bodies and for respiration. Carbohydrates (sugars, starches) are made from water taken

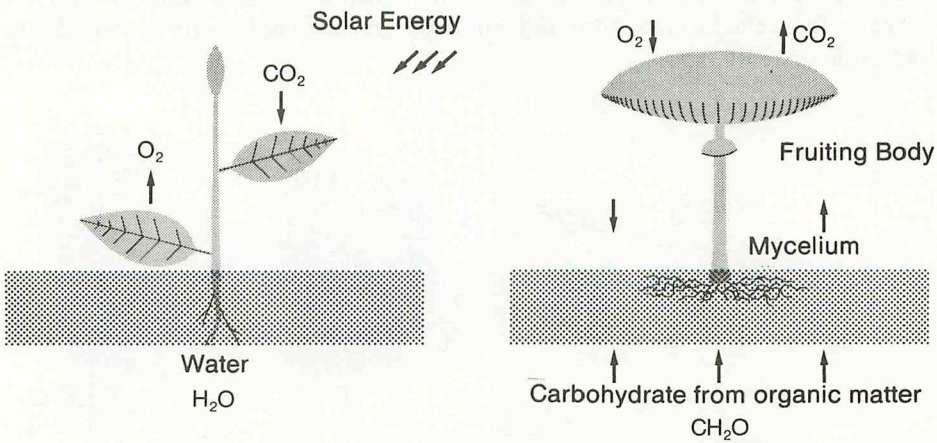



*Fig. 2. Simplified diagram of energy acquisition by a green plant (autotroph) and in a higher fungus (heterotroph)*

up from the ground and carbon dioxide from the air, with the aid of the sun's energy. This process is possible only when living chloroplasts are present in the cells of a plant. Therefore, only green plants are autotrophic. In contrast, all animals and those plants not possessing chlorophyll are heterotrophic, because they depend on the availability of organic substances. Their own bodies are constructed from them, and they obtain their necessary energy from them during respiration.

Since fungi do not have chlorophyll, they need foreign organic substances for their structure. If these are acquired from dead plants, we call these fungi **saprophytes;** if they are taken from living plants, we call them **parasites.** When heterotrophic and autotrophic plants form an association, we call it **symbiosis** (living together), since nutrients are exchanged between both types of plants. A typical example of symbiosis is the lichens, which people formerly thought to constitute their own group of plants until they discovered that lichens were associations of fungi and algae which occur in thousands of forms.

Another type of symbiosis is especially important for the cultivation of fungi. Most forest trees (broadleaved and coniferous trees) grow in association with forest fungi. As early as the Devonian, mycorrhizal fungi, as they are called, lived demonstrably in symbiosis with the psilophytes. The name **mycorrhiza** (fungus root) denotes the fact that the fungi replace the root hairs of the trees. While roots of plants are usually covered on their tips with delicate root hairs, in mycorrhizae we find thick root ends, branched like coral, which are wound thickly about with the filamentous network of the fungal mycelium. The fungus is furthered in its development by the contents of the tree roots and provides the tree with substances (probably nitrogen, phosphorus, and others) which it extracts from the forest humus and which the tree cannot take up by itself in the available organic form.

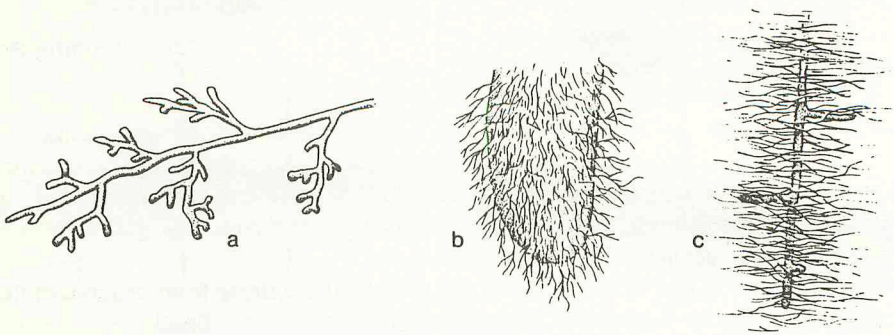



*Fig. 3. Mycorrhizae or fungus roots (a and c) root tip with mycelium wound around it (b)*

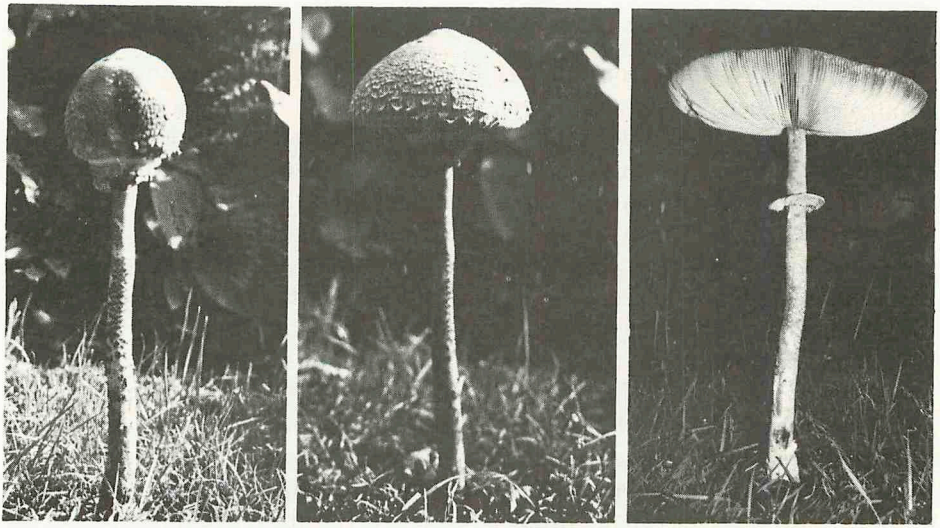


*Fig. 4. Stages of growth of the parasol mushroom*

Numerous species of fungi form mycorrhizae. Often, like the chanterelle, they are not strictly bound to one species of tree, although they usually prefer either broadleaved or coniferous trees. However, various species grow only in association with a particular species of tree, such as *Suillus grevillei* with the larch or *Leccinum scabrum* with the birch. Pure cultures of these symbionts do not produce fully-formed fruiting bodies; they can be formed only when the fungi are in association with their partners. This is the reason it is so difficult to cultivate *Boletus edulis*, chanterelles, and similar species, while it is easily possible with the common cultivated mushroom, a pure saprophyte.

What is customarily referred to as a mushroom is only the fruiting body, usually visible above the ground. The actual fungus is an extensively branched network of fine threads, which is referred to as the **mycelium.** The individual threads are called **hyphae.** They penetrate the nutrient-rich substrate and proliferate throughout it in all directions to take up nutrients, and because of their large collective surface area, they can take up considerable quantities of nutrients quickly. Structures similar to true tissues can originate through the fusion of numerous adjacent hyphae within the mycelium. The fruiting bodies known to everybody form in this way, as do even the hard durable structures of many fungi which can last for years.

## Life cycle

Fungi do not develop from multicellular seeds, like higher plants, but from single-celled spores which are formed on the fruiting bodies by constrictions. When moisture is available, a thin colorless tubular structure grows out of the spore and branches repeatedly in all directions to become a filamentous network. It can grow in one particular direction so that later the fruiting bodies stand next to each other in rows, or equally in all directions so that circles form on whose outer periphery the fruiting bodies develop in a ring. The rings are recognizable even in seasons when fruiting bodies do not form, because the grass is usually darker-colored in the places invaded by the mycelium. Before people knew what caused these ring formations, they supposed that they were due to nocturnal dances of elves or witches and called them fairy rings (Shakespeare alludes to them in *A Midsummer Night's Dream*).There is a second form of fairy rings, which originates from mycorrhizal fungi. Since the latter are to be found especially abundantly on the outermost root tips, and the underground extent of the roots corresponds approximately to the aboveground extent of the crown, the most vigorous mycelium develops under the eaves of the tree and causes the same visual effect as true fairy rings.

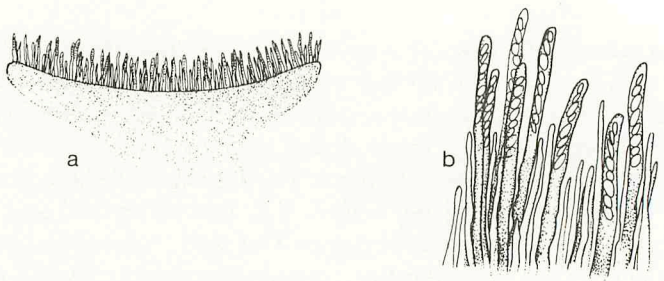



*Fig. 5. Ascomycetes: fruiting body and spore sacs (asci) with spores*

Thicker threads and strands form small knots on the mycelium of the mushroom. From these, under favorable conditions, develop the fruiting bodies. Because they are formed extremely fast (hence the expression "to mushroom"), they require well-developed conducting hyphae which can transport much water and nutrients. The form of the fruiting bodies is extremely variable: they have the task of forming the spores necessary for reproduction.

In the ascomycetes the spores develop in tubular spore sacs, each of which contains eight spores; in the basidiomycetes four spores generally arise exposed on the surface of usually club-shaped supports or basidia.

To the ascomycetes belong the yeasts, many molds, and numerous pathogens which attack our useful plants. Of the edible fungi, truffles, cup fungi, morels, and saddle fungi are members of this group.

To the basidiomycetes belong the mushrooms, puffballs, and earlobe fungi, along with the rust and smut fungi which cause diseases of our cultivated plants.

People who would like to cultivate fungi must acquire some knowledge of their structure, life history, and living requirements. They must be able to imagine what it is like to be a fungus in order to understand the reaction of fungi to various culture methods.

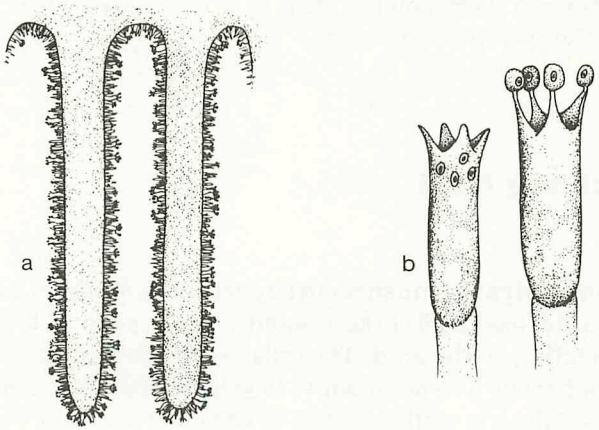



*Fig. 6. Basidiomycetes: lamellae with basidia (a), basidia with spores (b)*

# Mushrooms for the garden

## Edible fungi suitable for cultivation

Since until now relatively few mushrooms have been cultivated in the garden, the number of species which have been tested for cultivation is correspondingly small. Success in cultivating them is considerably more strongly influenced by climate, soil conditions, and the surrounding plants than when vegetables, fruits, and ornamental plants are cultivated.

Therefore, the species described here can represent only a selection of mushrooms whose culture seems, on the basis of present experience, promising of success under the specified conditions.

## Humus-inhabiting fungi

*Gilled fungi*

The **common cultivated mushroom** (*Agaricus bisporus*) is a medium-sized mushroom whose cap is 12-15 cm across and is white, yellowish-white (blonde), or brown, depending on the kind. The gills are delicate pink when young and later turn dark brown. The stout white to yellowish stalk is 6-8 cm long. The firm but delicate flesh is white at first, later yellowing somewhat, and sometimes turns reddish when bruised. It smells pleasant and tastes mildly nutlike.

This species is prized throughout the world as a cultivated mushroom and is grown in numerous countries. It was first found around 1600 near Paris on horse manure which was used for growing melons. It turned out that mushrooms could be grown deliberately on rotted horse manure if it were mixed with trimmings from the mushrooms and wash water from mushrooms were poured over it. The intensive culture in climate-controlled culture rooms which is usual today developed over the centuries from cultivation out of doors. Altogether about 900,000 tons of this mushroom are harvested yearly throughout the world.

In the wild this mushroom is found in meadows, wastelands, and gardens. The common cultivated mushroom is suitable for growing in gardens on the north side of asparagus hills or on mounds of earth between rows of dwarf fruit trees. For details on culture methods see "Cultivation of the most important edible fungi".

Although one can buy this delicious mushroom in stores everywhere, one should try growing it in one's own garden. The mushrooms raised there are very aromatic and vitamin-rich and, fresh from the garden to the pan, a special delicacy.

The white to yellowish cap of ***Agaricus edulis*** (= *Agaricus bitorquis* = *Psalliota edulis*) is flattened and thick-fleshed, with a diameter of 10-15 cm; its gills are pink, later dark brown. The stalk is stout, the firm flesh white and light reddish when cut; it smells pleasant and tastes nutlike. This aromatic mushroom keeps well, especially before it opens, and is suitable for storing and preserving.

In Europe *Agaricus edulis*, like *Agaricus bisporus*, is cultured commercially in special climate-controlled rooms and is ready to harvest in eight weeks with a yield of up to 20 kg per $m^2$. Because of its tolerance for high temperatures (optimal growth at 30°C) it is suitable for cultivation in southern countries. It is very resistant to fungal pathogens and resistant to viruses.

A tropical species (*Agaricus subedulis*) forms fruiting bodies at any time of year in dried-up riverbeds after downpours; this species is also cultivated in central Africa on compost of savanna grass mixed with sheep, horse, or cow manure.

*Agaricus edulis* forms fruiting bodies from May to fall; it is found in front yards and orchards, on paths and roadsides, but only rarely in forests. It breaks through hard ground and can lift paving stones up and force asphalt open. In the garden this mushroom is suitable for cultivation on the north sides of asparagus hills and the mounds of earth between rows of dwarf fruit trees. It thrives also in lawns and along the edges of border shrubbery. Since it tolerates temperatures up to 35°C and can form fruiting bodies even at 5°C, it is better suited for growing in the garden than the common cultivated mushroom. The best substrate to use in hill cultivation is a compost of horse manure or straw (for preparation of compost see "Cultivation of the most important edible fungi").

In lawns, small disks are cut out with a spade, and composted horse manure inoculated with grain spawn is put in the holes. The disks of sod are then replaced. After about 2-3 months the first fruiting bodies can form. Acid soils are not suitable. Grain spawn can be purchased under the name "Psalliota

edulis Vittadini". This mushroom is especially recommended for growing in gardens because it can be harvested for several months, has an outstanding aroma, and its whiteness contrasts well with the green of the grass and brown of the soil.

The **horse mushroom** (*Agaricus arvensis* = *Psalliota arvensis*) is a medium-sized mushroom with a white cap 5-15 cm wide with gills light gray at first, then reddish and later dark brown. The white stalk is 6-15 cm long. The firm but delicate flesh is white when young, later yellowing somewhat; it smells pleasantly of anise and tastes mild and nutlike. In preparing it for cooking, the dark lamellae should be removed.

It generally grows gregariously in open forests, in clearings, in forest glades and cow pastures along the forest edge, and also under shrubs in park grounds. It forms its fruiting bodies in wide rings from July to October.

In gardens it is introduced under ornamental shrubs and conifers adjoining lawns. It likes deep humus-rich soil with a pH of about 7.0 (never acid) and not too dark a location. In the spring one adds a mixture of limed peat and chopped straw or composted horse manure to the soil in the desired places and mixes it well with grain spawn. For protection against heavy rain one should lay a plastic sheet over the substrate until the mycelium has permeated it. A few weeks later, after removing the sheet, cover with 5 cm of humusy soil.

Cultivation of this highly prized, delicate edible mushroom, with its bright white caps, is greatly recommended, especially since it can form fruiting bodies from early summer until fall, if the soil temperature is high enough.

The **field** or **meadow mushroom** (*Agaricus campestris* = *Psalliota campestris*), also called pink bottoms, is a medium-sized edible mushroom with a white cap and pink lamellae which later turn dark brown to black. It is 5-10 cm across. Its stalk is 5-8 cm long, white, later becoming darker. The white flesh turns somewhat pink, especially when old, and is delicate and soft. It smells pleasantly spicy and tastes mildly nutlike. In preparing it for cooking, the brown lamellae are cut away.

It is found between June and September in cultivated fields (especially after the ground is broken), cow pastures, meadows, and lawns. Especially in warm dry years, its white caps often shine out everywhere in great numbers in green grass after abundant rain, appearing usually in groups but also in fairy rings.

In gardens it will thrive best in lawns which are not too acid and therefore do not grow moss. A good dressing of the lawn in fall with humus (limed peat, rotten horse manure, or old mushroom compost) is recommended. In spring one should cut out disks of turf here and there, dig out about 10 cm of the soil from

under them, add a peat-straw substrate or mushroom compost, inoculate this with spawn, and then replace the disks. If weather and soil are favorable it may suffice to lay ripe mushrooms, cut in late summer and with good spore-set, on the lawn and cover them with some leaves to enable the spores to germinate there. Where mycelium develops in the soil, the grass is a darker green.

This delicious aromatic mushroom enriches our garden, and even at times when no fruiting bodies are to be seen it often enlivens lawns with its dark-green fairy rings.

The **scaly wood mushroom** (*Agaricus silvaticus* = *Psalliota silvatica*) is a medium-sized edible mushroom which has a light-brownish scaly cap 4-10 cm in diameter, with lamellae which are pale pink at first and later become dark brown, and a generally white stalk which is 6-10 cm long. The whitish flesh turns brownish in age and becomes blood-red when injured; it has a pleasant odor and a mild flavor. To keep the food it is cooked with from turning brown, the dark lamellae are cut off.

This mushroom usually grows in troops in spruce forests or in mixed forests under spruces. It is found especially under the vigorously growing trees at the edge of the forest, in thick needle litter from which often only the cap projects.

In gardens it will grow best under spruce hedges and fairly small groups of spruces, since it does not thrive in full shade. The ground under the needles should be well limed because of its preference for limy soil. One should never under any circumstances remove the covering of needles from under the trees, but instead increase it with additional needle litter. A mixture of rotten needle litter and lime-rich soil should be inoculated with mycelium and then covered with a layer of spruce needles.

This good edible mushroom, which forms fruiting bodies from July to October, does especially well under evergreen spruce-hedges and enlivens the monotonous brown needle litter.

The **common wood mushroom** (*Agaricus silvicola*) has a white to yellowish cap 5-10 cm across, with light gray, somewhat reddish lamellae which later turn dark brown. The white stalk is 6-12 cm long. The flesh is white when young and later becomes dark; in the stalk it becomes brown to blackish in age. It smells pleasantly sweetly of anise, has a mild flavor, and is well suited for making mushroom salads.

Because of its resistance to soil nematodes, attempts have been made in France to cross it with the common cultivated mushroom.

The mushroom grows solitarily and in groups, sometimes in rows but also in

fairy rings, in broadleaved and coniferous forests. It likes finely divided forest humus and thick leaf and needle litter.

It will thrive in gardens in partial shade under not-too-dense border shrubbery and thrust its medium-sized caps through the leaves covering the ground. It also finds a favorable habitat under vigorously growing blackberry hedges where the leaves are not dug under. A well-developed humus layer is necessary for good growth.

This delicious mushroom, which is found from late spring to fall, can bring us a flavorful, although usually small, harvest.

The **prince** (*Agaricus augustus*) is a large mushroom whose dark-brown-scaled cap becomes 10-30 cm across; the lamellae are pink, later brown to black. The white to brownish stalk is 10-20 cm long and becomes 2-4 cm thick. The white flesh turns more or less brownish; it smells of anise and has a mild taste.

This mushroom is found usually gregariously in coniferous forests, especially near spruces. In the garden it would do well under groups of spruces and spruce hedges.

This delicious edible mushroom, which produces fruiting bodies from August to October, is especially effective, for it is larger than all other species of *Agaricus*.

A large edible mushroom is ***Stropharia rugoso-annulata*** (= *Stropharia ferrii*), with a yellow-brown to dark-brown cap 15-18 cm in diameter. The lamellae are pale bluish at first, later darker; the stalk is whitish to brownish, 8-12 cm long and 2-4 cm thick. The white flesh is somewhat yellowish under the surface of the cap. It smells slightly of radish and in young mushrooms has a mild flavor which often becomes unpleasant in old ones. During preparation for cooking, the surface layer is usually peeled off and the lamellae are removed. This mushroom can be cut into small pieces and preserved and then used for soups and sauces; it tastes good mixed with species of *Agaricus* or as an accompaniment to game.

This species is cultivated in rather large numbers in East Germany, Berlin, and Austria. New culture methods have been tried, and spawn of cultivated varieties has been produced in fairly large quantities. An increase in its cultivation can be expected.

One can find this species growing naturally from June to October in gardens and on rotten straw from old haystacks and so on.

Regular cultivation of this species is recommended for gardens, since culture methods are already known for it and spawn can be obtained commercially.

Cultivation can be carried out most favorably in orchards between rows of dwarf fruit trees or in vegetable gardens between runner beans or rows of tomatoes, since the shade of these cultivated plants keeps the soil there from drying out too much. Moreover, such places usually have provision for watering in dry spells. A detailed description of culture methods follows in the chapter "Cultivation of the most important edible fungi".

Because of its suitability for regular cultivation and its high yields, one should not omit this species from the garden, even if its taste cannot compete with that of *Boletus edulis* or *Agaricus*.

A small edible mushroom with a sticky green cap which later turns yellowish is ***Stropharia aeruginosa.*** The cap is 4-8 cm across and has gray, later brown, lamellae. The greenish stalk has a length of 5-8 cm and is 0.5-1 cm thick. The pale, whitish flesh is soft, smells slightly of radish, and has a mild flavor. This mushroom is best used mixed with others.

*Stropharia aeruginosa* grows on the edges of broadleaved and coniferous forests, in pastures and grassy places, in orchards, and on pathsides. Its fruiting bodies appear gregariously, often in clusters, in fall until November.

In the garden it is most favorably established under open hedges and on the edges of border shrubbery under which a thick layer of coarse humus has formed from the fallen leaves. A substrate made from rotted leaves and some peat can be inoculated with mycelium and then put under the humus layer. It also grows well on rotting stems.

This little mushroom can be very effective in enlivening the brown leaf or needle layer with its green caps; thus it serves to enrich the garden with color despite its low productivity.

The **wood blewit** (*Lepista nuda* = *Tricholoma nudum* = *Rhodopaxillus nudus*) is of medium size. Its cap is 6-15 cm across, intense blue-violet to brown-violet when young, later fading to brownish. The lamellae are violet at first and later brownish. The blue-violet stalk is 1.5-2 cm thick and 6-8 cm long. The flesh is violet at first and later fades; it smells sweetish to pleasantly radishlike and tastes mild and sweet-sour. This mushroom is especially suitable for mixing with others and for drying; it should not be eaten raw.

It grows principally in broadleaved and coniferous forests, especially along the edges, also in park shrubbery where the soil is abundantly covered with needles or rotten leaves. It usually occurs gregariously and is almost always arranged in rings; since the mycelium grows equally in all directions in the soil, it very often forms fairy rings. Frequently it is found in association with *Clitocybe nebularis*.

This species is restricted to humus and therefore needs thoroughly decomposing leaf or needle litter in order to thrive; it does not grow on marshy soil.

In addition to leaf litter (except poplar leaves), sewage sludge has been used as a culture substrate with good success. Back in 1946 spawn was brought into parks where the soil had been mixed with leafy humus, and every year fruiting bodies could be harvested there in fall, especially in places which had been fertilized with fresh organic refuse. For cultivation in cellars at about 12°C, a substrate of 7 parts fir needles, 1 part alder leaves, and 2 parts horse manure is recommended. Spawn has been produced repeatedly and has proved to keep well. In gardens the mushrooms will do best under border shrubbery and groups of conifers which have a thick humus layer underneath. The mycelium develops best at temperatures of 15-20°C.

This useful and productive edible mushroom, which thrives even in late fall (forms fruiting bodies from September to December, most favorable temperature ca. 10°C) and is not attacked much by maggots, should also find a place in the garden because of its splendid coloration.

**St. George's mushroom** (*Tricholoma georgii* = *Tricholoma gambosum* = *Calocybe georgii* = *Calocybe gambosa*) has a cream-white to pale yellow cap 6-15 cm in diameter. The lamellae are white. This medium-sized mushroom has a white to flour-colored stalk 5-8 cm long and 1.5-3 cm thick. The whitish flesh is soft, fibrous only in the stalk, thick and pleasantly mild-tasting; it smells strongly flourlike. One should mask the strong odor and taste by adding spices or herbs.

This species is especially at home in meadows, pastures, and other grassy locations. It rarely occurs in forests, but it comonly grows in grassy places along the edges of forests and on forest paths. It is also found in moorlands and in park grounds under shrubbery. It usually grows in fairy rings, horseshoe-like semicircles, and in rows. The mycelium growing in meadow soils enhances the growth of grass and herbs, so that the places where it grows show up dark green. Its fruiting bodies appear in spring and early summer (April to June).

It can thrive in orchards in grassland, in parks in grassy areas and into the bordering shrubbery, and on lawns which are not mowed too often. The soil should not be acid but at least neutral. Spawn should be put in the soil in grassy spots in partial shade.

Since *Tricholoma georgii* produces its bright white fruiting bodies in succulent grass very early in the year, shortly after the morels, it is a very prized edible mushroom in spring.

The **man on horseback** (*Tricholoma flavovirens=Tricholoma equestre*), also called the yellow knight fungus or the canary mushroom, is a medium-sized edible mushroom with a yellow to yellow-green cap 4-10 cm across, whose lamellae are sulfur-yellow. The stalk is yellow, tinged with green, 4-6 cm long and 1-2 cm thick. The whitish to yellowish flesh is bright yellow under the surface of the cap; it smells slightly of flour and tastes pleasantly cucumberlike. This superior edible mushroom is suitable for every method of cooking and preservation.

It is at home in sandy pine forests and moorlands, more rarely in spruce forests. It usually lies nested deep in the needle litter, lifting the needles only slightly, and can be harvested from August to November, often in great numbers.

It can also produce good harvests in the garden on sandy soil under pines in the heath garden, and under groups of spruces. If the soil is limy, the subsoil should be made acid by mixing in decomposed needle litter or soil derived from decomposed needles before this mushroom is introduced. Then a mixture of partly decomposed pine needles and some peat, which has been previously inoculated with mycelium, should be put on the soil and covered with a loose layer of needles. Well-drained sandy subsoil, moisture, and shade are necessary.

This outstanding edible mushroom can bring us a good harvest in fall under conifers.

The **field blewit** (*Lepista personata=Rhodopaxillus personatus=Tricholoma personatum*), also called blue-leg, is a medium-sized mushroom. The cap is 6-12 cm wide, pale lilac to brownish, and the initially whitish lamellae change color through pale lilac to brownish; the stalk, glowing in splendid lilac, is about 8 cm long. The flesh is whitish, smells acidic when fresh, and has a mild flavor. This often productive edible mushroom is delicious when young; however, brownish parts should not be eaten.

The field blewit is found in damp meadows, in cow pastures, and in grass in orchards. It hardly ever grows in coniferous forests and only rarely in broad-leaved forests, but it does grow in shrubbery outside forests and also in riparian forests near stream- and rivercourses. In late fall until frosty nights begin, one finds the fruiting bodies in meadows among the grass and herbs. They commonly form fairy rings which stand out in the grass because of their strong dark-green color. The chief time of harvest is October to November.

In the garden, orchards which are in grass and have enough moisture would be suitable for this mushroom. Lawn areas in parks or gardens, if they are no longer cut in the fall, can be a suitable habitat, possibly also open shrubby borders adjacent to the lawns. This splendidly colored, frost-resistant mushroom can add further enrichment of color to the garden in late fall and winter.

The **amethyst deceiver** (*Laccaria amethystina*) can also bring us much color in shady places. It is entirely blue and forms its 2-4-cm-wide fruiting bodies from July to September in broadleaved and coniferous forests. In the garden this little edible mushroom can produce blue flecks of color on the humusy soil as if by magic, especially under groups of trees and border shrubbery in the ornamental tree-mushroom garden.

The **parasol mushroom** or pasture mushroom (*Macrolepiota procera* = *Lepiota procera*) is a very large member of the gilled fungi. The soft brownish cap, 10-30 cm wide, has ochre-brown scales on a pale background. The lamellae are white to whitish. The stalk is 10-30 cm long and about 1-2.5 cm thick, with zones of brown scales on a white background. The flesh is white, in the cap very delicate and soft to flaky (leathery when old), in the stalk firm and granular and later woody and fibrous. In the young "drumstick stage" it is among the most flavorful of mushrooms. The odor is not unpleasant, mildly acid, and aromatic; the taste is nutlike and rather sweetish.

The caps are a delicacy when they are breaded and fried like cutlets. The parasol can also be cut up and dried. The raw mushroom tastes very pleasantly like hazelnuts but does not always agree with people when raw and should therefore not be consumed uncooked.

One often finds especially beautiful individuals of this splendidly handsome mushroom in open grassy places in forests, e.g. pine forests, partly sunny places at forest edges, clearcuts, and forest paths. In gardens and park grounds also, frequently under solitary trees, they stand like open umbrellas. In contrast, they are rarely found on poorly fertilized meadows and fields. Usually only a few mushrooms occur together; they are found gregariously but are sometimes in fairy rings. The fruiting bodies appear from July to October.

In gardens and parks these often plate-sized mushrooms standing on tall slender stalks are most effective in highly visible open sunny places, at the edge of shrubbery, or under solitary trees in lawns. These mushroom giants have also been cultivated on compost heaps. Sandy subsoil and adequate moisture seem to favor their growth.

This giant parasol mushroom is not only an outstanding edible mushroom but also a splendid eye-catcher, both in the young stage when it extends its caps, still rounded like drumsticks, out of the grass, and when old, when the huge umbrellas attract all visitors' eyes to themselves.

The **shaggy parasol** or woodland parasol (*Macrolepiota rhacodes* = *Lepiota rhacodes*) is only medium-sized. Its cap generally has brown scales on a gray-

brown background and is 8-15 cm in diameter. The stalk is 10-15 cm long, pale to brownish. The white flesh turns saffron-red when broken. The mushroom is edible and is truly flavorful when young, especially fried, but somewhat tough when old. The tough stalks are not usable. The flesh is soft, the taste mild, the odor faintly aromatic.

This parasol is much more gregarious than the giant parasol and sometimes occurs in fairly large troops or in fairy rings under spruces, especially at the edges of forests and along forest paths in the thick needle litter. However, it also occurs in parks and gardens and on compost heaps. Its fruiting bodies appear from July to November.

In gardens it can be cultivated in composting places. The topmost layer of compost is mixed with peat, and spawn is scattered over it and covered with wet soil; or the wash water and trimmings of parasols are put on the compost, and leaves are thrown over them. One can also try establishing it under spruce hedges which are not too dense and under groups of conifers in soil which has been improved with peat.

Since the mushrooms are very delicate when young, one should take into consideration any use of the compost heap during the time this parasol is being cultivated.

**Clouded agaric** (*Clitocybe nebularis*) is the name of a common medium-sized mushroom. The thick-fleshed, light gray cap has a diameter of 7-15 cm; the lamellae, which are easily detached from the flesh of the cap, are whitish to yellowish. The whitish to brownish stalk is 7-10 cm long. The white flesh, which does not discolor, is thick and firm when young, later becoming soft and spongy; the surface is easily peeled off. The odor is strong and spicy, but it is often perceived as unpleasant. The taste is acidic and mild, but it does not please everybody; accordingly, one should use this only mixed with other mushrooms, for which purpose it is very useful. It is advisable to use only young mushrooms, scald them before preparing them, and pour off the water. Do not harvest them after the beginning of frost.

In broadleaved and coniferous forests the gray mushrooms often break through the thick leaf and needle litter in great numbers. They are almost always found growing gregariously, often in association with the wood blewit, usually in rows or in extensive dense fairy rings. The clouded agaric lives only in humus and is not dependent on the species of tree cover. It is encountered from September to November in woodlands, brush, and parks.

It can thrive in the garden under border shrubbery and bushes, if the leaves are not dug under but instead cover the soil as a thick layer of humus. Since it is best cultivated on beech leaves, it is advisable first to place a layer of decom-

posed beech leaves on the soil where one wishes to establish it and to inoculate them with spawn.

Since the clouded agaric is a very productive edible mushroom which does well in good humusy soil under shrubbery, introducing it seems useful even if it does not meet high standards of palatability.

***Clitocybe geotropa*** is a large agaric with a light ochre to leather-colored cap. The cap is 10-20 cm across, has ochre-colored lamellae, and is enthroned on an ochre-yellow stalk 2.5-3 cm thick and 8-20 cm long. The flesh is whitish to faintly brownish, firm when young and soon becoming tough; it is resistant to attack by rot-causing organisms. The taste is mild, the odor pleasantly spicy. Once the mushrooms have become funnel-shaped, they are tough and lose their pleasant taste; one should therefore eat only young ones and be sure to cut away the stalks of older individuals.

The substance clitocybin which is present in Clitocybes has a bactericidal effect; for this reason rot does not occur near fairy rings.

This autumn mushroom, which is conspicuous in the forest because of its size, is not dependent on the kind of soil or trees of its habitat; it likes humusy soil. It grows in damp forest meadows with abundant herbs, in riparian forests, and in pastures, often in rows and fairy rings. Harvest season is September to November.

This attractive mushroom can enliven the ground in one's garden among the colorful autumn leaves in damp orchards, in grassland, and in damp humus-rich places between groups of shrubs.

The **shaggy mane** or lawyer's wig (*Coprinus comatus*) has a peculiar egg-to candle-shaped, cylindrically elongated cap. The cap, which is snow-white at first with a pale ochre apex, disintegrates after a short time to become black and inklike (hence the common name inky-cap for this genus); it is about 5-15 cm tall and 3-6 cm across. The initially white lamellae gradually turn pink and later disintegrate to become ink-black. The white stalk is 10-20 cm long and 1-2 cm thick. The white flesh of the cap and stalk is rather fragile and very delicate; in the young stage, when the lamellae and cap are still snow-white, the mushroom is very delicious. The odor is pleasant and faintly radishlike, the taste mild. It does not store well; it should keep overnight, but only if immersed in salt water. The mushroom is especially flavorful in soups and sauces and yields a good mushroom extract. Since other species of inky-caps can cause circulatory problems when consumed with alcohol, it seems a good recommendation to avoid alcohol also when consuming the shaggy mane.

This inky-cap lives on rubble-covered ground and is often found in large numbers in new park grounds and sports fields, in old composting places, and in areas freshly sown with grass. It is also frequently seen along roadsides and in meadows and lawns. It usually grows gregariously or in clusters and likes fertile nutrient-rich soil.

This mushroom can enliven our often monochromatic garden lawns with its candle-shaped caps; it can adorn the bare garden soil between shrubs and borders with patches of white, and produce crops on compost heaps and garden beds from April to November. Fertile nutrient-rich compost soil is suitable for its culture; manured places are not usable, as they promote the growth of other species of inky-caps (culture, p. 122).

The **fairy-ring mushroom** or Scotch bonnet (*Marasmius oreades* = *Marasmius caryophylleus*) is a frequently found small mushroom. The ochre-yellow to brownish cap is 2-6 cm across and has pale brownish lamellae. The thin (0.3-0.5 cm), firm, likewise pale-brownish stalk is 4-8 cm long. The thin flesh is light brownish, smells pleasantly spicy, and tastes mild and nutlike. The stalk is not edible; it is so tough that one can pull the mushroom out of the earth. Although the mushroom is small, it is nevertheless productive because it occurs so abundantly. The mushrooms can dry out during dry periods and swell up again during rainy weather and continue growing.

This delicious edible mushroom is suitable for frying, soups, drying, and making mushroom powder. The tough stalks and old mushrooms re-softened after rainy weather are not used. Harvest time extends from June to October.

They are found growing gregariously to clustered and often in rows and large fairy rings on grassy paths between cultivated fields, in meadows and pastures, and on the edges of forests. One also finds this mushroom in reforested areas in semi-shade in turf.

In gardens the fairy-ring mushroom will find a suitable place in grassy paths, lawns, or orchards which have grown up in grass, and will form its mysterious fairy rings. Since damage can occur in lawns during severe dryness, it should be introduced only where abundant moisture is available. If we want to start a permanent culture in the kitchen garden, we can dig shallow trenches in the open strips under rows of fruit trees, add a mixture of sawdust and cow manure, inoculate it with spawn, and then cover it over with garden soil.

The **garlic mushroom** or mousseron (*Marasmius scorodonius*) is a seasoning mushroom. This tiny mushroom has a pale brown, somewhat wrinkled cap

1-3 cm in diameter; the lamellae are whitish to brownish; the thin (0.1-0.2 cm) stalk is 3-6 cm long, brown, bare, and hard. The flesh is pale brownish and very thin. It is highly prized as a seasoning mushroom, especially for mutton and roasts, since it smells and tastes strongly of garlic. When dried it can hold its flavor for a long time. It should be added to hot dishes at the last minute, or its aroma will evaporate.

Especially after heavy thunderstorms the little mushrooms often appear in great numbers in forests and in grassy places. It grows gregariously on good humusy soil, especially on needle litter, from June to October. It must not be confused with the more common moldy-smelling *Micromphale perforans*, which has a black stalk.

At home it should find a spot in the herb garden, where it can be established in a shady place in humus which has been mixed with needle litter, broken-up twigs, and some cow manure.

Likewise suitable as a seasoning mushroom is the **leek mushroom** (*Marasmius alliaceus*). It has a black stalk which is brown above, and it grows on forest humus and rotten wood. Decomposed beech leaves and sawdust would be suitable as a substrate for it.

The **bare-toothed** or **edible Russula** (*Russula vesca*) is a medium-sized mushroom with a pink to red-brown cap. The cap is 6-10 cm across and has white, fragile lamellae. The white stalk is 3-6 cm long, firm, and about 2 cm thick, tapering somewhat at the base. The flesh is white and firm, almost odorless, the taste pleasant and nutlike. One should peel off as much of the surface of the cap as will come off.

This species is found from October to July in broadleaved and coniferous forests, frequently in grown-up tree farms and at the forest edge, sometimes in association with bilberries and heather, occurring singly or gregariously. It occurs usually on sandy soil but also on loamy soils.

This flavorful edible mushroom, which is initially pale when young but later usually flesh-pink, will stand out beautifully in green moss under open groups of trees and will bring color into the garden. It will also do well in the garden in light humusy earth which has been improved with beech-leaf soil. It thrives in symbiosis with beeches and other trees.

Because of its colorful effect and its good taste, one should try to find a suitable place in the garden for the bare-toothed Russula.

***Collybia butyracea* var. *asoma*** is the gray variety of the butter-cap. This small mushroom has a gray-brown cap 3-6 cm across, with pale lamellae. The gray-brown stalk is 5-6 cm long and about 1 cm thick. The flesh is whitish, soft, and watery; the taste is mild. This species, which is very useful when mixed with other mushrooms, is found in coniferous and broadleaved forests. It is very common and occurs gregariously, often in rings, from August to October.

It can be established in the garden in semi-shade, especially under conifers. The soil should be sandy and provided with adequate lime. It will thrive on a substrate of wood chips and decomposed needle litter.

The **spring agaric** (*Agrocybe praecox* = *Pholiota praecox* = *Pholiota candicans*) has small light ochre-yellow caps, 4-10 cm across, with brown lamellae. The stalk is whitish, 0.5-1 cm thick and 10-15 cm long. The flesh is soft and rather watery but nevertheless keeps fairly well. It smells and tastes flourlike. This mushroom is suitable for soups and, well seasoned and cooked in fat, as an accompaniment to the noon meal.

It occurs in forests, along the edges of cultivated fields and paths, and in lawns and gardens, frequently on soil fertilized with stable manure. It forms fruiting bodies from mid-May, when the soil temperature has reached ca. 12°C, into summer. It occurs commonly, usually gregariously.

In the garden it completes the group of spring mushrooms. It will thrive well in places which sometimes receive sun. Improving the soil with a mixture of wood chips and barley chaff, such as is often done when growing mushrooms in cellars, perhaps fertilized with spent commercial-mushroom compost, creates a favorable substrate for the growth of the spawn.

*Chanterelles*

One of the best-known edible fungi is the **chanterelle** (*Cantharellus cibarius*). This small mushroom, which occurs in crowds, has a yolk-yellow, funnel-shaped cap 2-8 cm in diameter, with ochre-colored ridges. The yellow stalk is 2-6 cm long. The yellowish-white flesh is very firm, almost tough. Larger mushrooms should be cut quite small during preparation, since they are otherwise hard to digest. The odor is spicy with an apricot-like aroma; the taste is strong and rather pepperlike. The chanterelle almost never has maggots, keeps well, is versatile to use, and is well suited for preserving in jars.

This mushroom, usually grouped in fairly large numbers and shining yellow out of the green of moss and grass or the brown needle litter, occurs from July in broadleaved and coniferous forests. It is found in open grown-up tree farms

under pines, spruces, and beeches in forest grass and moss, in spruce thickets among bilberries, in thick cushions of moss, and in the needle litter. Since its mycelium grows mostly in the topmost layer of the soil or humus, it is destroyed when the moss and leaves are torn open and usually does not recover. The fruiting bodies should therefore not be pulled up but should be cut off.

In the garden one would like to see this aromatic mushroom everywhere, if it could be successfully made at home there. Moss could be established especially under small dense groups of pines and spruces where the soil is enriched with needle humus, or bilberries could be grown under more open groups as an underplanting. A chanterelle garden would delight many mushroom lovers. For its cultivation see "Cultivation of mycorrhizal fungi".

In contrast to the normal form, ***Cantharellus cibarius* var. *pallidus,*** the form of the chanterelle found in broadleaved forests, occurs less on acid soils and in coniferous forests but rather in half-grown beech forests and on neutral to lime-rich soil. The light yellow cap is up to 12 cm across and has pale yellow ridges. The flesh is white, firm, delicious, and seldom attacked by maggots. Since this variety promises larger yields, the effort to establish it also in the garden, in the shade of beeches on soils covered with decomposed beech leaves, should be rewarding.

*Boletes*

***Boletus edulis,*** the Steinpilz, cèpe, or penny-bun or king bolete, is a mycorrhizal fungus, as they are called, which can form fruiting bodies only in association with particular species of trees, whose finest root hairs are closely united with the mycelium of the fungus. There are various types which are specialized for different species of trees.

The cap of the desirable spruce king-bolete is 8-25 cm across, whitish at first, later light brown, and dark brown when fully grown. The pore layer on the underside of the cap is initially whitish and later yellow-greenish. The sturdy

*Fig. 7. Bare-toothed Russula (Russula vesca)*

*Fig. 8. Fairy-ring mushroom (Marasmius oreades)*

*Fig. 9. Wood blewit (Lepista nuda)*

*Fig. 10. Parasol mushroom (Macrolepiota procera)*









stalk, 3-5 cm thick, is whitish to pale brown and has a height of 10-20 cm. The pure white flesh sometimes turns rather reddish under the surface of the cap; the granular flesh is firm, almost hard, when young, but becomes soft and spongy in age. The odor is mild and pleasant, the taste nutlike. The king bolete is suitable for all methods of cooking. It tastes outstanding in omelets or breaded and fried. Cut into small pieces and steamed with onions it can be used in numerous dishes; it also goes splendidly with roast game. Older mushrooms can be cut up and dried and thus still be used in many ways months later.

It occurs in mixed and coniferous forests, along forest edges and paths, under stands of young spruces, and in grown up tree farms, especially when heavy thundershowers follow periods of high summer heat. Severe maggot attack usually follows dry cool periods. The fly agaric frequently indicates the presence of this bolete. Time of harvest is from June to October.

The **oak king-bolete** (*Boletus edulis* ssp. *reticulatus*) has a pale brown cap and stalk. Its white soft flesh is somewhat brownish under the surface of the cap; the odor is very pleasant, mild, and delicious. It occurs especially in broadleaved forests under open stands of oaks and beeches and apears from May to July in great numbers.

The **pine king-bolete** (*Boletus edulis* ssp. *pinicola*) has a red-brown cap with an initially white, then yellowish pore layer. The thick swollen stalk is brownish and strongly netted. The flesh is soft and white, tinted reddish or yellowish in the cap, red under the surface of the cap; it becomes yellow-green on cooking. The odor is spicy, the taste mild and pleasant. This mushroom grows gregariously in mixed and coniferous forests, especially at the bases of tree trunks. Harvest season is from early summer to fail.

Establishing *Boletus edulis* in the garden will not be easy. In larger gardens, suitable places would be groups of spruces, pines, or birches, or solitary beeches or oaks. In smaller gardens a suitable place is to be found under open groups of pines or in the heath garden, perhaps also under a group or hedge of spruces.

As early as 50 A.D. people attempted to grow this bolete from remains dug up from the soil or by pouring an extract of the fungus over the ground. It is reported that in Dresden in 1883, spores of the king bolete mixed with sand were scattered over grassy areas under conifers and broadleaved trees, and that an abundance of mushrooms formed in the second year in the places so treated. In Munich also, people are supposed to have succeeded in producing king boletes by laying spore-laden fruiting bodies on the ground and covering them with leaves. The process of rotting of the fruiting bodies was supposed to

stimulate the spores to germinate. Other observers believe that the stimulation occurs in the stomachs of animals which readily eat the mushrooms. In Poland, Holland, and Japan, nutrient soil was inoculated with mycelium obtained from pieces of king-bolete tissue, and formation of fruiting-body primordia has been achieved. A substrate of peat, sawdust, and certain supplements with a pH of 4.5-5.5, high humidity, and good ventilation proved suitable for growth of the mycelium. It is indeed better to inoculate young oaks, spruces, or pines in a fungal laboratory, as in truffle culture, and then set the young plants out in the garden; in South America seed for sowing pine plantations is inoculated with *Boletus* species. Sandy soils and loamy sand with a covering of coarse acid humus are suitable.

The **larch bolete** (*Boletus elegans* = *Suillus grevillei*) is a beautiful bolete which lives only in association with larches. The gold-yellow to gold-brown, somewhat slimy cap is 7-15 cm across and has a yellow pore layer. The stalk is approximately 2 cm thick and 6-12 cm long; it is brownish below, yellowish above. The lemon-yellow flesh of the cap and stalk discolors when bruised. The flesh becomes spongy in older specimens. The odor is pleasant, the taste mild. The surface of the cap is easily peeled away; the stalk should be thoroughly cleaned before cooking.

This bolete grows in open grown-up tree farms and in the bordering meadows in the vicinity of larch roots, sometimes as far as 12 m from the nearest tree. The mycelium covers the roots of the tree with which it lives in symbiosis, whether a native or foreign species, like a thick mantle.

In the garden its growth has to be limited to places where there are larches. In good garden soil such vigorous trees generally develop that the neighboring plants are suppressed. Therefore one can establish the larch bolete only under the weeping larch (*Larix kaempferi*). Since forestry experience has shown that frequently the mycelium is already brought along with the roots of young plants, it seems that setting out inoculated trees is again the best way to establish this bright gold good edible fungus, whose harvest season extends from June to October.

The **bay bolete** (*Boletus badius* = *Xerocomus badius*) is a prized edible mushroom which, however, should not be eaten raw. This small to medium-sized mushroom has a brown cap 5-15 cm in diameter with yellow, later olive-green, pores which turn blue-green when bruised. The light brown stalk is 6-12 cm long and 1-4 cm thick. When damp the yellowish-white to brownish flesh turns blue when bruised, but when dry it frequently does not. It is firm









when young and later becomes soft, and becomes fibrous in the stalk. The faint odor is pleasantly fruitlike, the taste mild and a match for the king bolete.

Bay boletes which grow in moss are usually larger, long-stalked, soft-fleshed, and less valuable than the mushrooms growing in needle litter, which are firm-fleshed, keep well, and are not very maggoty. Its best habitat is open coniferous forest, while in broadleaved forests it is found only under groups of conifers. It prefers older stands of pines, spruces, and firs and is commonly found at the root crown of larger trees and on dry needle litter. In denser stands and at the forest edge it often grows in deep moss and thin forest grass; it forms its fruiting bodies from July to October.

It is usually suitable only for larger gardens. It can grow in the needle litter lying on the ground under groups of pines or spruces where sun can get in, and it will form better fruiting bodies there than on damp soil covered with moss and grass. It needs acid forest humus of decomposed needles and rotten wood with sandy soil beneath in order to thrive.

This excellent edible mushroom can produce good crops on the unused ground under conifers on dry needle litter, or also in moss and forest grass, and can substitute for the king bolete.

***Boletus granulatus*** (= *Suillus granulatus*) is found principally in pine forests. The yellow-brown, somewhat shiny cap is 6-10 cm across, convex, and has initially yellow, later olive-colored, pores. The stalk is 5-8 cm long, pale yellow, somewhat brownish below and covered with little granules above, and lacks an annulus. The flesh is yellowish, firm in young mushrooms, later soft; the odor is fruitlike, the taste mild. This bolete is a good edible mushroom; the surface of the cap should be peeled off before cooking.

This mushroom is found especially in dry sandy pine forests, as well as along the edges of forests, in forest glades, and long grassy pathsides. Harvest season is from June to October.

In gardens it does best on limy soil under groups of pines. Since its mycelium is relatively fast-growing, it is used in forestry for inoculating pines (see under "Cultivation of mycorrhizal fungi").

*Fig. 11. Shaggy mane (Coprinus comatus)*

*Fig. 12. Brown birch bolete (Boletus leucophaeus)*

*Fig. 13. Hornbeam bolete (Leccinum carpini)*

*Fig. 14. Larch bolete (Boletus elegans)*

The **brown birch bolete,** cow fungus, birch rough stalks, or rough-stemmed bolete (*Boletus leucophaeus* = *Boletus scaber* = *Leccinum scabrum*) is medium-sized; it has a brownish cap 5-12 cm across, with whitish, later gray, pores. The scaly gray-white stalk is slender (1-2 cm thick) and 8-17 cm long. The white flesh becomes somewhat gray where broken, dark when cooked; in the cap it is soft and soon spongy, in the stalk it is firm and fibrous. The odor is pleasant, the taste mild. When young this is a good soft-fleshed edible mushroom which is suitable as a vegetable and for use in sauces and soups.

It is solitary but common in open broadleaved forests and brush as well as in moors and heaths where birches grow. Harvest season is June to October.

In the garden, also, it can do well in the heath garden or front yard under groups of birches. Since the brown birch bolete likes partial shade, the birches, if they are free-standing, should have branches all the way to the ground if possible. The soil needs a surface layer of humus, perhaps also some ornamental grass or moss. Here also perhaps the best method would be to plant young birches which already have mycelium.

Very similar to the brown birch bolete are the **orange birch bolete** (*Leccinum testaceo-scabrum*), which thrives in mixed and coniferous forests as well as in pure birch stands and is a good edible mushroom, and the **orange-cap bolete**, *Leccinum aurantiacum*, which grows especially in broadleaved forests under aspens, hornbeams, and birches and is an outstanding large edible mushroom which nevertheless should not be consumed raw. Under hornbeams and aspens one finds ***Leccinum carpini.***

The orange birch bolete is especially suitable for mixed plantings of conifers and birches, the other two under poplar and hornbeam hedges, if the fallen leaves are not removed and a coarse humus layer is allowed to form under the hedges. The young hornbeams and poplars should already have the mycelium of their symbiotic fungi on their roots.

*Toothed fungi*

The **hedgehog fungus** or wood hedgehog (*Hydnum repandum* = *Sarcodon repandus*) and its subspecies will be mentioned as a representative of the family Hydnaceae, the toothed fungi. The medium-sized fruiting body is yellowish-white to ochre and forms the spores on light-colored points (teeth) on the underside of the cap. The cap, 6-15 cm across, sits on a short, sometimes eccentric stalk. The white flesh is fragile but granular and is well suited for frying. The odor is very pleasant, the taste of young mushrooms mild, some-

what bitter in old ones; the latter should therefore be scalded before using.

It grows in broadleaved and coniferous forests and is very commonly found under open beech stands. It occurs usually in troops but often in rows or fairy rings. Its fruiting bodies form from July to November. Since it grows slowly, its flesh keeps very well, and the caps are also usable for decoration.

In the garden it can thrive everywhere in partial shade; it grows not only on humusy soil but even on rotting wood, so that in the garden it can be found also on the logs which have been inoculated with wood-inhabiting fungi.

Since this mushroom forms its beautiful bright fruiting bodies into late fall and is usable in many ways, it can be recommended for establishing in the garden.

*Puffballs*

The **devil's tobacco pouch** (*Lycoperdon gemmatum* = *Lycoperdon perlatum*) is a puffball. Its fruiting body, shaped like an upside-down flask, is 5-10 cm high and 3-6 cm across. The surface is covered with small pointed bumps; it is white at first, later yellowish to brownish. The flesh is initially snow-white, later yellowish, and then greenish to brownish, and then breaks up into spores, which at the slightest pressure leave the outer skin through an opening at the top of the fruiting body. When young this is a good edible fungus with a mild flavor, which nevertheless should be cooked long enough to lose its rather strong odor.

*Lycoperdon gemmatum* grows in meadows and pastures and in open forests as well as beneath undergrowth. It usually grows gregariously and is found from May to November.

Since it prefers places where a humus layer does not cover the soil, it can grow well in the garden under border shrubbery when the fallen leaves are removed. Even though it is not very productive, nevertheless it is an unusual and interesting fungus which from spring to fall can provide a small contribution to meals.

*Cup fungi and morels*

The **hare's ear** (*Otidea onotica*) is a small fungus 3-5 cm high. The orange-yellow fruiting body is elongated on one side like an ear and is incised in one place all the way to ground; it is about 3-6 cm across. The thin flesh is waxlike and fragile. This is a good edible fungus which, on account of its thin flesh, does not yield much food.

The hare's ear is common in broadleaved forests and is commonly found there under beeches, where it finds the fine forest humus which it prefers. It is less

frequently found in coniferous forests, since it occurs especially on lime-rich, loamy humus soils, while it avoids the slightly acid needle litter. Harvest season extends from summer to fall. When the fully mature fruiting bodies are brought into a warm room, one sees them hurl out little clouds of spores as they warm up.

The hare's ear thrives, especially after heavy rainfall, in shady humus-rich places where the soil is constantly moist.

***Otidea leporina*** is somewhat smaller than the hare's ear and has leather-yellow to brown fruiting bodies, 2-5 cm high and 2-5 cm across, which are ear-shaped and slit. The flesh is thin, waxlike, and fragile; the odor is pleasant, the taste mild. The yield of this savory little fungus is small.

It grows generally clustered to carpetlike on needle and leaf humus, at times also on rotting wood, more in coniferous forests than in broadleaved forests. The harvest season extends from summer to fall.

Like the hare's ear, it thrives in shady, humus-rich places where the soil is constantly saturated, especially after rainfall.

A splendidly colored species of cup fungus is the **orange-peel fungus** (*Peziza aurantia* = *Aleuria aurantia*). The fruiting body, 3-10 cm across, is colored bright orange-red with a pale outer surface. The stalk is 1-3 cm long. The thin waxlike flesh is very delicate and fragile; its taste is mild, the odor very faint. Harvest season is from summer to fall.

This handsome fungus appears gregariously in forests, especially on loamy moist paths and newly graded roads and in clearings, often in great numbers. It is also not uncommonly encountered in forest glades and pastures.

In the garden, in moss or ornamental grass along partially shady pathsides this colorful little fungus, which lies on the ground sometimes like little saucers and sometimes like little plates, can delight the viewer with its beautiful color. It should always be grouped, so that the patch of color in the garden is not too small. In orchards, also, it enlivens the bare ground under the trees, especially along paths and on gravelly-loamy soil, if enough moisture is present.

This delicious little fungus does not produce great yields, to be sure, but it is delightful because of its color and decorative shape.

The **edible morel** (*Morchella esculenta*) is a medium-sized edible fungus with an ochre to gray-brown fruiting body, 3-8 cm in diameter and 5-12 cm tall. The cap is spherical to conical, and its outer surface is honeycomblike. The cartilaginous yellowish to brownish stalk is 1-3 cm thick and 3-8 cm long. The flesh of

this desirable edible fungus is white, delicate, and fragile; it has a strong aromatic flavor and a characteristically spicy fragrance. It ranks as a delicate fungus which can be used in many ways, including as a condiment when dried and ground into powder. Spells of mild dizziness have occured after meals rich in these morels. Therefore, in order to avoid trouble, boiling water should be poured over morels and then drained off after about 5 minutes, before they are cooked.

Morels appear after the first warm rains when the trees are beginning to turn green, and soon reach their full size. They prefer to grow on crumbly, limy, and humusy or loamy soils. They are found particularly frequently in riparian forests under poplars, elms, willows, and especially ash trees. They are to be expected also in ash groves, since these fungi apparently like the humus originating from ash leaves. Loose turf and a little fallen leaf litter are advantageous for their growth. Morels are also found in shrubbery in parks, along orchard paths, under hazel hedges, and on ditch banks. One can often find them year after year in the same spot.

In the garden they could thrive best under hedges and groups of shrubs where the soil is improved by adding lime, peat, and ash or poplar leaves. In well-limed orchards with grassy turf one can make a start under the rows of trees by enriching the soil with humus and introducing mycelium.

Since this is one of the earliest species of fungi to appear each year and moreover is a superior edible fungus, its presence in the garden would be desirable, even if scalding it before cooking must be advised.

The somewhat smaller **common morel** (*Morchella vulgaris*), whose cap is egg-shaped and which is similar to *Morchella conica*, also occurs on humus-rich soil in partial shade and in gardens; it forms its fruiting bodies even somewhat earlier (April to June) than the edible morel. One should try to make it at home in the garden.

***Morchella conica*** is a medium-sized fungus with gray-brown to olive-brown fruiting bodies. The pointed cap is conical to egg-shaped and has honeycomb-like chambers on the outside; it is 3-5 cm across and 5-10 cm tall, on top of a yellowish stalk 2-6 cm long. The waxlike fragile flesh is very delicious, the odor pleasantly spicy. It is also suitable for drying and for making an outstanding mushroom powder.

It occurs along the edges of coniferous forests and paths as well as in glades in coniferous forests near ferns, and in riparian forests on streambanks and in damp meadows; it also likes clearcuts and burned areas. The harvest season

begins in March to April and ends usually in May.

In the garden it can thrive in lightly shaded lawns and the bordering shrubbery, as well as under spruce hedges. It likes sandy soils which, however, should not be acid, sufficient moisture, and some sun.

Although less productive than the edible morel, this one nevertheless is preferable because of its flavor. It is a delicate spring fungus.

*Truffles*

The medium-sized **Perigord truffle** (*Tuber melanosporum*) is a true truffle and has a red-brown to black fruiting body 3-8 cm across, which at first is almost white within, later reddish-black. It is especially highly prized in France as a flavoring fungus with a superior aroma. It is harvested from September to winter.

The fruiting bodies are found in broadleaved forests near beeches and especially near oaks, with which the fungi live in symbiosis; they like lime-rich soils. The fruiting bodies grow 10-20 cm under the surface and therefore are difficult to find. Dogs and pigs are trained to search for them. Since no one has yet succeeded in cultivating truffles, semicultivation is usual today. The truffle fungus lives especially in association with oaks and can form fruiting bodies only where they grow. In France young oaks are accordingly inoculated with truffle mycorrhizae and sold to the truffle growers, who plant them in suitable places in order to harvest the valuable fungi later (inoculated hazels are also commercially available).

Thus it is possible to buy inoculated oaks or hazels and plant them in the garden. Oaks are strong-growing, however, so the garden must be big enough. If one wants to set them out in larger grounds as a solitary plant or as a group of trees, it would be advisable to use plants inoculated with truffle mycelium.

The **winter truffle** (*Tuber brumale*) forms only small fruiting bodies. They have a diameter of 1-5 cm and are rounded, warty, and red-brown on the outside, later black; they are initially whitish within, later brown. The odor at maturity is strongly aromatic. This superior seasoning fungus stores well when cut into slices and dried.

This species of truffle, which is found at the roots of broadleaved trees, principally oaks and beeches, with which it lives in symbiosis, is harvested from September into winter.

The summer truffle is preferable for cultivating in the garden, since it forms larger fruiting bodies, and since it is difficult to accommodate oaks, which require a great deal of room, in gardens of the usual size.

The **summer truffle** (*Tuber aestivum*) has medium-sized fruiting bodies 3-10 cm across; they are spherical to kidney-shaped, coarsely warty, and black on the outside, initially light brown within and later marbled with brown. The development of the fruiting bodies begins in early spring with the onset of warm weather and continues for 5-6 months until the beginning of harvest in late summer. They usually do not reach full maturity until September. They have scarcely any odor when they are harvested too early but are spicy and aromatic when mature. When dried and cut into slices, the truffles can be kept for a long time in screw-top jars and be used as a flavoring for roasts and sauces.

This species of truffle is restricted to limy soils. It is found in pure oak and beech forests and in open mixed forests, but not in understory or in woods with very grassy or weedy ground. It avoids deep shade and constant moisture; it likes loose rich soil and flat-growing tree roots, and it lies at most 10 cm deep in the ground.

Although this truffle is native also to Germany and Austria, it is not semi-cultivated as it is in France. However, it ought to be possible to inoculate young trees with mycelium and plant them in gardens in the same way here, so that we can harvest this outstanding seasoning fungus also in our own gardens. Solitary beeches, especially weeping beeches, groups of beeches, and hornbeam hedges, which are on limy ground well provided with nutrients, should be suitable.

***Choiromyces maeandriformis*** is a true truffle. The fruiting body is approximately fist-sized, 6-10 cm in diameter, whitish, later brownish, and resembles a potato tuber. It is initially smooth on the outside and later becomes fissured. The granular flesh is whitish at first, then brownish; it is odorless when young and strongly aromatic when mature. It is an especially valuable seasoning fungus which is preeminently suitable for cutting into strips and frying, as a meat and vegetable accompaniment, and for sauces and soups.

This truffle grows in stands of spruces, even thickets of young trees, in mixed forests and beech forests. In general, it prefers light loamy limy soils. It develops in the earth, and when mature it emerges somewhat from the ground, so that it is considerably easier to find than the species of *Tuber*. The fruiting bodies ripen from summer until early fall.

This species ought to be better suited to the garden than those species which lie deep in the ground and whose fruiting bodies are found only with difficulty. In this case also, inoculating young trees with truffle mycelium would be the best solution. A location under groups of spruces or spruce hedges with a soil of limy and loamy sand, where they push through the needle litter when mature and can be discovered by the attentive gardener, would be most favorable.

This species of truffle is one of the most useful hypogeous (subterranean)

fungi and deserves an especially favorable place in the garden because of its outstanding aroma.

## Wood-inhabiting fungi

*Gilled fungi*

A species of mushroom which lives saprophytically on dead wood is the **oyster mushroom** (*Pleurotus ostreatus*). The medium-sized to large oyster-shaped fruiting bodies occur in various colors, whitish to ochre-yellow, gray to gray-brown, and dark brown. The cap, which usually grows attached to the trunk by one side, is 5-15 cm across and has whitish to light-gray lamellae. The short whitish stalk is 1-3 cm thick and 2-4 cm long. The white flesh is soft in young fruiting bodies whose outer margin is still turned under, and sometimes tough and woody in old specimens and in the stalks. The odor is pleasantly aromatic, the taste mild. The main harvest season is from October to December in the native types, May to June in the Florida type. In mild winters, occasional mushrooms can still be harvested up to March.

Oyster mushrooms are often attached to fallen or dead tree trunks and stumps in several layers, overlapping each other like shingles. They are found especially frequently on copper beeches; however, they thrive also on numerous other broadleaved trees.

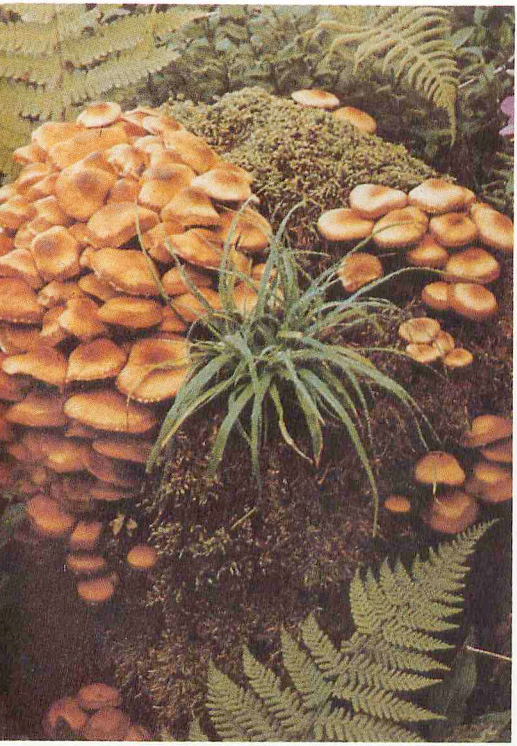
This mushroom does well in the ornamental garden on short logs set up vertically or on long prostrate trunks where there is room between the trees, for decoration and for harvest in fall and winter. In the orchard, blocks of wood placed in rows under standard fruit trees or among the rows of dwarf fruit trees can provide a profitable undercrop of mushrooms. The methods of cultivation are relatively simple and can be learned by every gardener. In Germany the oyster mushroom is probably the mushroom most cultivated in gardens now (see "Culture of the most important edible fungi").

*Fig. 15. Changeable agaric (Kuehneromyces mutabilis)*

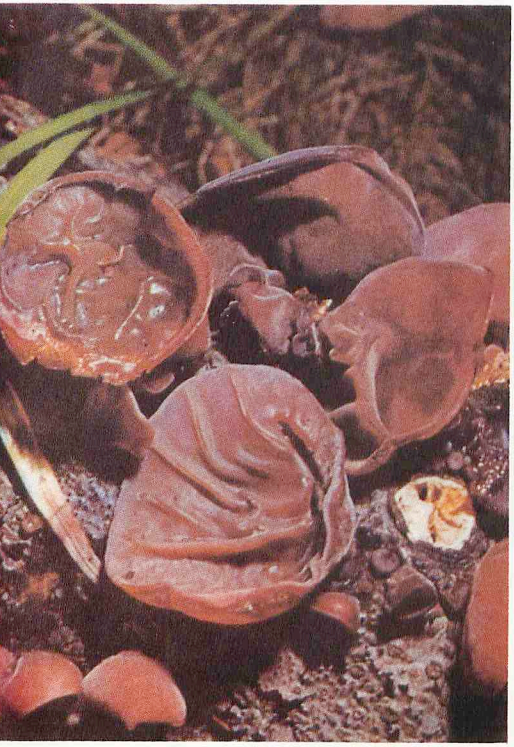
*Fig. 16. Devil's tobacco pouch (Lycoperdon gemmatum)*

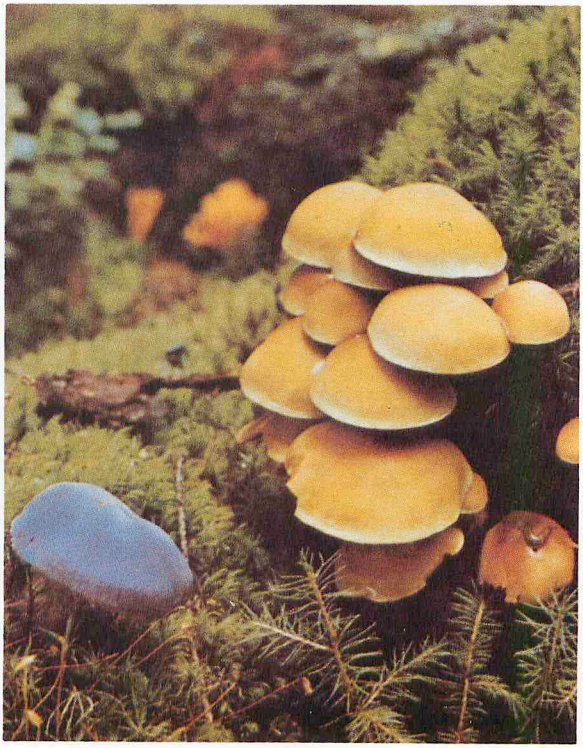
*Fig. 17. Jew's ear (Auricularia auricula-judae)*

*Fig. 18. Nematoloma capnoides*









Another species of *Pleurotus* is the medium-sized to large ***Pleurotus ulmarius*** (= *Lyophyllum ulmarium*). The cap is pale olive-gray to ochre-whitish, with pale yellowish lamellae; it has a diameter of 8-20 cm and a pale yellow stalk 6-18 cm long and 2-3 cm across. The white flesh is firm; the stalk flesh turns light blue-grey when bruised. The odor is pleasant and yeastlike, the taste mild.

The fruiting bodies of this mushroom are found from September to November on dead trunks, branches, and stumps of broadleaved trees, especially elms. Forested regions with high humidity, especially sites near rivers or streams, and park grounds are places to find this *Pleurotus*.

In the garden the same places are suitable for it as for the oyster mushroom. Because of its size, one should preferably cultivate it on logs set up in the ornamental garden, where it will have a decorative effect. With a combination of this and the oyster mushroom on the same log or stump, one can enliven the picture even more (see "Culture of the most important edible fungi").

The medium-sized ***Pleurotus cornucopiae,*** which has a pale ochre cap with white lamellae, should be cultivated like the previous two species. Bright yellow and reddish types of this species enliven the parts of the ornamental garden lying in partial shade with their beautiful colors.

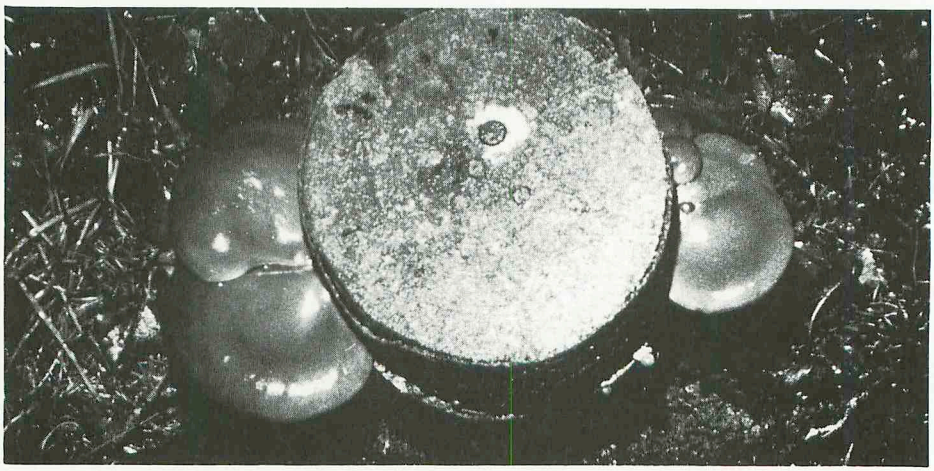


*Fig. 19. Oyster mushroom (Pleurotus ostreatus) on logs in an orchard*

***Pleurotus columbinus*** is a medium-sized species whose cap is bright gray-blue. The lamellae are pale bluish.

In contrast to the previous species, it grows principally on conifer wood.

It is effective in the garden with its beautiful color and can therefore be used well in the ornamental garden, possibly combined with yellowish and brownish species. Since in many areas conifer wood is more available than hardwood, it is possible to cultivate *Pleurotus* in such places also. In general, the same cultural advice applies as for the other species.

A species with small fruiting bodies is ***Pleurotus nidulans*** (= *Phyllotopsis nidulans*), which has orange-yellow caps approximately 6 cm across and orange lamellae. It fruits from September to December. The flesh is orange-yellow, and since it is rather tough, it is recommended for use only mixed with other fungi. The odor is aromatic, the taste mild.

These small mushrooms are usually attached like overlapping shingles to dead and rotten wood of hardwoods and conifers, especially beech and pine stumps.

It should be grown only in the ornamental garden, since its taste is not especially valuable, and other species are better suited for the kitchen garden. However, since its color is striking, it should be used in conspicuous places as an ornamental mushroom.

The **changeable agaric**, *Kuehneromyces mutabilis* (=*Pholiota mutabilis*), is a small wood-inhabiting mushroom with honey-yellow to yellow-brown fruiting bodies 3-8 cm in diameter which have pale brownish lamellae. The pale brown, rather thin stalk is 4-7 cm long. The more or less thin flesh is pale yellowish and somewhat watery. The odor is strongly aromatic, the taste mild and pleasantly spicy. It can be prepared in many ways. It is outstanding for use as a soup mushroom because of its pleasant aroma. Even very thin-fleshed specimens are good when fried or used as a flavoring for mixed mushroom dishes. It is also suitable for freezing, canning and drying. Since it usually appears in large numbers at the same time, it is very productive despite its small size.

This species is one of the most common fungi on wood, primarily colonizing stumps of beeches and other hardwoods. It does less well on conifers; nevertheless, there are types which yield well there also. Along streamcourses it occurs principally on stumps of poplars and alders. It usually grows densely crowded and in large clusters. Harvest season extends from May to December, but it fruits especially from May to June and in fall.







In the ornamental garden it needs damp shady places which are exposed to the sun for only a short time, since the wood on which it grows must not dry out. Therefore, it is recommended that the pieces of wood be buried rather deeply in soil which has been enriched with peat; it does not matter whether the wood is half-embedded vertically or horizontally. The better the wood is protected against evaporation, the higher will be the yield.

In the kitchen garden, shady places under standard fruit trees are suitable for growing them. The best method is to dig out a trench about 30 cm deep and 20 cm across, stand inoculated wood vertically in it every 20-30 cm, then fill it in with 15 cm of garden soil improved with peat. Thus abundant moisture can get to the wood continously from below, and the walls of the trench provide the upper part with shade and protection from the wind. For inoculating the wood with mycelium, one obtains trunks 10-20 cm in diameter in spring and cuts them into 45-cm lengths. Beechwood is especially suitable. One cuts a disk about 5 cm thick off each piece of wood and applies spawn or paste to the cut surfaces. Then the disk is nailed back on. The logs are placed close together in a trench in the ground or in low stacks, the trench or stack is covered with a plastic sheet, and boards or twigs are laid over them for shade. After 2-3 months, when the mycelium has grown out well, the logs are taken out and buried 1/3 to half way in the ground, in trenches in the orchard or in shady damp places in the ornamental garden. One can expect the first harvest in fall.

Damp wood waste mixed with spawn can also be placed in plastic sacks and set in a warm place until entirely permeated with the mycelium. Then, in small grassy areas of the garden in the shade, plugs of turf are cut out and the soil dug out under them to 20 cm. The wood waste permeated with mycelium is put in the hole and the sod laid back over it. Clusters of the mushrooms can develop in the grass in the places so prepared.

There are already various types of cultivated varieties which can form fruiting bodies either especially early in the spring, in summer, or in fall. If some of one's logs are inoculated with each of these types, one can obtain yields in different seasons.

This mushroom with its excellent aroma, which has been cultivated for decades, should not be left out of any garden, even though it produces only small fruiting bodies.

*Fig. 20. Stropharia culture in boxes*

*Fig. 21. Culture of the changeable agaric on logs*

*Fig. 22. Dryad's saddle (Polyporus squamosus)*

The Japanese mushroom **"nameko"** (*Pholiota nameko*) is a relative of the above species with a larger cap (5-10 cm in diameter) and a substantially thicker stalk. The cap is colored orange or brown; the stalk is somewhat lighter. This is a very delicious mushroom and is usable in many ways; it is cultivated on tree trunks or wood chips.

The **velvet shank** or **winter mushroom** (*Collybia velutipes* = *Flammulina velutipes*) generally has a honey-yellow to brown fruiting body, darker in the center of the cap, 2-8 cm in diameter. The lamellae are pale yellow; the rather thin, pale yellow to dark brown stalk is 4-10 cm long. The thin delicate flesh is whitish to pale yellowish; the taste is mildly acidic, the odor faint. The fruiting bodies appear from October to April, even in mid-winter when the weather is mild. This is a delicious soup mushroom and is also suitable for drying and freezing.

When the first frosts have killed most mushrooms, the season of the winter mushroom begins. Short periods of frost do not harm them, and even if they are frozen rock-hard, they can continue growing when mild weather follows. New clusters of mushrooms continue to crop up, especially during thaws, and can be harvested until March even when frozen.

They grow on tree stumps and dead trunks in broadleaved forests, rarely in coniferous forests, and especially in riparian forests near parks and on street trees; on ashes they often grow high up on the trunks. They are found also in the garden on dead wood.

There are many ways of making the winter mushroom at home in the garden. In the ornamental garden, in places which are as shady as possible, old tree stumps can be left after being rooted up or can subsequently be half-buried in the soil. As early as the beginning of the 20th century, this mushroom was introduced to gardens by smearing old wood with the slimy ripe caps, and good yields were obtained. One can also half-bury inoculated logs in the soil vertically or horizontally in shady places, as for *Kuehneromyces*, and harvest mushrooms throughout the winter. For large-scale cultivation, rows of logs can be set up in shade in the orchard, as for the oyster mushroom. In the ornamental garden the inoculated pieces of wood should not be put too close to ash trees, nor in the kitchen garden too close to fruit trees, although spreading into the trees need not be feared greatly. The fruiting bodies are harvested as young as possible, in order to hinder dispersal by spores. It is better to cultivate this mushroom on wood chips, excelsior, leaves, and similar substrates in the cellar or on the window-sill. The velvet shank, of which several strains of spawn are already commercially available, should be cultivated in every garden, since it can be harvested in winter.

Another species is ***Collybia platyphylla*** (= *Tricholomopsis platyphylla* = *Oudemansiella platyphylla*). Its cap is gray-brown, 5-12 cm across, and has white to yellowish lamellae. The whitish stalk is 7-10 cm long and 1-2 cm thick. The white flesh is tough in the stalk, odorless, and mild-flavored; this mushroom is a good extender for mixing with others.

This mushroom is usually found solitarily on rotten stumps of broadleaved trees or conifers. It produces fruiting bodies in summer and fall.

Since this *Collybia* fruits in the warm season, it is a complement to the velvet shank, which is harvested in winter. In the garden it can be cultivated in combination with the latter on the same logs.

Yet another species of this genus is ***Collybia dryophila.*** It is a small mushroom with a brown cap 3-6 cm in diameter. The lamellae are yellowish. The light-brown stalk is 0.5 cm thick and 4-6 cm long. The flesh is yellow-brown, pale, and somewhat watery; the taste is mild, the odor aromatic. When harvested young, this is a good soup mushroom.

***Nematoloma capnoides*** (= *Hypholoma capnoides*) is a wood-inhabiting mushroom. It has a pale yellow to brownish cap, 2-7 cm across, with yellowish lamellae which appear dark when the dark-brown spores mature. The stalk, brown below and yellowish above, is 5-10 cm long. The firm flesh is whitish, has a faint odor, and tastes pleasantly mild. The stalks are not used. Since it forms fruiting bodies from August to November and even to February in mild winters, one can also look foward to an occasional fresh mushroom dish made from it in the winter. It often appears also in early spring in dense clusters on tree stumps.

This *Nematoloma* grows on tree stumps and dead conifer wood; it prefers spruce stumps. The mycelium proliferates in the wood; the white network of hyphae is sometimes visible between the sapwood and the bark. Since the fruiting bodies usually appear in clusters and in great numbers, the harvest can be very productive.

This mushroom produces harvests for many months, even in the cold season, so that establishing it in the garden is of interest. Spawn was prepared from it as far back as 30 years ago. Today spawn is commercially available again and can be obtained by gardeners. It can be cultivated in the garden, like the other wood-inhabiting species, on vertically buried logs under open groups of trees. In the orchard it can stand alongside the oyster mushroom and the winter mushroom. While most of the fungi on wood prefer broadleaved trees, this *Nematoloma* grows on spruce wood, which is more available in many areas.

This flavorful edible mushroom, which fills in so many intervals between the harvest times of other species, is recommended for cultivation in the garden.

***Agrocybe aegerita*** is a small to medium-sized mushroom with a yellowish-brown cap 5-7 cm across. The stalk is 1 cm thick and 6-8 cm tall.

It grows in clusters on dead poplar wood. In southern Europe, especially southern Italy, it is cultured on poplar wood. Attempts at commercial cultivation have been made in Holland.

In the ornamental garden this mushroom can be cultivated on logs, like the other wood-inhabiting species. Cultivating it in beds between rows of dwarf fruit trees would probably be more interesting. In spring a hole 80 cm across and 20 cm deep should be dug in the soil, and a thoroughly wetted mixture of 3/4 poplar wood chips and 1/4 barley chaff introduced, inoculated with mycelium, and covered with a plastic sheet. When the substrate is permeated, the sheet must be removed and replaced with a thin layer of sand to prevent too rapid drying.

The **shiitake** (*Lentinus edodes*) is a medium-sized mushroom cultivated in east Asia in large numbers. The light- to dark-brown cap is 5-10 cm across and has yellowish-white, later brownish, lamellae. Sometimes the surface of the cap is subdivided by large white cracks or covered with shaggy scales. The stalk is 1-1.5 cm thick and 3-5 cm long and is whitish to brownish. The flesh is white, brownish in the stalk; it is firm, smells aromatic, and has a spicy flavor. The fruiting bodies should be harvested young, not later than when they begin to shed spores. They are used in soups, sauces, and meat pies and are also eaten raw; the aroma is said even to improve when they are dried. The mushrooms have an excess of base which is important for our nutrition, are rich in vitamins, and contain cholesterol-reducing substances. For these reasons the Japanese consider that they prolong life.

They grow in open woodlands on dead wood of various broadleaved trees, especially oaks, white beeches, birches, and chestnuts, and form fruiting bodies in spring (with the first plum blossoms) and in fall. For centuries the shiitake has been cultivated in east Asia, especially in Japan, Korea, and Taiwan and on the Chinese mainland. Originally logs and branches of broadleaved trees approximately 10 cm thick were cut in lengths of 1 to 1.5 m, and spores were strewn over them and cut into the wood with an ax. The pieces of wood were then laid on top of one another, covered with twigs, and earth was thrown over them, in order to obtain rapid growth of the mycelium by providing high humidity, high $CO_2$ concentration, and warmth. The pieces of wood, permeated

by mycelium, were set out a few months later in an open broadleaved forest, and produced the first harvests 1-2 years after inoculation. They were harvested twice yearly for 4-6 years after that. A humidity of 70-80% is advantageous for growth of the fungus and 10-15°C for formation of fruiting bodies.

Instead of inoculation with spores, wood permeated with mycelium is also stacked on top of or next to un-inoculated wood and covered with twigs and earth. It remains there until mycelium has spread throughout the wood.

Since Japan began producing spawn, the wedge method has been used for most work. Small wedges of wood are inoculated with mycelium, and when it has spread through them, they are hammered into corresponding holes which have been bored with a drill into the rounds of wood. These can either be stacked in a pile to be permeated by the mycelium or set out in a forest with high humidity and protected from temperatures over 20°C. As early as 1908 shiitake were cultivated in Germany using a similar wedge method. In addition to cultivation on wood, mushrooms are also grown at a temperature of 25°C on substrates of sawdust and rice bran which are enriched with soybean extract. To improve the formation of fruiting bodies, various bacterial cultures are added to the compost.

In Japan there are already several sorts or this mushroom (tempaku-donko, nami-donko, jo-donko, hana-donko, koko, nami-koshin, jo-koshin), each of which forms fruiting bodies at a particular season, so that it is possible to harvest shiitake for the greater part of the year.

In the garden the shiitake is cultivated in the same way as *Kuehneromyces* and the oyster mushroom. In the kitchen garden inoculated logs can be set up in rows under standard fruit trees. In the ornamental garden, set up in the shade under groups of trees, they introduce a breath of East Asia. Larger trunks can be inoculated by the wedge method (preferably by sawing out triangular pieces which after inoculation are set back in place and wrapped in a plastic sheet until the mycelium binds them together) and set out in groups in the shade or laid on the ground.

This Asiatic mushroom with all its valuable qualities should receive a good place in the garden.

The **deer mushroom** (*Pluteus cervinus*) is a medium-sized gilled mushroom with a brown cap 4-10 cm in diameter. The white lamellae later turn pinkish because of the pink spores. The stalk is streaked with dark fibers and is about 1 cm thick and 6-8 cm long. The white flesh has a mild flavor and smells rather radish-like. The fruiting bodies appear from spring into November. Since it is not particularly good, it is used only mixed with other mushrooms.

This mushroom usually grows on stumps of broadleaved trees, but it also

occurs on conifers. On conifers, however, one is more likely to find the dark-brown, somewhat larger *Pluteus atromarginatus*. The caps of *Pluteus cervinus* are initially bell-shaped, later umbonate, and appear singly or in small groups.

In the garden it can be cultivated on logs or on sawdust. It can be established under shrubbery and in the ornamental tree-mushroom garden on tree stumps or on a layer of sawdust between logs.

Although this mushroom can not be considered valuable for its flavor, it should be useful to grow in the garden because of its long harvest season.

*Polypores*

Of the polypores, the **dryad's saddle** or scaly polypore (*Polyporus squamosus* = *Melanopus squamosus*) is of interest to us. The cap, up to 50 cm across, is ochre-yellow with brown scales and has pale yellowish pores. The stalk is whitish, black above, 3-6 cm thick and 4-8 cm long. The flesh is soft and edible in young individuals; the odor is flourlike and sweetish, the taste acrid.

It is found on stumps and trunks of broadleaved trees, growing gregariously and often overlapping like shingles, from April to November. In the garden it will do very well on tree stumps in rather sunny places in lawns. If a flowerpot is set on the stump, the overlapping fruiting bodies visible below can provide a splendid background. It serves primarily as a decoration and also supplies an occasional meal. However, it must be situated only where it does not have any contact with living trees.

The **sulfur shelf** or chicken-of-the-woods (*Laetiporus sulfureus*) is a large fungus with bracket-like fruiting bodies attached above each other; they are sulfur- to orange-yellow, stalkless, and 2-8 cm thick and 10-30 cm across. The pores are bright sulfur-yellow. The initially yellowish, later white flesh is tender and juicy when young, later fibrous and hard. The odor is faintly acidic; the flavor is mild, bitter in age. The cooking water should be poured off to obtain a milder flavor.

This polypore lives on trunks and dead wood of broadleaved trees. It is frequently found on willows, cherries, and pear trees; sometimes it also occurs on larches and spruces. It often forms great carpets of fruiting bodies in spring and summer.

This fungus is very decorative with its splendid coloration. When establishing it in the garden, on tree stumps left or placed in lawn areas, one should keep it far from living trees. When young it can make a flavorful meal.

*Coral fungi*

The **cauliflower** or brain fungus (*Sparassis crispa*) belongs to the coral fungi. It has a spherical cauliflower-like fruiting body (resembling a broody hen) 15-40 cm across. It is yellowish and has white flesh which is fragile and waxlike. When young it is delicious, with a spicy odor and nutlike flavor. Old wet fungi are bitter and cause digestive upsets. Before cooking, they must be thoroughly washed; they taste especially good cut into slices, breaded, and fried.

This usually solitary fungus forms its fruiting bodies from August to November at the bases of conifers, especially in pine forests at the feet of older trees and also on stumps. The related oak cauliflower fungus is found in broadleaved forests.

In the garden the cauliflower fungus can be established on pine stumps. A single fruiting body often suffices for a whole family. As early as 30 years ago, spawn for growing this fungus on conifer wood was commercially available.

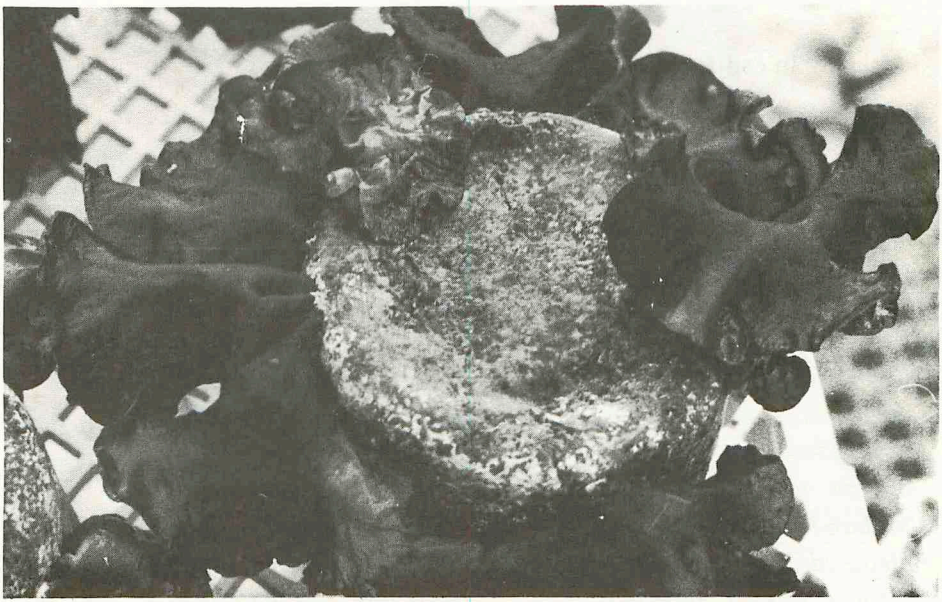


*Fig. 23. The jew's ear is easily cultivated on logs*

*Jelly fungi*

Of the earlobe fungi, the **jew's ear** (*Auricularia auricula-judae=Auricularia sambucina*) is frequently cultivated in Asia. In Germany it was formerly collected for medicinal purposes. The small fruiting body is ear- to mussel-shaped and usually attached to the wood without a stalk. It is brown with a lighter inner surface. In east Asia it is considered a delicacy, and for this reason it is also eaten here in Japanese and Chinese restaurants. The flesh is gelatinous, odorless, and mild in flavor.

It usually grows gregariously throughout the year on broadleaved trees, especially elder, but is not common.

It would be possible to cultivate it like the velvet shank, on elder logs. This fungus has already been cultivated on a substrate of rotten wood and bark, moss, and some ground limestone. Growing the jew's ear and some related species which are cultivated in Asia could be interesting for enthusiasts of Asiatic cooking.

**List of fungi by natural habitats**

These tables show where the fungi usable in the garden occur in nature (W=living on wood).

Occurring in coniferous forests

*Agaricus arvensis*
*Agaricus silvaticus*
*Agaricus silvicola*
*Agaricus augustus*
*Tricholoma flavovirens*
*Macrolepiota rhacodes*
*Clitocybe nebularis*
*Clitocybe brumalis*
*Marasmius scorodonius*
*Russula vesca*
*Collybia butyracea* var. *asoma*
*Cantharellus cibarius*
*Boletus edulis* ssp. *fibrillosus*
*Boletus edulis* ssp. *pinicola*
*Boletus elegans*
*Boletus badius*
*Boletus granulatus*
*Leccinum testaceo-scabrum*
*Hydnum repandum*
*Otidea leporina*
*Morchella conica*
*Choiromyces maeandriformis*
*Pleurotus columbinus* (W)
*Pleurotus nidulans* (W)
*Collybia velutipes* (W)
*Collybia platyphylla* (W)
*Collybia dryophila*
*Nematoloma capnoides* (W)
*Sparassis crispa* (W)

Occurring in broadleaved forests, shrubbery, and parks

*Agaricus arvensis*
*Agaricus silvicola*
*Lepista nuda*
*Tricholoma georgii*
*Lepista personata*
*Macrolepiota procera*
*Clitocybe nebularis*
*Clitocybe brumalis*
*Russula vesca*
*Collybia butyracea* var. *asoma*
*Agrocybe praecox*
*Cantharellus cibarius*
*Boletus edulis* ssp. *reticulatus*
*Macrolepiota rhacodes*
*Boletus leucophaeus*
*Otidea leporina*
*Morchella esculenta*
*Morchella conica*
*Tuber melanosporum*
*Tuber brumale*
*Tuber aestivum*
*Choiromyces maeandriformis*
*Pleurotus ostreatus* (W)
*Pleurotus ulmarius* (W)
*Pleurotus cornucopiae* (W)
*Pleurotus nidulans* (W)
*Kuehneromyces mutabilis* (W)
*Collybia velutipes* (W)
*Collybia platyphylla* (W)
*Collybia dryophila*
*Leccinum testaceo-scabrum*
*Leccinum aurantiacum*
*Leccinum carpini*
*Hydnum repandum*
*Lycoperdon gemmatum*
*Otidea onotica*
*Agrocybe aegerita* (W)
*Lentinus edodes* (W)
*Polyporus squamosus* (W)
*Laetiporus sulfureus* (W)
oak *Sparassis* (W)
*Auricularia auricula-judae* (W)

Occuring in forest edges, paths, glades, clearings

*Agaricus arvensis*
*Agaricus silvaticus*
*Stropharia aeruginosa*
*Lepista nuda*
*Tricholoma georgii*
*Macrolepiota procera*
*Macrolepiota rhacodes*
*Clitocybe geotropa*
*Marasmius oreades*
*Marasmius scorodonius*
*Russula vesca*
*Agrocybe praecox*
*Boletus edulis* ssp. *fibrillosus*
*Boletus edulis* ssp. *reticulatus*
*Boletus elegans*
*Boletus granulatus*
*Lycoperdon gemmatum*
*Peziza aurantia*
*Morchella conica*

Occurring in meadows, pastures, lawns, grassy places, pathsides, embankments

*Agaricus bisporus*
*Agaricus edulis*
*Agaricus arvensis*
*Agaricus campestris*
*Stropharia aeruginosa*
*Tricholoma georgii*
*Lepista personata*
*Clitocybe geotropa*
*Coprinus comatus*
*Marasmius oreades*
*Agrocybe praecox*
*Peziza aurantia*
*Morchella esculenta*
*Morchella conica*

Occurring in gardens

*Agaricus bisporus*
*Agaricus edulis*
*Agaricus campestris*
*Stropharia rugoso-annulata*
*Stropharia aeruginosa*
*Lepista personata*
*Macrolepiota procera*
*Macrolepiota rhacodes*
*Coprinus comatus*
*Agrocybe praecox*
*Morchella esculenta*
*Pleurotus ostreatus* (W)
*Collybia velutipes* (W)
*Polyporus squamosus* (W)
*Laetiporus sulfureus* (W)
*Auricularia auricula-judae* (W)

## Possibilities for growing mushrooms in the garden

### Kitchen garden

The gardener often assumes that the common grocery-store mushroom is the only kind cultivated and that it can be grown only in dark rooms, while all other edible mushrooms must be collected from forests and fields. With many other edible mushrooms, however, one can utilize just those places in the garden which are not usable for growing anything else because of inadequate light. Fungi generally thrive especially well in shady and partially shady places.

*Cultivation in the orchard*

The orchard is immediately available for growing fungi under trees. Fruit trees, both standard and dwarf, ensure that the fungi growing under them do not dry out from strong sunlight and that the ground contains constant moisture, if one is careful when watering during longer dry periods that the fruit trees do not take up all the water from the soil. The more humus the soil contains, the less one need fear deficiency of water and the better the fungi do. In my garden, not only did the mushrooms which I had established produce good crops, but after only a year five other species of edible mushrooms had established themselves without my having done anything, a sure sign that suitable soil conditions and the right climate for mushrooms made the fungi feel at home here.

In plantings of dwarf fruit trees, cultivation of fungi should be confined to the strips shaded by the trees. Grassy turf does not harm either the species which grow on wood or the humus-inhabiting fungi which in nature occur in meadows and pastures or grassy paths.

The more species grown, the more likely it is that fungi can be harvested during most of the year. When a particular species fails to produce a harvest in a given year because of unfavorable weather conditions, another can often make up for its absence.

The first fungi which one should grow under standard and dwarf fruit trees are species living on wood. To do this, logs about 40 cm long are inoculated with the mycelium and, after they are permeated, set up in the garden. The logs are sunk 10-20 cm deep in the ground, so that mycelium can penetrate the soil abundantly, and so that the wood and mycelium will conduct as much water as possible into all parts of the wood to enable fruiting bodies to form. The logs can be set up in rows or in groups. One figures on about 4-5 logs per square meter. Peat or rotten manure are brought in to cover the soil between the pieces of wood. Fruiting bodies often also form out of the mycelium in the soil near the

wood; one should therefore look for these when harvesting. For watering one should use sprinklers which do not throw water up to the tops of the trees, since heavily falling drops can soil the lamellae easily by splashing bits of dirt up onto them. Frequent breaking up and aeration of the soil between the rows has proven favorable, since new mycelium forms quickly in the loose humus. Occasional weeds cause no harm and provide additional humus material after the soil is broken.

Several species are suitable for this culture which even produce crops in different seasons. In this category the delicious *Kuehneromyces mutabilis* is especially suitable, since it produces fruiting bodies in different seasons. For this purpose one should grow strains which produce primarily in spring, summer, or fall, to spread the harvest out evenly over the year.

*Nematoloma capnoides*, which does well on spruce wood and appears in clusters on the wood in early spring and produces a second harvest in fall, is also recommended for cultivation.

A species of mushroom which is preferentially cultivated in east Asia, especially Japan, and has the merit of being both delicious and healthful, is the shiitake; it has been cultivated in Asia for centuries and does well in our climate also. There are various sorts of this species which fruit in different seasons. One should therefore grow spring, summer, and fall varieties in this country also, as is customary in Japan. The shiitake dries very well and can be preserved for winter in this way. The harvests in Germany are, to be sure, considerably smaller than those usual in Japan, since varieties and methods of cultivation must first become better adapted to our climate; but nevertheless we should not do without this choice mushroom.

Like *Nematoloma*, the aromatic cauliflower fungus, which forms fruiting bodies in summer and fall, can be cultivated on conifer wood; pine wood is the best to use for this.

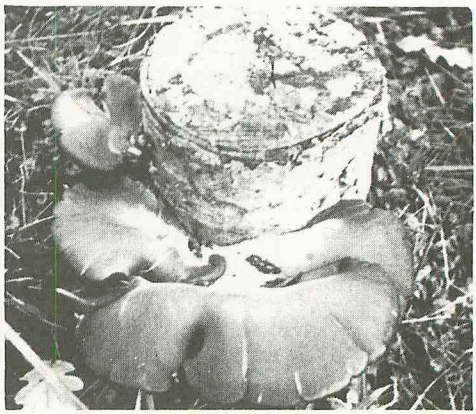


*Fig. 24. Fruiting bodies growing too close to the ground become dirty easily*

A species which is already commercially available today as a cultivated mushroom, the oyster mushroom, is particularly rewarding, because as a native species it is adapted to our climatic conditions and produces high yields. Types which are found in nearby forests should be preferred especially. It seems advisable to select strains which fruit in the spring particularly, since the main harvest season generally falls in the months of October to November. As for color, fruiting bodies from light beige to dark brown are available; spores and lamellae are white. One will prefer different colors depending on how the mushroom is to be used, for example, light ones for soups and brown ones for game stews. Summer types which come from warm climates have recently become available. Even in higher temperatures, for example in May or June, they form splendid large fruiting bodies.

In addition to the oyster mushroom, *Pleurotus columbinus*, which grows on conifer wood, can be cultivated. *Pleurotus ulmarius*, which forms large fruiting bodies, prefers elm wood, as the name suggests. *Pleurotus nidulans* with its orange-colored lamellae can be grown on wood of broadleaved as well as coniferous trees.

For harvest in winter, the velvet shank, which can withstand temperatures down to -10°C, is especially suitable. It grows preferentially on willows and alders but also on beech wood. It generally forms rather small fruiting bodies, so one should use larger cultivated varieties such as have been developed for commercial production. Since it makes harvest throughout the winter possible, this mushroom should not be missing from our gardens.

The two diagrams (Fig. 25) give examples of how the different species can be arranged in a garden planned for a household of four people. With this layout, one can count on a harvest distributed over most of the year.

When growing fungi under dwarf trees, one will generally set up only one row of logs between trees, so that there is plenty of shade. Other wood-consuming species of fungi could be raised here also, for example *Collybia platyphylla* and *Agrocybe aegerita*. If the strip between the trees has grown up in grass, fungi which are found in meadows and pastures will also grow there.

In well-limed situations the desirable edible morel ought to do well in the grass. It forms its fruiting bodies as early as April to May, followed shortly by St. George's mushroom.

For harvest in summer, the fairy-ring mushroom can be established. It is a small species of mushroom which is highly prized for its pleasantly spicy aroma and is harvested from early summer to fall.

From September on, *Clitocybe geotropa* forms large ochre-colored fruiting bodies, and in October the medium-sized field blewit appears in the grass with its splendid coloration.

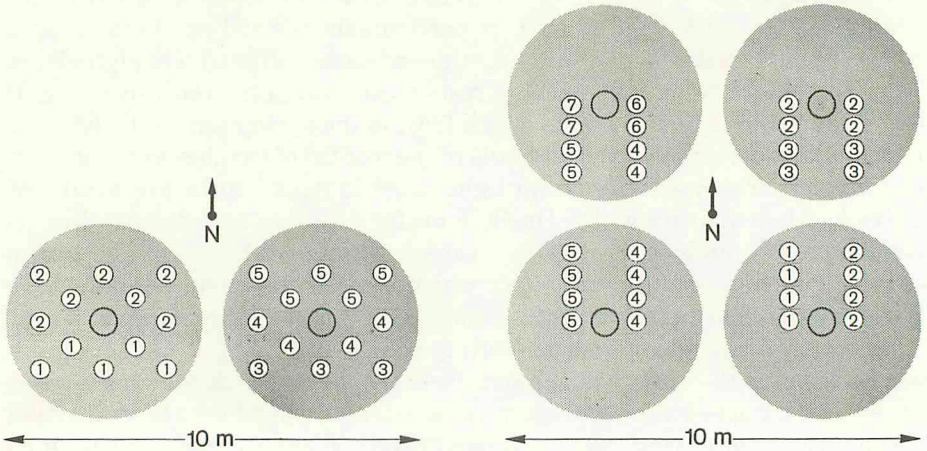



*Fig. 25. Arrangement of mushrooms under fruit trees. 1 oyster mushroom (summer), 2 oyster mushroom (fall), 3 velvet shank, 4 shiitake, 5 changeable agaric, 6 Nematoloma capnoides, 7 jew's ear*

Since the soil between the rows of trees in larger orchards is usually worked regularly, cultivating mushrooms beneath fruit trees is recommended only for home gardens. A trench approximately 10 cm deep and 0.5-1 m wide is excavated in the strip midway between the trees. Straw is put in the trench, soaked thoroughly with water, and spread with spawn of *Stropharia rugoso-annulata.* After the mycelium has grown throughout the straw, earth is replaced over it. Harvest of the first fruiting bodies can be expected a few weeks later; it continues in waves to late fall and provides large brown mushrooms which are similar to the king bolete.

As in the vegetable garden, *Agaricus bisporus* and *Agaricus edulis* can also be cultivated in beds between the rows of trees. Numerous other possibilities are open to the garden owner and entice one to try them out. Thus in Hungary in late summer I saw plastic sacks, filled with corn substrate and then inoculated with *Pleurotus* spawn, lying under fruit trees. After the mycelium had penetrated the substrate, the sacks were cut open and set out in the shade of the trees. Numerous splendid fruiting bodies formed later at the openings in the sacks.

Of the various berries, blackberries are particularly suitable for providing shade for culturing mushrooms, since they are generally raised on trellises and

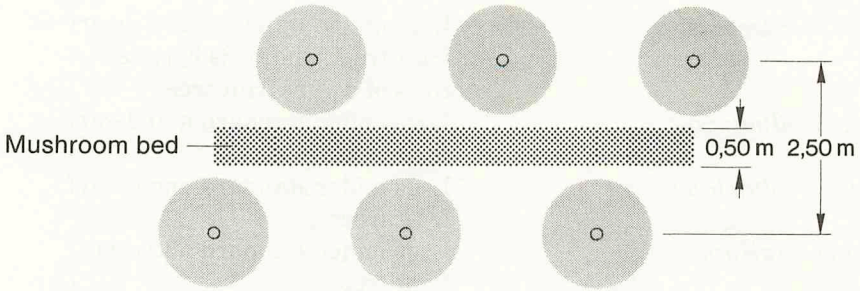



*Fig. 26. Mushrooms between rows of bush fruits*

the plants are set far apart, so that enough room remains for growing things underneath. If one excavates a narrow trench under the trellis, fills it with straw which is permeated with *Stropharia* mycelium, and then puts soil back over it again, one can harvest the first mushrooms in a few weeks. Like *Stropharia*, the wood mushroom could be at home under rows of blackberries.

Growing mushrooms in the orchard

| | |
|---|---|
| *Agaricus bisporus* | In beds between rows of dwarf fruit trees |
| *Agaricus edulis* | In beds between rows of dwarf fruit trees |
| *Agaricus silvicola* | Under blackberry trellises |
| *Stropharia rugoso-annulata* | Under blackberry trellises and in beds between rows of dwarf fruit trees |
| *Tricholoma georgii* | Strips of grass between rows of dwarf fruit trees |
| *Lepista personata* | Strips of grass between rows of dwarf fruit trees |
| *Marasmius oreades* | Strips of grass between rows of dwarf fruit trees |
| *Sparassis crispa* | Strips of grass between rows of dwarf fruit trees, on pine wood |
| *Morchella esculenta* | Strips of grass between rows of dwarf fruit trees |
| Truffles | Under plantings of hazels |

| | |
|---|---|
| *Pleurotus ostreatus* | Logs under standard and dwarf fruit trees, and beds between rows of dwarf fruit trees |
| *Pleurotus ulmarius* | Logs under standard and dwarf fruit trees |
| *Pleurotus columbinus* | Logs under standard and dwarf fruit trees |
| *Collybia velutipes* | Logs under standard and dwarf fruit trees |
| *Nematoloma capnoides* | Logs under standard and dwarf fruit trees |
| *Agrocybe aegerita* | Logs under standard and dwarf fruit trees |
| *Lentinus edodes* | Logs under standard and dwarf fruit trees |
| *Auricularia auricula-judae* | Logs under standard and dwarf fruit trees |
| *Kuehneromyces mutabilis* | Logs under standard and dwarf fruit trees |
| *Peziza aurantia* | On paths under standard and dwarf fruit trees |

*Cultivation in the vegetable garden*

Cultivation of mushrooms in the vegetable garden is somewhat more difficult than in the orchard, because constant shade is lacking. Therefore only species of mushrooms which are exposed to sunshine in their natural habitats can be grown. If possible, a place should be found which receives shade from the neighboring vegetables for a long time. Two rows of pole beans or tomatoes which are planted in an east-west direction provide protection against too intense drying, especially at midday; mushrooms can be grown between them as an intercrop. Cultivation is carried out—as between rows of dwarf fruit trees—by digging out a trench only about 40 cm across and 10 cm deep and piling straw or old manure in it to a height of about 20-30 cm. The highly mounded substrate is laid down in several layers, tamped down firmly, wetted well, and covered with a transparent plastic sheet. To keep the sheet from blowing away in the wind, it is weighted down at the edges with soil or rocks. After a few days the substrate will have warmed up and the straw will have become soft; then one side of the sheet is turned back and spawn is mixed with the straw or manure. The substrate is moistened slightly and covered again. In

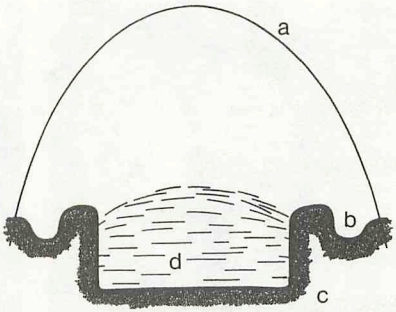



*Fig. 27. Mushroom culture bed*

*a. wire bow with plastic sheet*

*b. ditch*

*c. ground*

*d. straw substrate*

the humid warmth, a vigorous white mycelium develops from the spawn and penetrates the whole substrate. Then it is time to remove the sheet or to stretch part of it over a curved wire and to put a layer of humusy soil on top of the substrate. A few weeks later, the first fruiting bodies are formed, and production continues into fall. A plastic sheet can be stretched over the bed for protection against rain.

*Stropharia rugoso-annulata*, which usually produces well and can withstand some sun, is suitable for this cultivation. The shaggy mane can also be cultured in this way. It is easily grown on commercial-mushroom compost or straw substrate (p. 91-94). The covering of soil should not be too thin. After harvesting, the fruiting bodies of the shaggy mane can be kept for only a short time, since they quickly become unattractive. These mushrooms can withstand a good deal of sun.

We can use another method of growing mushrooms between pole beans. Straw can be saturated with water and cooked 2-3 hours to kill disease germs, then put in plastic sacks 50 cm long or small peat bags. After cooling, the straw is inoculated with spawn of *Pleurotus* varieties which form fruiting bodies at higher temperatures, then placed in the dark at 20-25°C until the substrate is permeated so thickly that it has become a firm block. After the plastic covering has been removed, the blocks are stood in a cool cellar until the fruiting bodies have just started to form, and then placed in the garden. Here they are set 50 cm apart in a row in the shade of the beans, and sunk about 10 cm deep in the ground so that water can rise from the damp soil to the topmost layer of the blocks. The surface of the soil should be kept as wet as possible so that the humidity of the air is high and the fruiting bodies can develop well.

It is usually possible to cultivate *Agaricus* where asparagus is grown in the vegetable garden. These rows should also run in an east-west direction, so that the north sides of the hills, which are protected against the sun's rays, can be

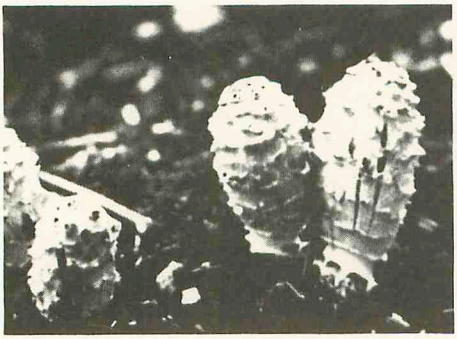


*Fig. 28. Shaggy manes on a compost heap*

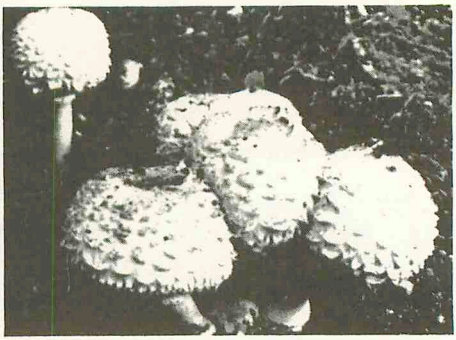


*Fig. 29 Shaggy parasol (Macrolepiota rhacodes) on a compost heap*

used. They can be grown only after the asparagus harvest has ended, that is, approximately from the end of June on. At that time, about 10 cm of thoroughly composted horse manure is layered on the north sides of the hills and inoculated with spawn. After about three weeks the substrate has become permeated with mycelium and should then be covered with about 4 cm of humus-rich soil well saturated with water. After another 3-4 weeks one can expect the first fruiting bodies. The soil must always be kept very moist.

The common cultivated *Agaricus* can be grown in this way, if it can be given enough moisture; it does not form fruiting bodies at high temperatures. It is preferable, therefore, not to start growing it until August. *Agaricus edulis* is essentially insensitive to heat and drought and withstands temperatures of 30°C. It is as delicious as the common cultivated mushroom.

The garlic mushroom can be grown in a shady spot in the herb garden, perhaps in the protection of lovage plants. It tastes characteristically like garlic and goes especially well with mutton. This is a very small mushroom. A suitable substrate is a mixture of needle litter and wood chips with decomposed manure; it is covered with a layer of humusy soil, preferably from a spruce forest.

*Fungi on the compost heap*

The compost heap should also be used; it is often planted with squashes, which give good shade but also remove many nutrients. Shade is better provided by a hedge, which simultaneously hinders drying by the wind and conceals the sight of the fresh refuse. Turned compost which will be kept for one or two more years of further decomposition can be used for cultivating mush-

rooms. Spawn is introduced into the uppermost 10 cm, pressed down lightly, and covered with leaves.

The parasol mushroom, which likes light partial shade, and the smaller shaggy parasol, which forms a larger number of fruiting bodies, are suitable for growing this way. These delicious species often fruit even in the warm season, when other mushrooms are scarcely to be found. The shaggy mane, which is encountered growing wild on street sweepings and old composting places and likes nutrient-rich soil, grows even better on compost than the parasols.

*Using cold frames for culturing fungi*

After cold frames are used for head lettuce, kohlrabi, black radishes, and beets, they are usually planted with cucumbers or paprika. Often the windows are taken up immediately after use early in the year and then stored in a dry place. The cold frames can be used for growing mushrooms in late summer and fall. The windows are covered with black plastic sheeting and reed mats as protection against the warmth of the sun. The soil in the boxes is dug out to a depth of about 15 cm, and composted horse manure is brought in. The manure heats up at first; after it cools down to 25°C it is inoculated with *Agaricus* spawn. After the mycelium has grown throughout it, about 4-5 cm of humusy soil is put on top; a few weeks later the fruiting bodies begin to form.

For a crop in the warmer season, we use *Agaricus edulis*, which can withstand high temperatures, for this kind of culture. For fall, our common cultivated *Agaricus* is suitable, especially the aromatic blond and brown sorts. In

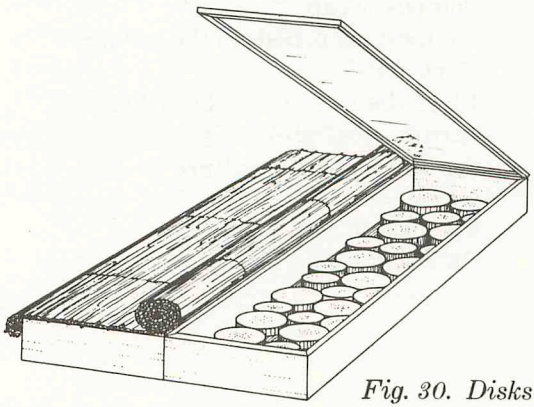


*Fig. 30. Disks of inoculated wood in a cold frame*

this way, the soil in the cold frame is provided abundantly with humus and nutrients for the next year's replanting. *Stropharia* can also be cultivated in cold frames.

In the fall, the cold frames are well suited for cultivating fungi which grow on wood, if the soil is kept well moistened and loosely woven reed mats are provided for partial shade. Logs 40-50 cm long can be used for this only if they are laid flat and half buried in the ground. Otherwise, pieces of wood approximately 10 cm long, consisting of two disks of wood nailed together after placing spawn between them, are more suitable. The lower disk is half buried in the soil so that enough moisture can penetrate the wood. In the partial shade of the cold frame one can easily obtain the humid climate desired by many species of fungi. The humus-rich soil of the cold frame provides good nutrition and luxuriant growth. *Kuehneromyces mutabilis*, shiitake, and the jew's ear will show their gratitude by their good yields.

Growing mushrooms in the vegetable garden (including the compost heap and the cold frame)

| | |
|---|---|
| *Agaricus bisporus* | Beds on asparagus hills, hill beds between rows of tomatoes and pole beans |
| *Agaricus edulis* | Beds on asparagus hills, hill beds between rows of tomatoes and pole beans |
| *Stropharia rugoso-annulata* | Beds between rows of tomatoes and pole beans |
| *Macrolepiota procera* | Compost heap |
| *Macrolepiota rhacodes* | Compost heap |
| *Coprinus comatus* | Compost heap, beds in the garden |
| *Marasmius scorodonius* | Herb garden |
| *Pleurotus ostreatus* | Blocks between rows of pole beans (straw substrate) |
| *Kuehneromyces mutabilis* | On wood and pot culture in cold frame |
| *Lentinus edodes* | On wood in cold frame |
| *Auricularia auricula-judae* | On wood in cold frame |

## Ornamental garden

The ornamental garden should offer us the opportunity to relax out of doors when the weather is warm; it should be beautiful with its flowers and flowering shrubs and its well-tended lawns, but it should also provide us with a substitute for a bit of forest and meadow. Living mushrooms give us an image of undisturbed forest, quiet heath, or natural meadow. Thus we should also have mushrooms growing among the trees and shrubs of the garden and on the lawn. There are suitable nooks for this even in the smallest garden.

*Planting under ornamental trees*

In larger gardens, solitary plantings of **individual trees** or small groups of trees are arranged in lawns to break up overly large areas. Mushroom species which extend outward from year to year in ever-increasing circles give a very picturesque effect growing under the trees. The mycelium radiates outward in all directions from a center as it grows, and the fruiting bodies are formed at the periphery of the mycelium. Even when fruiting bodies are not visible, rings called fairy rings stand out distinctly because of their darker coloration (cf. p. 16). These species can also be established under open groups of trees and border shrubbery, where the formation of rings is not so clearly recognizable. However, one must carefully select mushrooms species which are appropriate for growing under groups of trees. This holds especially for establishing those mushrooms which live in symbiosis with particular species of trees. These also sometimes form rings which, however, arise because the mycelium is most strongly developed at the tips of the roots and forms the fruiting bodies there. The number of mushroom species which can do well under solitary trees in the garden is not very great; in most gardens, however, there is no room for large trees anyway.

Free-standing pines have an extemely decorative effect in larger grounds. *Tricholoma flavovirens* could thrive here under the fallen pine needles and enliven the brown surface in fall with its yellow-green caps. The splendid parasol mushroom, which is not associated with a particular species of tree, stretches its umbrella, up to 30 cm across, over the surface of the grass. It is an outstanding eye-catcher if it is not placed too far from the garden path. In contrast, the larch bolete is restricted to the vicinity of larches, with which it lives in symbiosis. Since free-standing larches need a great deal of room, it would be possible to establish this bolete with its bright gold-brown caps in the light shade of a weeping larch instead. The brown birch bolete can do well under solitary birches, in the front yard for example, if partial shade, humusy

soil, and a light covering of leaves are present. Edible morels grow especially well under ash trees, and in the garden they can become at home in grass under a weeping ash, for example, if lime-rich soil, well provided with humus, is available. It is more difficult to introduce truffles under solitary trees, since the fruiting bodies are formed on the tree roots 10-20 cm under the surface. One is therefore forced to dig up the ground when harvesting them, taking care to damage as few roots as possible. If there is a lawn under the trees, the upper layer must be raised as a slab of turf and replaced after the harvest; also, people do not have dogs and pigs trained to search for truffles. Because of all of these difficulties, their culture will probably remain confined to larger parklike gardens, where truffles can be introduced, for example, under solitary oaks, copper beeches, weeping beeches, or pines.

Mushrooms under solitary trees

| | |
|---|---|
| *Tricholoma flavovirens* | Under pines |
| *Boletus elegans* | Under larches |
| *Boletus leucophaeus* | Under birches |
| *Tuber aestivum* | Under beeches, oaks, hornbeams, pines |
| *Morchella esculenta* | Under ashes |
| *Agaricus arvensis* | Under beeches, chestnuts, and others |
| *Macrolepiota procera* | Under maples, lindens, magnolias, and others |

**Groups of trees** are planted in the garden more commonly than solitary trees. In groups of three or more trees, one can use species which are not strong-growing and have branches as close to the ground as possible. Partial shade is generally present under the groups of trees, and the humus layer desired by the majority of mushrooms is formed by the fall of leaves and needles. Mosses, ferns, bilberries, and heather can also be established here, and the plant community corresponding to the natural habitat of the tree can be created. Then we must provide also for the suitable species of mushrooms. For symbiotic mushrooms, it is best when planting the group to use young trees whose roots have already entered into association with the desired species of mushroom, since it will usually be difficult or even impossible to inoculate them later. The mycelium of some species of mushrooms will remain in the partial shade of the groups of trees, while others which can take more sun will grow into the adjacent lawns and show their fruiting bodies there in troops and rows

in the various seasons or even form semicircles and fairy rings. Thus the groups of trees and the lawns are further woven together, forming an organic whole out of the parts. Only in such group planting could it be possible to make *Boletus edulis*, truffles, and chanterelles at home in the garden.

Under groups of conifers

*Agaricus arvensis*
*Agaricus silvaticus*
*Agaricus augustus*
*Lepista nuda*
*Tricholoma flavovirens*
*Macrolepiota rhacodes*
*Russula vesca*
*Collybia butyracea* var. *asoma*
*Cantharellus cibarius*
*Boletus edulis* ssp. *fibrillosus*
*Boletus edulis* ssp. *pinicola*
*Boletus badius*
*Leccinum testaceo-scabrum*
*Hydnum repandum*
*Otidea leporina*
*Morchella conica*
*Choiromyces maeandriformis*

Under groups of broadleaved trees

*Macrolepiota procera*
*Agaricus arvensis*
*Lepista nuda*
*Russula vesca*
*Collybia butyracea* var. *asoma*
*Cantharellus cibarius*
*Boletus edulis* ssp. *reticulatus*
*Boletus leucophaeus*
*Leccinum testaceo-scabrum*
*Hydnum repandum*
*Otidea onotica*
*Peziza aurantia*
*Morchella esculenta*
*Morchella conica*
*Tuber aestivum*
*Tuber melanosporum*
*Choiromyces maeandriformis*

After lawns, the **border shrubbery**, often interspersed with groups of trees, occupies a large part of the available space in the ornamental garden. Ornamental shrubs, evergreens, and conifers are found here, depending on the taste of the garden owner. Plantings under this border shrubbery, bushes, and low conifers are only rarely present, perhaps some ivy or a few ferns, and along the outer border where some sun shines between the shrubs there may be perennials grown for their foliage or flowers, It is worthwhile to use this shady part of the garden also. Instead of annually shoveling or raking out fallen leaves, one should provide for abundant life here. Therefore, the fallen leaves should be left lying on the ground to allow the formation of as thick a humus layer as possible, from which the mycelium can remove all the nutrients it needs. In the shade of the shrubbery moisture remains in the soil, and a warm humid microclimate, which is especially well suited for fungal growth, develops during warm weather. When a thunderstorm provides abundant moisture during warm dry weather, mushrooms will shoot up out of the ground and offer abundant meals.

Some species of mushroom thrive better deep under the bushes and shrubs, others more along the edge of the shrub border where some sun shines through. The mycelium of the latter often penetrates far into the adjacent lawn areas, where the mushrooms form semicircles and fairy rings or grow together in troops or rows.

In this way formerly unused areas could provide many a delicacy, and a multitude of colors and odd forms in previously unnoticed places in the garden would offer us much delight.

Under border shrubbery

*Agaricus arvensis*
*Agaricus silvicola*
*Lepista nuda*
*Clitocybe nebularis*
*Clitocybe brumalis*
*Clitocybe geotropa*
*Boletus leucophaeus*
*Lycoperdon gemmatum*
*Morchella esculenta*

At the edge of border shrubbery

*Stropharia aeruginosa*
*Tricholoma georgii*
*Lepista personata*
*Macrolepiota procera*
*Macrolepiota rhacodes*
*Agrocybe praecox*
*Xerocomus subtomentosus*

**Hedges** are usually planted (along fences) for protection against wind and dust as well as for privacy from the neighbors. Often a row of flowering shrubs, which bring color to the garden and provide abundant decorative material, especially for large vases, forms the boundary with the neighboring piece of land. However, taller hedges, which offer better protection against wind and dust and which can be kept narrow by constant cutting, are frequently planted. Alternatively, evergreen hedges, which perform their task even in winter, border the garden plot. One should use the space under these hedges also for establishing fungi. To be sure, a humus layer would have to be maintained here, as under border shrubbery and groups of trees, so that the mycelium can find enough nutrients. It is true that a profuse growth of mushrooms will not form under hornbeam and poplar hedges, but even solitary fruiting bodies can enliven the picture. Under spruce hedges, in contrast, several species of mushroom in troops of various sizes could bestow many a delicious meal from spring to fall and conjure up for us a bit of spruce forest in the garden.

Mushrooms under hedges

| | |
|---|---|
| *Leccinum carpini* | Hornbeam hedges |
| *Leccinum aurantiacum* | Hornbeam, poplar hedges |
| *Stropharia aeruginosa* | Poplar hedges |
| *Morchella esculenta* | Poplar hedges |
| *Agaricus silvaticus* | Spruce hedges |
| *Agaricus augustus* | Spruce hedges |
| *Macrolepiota rhacodes* | Spruce hedges |
| *Boletus edulis* ssp. *fibrillosus* | Spruce hedges |
| *Xerocomus subtomentosus* | Spruce hedges |
| *Morchella conica* | Spruce hedges |
| *Choiromyces maeandriformis* | Spruce hedges |

*Mushrooms in lawns*

Where lawns border groups of trees, ring-forming mushrooms such as *Tricholoma* and *Stropharia* can grow out from the trees into the lawn and enliven it with numerous colorful fruiting bodies. In spring one delights in white, yellow, and blue crocuses in the lawns. Mushrooms in small or larger groups can similarly break up the green of the grass with color in summer and fall too. Delicious white species of *Agaricus* grow in sunny cow pastures and parks in summer and fall until the first frosty days; these frequently establish themselves in lawns even without our interference. Our garden can be enriched by introducing mushroom spawn here, not only making it visually noteworthy but also some day giving children the joy of collecting mushrooms themselves for the noon meal. The field mushroom, the horse mushroom, and *Agaricus edulis* are suitable here.

Mushroom species which can withstand rather strong sunlight should be introduced to the garden in fairly small groups. Shaggy manes emerge from the grass like beautiful candles, even if the lawn is only on hard ground with low nutrient content. The light-colored fruiting bodies appear repeatedly from summer into late fall.

The broad caps of the usually solitary parasol mushroom look especially picturesque perched on their tall stalks. When young they look like drumsticks. A solitary free-standing mushroom often is enough to serve as a decorative eye-catcher. It likes light shade such as exists under a free-standing tree. In short grass, especially on grassy paths, grow the small fruiting bodies of the particularly aromatic fairy-ring mushroom, whose caps dry out during very dry conditions but often regain their usefulness after a rain.

In grass which is rarely cut, *Tricholoma georgii* and *Agrocybe praecox*, fruit-

ing in spring, and *Stropharia aeruginosa* and *Clitocybe geotropa*, appearing in fall, do well also.

Introducing various species of mushrooms could give the lawn again the character of luxuriant pastures and lush meadows.

Mushrooms in lawns

*Agaricus edulis*
*Agaricus arvensis*
*Agaricus campestris*
*Tricholoma georgii*
*Clitocybe geotropa*
*Stropharia aeruginosa*
*Coprinus comatus*
*Agrocybe praecox*

Fungi on tree stumps left in grass

*Polyporus squamosus*
*Laetiporus sulfureus*
*Sparassis crispa*
oak *Sparassis*

*Mushrooms growing on wood*

Regardless of the kind of wood, logs which have been inoculated with wood-inhabiting fungi can be half-buried in the soil, either upright or lying down, in places with shade or partial shade. Trunks can be used which are permeated by only one species of fungus or by combinations of several species, which one can enjoy at different seasons for the odd forms of their fruiting bodies. Much as one can shape a part of the garden with dressed or native stone, a place can be laid out like a bit of virgin forest with tree stumps, rotten trunks, logs, and branches. Tall or low-growing ferns can be planted between the pieces of wood; ornamental grasses and luxuriant cushions of moss serve as a ground cover between which groups of the orange-peel fungus can be established, and ivy or clematis is encouraged to climb on the logs. The wood is colonized with white, brown, or green polypores, among which are honey-brown *Collybia velutipes*, roe-brown *Kuehneromyces mutabilis*, and *Pleurotus* in yellow-white, bright yellow, reddish, dark brown, and blue colors. More value will be placed on the color effect than on productivity for the kitchen, more attention paid to distributing fruiting-body formation evenly throughout the year, than on particularly delicious species. Such an ornamental tree-mushroom garden can be more attractive than the original border shrubbery among which it is placed.

One can lay a tree trunk 3-4 m long in a shady spot and inoculate it with several species of fungi. A place at the margin of a pool, a small pond, or a bog garden, where the fungi do well in the humid climate prevailing there, is very

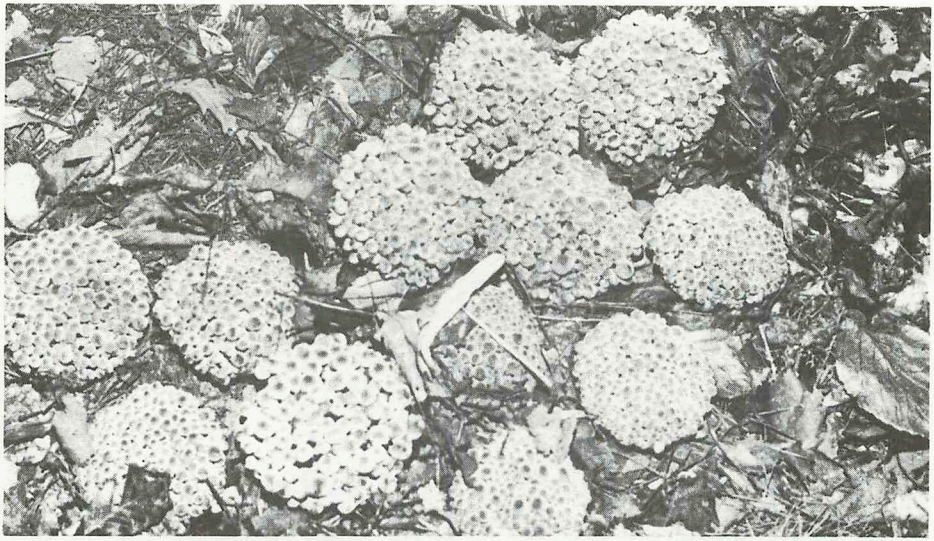


*Fig. 31. Plastic sacks buried in the ground, with velvet shanks on sawdust substrate*

suitable. The shady edge of a group of trees or a shrub border is also available. One should not inoculate the middle portion of the trunk but provide an opportunity to sit, to have a contemplative resting place for warm days and evenings.

A group of seats consisting of several sturdy blocks of wood inoculated with mycelium is likewise suitable for this purpose. The wood is buried about 20 cm deep in the ground to make enough moisture available for the growth of the mycelium and to create enough support. In the middle of the group a longer section of trunk, on which a large disk of wood about 60 cm across is nailed, is set up as a table. Such a sitting group is best put under a shade-providing tree, perhaps a weeping birch or the weeping forms of ashes or beeches. For inoculation one should use mushroom species such as the oyster mushroom, *Pleurotus ulmarius*, and the velvet-shank, which do not form their fruiting bodies until fall when the wood is no longer used as seats.

For railings bordering the edges of pools and banks, one can use vertically placed logs over which longer trunks can be nailed horizontally. The railings are inoculated with mycelium of various species; drought-resistant polypores, whose fruiting bodies last the whole year and can be used for decorative purposes when needed, are suitable here. Short logs permeated with mycelium, like those set out in orchards for growing mushrooms, can also be put up in partially shady places in the ornamental garden to achieve new effects by the

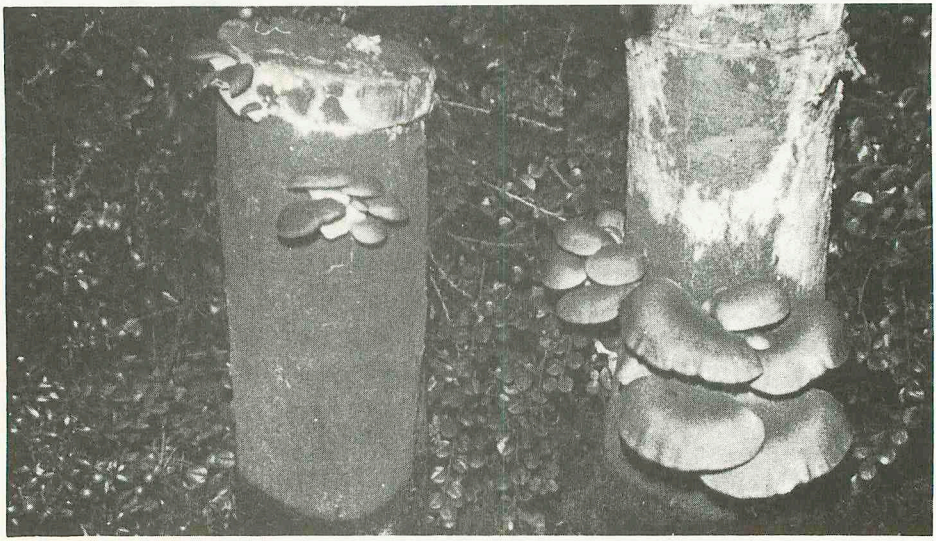


*Fig. 32. Oyster mushrooms (fall type) among cotoneaster bushes*

color and forms of the mushrooms growing on them. They must be set out in such a way that the mushroom-covered wood is protected from too-strong sun by trees and shrubs but is visible from the paths. Near bird-baths they can serve as a place for the birds to sit. Thicker logs are suitable as supports for flower tubs; tree stumps left in lawns and at the edge of shrubbery and groups of trees after clearing the garden area or thinning trees are good to use for this. If one establishes *Sparassis crispa* or the oak *Sparassis* here, or if the dryad's saddle or the sulfur polypore is established on tree stumps left standing alone and far apart in lawns, one can harvest large oddly shaped fruiting bodies or can have the splendidly colored polypores serve for a long time as decorations.

In the ornamental garden one should strive to make as many species of mushrooms at home as possible, above all those with strong color effects or especially interesting shapes, and to put less emphasis on their productive value. Here we wish to enjoy the mushrooms growing in the garden and to have the feeling that we were far away in a meadow or forest.

| Species | Height (cm) | Width (cm) | Color | Location in garden (Fruit, Vegetable, Ornamental gardens) | | | Season |
|---|---|---|---|---|---|---|---|
| *Agaricus bisporus* | 6-8 | 12-15 | white, blond, brown | F | V | | Aug-Dec |
| *Agaricus edulis* | 5-8 | 10-15 | white, yellowish | F | V | O | May-Oct |
| *Agaricus arvensis* | 6-15 | 5-15 | white | | | O | Jun-Sep |
| *Agaricus campestris* | 5-8 | 5-10 | white | | | O | Jun-Sep |
| *Agaricus silvaticus* | 6-10 | 4-10 | light brown | | | O | Jul-Oct |
| *Agaricus silvicola* | 6-12 | 5-10 | white to yellowish | | | O | Jun-Sep |
| *Agaricus augustus* | 10-12 | 10-30 | dark brown | | | O | Aug-Oct |
| *Stropharia rugoso-annulata* | 8-12 | 15-18 | brown | F | V | | Jun-Oct |
| *Stropharia aeruginosa* | 5-8 | 4-8 | green to yellowish | | | O | Sep-Nov |
| *Lepista nuda* | 6-8 | 6-15 | violet | | | O | Sep-Nov |
| *Tricholoma georgii* | 5-8 | 6-15 | white to yellowish | F | | O | Apr-Jun |
| *Tricholoma flavovirens* | 4-6 | 4-10 | yellow to green-yellow | | | O | Aug Nov |
| *Lepista personata* | 8 | 12 | lilac | F | | O | Oct-Nov |
| *Macrolepiota procera* | 10-30 | 10-30 | brownish | compost | | O | Jul-Oct |
| *Macrolepiota rhacodes* | 10-15 | 10-15 | brown | compost | | | Jul-Nov |
| *Clitocybe nebularis* | 7-10 | 7-15 | light gray | | | O | Sep-Nov |
| *Clitocybe brumalis* | 4-5 | 2-4 | light brown | | | O | Nov-Dec and Mar |
| *Clitocybe geotropa* | 8-15 | 10-20 | ochre | F | | O | Sep-Nov |
| *Coprinus comatus* | 5-15 | 3-6 | white | compost | V | O | Apr-Nov |
| *Marasmius oreades* | 4-8 | 2-6 | ochre | F | | O | Jun-Oct |
| *Marasmius scorodonius* | 3-6 | 1-3 | pale brown | | V | | Jun-Oct |
| *Russula vesca* | 3-6 | 6-10 | pink to red | | | O | Jul-Oct |
| *Collybia butyracea* var. *asoma* | 5-6 | 3-6 | gray-brown | | | O | Aug-Oct |
| *Agrocybe praecox* | 10-15 | 4-10 | ochre | | | O | May-Jun |

| Species | Height (cm) | Width (cm) | Color | Location in garden (Fruit, Vegetable, Ornamental gardens) | | | Season |
|---|---|---|---|---|---|---|---|
| *Cantharellus cibarius* | 2-6 | 2-8 | yellow | | | O | Jun-Sep |
| *Cantharellus cibarius* (broad-leaved forest) | 3-8 | 4-12 | light yellow | | | O | Jun-Sep |
| *Boletus edulis* | 10-20 | 8-25 | brown | | | O | May-Oct |
| *Boletus elegans* | 6-12 | 7-15 | gold-brown | | | O | Jun-Oct |
| *Boletus badius* | 6-12 | 5-15 | brown | | | O | Jul-Oct |
| *Boletus granulatus* | 5-8 | 6-10 | brown | | | O | Jun-Oct |
| *Boletus leucophaeus* | 8-17 | 5-12 | brown | | | O | Jun-Oct |
| *Hydnum repandum* | 2-5 | 6-15 | light to ochre yellow | | | O | Jul-Nov |
| *Lycoperdon gemmatum* | 5-10 | 3-6 | white to yellowish | | | O | May-Nov |
| *Otidea onotica* | 3-5 | 3-6 | orange-yellow | | | O | Jun-Sep |
| *Otidea leporina* | 2-5 | 2-5 | leather-yellow | | | O | Jun-Sep |
| *Peziza aurantia* | 1-3 | 3-10 | orange-red | F | | O | Jun-Oct |
| *Morchella esculenta* | 5-12 | 3-8 | ochre to brown | F | | O | Apr-Jun |
| *Morchella conica* | 5-10 | 3-5 | brown | | | O | Mar-May |
| *Tuber melanosporum* | | 3-8 | brown to black | | | O | Nov-Feb |
| *Tuber brumale* | | 1-5 | brown to black | | | O | Sep-Nov |
| *Tuber aestivum* | | 5-10 | black | | | O | Aug-Nov |
| *Choiromyces maeandriformis* | | 6-10 | light brown | | | O | Jul-Sep |
| *Stropharia rugoso-annulata* | 8-12 | 15-18 | ochre, dark brown | F | V | O | Jun-Oct |
| *Pleurotus ostreatus* (fall) | 2-4 | 5-15 | light brown, gray-brown | F | V | O | Oct-Dec |
| *Pleurotus ostreatus* (summer) | 2-4 | 5-20 | yellow-brown | F | V | O | May-Jun Sep-Oct |
| *Pleurotus ulmarius* | 6-18 | 8-20 | gray | F | | O | Sep-Nov |

| Species | Height (cm) | Width (cm) | Color | Location in garden (Fruit, Vegetable, Ornamental gardens) | | Season |
|---|---|---|---|---|---|---|
| *Pleurotus cornucopiae* | 4-6 | 5-8 | yellow to reddish | | O | Sep-Nov |
| *Pleurotus columbinus* | 2-4 | 5-12 | gray to blue | F | O | Oct-Nov |
| *Pleurotus nidulans* | 2-3 | 5-7 | orange-yellow | | O | Sep-Dec |
| *Kuehneromyces mutabilis* | 4-7 | 3-8 | brown | F | O | May-Nov |
| *Collybia velutipes* | 4-10 | 2-8 | yellow-brown | F | O | Oct-Apr |
| *Collybia platyphylla* | 7-10 | 5-12 | gray-brown | | O | Jul-Sep |
| *Collybia dryophila* | 4-6 | 3-6 | brown | | O | Jun-Oct |
| *Nematoloma capnoides* | 5-10 | 2-7 | yellow-brown | F | O | Aug-Feb |
| *Agrocybe aegerita* | 6-8 | 5-7 | yellow-brown | F | O | Aug-Feb |
| *Lentinus edodes* | 3-5 | 5-10 | brown | F | O | Feb-May |
| *Polyporus squamosus* | 4-8 | 10-30 | yellow to brown | | O | Apr-Nov |
| *Laetiporus sulfureus* | | 10-30 | yellow | | O | Apr-Aug |
| *Sparassis crispa* | | 15-20 | yellowish | | O | Aug-Oct |
| *Auricularia auricula-judae* | | 3-5 | brown | F | O | Jun-Dec |

# Methods of cultivation

## Cultivation of the most important edible fungi

### Propagation

How to propagate flowers, vegetables, and strawberries is probably familiar to everyone who has a garden. We have surely bought many packets of seeds and sown them in our gardens, or taken layers from our strawberries and planted them in beds. We will generally leave the propagation of trees and shrubs to the specialist and will strive to make these purchased plants continue to do well once they are in our gardens. It is not quite so simple with fungi. The desire to be able to cultivate for oneself these forms which suddenly shoot out of the ground so mysteriously has existed for over two thousand years.

As early as 300 B.C., Theophrastus in Greece concerned himself with the development of mushrooms, and around 50 A.D. people endeavored to propagate *Boletus edulis* by digging up its remains from the soil or by placing them in water and pouring it on the ground in places similar to the natural habitat. Almost the same method was used about 1650 by gardeners in Paris when the common cultivated mushroom was first propagated by putting trimmings and mushroom wash water on the manure removed after growing melons. In a similar way, people have tried up to the present to establish truffles and morels in suitable places. It was reported in 1816 that a clod of earth permeated with the mycelium of the "Steinröhrenpilz" was collected in Italy in fall and taken to Vienna, where it produced many fruiting bodies in spring. Attempts in Germany to pick mushrooms with their stalks before they were ripe and to transplant them to suitable places in the forest were not successful. The mycologist Heckenstaller reported that he managed to establish *Boletus edulis* in the English Garden in Munich. He laid ripe caps on the ground and covered them with leaves. In his opinion, the process of rotting of the cap stimulated the spores to germinate. He was also able to grow whole colonies of the velvet-shank by rubbing old stumps with the ripe caps.

When it became clear in the nineteenth century that fungal spores had the same function as the seeds of the familiar green plants, the spores were used for

propagation. Thus it was reported in 1883 that viable spores of the Steinpilz were mixed with sand and sown on grassy areas in Dresden under broadleaved and coniferous trees. In the second year, the first mushrooms appeared under the conifers and later under the broadleaved trees. It was recommended to let the spores germinate in a warm humid room on leaves and to put the leaves and germinated spores under a warm damp layer of moss. Until a few decades ago, wood-inhabiting mushrooms were still propagated by scattering spores on tree trunks and logs and then chopping them into the wood.

The primitive methods mentioned above rarely led to success, and the results were so unsatisfactory that matters got no farther than isolated attempts. The change from propagation by spores to propagation by a mycelium-permeated substrate made more reliable cultures possible. French gardeners discovered that well-developed mycelium could be found in the piles of horse manure in fields and in the piles of rubbish mixed with horse manure along streetsides. Remains of composted horse manure were inoculated with this mycelium and protected from rain and sun to encourage further development. The well-permeated substrate of these beds was divided up into pieces and sold as champignon manure spawn. In Germany, people looked particularly under mangers in horse stalls of barracks for the champignon mycelium to use as manure spawn. So-called "Brutsteine" ("spawn stones") were produced by mixing the spores with horse fodder to get the mycelium to form in the horse



*Fig. 33. Manure spawn and bottled spawn*

manure. The mycelium so obtained was mixed with horse manure, loam, and other additives, then "stones" were formed from it and used as spawn. Since in woods abundant fungal growth is usually found where there is much wild-animal dung, it seems that the method of encouraging the formation of mycelium by passing spores through animal stomachs is worth examining. The mushrooms raised by the methods given were naturally very variable in form and color, and so new methods had to be found as the consumer's demands for the quality of mushrooms grew.

In order to cultivate uniform mushrooms, spores were put on agar in reagent glasses to germinate and the mycelium was transferred to a previously heat-sterilized nutrient substrate. Bars were cut out of the spawn beds so obtained, packed neatly, and put on the market. Since moist spawn does not keep long, dried spawn, which had to resorb moisture before use, was generally employed. The bars, which were uniformly enveloped in a fine white mycelium, were broken up into small pieces for inoculating the mushroom beds.

Using glass flasks or plastic bags makes it possible to sterilize the substrate thoroughly and to keep it sterile without hindering gas exchange, by using germ-free stoppers of cotton or polypropylene film. Nowadays an outstanding manure spawn can be obtained from good growers. Commercial *Stropharia* spawn can be stored for several months at 2-5°C and up to three weeks at 10-15°C. With spawn paste one can expect a storage life of 3-10 days after it is put in the containers.

Today, spores are usually put on nutrient agar in rooms which are kept perfectly sterile, and the mycelium grown on it is used for inoculation. These

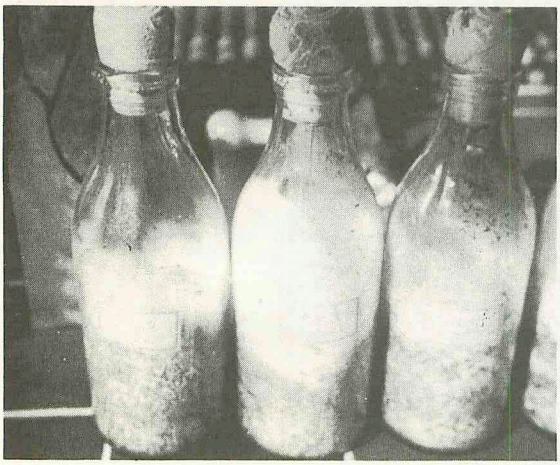


*Fig. 34. Spawn in bottles*

spore cultures are grown as single-spore or multi-spore cultures, depending on the purpose of cultivation. Further propagation is generally by division of the mycelium. Instead of the spores, pieces of the fruiting bodies can also be used to obtain mycelium.

In commercial mushroom cultivation, mycelium which has been transfered to cereal grain, **grain spawn**, is generally used for propagation because the grains can be evenly distributed in the nutrient substrate and therefore the numerous places from which the mycelium penetrates it permits the mycelium to grow throughout it more quickly and evenly. The more quickly the mycelium grows throughout the substrate, the less is the danger that infection by foreign species of fungi can damage or even destroy the desired species.

To prepare grain spawn, grain (wheat, rye, barley, millet) is boiled until it has a moisture content of about 40%, and, after it has begun to dry somewhat, brought to a pH suitable for growth of the mycelium, which for the common cultivated mushroom for example is pH 7.5, by adding calcium carbonate or gypsum or a mixture of the two. Flasks or plastic bags are filled with this and sterilized for two hours at 120° C. The containers are shaken to loosen the masses of grain which ball up during sterilization. In a sterile room, pieces of mycelium are then transferred from the pure cultures to the containers, then stored in the spawn-running room at about 25° C. The nutrient medium is densely permeated by mycelium after about 2-3 weeks and can now be sold as spawn. For sale, it is transferred to a special sales packaging or left in the plastic bags. The prepared packages can be stored for a few weeks at temperatures just above 1°C, but since they are usually exposed to higher temperatures during transport to the consumer, especially in summer, the spawn should be ordered as close to its use as possible and used at once or at least kept opened in a refrigerator.

Construction of the fully climatized rooms needed for spawn of the best quality, which are kept completely sterile and must be ventilated by special filtering equipment, is naturally very expensive. Therefore, the number of producers of spawn has become smaller and smaller, while the places of production have become larger and larger. Breeding new varieties especially suited for cultivation requires a scientific staff and the most modern research equipment, the high cost of which can be borne only by large firms. A person who wishes to produce spawn himself must therefore be satisfied with primitive methods and must not be surprised if the desired success commonly fails to appear.

In the case of the little-cultivated species of fungi, other methods of cultivation are possible besides grain spawn and various kinds of manure spawn. Thus, so-called spore paper can be used, or one can use wedges of wood (so-

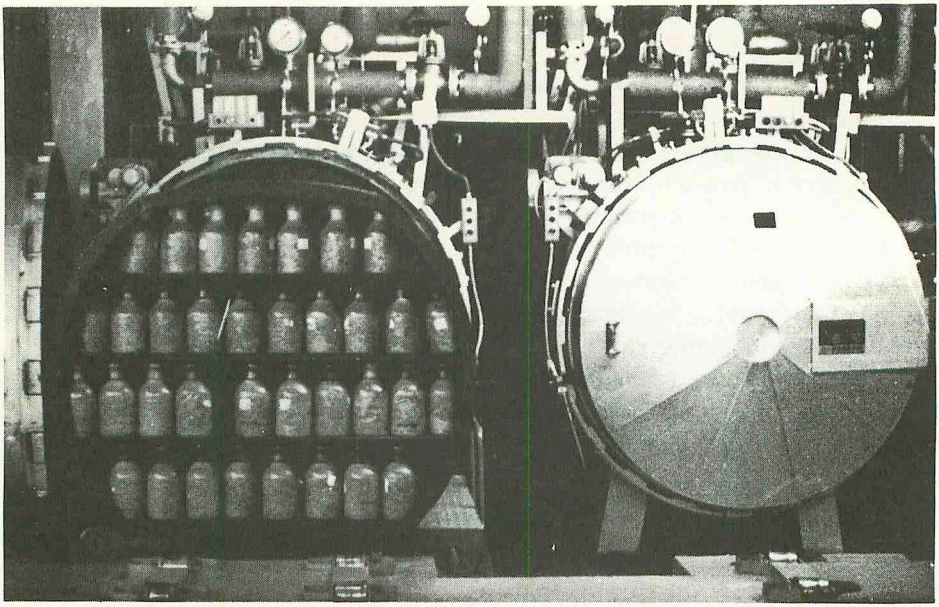


*Fig. 35. Substrate for spawn production sterilized by heating in an autoclave*

called spawn wedges) permeated with mycelium for inoculating logs, following the Japanese example. For wood-inhabiting fungi, spawn paste is frequently prepared from, for example, water, wood shavings, malt, and peptone (after W. Luthardt). The paste can be spread evenly on the cut surfaces of the wood, and it protects them from drying and foreign infection. In the case of symbionts, seedlings of the trees with which the desired species lives in symbiosis are raised in sterile conditions, inoculated with the mycelium, and later planted in a suitable place.

Whoever wants to go into propagating fungi must clearly understand from the start that not only are much expense and many difficulties involved, but also much vexation from repeatedly occurring failures, since a person growing fungi as a hobby is not in a position to work under as sterile conditions as fungi require. Propagating fungi which one collects oneself by culturing spores or pieces of tissue on a nutrient agar substrate, and then transferring the mycelium so obtained onto a substrate to be used as spawn, is usually very complicated. It is simpler to propagate available spawn on manure, straw, or wood. It has proven favorable to use preserving jars for producing one's own spawn. The jars are filled with the appropriate substrate and then sterilized in a canning

kettle or oven for about two hours at 120°C. After the substrate has cooled to about 30°C, some spawn is quickly mixed with it, and the lid is replaced or the jar is wrapped with a polypropylene sheet. If a washer is not put on, some air can still penetrate between the lid and the glass. Depending on the species of mycelium and the suitability of the substrate, the contents of the glass will be permeated by the mycelium and can be used for further propagation or for inoculation. Grain, short or chopped straw, wood chips, peat, or a mixture of various materials are used as substrates, depending on the species of fungus.

For wood-inhabiting fungi one can use the "tree-slice method", which is especially simple. Logs well permeated with mycelium are cut into slices 3-5 cm thick. Logs without any mycelium growing in them are cut into 40 cm lengths, and the permeated disks are nailed tightly to the logs, after the cut surfaces have been well moistened and possibly even covered with some sawdust. Then the logs are placed in a pit or in a stack where the humidity is high for the mycelium to grow throughout them, or, if there are only a few, are kept warm in a cellar in a plastic sack into which some water is poured and sprayed over the wood.

If one wishes to produce spawn from spores or pieces of tissue from fruiting bodies which one has collected oneself, one must create a small laboratory in an available room. In general, a cellar room, which can be heated and ventilated, which is not harmed by high humidity, and in which electricity is available,



*Fig. 36. Pleurotus spawn propagated at home*

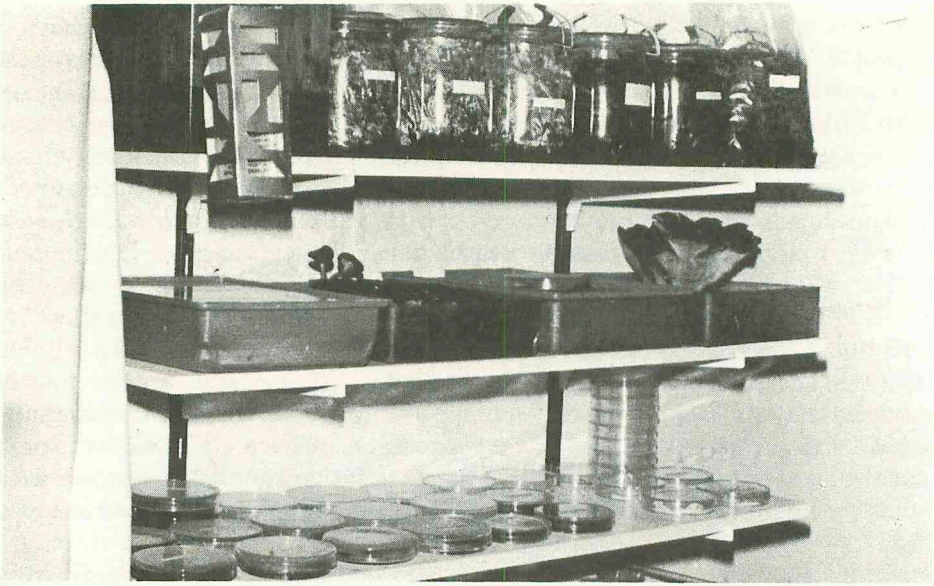


*Fig. 37. Simple spawn laboratory in a home cellar*

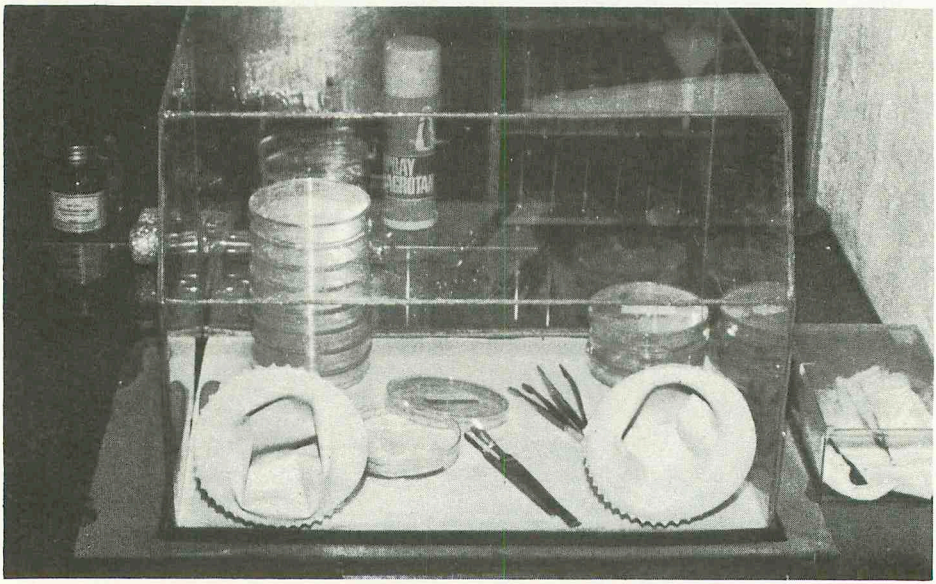


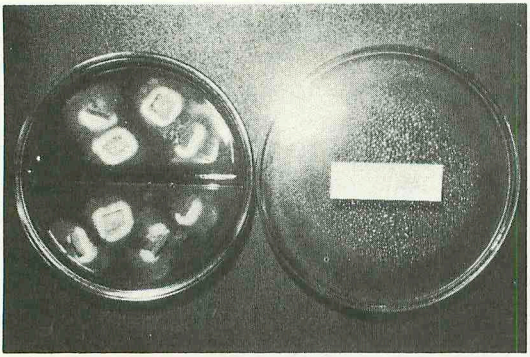
*Fig. 38. Spawn laboratory in a cellar with inoculation chamber*

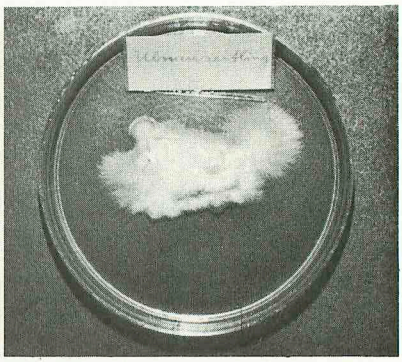
will be suitable for this purpose. In the room one needs a shelf for placing Petri dishes, reagent bottles, preserving jars, etc. and a worktable, with a plastic top if possible. For lighting the room a fluorescent lamp (daylight), a table lamp, and an ultraviolet light over the workspace should be present.

For propagating, Petri dishes are used. Sterile plastic dishes can be purchased, packed 10 in a plastic bag. When using glass dishes one sterilizes them in the oven at 120°C. Agar is put into the dishes as a nutrient substrate. Usually ready-to-buy malt extract agar is suitable. It is soaked for 15 minutes in distilled water and then cooked in a pressure cooker until completely dissolved, and preferably finally autoclaved for 20 minutes at 120° C. So treated, it is completely sterile. About 10 ml of the agar solution is put in an ordinary Petri dish. This is allowed to cool and is stored in a sterile condition. For inoculating many species it suffices to open the dishes quickly, put in the pieces of tissue or spores, and immediately close them. Since there are usually numerous bacteria and fungal spores in the air of the room, an ultraviolet light is put over the workspace if possible (turn it off when working) to kill the germs, or the air is disinfected by turning on an air disinfector half an hour before starting to work. The work is carried out in a kind of miniature greenhouse (inoculation box), which one can make oneself out of plastic. One uses sterile rubber gloves when working. Before inoculating, the box is sterilized inside with formalin or Sagrotan, the Petri dishes are cleaned with ethyl alcohol, and sterile tools are used. When one is propagating by the generally simple method of using pieces of tissue, it is essential that they also be sterile. Therefore one uses, for example, pieces of lamellae from unopened caps cut off in the inoculation box, or pieces of stalk which are taken from the inner portion of the stalk, since foreign bodies which can cause infections occur all over the outside of the fruiting bodies. In the inoculation box these pieces of tissue are placed very quickly on the nutrient substrate in the Petri dishes. The inoculated dishes are then put in plastic bags and placed on the shelf for the mycelium to develop. After only a few days one can determine whether the mycelium is growing or whether bacteria or injurious fungi managed to get into the dishes. After the mycelium has grown over the nutrient substrate, the culture is ready to be used for inoculating the spawn substrate.

Small pieces of agar with mycelium growing on them are put on grain, straw, wood chips, etc. so that the mycelium can grow into the spawn substrate. Information about this has already been given under "How to make grain spawn" and "How to produce spawn oneself", so further explanation here is superfluous. Usually a temperature of about 25°C is favorable for mycelial growth in edible fungi.

Within the scope of this book, these extremely delicate operations must be





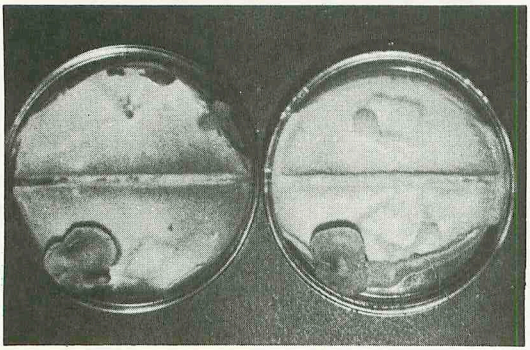


*Fig. 39. Obtaining mycelium from pieces of tissue*

*Fig. 40. Mycelium formation by Pleurotus ulmarius*

*Fig. 41. Old shiitake mycelium with miniature fruiting bodies*

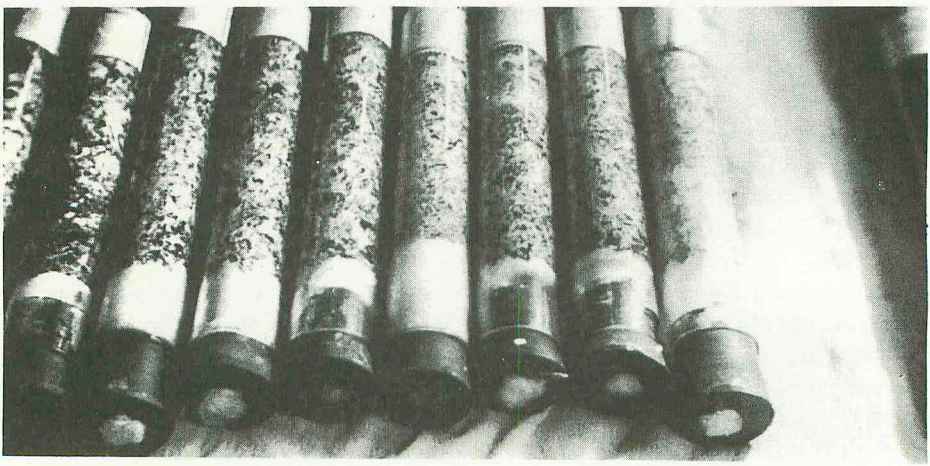


*Fig. 42. Spawn production in glass tubes for inoculating bore holes*

briefly described, but it is done to give mushroom enthusiasts at least a glimpse into the subject and to stimulate them to try it for themselves. Failure cannot be avoided, since even the smallest mistakes can cause complete failure.

| Spawn on the market in 1946 | Spawn on the market in 1980 | Present-day culture attempts |
|---|---|---|
| *Agaricus bisporus* | *Agaricus bisporus* | *Agaricus arvensis* |
| *Pleurotus ostreatus* | *Agaricus edulis* | *Agaricus campestris* |
| *Kuehneromyces mutabilis* (brown-stalked) | *Pleurotus ostreatus* (summer type) | *Agaricus silvicola* |
| *Kuehneromyces mutabilis* (white-stalked) | *Pleurotus ostreatus* (fall type) | *Macrolepiota rhacodes* |
| *Collybia velutipes* | *Pleurotus cornucopiae* | *Marasmius scorodonius* |
| *Lentinus edodes* | *Kuehneromyces mutabilis* | *Morchella esculenta* |
| *Nematoloma capnoides* | *Collybia velutipes* | *Morchella conica* |
| *Nematoloma sublateritium* | *Lentinus edodes* | *Boletus badius* |
| *Polyporus squamosus* | *Nematoloma capnoides* | *Xerocomus subtomentosus* |
| *Meripilus giganteus* | *Auricularia auricula-judae* | *Boletus edulis* |
| *Sparassis crispa* | *Lepista nuda* | *Cantharellus cibarius* |
| *Agrocybe praecox* | *Stropharia rugoso-annulata* | *Pleurotus ulmarius* |
| *Lepista nuda* | *Agrocybe aegerita* | *Pleurotus columbinus* |
| *Clitocybe nebularis* | *Coprinus comatus* | |
| *Marasmius oreades* | Oaks and hazels inoculated with truffle mycelium | |
| *Lyophyllum fumosum* | *Boletus granulatus* and others for forestry | |
| *Macrolepiota procera* | | |

## Instructions for cultivation

*Cultivation of the common commercial mushroom*

The common cultivated mushroom is grown commercially in Germany the year round in large and costly special culture rooms. However, naturally it is also possible for mushroom enthusiasts to grow their own mushrooms in their gardens in summer and fall. Since setting out the mushrooms in too much sun must be avoided and the substrate for cultivating should not dry out, protection with earthworks is recommended for cultivating them in the garden. In some gardens existing asparagus hills are available for this purpose. The beds should be arranged in an east-west direction so that shade is cast by the asparagus hills to protect the mushroom beds from irradiation by the midday sun. After the asparagus is harvested, the mushroom bed is laid out between the first and second asparagus rows; room is left between the second and third rows for tending the mushrooms and harvesting them; the next mushroom bed follows, and so on. Since the hills are already present, some soil only has to be dug out for the lower part of the mushroom bed; a suitable nutrient substrate (mushroom compost) is layered on the north side of the hills and is then covered with a layer of the soil.

Since most gardens do not have asparagus beds, ridge beds are laid out

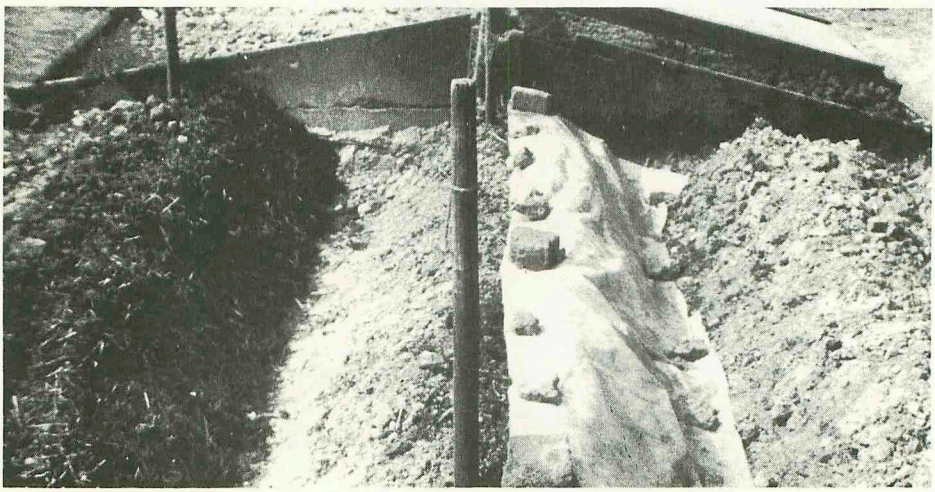


*Fig. 43. The north side of an asparagus hill is covered with Agaricus compost, inoculated, and then covered with a plastic sheet.*

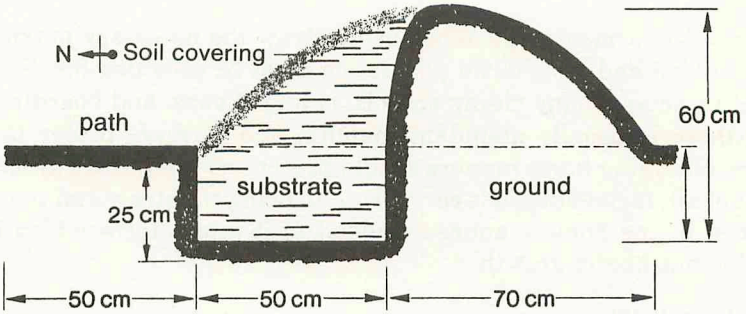



*Fig. 44. Agaricus hill bed*

between rows of dwarf fruit trees or in the vegetable garden. These will have to be limited to one row between the rows of fruit trees; otherwise tending the mushrooms as well as the fruits will be too difficult. To prepare the bed, a trench 50 cm wide and 20-25 cm deep is dug, and a ridge is built up on the south side out of the excavated soil. The ridge should be as steep as possible on the side toward the ditch and slope more gradually toward the south. The top of the ridge will be about 60 cm higher than the bottom of the trench; the ridge may be about 70 cm across. Finally, a path 40-50 cm wide is left for tending the beds before the next bed is begun. A suitable nutrient substrate must be available for cultivating the common mushroom successfully. Only rarely will a commercial mushroom house be nearby, from which prepared, pasteurized, unused mushroom compost can be obtained. Of course, one can expect a substantially better result with a supply of such a sterilized compost, prepared from the best materials, than from one's own preparation, especially since foreign infection by harmful disease-causing fungi can be avoided in the specialized operation.

To be able to prepare a suitable substrate, one must first of all be clear about what is to be achieved. Since the mushrooms do not have chlorophyll and therefore cannot synthesize carbohydrates themselves, they are dependent on organic substances for their nutrition. They take up carbohydrates, proteins, and minerals from dead organisms; these are changed into a usable form for them by the activity of microorganisms. The protein requirement is supplied from dead microorganisms and the nitrogen-rich lignin-humus complex. In addition, it seems that they need to be provided with vitamins, which are produced by the microorganisms which decompose the cellulose in the substrate. Straw is especially suitable as the main substrate. In making one's own compost it is best to use straw-rich horse manure, since it already contains nitrogen and all other nutrients needed by the mushrooms and has the bacteria

necessary for fermentation. When using straw the necessary nutrients must first be added and a bacterial population must be provided for. Since at the present there are many riding schools, riding arenas, and boarding stables, where there is usually abundant manure, and farmers prefer to use cow manure, obtaining horse manure should present no great difficulties.

First of all, fermentation is carried out to bring the straw and the nutrients contained in the horse manure or added to it into a form which promotes favorable mushroom growth.

The object is to:

1. Loosen and soften the straw component
2. Increase the moisture content
3. Break up and mix the substrate to form a loosely structured mass which is as homogeneous as possible
4. Transform the components into forms of the nutrients which are more readily available to the mushroom mycelium
5. Bind ammonia (nitrogen)
6. Neutralize the acids
7. Regulate the pH value

The fermentation is usually carried out by composting. The changes in the compost are carried out by small organisms (microbes). First of all, bacteria and fungi which do especially well at temperatures around 25°C establish themselves. When the temperature rises, these species die off and others which endure 45°C take their place, while the warmth-loving actinomycetes (ray fungi) do especially well at 45-55°C. For this process to run its course successfully, the substrate must be turned over several times so that all parts are equally treated and a good supply of oxygen in the compost heap is guaranteed. The ideal moisture content is attained by adding water.

The more easily decomposed carbohydrates are broken down by the activity of microbes (bacteria, actinomycetes, and fungi), and heat is generated. The straw is softened by the high temperatures developed in the compost, acting along with the ammonia present. Since too-high temperatures would cause combustion, the compost must be turned over in a timely manner. A considerable part of the dry matter is lost during the fermentation process, since much organic matter is broken down in it. The microbes use the ammonia present in the compost for their own structure, and after their death their body proteins can be utilized by the mushroom mycelium.

Because of the small quantities needed, proper composting unfortunately causes considerably more difficulties for the gardener than in commercial cultivation, since the manure has to be piled high enough for the substrate to

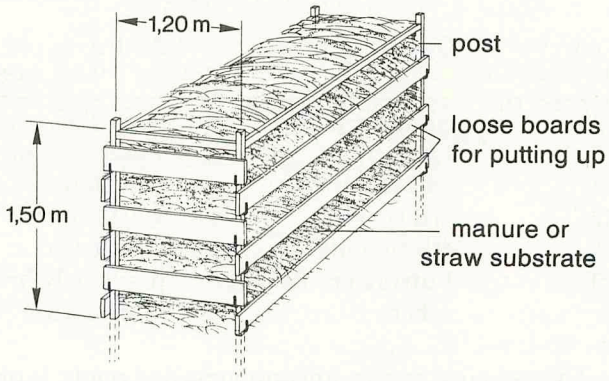



*Fig. 45. Composting for Agaricus culture*

become well heated. To achieve this, some posts of fruit wood are first driven in at about 1 m intervals to bound the sides, and some boards are placed on the long sides. Then the horse manure is piled in layers, tamped down firmly, and moistened. As the height of the compost heap increases, the boards are put higher and higher so that the outer surfaces end up smooth, as can be seen in dung heaps on many farms. The heaps should be piled about 1.5 m high and 1.2 m across. The length corresponds to the quantity of manure desired. Chicken droppings are added as supplementary manure, and the substrate is mixed with gypsum to obtain a favorable calcium content (pH 7.5-8.0). To obtain a uniform compost, it must be turned over several times and water must be added so that the substrate ends up containing about 73% water. Since the gardener does not have pasteurizing equipment, he must wait to use to the substrate until there is no more ammonia in it, because mushroom mycelium would not be formed otherwise.

When setting up the compost pile, tamp it down firmly so that it will take up a lot of water; when turning it over, layer it loosely. In several turnings the following should be achieved:

1. Moisture of the substrate approximately 72-75%
2. pH 7.5-8.0
3. Straw still yellow brown to dark brown with white spots composed of actinomycetes (ray fungi)
4. Straw crumbly and capable of being broken up by hand
5. No odor of ammonia

For the amateur mushroom grower only so-called long composting will lead to the desired result. For this one must make sure that the compost heap is firmly tamped down when being piled so that it will take up a lot of water. When it is turned subsequently it should be replaced only loosely, for better aeration.

Procedure with horse manure as the chief component

| Day | Operation | Additives per ton horse manure (example) |
|---|---|---|
| 1. | compact piling | abundant water + 50 kg chicken manure |
| 5. | 1st turning | water + 50 kg chicken manure |
| 11. | 2nd turning | a little water + 25 kg gypsum |
| 15. | 3rd turning | a little water |
| 19. | 4th turning | a little water |
| 21. | Putting on the ridge bed | previously brought to a water content of 72-75% |

The compost, now free of ammonia and ready, is placed in a layer about 15 cm thick in the trenches and layered deeply on the north side of the mound, then lightly tamped down, and finally inoculated with manure spawn; or before tamping, it is mixed with grain spawn (150 g/m$^2$ of the bed area), afterwards has some spawn lightly strewn over it, and then is pressed down. After inoculation, a moist layer of good and crumbly soil (pH 7.5) 2-3 cm thick is put over the compost for protection against drying, is sprayed only lightly so that the water does not seep into the compost, and the whole thing is covered with a thin sheet of plastic so that the heat forming in the compost and the moisture are retained.

After a few weeks the compost substrate will be permeated by the mycelium, and the covering layer of soil, which is made of peat, coarse sand, and lime or peat, loam, and lime, can be increased to a thickness of 5-6 cm. After the soil is moistened, the plastic sheet is replaced until the mycelium has grown into this layer also. After that the culture must remain without a covering to stimulate the formation of fruiting bodies.

*Cultivation of Stropharia*

*Stropharia rugoso-annulata* is known not only in Europe, but also in Asia and America. A few businesses cultivate it commercially, primarily in culture rooms, or as a summer culture in cold frames and in the open. Until now it has been in the first rank of interest for amateur cultivation.

One can grow this mushroom like a vegetable in beds and cold frames in order to obtain a harvest from summer into fall, or can establish it in suitable places in the garden in the shade of shrubbery or hedges to enhance the assortment of mushrooms there.

Cultivation in beds should be discussed first. Beds for culturing *Stropharia* are laid out 40-60 cm wide under standard fruit trees, between rows of dwarf

fruit trees, or in the vegetable garden in the shade of rows of pole beans. The margin of the bed is raised about 10-15 cm so that a shallow trench is formed behind it, to keep runoff from adjacent ground from soaking the nutrient substrate during heavy rainfall. The chief component of the substrate is straw, which is stacked before use and watered 3 times a day for 3-5 days. If the straw is already rather old and moist it can be used immediately. However, the water must already have penetrated the pieces of straw, but decomposition must not have begun; the straw should still have its yellow color and not be already decayed or decomposed. When straw bales are used they can be placed in a container of water for 3 days (change the water daily).

The saturated straw is now laid in layers on the surface of the bed. Each layer is watered and tamped down firmly before the next layer is placed, until a bed about 30 cm high is formed. Before the last layer is laid down, the spawn is evenly distributed over the surface and then covered with straw and tamped down. The bed can also be first prepared and then inoculated with individual pieces of spawn which are inserted 5-10 cm deep, as in cultivating *Agaricus bisporus*. Then the bed is covered with a plastic sheet to maintain the moisture and warmth. If warm dry weather nevertheless threatens to dry out the bed, it should be sprinkled superficially, very lightly at most, since growth of the mycelium is disturbed by watering. Good shade provided by straw mats or conifer twigs laid on the bed is better.

When the substrate is well saturated with water and the temperature is about 25° C, the mycelium will quickly spread from the spawn throughout the whole bed and pervade it with a dense white network of threads. The increased carbon dioxide content under the sheet also favors mycelial growth. After 6-7 weeks in favorable weather the substrate will be permeated so that the white fungal threads are visible at the surface. Now the time has come to remove the sheet and to cover the straw with a layer of soil to stimulate the formation of fruiting-body primordia. The layer of soil must be brought directly onto the well-permeated substrate so that the mycelium can continue to grow directly from one layer to the other. Therefore, if there is dry straw on the surface it must be removed beforehand. The covering of soil should be piled about 4-6 cm deep; the more permeable the soil is to water, the deeper the layer. Since the soil absorbs water well, but good aeration of the soil should be guaranteed also, a large proportion of humus (generally peat) is desirable. A mixture of peat with the upper layer of garden soil in a proportion of 1:1, or an addition of loam or compost soil, which should not contain lime, therefore seems suitable. Before covering the substrate with soil, the latter should be saturated with water; it should be kept constantly moist without the water running into the layer of substrate permeated with the mycelium and harming the growth of the fungus.

If one must be careful to provide abundant moisture, so one must at the same time keep the culture from becoming too wet. If the beds do not get enough shade, they should be given protection against drying out after the soil is laid down, with conifer twigs or similar material. For protection against downpours a sheet can be put 40 cm above the bed. Unhindered ventilation must be ensured in any case.

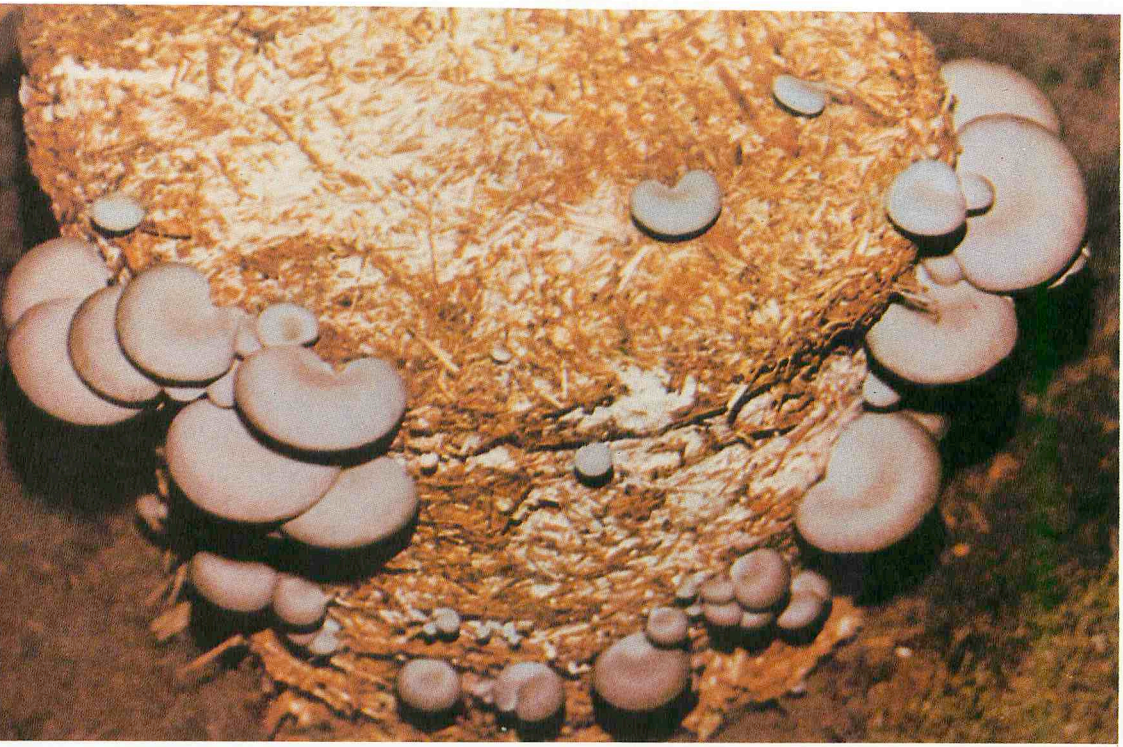
After another 5-6 weeks the first fruiting bodies can appear. In general, they begin at the edge of the bed, as in the common cultivated mushroom, possibly even next to the bed. One should not count on a continuous harvest. In general, the fruiting bodies appear in waves, which, however, may not occur in unfavorable weather. Although the mycelium survives the winter, new beds should be started again the next spring (May to June). Since with the usual culture methods the first harvest is not to be expected until summer, a fall culture can also be set up. For this fresh straw is watered at the end of August and inoculated at the beginning of September. The soil covering is added from early to mid-October. Then in November a sheet of plastic with a layer of straw shaken over it is laid over it as a frost protector, and this is removed at the end of March to early April. Harvest is to be expected from the end of April.

Instead of beds, which are laid out on the ground and not in trenches and therefore can more easily dry up on the outside or even fall apart if they are not piled carefully, wooden boxes with walls 30-40 cm high can be used. In these boxes, protection from solar radiation, wind, and wet is easier than in the beds. When laying down the sheet after inoculating with spawn, a distance of ca. 10 cm should remain between it and the layer of straw to give room for air. Above all it is also easier to provide protection against attack by snails and slugs. If the wood is well impregnated, the boxes last several years. Replacing the floor with a few supporting boards with wire mesh strung between them provides contact with the undisturbed soil. Utilizing cold frames after the early forced vegetables are harvested is easily possible, using the same method as in bed cultivation.

When *Stropharia* is grown in the ornamental garden and under hedges, bed culture is not possible. Here holes about 30 cm deep are dug in shady places, for

*Fig. 46. Blocks in the garden, made of substrate permeated by the mycelium of the oyster mushroom*

*Fig. 47. The fruiting bodies of Pleurotus are often arranged above each other overlapping like roof shingles*





example under blackberry hedges and border shrubbery, about 5 cm of peat is placed in them, and a straw substrate is put on top as in bed culture; instead of straw a mixture of spent mushroom compost and old straw can also be used. The substrate is inoculated, or the ink-blue wash water from harvested Stropharias, which contains abundant spores, is poured over it; it is covered after 4-5 weeks with humus-rich garden soil, and then a layer of decomposed leaves is put over it. If the leaves falling from the shrubs are not raked off or dug in, a leaf covering is continuously maintained and constantly provides new humus.

*Cultivation of wood-inhabiting fungi*

Wood-inhabiting fungi are especially simple to grow in the garden, since a special substrate is not necessary, but merely suitable wood must be available. Wood is easy to obtain at low prices; inoculation can be begun directly after procuring the necessary logs. Also, spawn of several wood-inhabiting fungi is now commercially available and therefore one does not need to propagate one's own mycelium. An example will be described here. When cultivating the various species, one has to consider only their special requirements for particular species of wood and climatic conditions.

The most frequently used method is culture on logs. Sound wood is necessary, but it should be taken from trunks which can not be used as quality wood in the lumber industry because of growth flaws etc. and which therefore are cheap to buy. Old wood is not usable since it either is already completely dried up or is often already attacked by other fungi. It is best to take wood felled in winter and stored in partial shade in the forest for 1-3 months; if it is already rather too dry it must be watered 1-2 days before inoculation. The trunks should have a diameter of about 10-25 cm, because thin trunks have a large proportion of sapwood, which is utilized quickly by the fungus, and trunks which are too thick are difficult to transport because of their heavy weight; the gardener will rather put up with a smaller harvest than with having to carry blocks which are too heavy around in the garden.

Most species of wood fungi thrive only on wood of broadleaved trees; almost all species can be used, even the wood of uprooted fruit trees. Those who wish to obtain high yields quickly, even if the culture will cease after only three years, should use poplar or birch. Those who wish the culture to remain a long time in the same place will be able to obtain a harvest for the longest time from oak wood, although the harvest will turn out to be only minimal in the first year. Wood which yields a harvest for about 5 years on the average, such as beech or cherry wood, is generally used. In my garden, besides the kind of broadleaved trees mentioned, I use pear, apple, hornbeam, elm, linden, ash, alder, acacia,

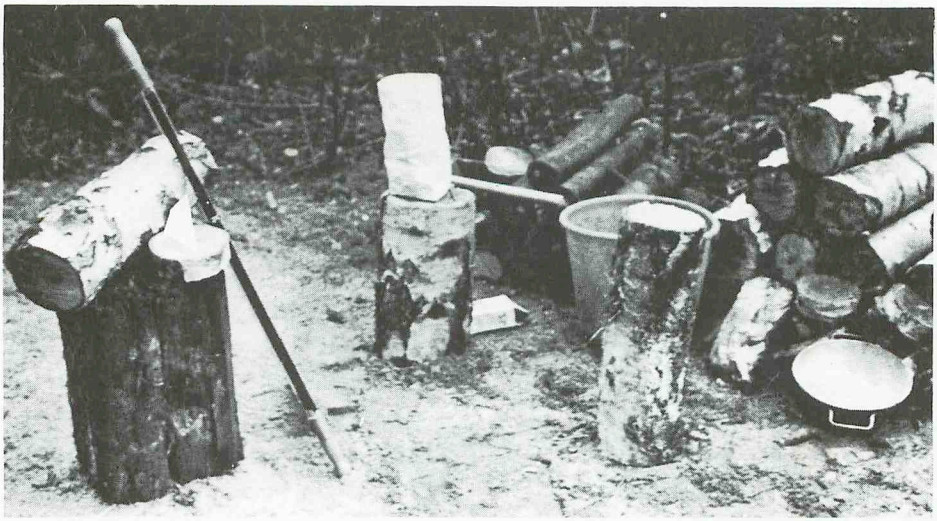
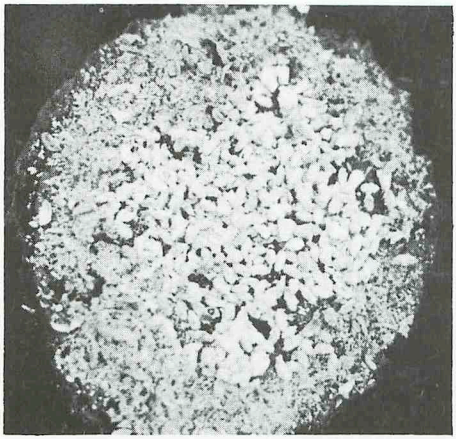


*Fig. 48. Place in the garden for inoculating*



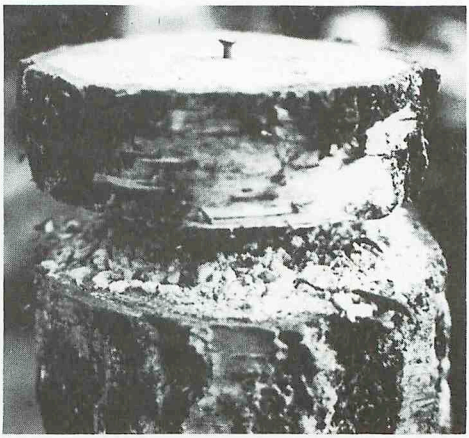


*Fig. 49. Inoculating a cut surface with grain spawn*

*Fig. 50. Nailing down the covering disk of wood*

elder, and maple, as well as the conifers spruce and pine.

It is best to inoculate the wood with mycelium from the end of March to mid-May during mild dry weather, especially since one can work out-of-doors then. First, the trunks are cut into lengths of 45-50 cm. Then one builds an





inoculating place, in which the completed blocks are stacked, saw horse and saw are kept ready, there is a large container with water, and a dry place for hammer, nails, and spawn is available. Now a section 3-5 cm thick is sawed off of each log; thinner rounds will split when being nailed, and thicker ones will require nails which are too long and which can often be driven through the thick rounds of hard wood only with very great difficulty. Next one dips the cut surfaces of the logs and rounds briefly into the water container, stands the wood up, scatters some sawdust around the margin of the fresh cut to keep the spawn from falling off, and distributes the spawn (about 30-40 g per log) over the entire cut surface. The outer sapwood of thicker wood especially must be inoculated, since the mycelium penetrates it better than the heartwood in the center of the log. Finally, one drives a nail through the center of the cut-off round far enough for it to project somewhat from the underside, lays the round on the log covered with spawn, and nails it down firmly so that the spawn can not fall out from the sides. The inoculated pieces of wood are stood up next to each other, protected from drying out by strong sun, and stacked after inoculation of all the wood has been completed.

In former years we used a more complicated method of inoculation. In this, 3-5 cm deep holes were bored around the trunk, filled with spawn, and then closed with a small piece of wood of the appropriate size. However, boring the holes is very laborious and the surface for the mycelium to attack is very small. Even when using an electric drill, the holes must usually be bored twice to obtain as large a bore hole as possible. Since the mycelium continues growing in the conduction pathways running vertically in the trunk, covering the entire cut surface with spawn is the most successful. Bore holes are inoculated in long logs which are used as seats, boundaries of banks, or as groupings within groups of trees or ferns, since the mycelium does not grow quickly through the whole length of wood which is several meters in length.

To be sure, it is also good to use the **wedge method** for this purpose. Every 20 cm along the length of a log one makes a cut 3-4 cm deep, then moves the saw 6 cm farther down the log and cuts out a wedge by sawing back to the first cut. The cut surface is moistened and some sawdust and spawn applied to it, then the wedge is moistened likewise and re-inserted. A strip of plastic sheeting is wound several times around the log at the inoculated places; under its protection the mycelium can grow into the wood. After about three months the wedge is bound to the log again by the mycelium, and the sheet is removed.

*Fig. 51. Log inoculated with Pholiota nameko, partially buried in the ground*

*Fig. 52. Plastic sacks buried in the ground, with Pleurotus on sawdust substrate*

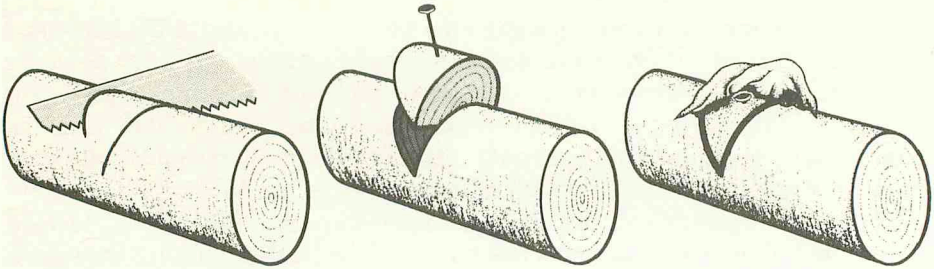


*Fig. 53. Long logs are best inoculated using the wedge method*

Instead of this wedge method, one can also cut slits 3-5 cm deep in several places along the trunk with a chainsaw, insert spawn into the cut, and close it with a sheet.

In Japan the following method is used: Holes about 2 cm deep are bored in the wood, and conical pegs about 1 cm across and 2 cm long and permeated with mycelium are driven in with a hammer; finally they are sealed up with some grafting wax. In summer, before inoculation the wood is laid in a water bath at 15-18°C for a day to saturate it with water; in winter, it is soaked for 2-3 days at 10-15°C.

After inoculating the logs one must see to it that the mycelium penetrates the wood well. High moisture content and warmth are necessary for good penetration. For this reason one generally digs a pit in not too sunny a place and stands the pieces of fungus wood up close together in it. The more pieces of wood standing next to each other, the better is the growth of mycelium, since warmth is generated as the myelium grows, and, when the pile is well sealed, natural warming sets in. Since in the garden one usually inoculates only a few logs, the pit should be about 50 cm deep; with larger quantities the pieces of wood are stacked 3 deep on top of each other in each pit, so that the pit must be about 1.5 m deep. Some spawn is scattered on the previously dampened ground, then the inoculated pieces of wood are stood up next to each other, moistened again and sprinkled with some spawn from above. Then a thin sheet is spread over the wood, and boards or lath are laid over the pit and covered with soil, leaves, straw, or small fir branches for protection against drying and loss of heat. During very warm and dry weather the pit must be opened and moistened once more. The mycelium grows so intensively through the pieces of wood that about 3-4 months later, when the wood is taken out, the individual logs can only be separated from each other with force. Digging a pit is difficult in unfavorable soil conditions, sometimes even impossible. In this case one digs out the soil to a



*Fig. 54. Protecting inoculated wood under a plastic sheet and twigs*

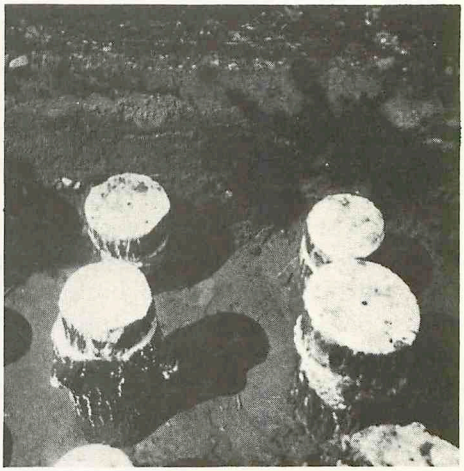


*Fig. 55. Equal spacing facilitates tending*

depth of only about 20 cm, sets the previously moistened pieces of wood close together in this shallow hole, scatters some spawn over them, covers them with a sheet, and throws soil (obtained from the hole and from a trench about 10 cm deep dug around the hole) toward the outside of the sheet covering the wood to hold it down firmly. For protection from drying and heat loss it is best to cover it over with old peat or manure sacks and leaves or conifer twigs as the topmost layer. If only a few pieces of wood are to be inoculated, it suffices, if they are well moistened after inoculation, to lay them in a peat sack or other plastic sack and to stand it up in a cellar, garage, or other room which has a temperature of at least 12°C.

In general the logs are stood with the nailed round at the top to keep an infection from possibly getting in from the soil. However, usually the mycelium penetrates the wood so rapidly that this danger does not arise. They normally do not differ from pieces of wood which are placed with the disk at the bottom, since the mycelium grows downward as fast as in the opposite direction. The most favorable season for setting the wood in the definitive place is the end of July to the middle of August. Moist soil is favorable for the rapid penetration of the mycelium from the wood to the soil below; therefore the arrangement should be intensively watered immediately after the pieces of wood are stood in place. Dryness in the outer layers of wood damages the mycelium, which is used to high humidity. Therefore, one should choose a shady place with abundant moisture, preferably with a high water table, which

however is not too dark and if possible has some sun in the early morning or afternoon, as a place to stand the wood. Should the soil dry out very much, it must be heavily watered, as is especially strongly recommended for September and early October.

About 4 logs are set up per square meter. The distance between rows should be somewhat greater than the distance within the rows to make it easier to tend the logs. For better contact with the soil the pieces of wood are set in about 20 cm deep; then the height of the logs above the ground still amounts to about 30 cm, which suffices to keep small bits of soil from dirtying the undersides of the caps during heavy rainstorms. Improving the soil with peat or old mushroom compost before setting in the pieces of wood is effective in increasing its ability to take up water. If the logs are set up under fruit trees, one need not fear that manuring the soil will injure growth of the fungi. Several species develop a mycelium which grows vigorously in the soil from which it also takes up nutrients. This is especially marked in the changeable agaric, which yields a substantially smaller harvest without contact with the soil. Nevertheless, signs of exhaustion of the soil develop after several years in the presence of strongly developed soil mycelium. For this reason, wood-inhabiting fungi should not be grown in the same place for several years after a culture has finished, or at least wood with other species of fungi should be set up (crop rotation). Growth of grass and weeds does not impair growth of the fungi.

It is usually not possible to put longer logs in pits; thus it is best to stack the inoculated pieces of wood close together, cover them with a sheet, and then throw soil over them. After the mycelium has permeated the wood they are brought immediately to the final place. If possible, they are laid 1/3 to halfway in the ground to provide a constant supply of soil moisture. In shady spots and when moistened occasionally, however, the mycelium can often survive without contact with the ground and form fruiting bodies for years. The mycelium remains in the interior of the trunk, especially thick ones, during dry spells and grows again through the wood during rainy periods to form fruiting bodies on its surface.

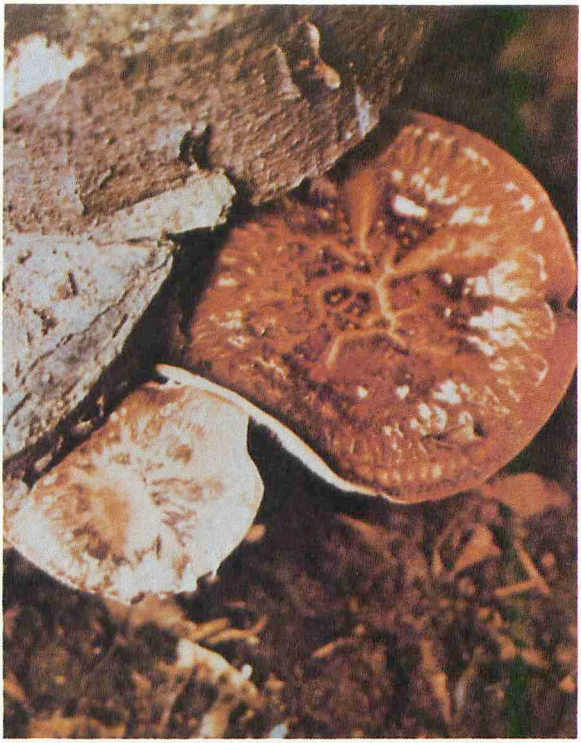
In addition to logs, branches and twigs can be used as a source of nutrients for cultivating fungi. For this purpose bundles of twigs 20-30 cm thick are pre-

*Fig. 56. In Japan, shiitake yield even in winter in greenhouses covered with plastic sheets*

*Fig. 57. Shiitake on disks of wood in a moss garden*

*Fig. 58. Logs which have been inoculated using the wedge method. Some of the inoculating places are still recognizable.*







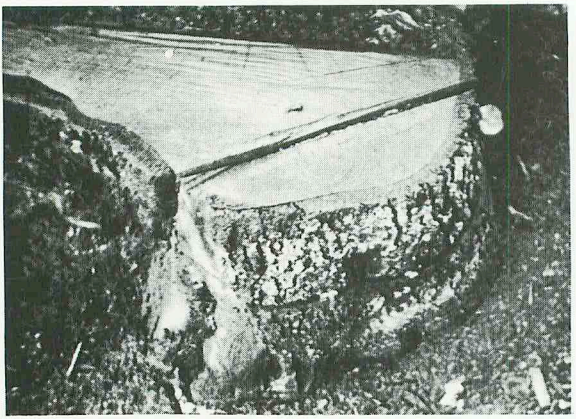


*Fig. 59. A wedge is cut out of a stump and after inoculation nailed back on*

pared and piled on top of each other about 1 m high. We scatter grain spawn between the bundles or put inoculated straw between them, such as is used for cultivation in beds or in culture rooms. The brush piles are well moistened, a sheet is laid over them, and they are covered with leaves or twigs. In late August to September the sheet is removed so that the fruiting bodies can form.

A few wood-inhabiting fungi can also be cultivated on straw in culture rooms. Likewise, cultivation in beds out of doors as in *Stropharia* culture would be possible. To obtain better permeation one should use chopped straw which is mixed with some sawdust. A covering of earth is not necessary for the fruiting bodies to form; however, one must keep the substrate from being too thoroughly saturated. Therefore the bed should be arched to facilitate the runoff of excess water and covered as completely as possible with a plastic sheet to protect it from rain. One can also let mycelium permeate straw in plastic bags, and, after removing the sheet, set up the resulting blocks side by side in the garden. Nevertheless, cultivation on logs seems more worth recommending because mushrooms can be harvested from one set-up for 5 years, while new cultures must be set up in beds again after a few months.

Inoculating tree stumps, which is probably the oldest culture method, must also be mentioned. Originally spores were put on the surface of the stump and chopped in with an ax. Then the surface was covered with moss or grass sod. Suitable spawn has been commercially available for decades and promises better success. One puts a layer of spawn on the surface, scatters sawdust over it, and lays bark or a sheet which is weighted down with earth or sod over that. However, it is better to saw off a 3-5 cm thick round first, insert the spawn, and nail it down again. To reduce the amount of spawn needed and to avoid having

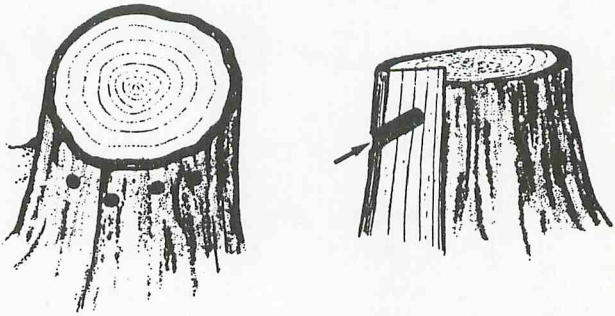


*Fig. 60. Bore holes for inoculating tree stumps*

too large a cut surface, cut a piece out of the stump, cover the inner surface with spawn, and nail the piece back on. Even with this method, protecting the inoculated piece is necessary to keep the wood from drying out. Boring holes about 5 cm deep, filling them with spawn, and closing the openings with moss will probably be done only where one can use a power cord and an electric drill. In this case one should be careful that the holes are bored obliquely toward the top to keep rain water from entering. Protection from strong sun is necessary to keep the inoculated stumps from drying out.

*Cultivation of mycorrhizal fungi*

Numerous species of fungi grow in association with green plants. They can only form fruiting bodies when they can withdraw particular substances from the plants with which they live in symbiosis (see also pages (14) and (15). Since we do not yet have exact information about the substances needed for development of fruiting bodies, we are forced to cultivate the corresponding symbionts along with these fungi.

It is true that success has been achieved with *Boletus edulis* in liquid culture by adding serine, pectin, thiamin, theophylline, and cyclic 3′,5′-AMP; however for cultivation in the usual sense this will not do.

Therefore, to cultivate the species chosen here, it is still necessary to look first for the suitable partners. They must be sown in sterile soil and then the mycelium of the particular species of mycorrhiza must be brought to the still germ-free roots of the seedling. Various ways to accomplish this in practice already exist.





## 1. Truffle (*Tuber melanosporum*)

In antiquity truffles were already highly prized because of their strong odor and were collected in forests. Semiculture (half culture) of this fungus species did not develop until the last 150 years. Oak seedlings were dug up under oaks under which truffles were found, and were planted out like dwarf fruit trees. The roots of these seedlings usually had truffle mycelium growing around them, so that after several years truffles could be harvested from the place where the trees were planted. This method is still used sometimes; seedlings from places where especially good yields have occurred and truffles of good quality have been found are used as much as possible.

Today, raising young plants is done more purposefully. In selecting oaks, people are considering the structure of the host plant and its requirements for soil and climate, and in the future the most suitable host plants will be propagated vegetatively. Fruiting bodies of truffles are also being selected to obtain suitable lines for breeding. Formerly, the acorns and hazelnuts used in truffle culture were collected from under productive trees, disinfected, and made to germinate aseptically. Mature spores of truffles which had previously been stored for several months at temperatures a little over 0°C were brought to the roots of the seedlings under sterile conditions. They germinated there, and the mycelium entered into symbiosis with the roots. Later the seedlings were planted in pots filled with disinfected soil and grown in greenhouses until being planted out. Also, sometimes roots which were densely covered with mycorrhizal mycelium were taken from trees under which abundant truffles had been found. The fresh roots were packed tightly between the roots of oak or hazel seedlings before they were potted up to allow the growth of truffle mycelium over them. When the roots of the young plants had grown throughout the pots, the plants were set out in areas where the soil and climatic conditions were suitable for the growth of the oak and hazel species in question and for the development of truffles.

Truffles should not be cultivated in valleys but preferably on hills with gentle slopes. Soil 10-30 cm thick is desirable. Since truffles like alkaline soil, the pH value should not be less than 7.5. A subsoil of limestone (sedimentary rock) and rocky soil are favorable. The rocks store heat from the sun and give it up again at night; if they lie densely on the surface they hinder the sun's rays from

*Fig. 61. In Japan the fungus Ganoderma lucidum is cultivated on sawdust substrate*

*Fig. 62. Fungi can be precultured on disks of wood and then placed on a window sill*

penetrating too deeply and drying out the soil. Abundant sand makes the soil permeable, and humus (3-6%) holds moisture. One should strive for a good crumbly texture.

Abundant precipitation in July and August is especially desirable for promoting development of the fruiting bodies; if necessary they must be sprinkled during this time. Too much water in late fall and winter can favor rot of the fruiting bodies. A covering of straw mulch put around the root crown, or plastic sheet or something similar on the surface, retains the moisture.

Hot summers and very cold winters are as unfavorable as a very even maritime climate. Temperatures staying below -10°C for several consecutive days can be very damaging. A mild climate is desirable.

Planting of the inoculated young plants takes place from March to April or October to November. In France they recommend planting 800 trees per hectare and subsequent thinning when the soil under the trees is not warmed enough by the sun because of too much shade.

After winter (especially in March) the soil is broken to a depth of about 15 cm. When the "burned zones" appear, only the uppermost layer may be cultivated very shallowly after the soil warms up (May). The other areas are normally cultivated annually.

Since the sun's rays should reach the soil, all branches 50-100 cm above the ground are removed from the trees; the lower branches are cut more, the upper ones less, so that the trees become shaped like inverted cones.

Harvest takes place from about November, when the fruiting bodies assume a blackish color; they have the best aroma in January and February.

From June to August, at the time of fruiting-body induction, so-called "burned zones" form around the trees (not in *Tuber aestivum*); most of the plants in these areas dry up because the mycelium withdraws water and has an antibiotic effect. The truffle fruiting bodies develop in the ground here. The place where the truffles are found, at a depth of 5-30 cm in the ground, is recognized by the formation of rather large cracks in the surface or by the presence of the truffle fly, which lays her eggs near the fruiting bodies. Since these search methods are very difficult and many fruiting bodies are not found, people generally utilize the sense of smell of dogs or pigs which are trained for hunting truffles.

Host plants

| | |
|---|---|
| *Tuber melanosporum:* (Perigord truffle) | *Quercus pubescens, Q. pedunculata, Q. sessiliflora, Q. ilex, Corylus avellana;* also *Tilia, Fagus, Populus, Castanea,* and *Pinus* |
| *Tuber aestivum:* (summer truffle) | *Quercus pubescens, Q. pedunculata, Q. sessiliflora, Q. ilex, Corylus avellana, Carpinus betulus, Betula alba, Fagus sylvatica, Pinus nigra* |
| *Tuber brumale:* (winter truffle) | especially oaks and beeches |
| *Choiromyces maendriformis* | above all spruces and beeches |

2. ***Boletus granulatus*** (=*Suillus granulatus*)

The cultivation of *Boletus granulatus* as a representative of the boletes will be described here, since it is already extensively cultivated and is relatively easy to propagate because of the strong growth of its mycelium.

*Boletus granulatus* has been used in Argentina to inoculate the seedlings of pines which are planted in large areas to provide wood necessary for industry and the building trade, since no species of mycorrhiza suitable for the pines is native there. The fungus is needed for maintaining the health and good growth of the pines. While in Argentina the mushroom crop in the newly forested areas is seen only as improving the economy of the tree farm, for us the garden plants and the mushroom crop are of equal value. We see an esthetic and practical value in fungi growing under the pines in the garden.

The mycorrhizal mycelium is obtained principally from pieces of tissue which are put on agar. In this way it is certain that the mycelium is derived from the desired species. Recently, appropriate types of the species of fungus in question have been selected and propagated separately for particular purposes (for example, promoting strong growth, suitability for particular climates, etc.). The mycelium is used in the form of liquid cultures, grain spawn, or peat spawn for inoculation. At first, the pine seeds were treated by adding liquid cultures to them, and spawn was added to the planting soil and to the pot soil. Today, at least in forestry, treating the seed with mycelium is generally dispensed with; on the contrary, the seed is disinfected to protect it from diseases. The soil of the growing beds is first disinfected, then mixed with

spawn immediately before planting the seedlings (possibly even before sowing) to introduce the mycorrhizal mycelium to the young plants.

In Argentina the pines are sown in cold frames whose soil had previously been disinfected. The seeds are sown ca. 1 cm deep in rows. Then the soil is smoothed and a layer of chopped pine needles is put over it. These are obtained from pure pine forests in which all trees stem from seedlings inoculated with *Boletus granulatus*. In the forest the dry upper layer of needles is lifted off, and the needles lying just above the ground, which are already partly decomposed and permeated with roots thickly wrapped with the mycorrhizal fungus, are removed. These needles are chopped up, moistened, and then used simultaneously as a covering and for inoculation of the seedlings. When the seedlings are ca. 6 cm tall they are planted in pots and remain there until being planted out.

For cultivating mycorrhizal inoculation material, Frau Friederike Göbl (Austria, Field Station for Subalpine Forest Research of the Viennese Federal Experimental Institute of Forestry*) recommends producing select pure cultures first. Grain spawn (wheat or millet) is then produced from a suspension of mycelium (with the addition of gypsum for species of *Suillus*). This is used for producing mycorrhiza-peat, in which grain spawn is mixed with suitable peat along with glucose. This peat spawn can be shipped in sterilized plastic sacks.

The young pines are planted out in their final location after reaching the desired size and after the soil in the place to be planted has been mixed with the peat spawn. Cow manure put on the ground near the roots can have a favorable effect on the size of the fruiting bodies.

### 3. Chanterelle (*Cantharellus cibarius*)

It is still premature to give instructions for cultivating chanterelles; however, it seems time to consider the possibilities which arise from present knowledge. Intensive research for years in the Netherlands unfortunately has so far resulted in failure. For amateur cultivation it would be very important if chanterelle spawn could be produced and made commercially available. It would probably then be possible to inoculate seedlings of suitable species of trees, just as in truffle culture. Young spruces seem especially suitable for this, particularly since the many ornamental forms planted in gardens will probably likewise enter into symbiosis with the chanterelle.

The better-known egg-yellow species (*Cantharellus cibarius*) prefers conifer forests; the lighter and larger form (*Cantharellus cibarius* var. *pallidus*) pre-

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* Oesterreich, Aussenstelle für subalpine Waldforschung der Forstlichen Bundesversuchsanstalt Wien

fers deciduous forests. The first requires acid soils (pH 4.2-4.8), while the second grows better on neutral to limy ground. Thus, it would be possible to grow chanterelles under very different soil conditions and in different stands of trees. The first possibility would perhaps be to plant young trees which had been grown where chanterelles have appeared in large numbers.

Inoculating spruce seedlings and subsequently planting them in groups, like those which occur in good chanterelle localities, on a foundation enriched and covered on top with inoculated peat and needle litter, might be the easiest method, since the inoculation would be left in the hands of specialists. In the groups of trees one would first mix the ordinary spruces (*Picea abies*) with ornamental forms and thin out the stands when they became too dense. In thick stands with damp mossy ground with an undergrowth of bilberries, the roots of the trees will be finely branched under the surface and so provide the best prerequisite for strong growth of chanterelle mycelium and the fruiting bodies later. It must likewise be tested whether putting spawn or inoculated peat on the fine network of fibrous roots of the young trees is sufficient to cause the mycelium to grow over the roots. The time from April to May would be the most suitable for this, since many new fibrous roots are formed then.

It appears that the influence of soil bacteria is particularly important in the formation of fruiting bodies by species of symbiotic fungi. Therefore, even when using inoculated young plants, it seems advisable to add some soil from the place where the species of fungus in question is found, in order to build up the proper bacterial flora.

The section on chanterelle culture is intended to give directions for cultivation in case anyone succeeds in producing chanterelle spawn in the next few years. In forestry, inoculation of young plants with the mycelium of numerous species of mycorrhizal fungi (for example, *Amanita*, *Boletus*, *Leccinum*, *Russula*, *Suillus*, *Xerocomus*, and others) is already being carried out.

### Protection against pests

Anyone who has ever collected fungi will have noticed that in addition to people there are other fungus-lovers. During damp weather numerous fungi are nibbled on by snails and slugs, and after dry periods especially large numbers of maggots are found in the rapidly developing fruiting bodies which appear when the weather is wet again. Birds and wild animals also taste many a fungus.

At home, one will strive to make the entry of snails and slugs into the garden as difficult as possible, even at the very fence. One will lay out bait, for example snail pellets, in damp shady places, and in the evenings, by the light of a

flashlight, gather up the voracious intruders from places where new fruiting bodies have formed. The greatest care is required when using poison bait; it must be placed where children and pets can not reach it. Also the prescribed waiting period before harvest must be observed. A stripe of quicklime, which is supposed to offer protection against snails and slugs, put around the places before onset of darkness, can be recommended. Immigration of new snails and slugs from forest and field is to be feared above all.

The maggots hatch from eggs of fungus flies and gnats, which are found almost everywhere, especially in warm places protected from the wind. Fighting them with insecticides is very difficult, since the fungi usually grow so quickly that the prescribed waiting period can not be observed. Perhaps they could be attacked with slightly poisonous botanicals if these were used very early. When in doubt it is better to dispense with any poison and harvest the fungi when still young, before the maggots have hatched. Damage from maggots rarely occures in species fruiting in fall, such as many *Pleurotus* and *Collybia* species, or which have very firm flesh, such as chanterelles.

Dichlorvos preparations have proven most effective against occurrence of fungus flies and gnats in the spawn laboratory and in cultures in the cellar and on the window sill; avoid overdosing.

For protecting enclosed beds against damage by birds or wild animals, one can at least lay a plastic net over the endangered places. One should not use fungicides against fungal parasites which attack our edible fungi and cause malformations, rot, or decomposition, but when a white coating or rot appears on the fruiting bodies one should immediately destroy affected individuals. When culturing the common edible mushroom and other species in the cellar, one must take care that moisture does not remain on the fruiting bodies long enough for bacteria to form spots, by providing adequate aeration after watering them.

The surest thing is not to let the fungi become too old, especially since they are also more wholesome when young.

The best way to protect one's fungi is to offer them a habitat which is made to be like the best localities in forest and field. When they are raised on other kinds of substrates, these should not be enriched too heavily with nutrients, since overnourished plants are frequently attacked by diseases. It is especially important that the specific requirements of the individual species for air and soil moisture are satisfied. Above all, care must be taken to provide sufficient shade for fungi which thrive in damp places, and to provide water if necessary.

## Miniculture in house and cellar

### Culture on the windowsill

*Culture in glasses*

Gardening on the window sill is actually nothing new; in many households not only flowers, but also pots or small trays with parsley, chives, cress, or paprika sit there. This assortment can be augmented also by a few species of fungi. In Japan the velvet-shank (*Flammulina velutipes*) which in Germany is found in winter on tree trunks in forests and parks, is grown in glasses and harvested in clusters. It is suitable for use in sauces and soups. Following the Japanese example, a mixture of 70% wood chips and 30% rice bran can be used as a substrate; but straw, sawdust, barley chaff etc. can also serve as substrates (pH about 5.5). It is pasteurized, mixed with spawn after cooling, put in bottles, and kept at 25°C for the mycelium to grow. When the substrate has been permeated, the glasses are set on a cool (15°C at most) an airy window sill. Double windows are especially suited for this. The harvest can begin 2-3 weeks later.

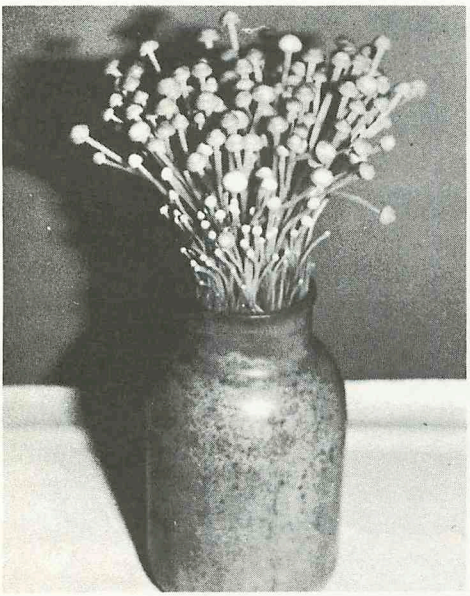


*Fig. 63. The velvet shank on sawdust substrate*

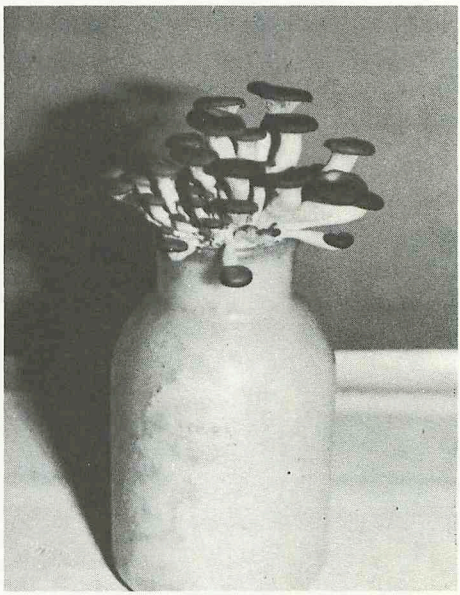


*Fig. 64. Oyster mushrooms in a plastic bottle*

Cultivation of the oyster mushroom is possible in the same way. Straw, preferably chopped, is pasteurized, mixed with spawn, put in glasses, and put in the dark at 25°C. After about three weeks the substrate is permeated, and the glasses are put in light and air. In summer the heat-tolerant types are used; in winter our native ones, which require temperatures below 15°C to fruit, are used. The fruiting bodies can be harvested when 3-5 cm across, or they can be allowed to grow to full size.

*Agrocybe aegerita* can also be cultivated, like the velvet-shank, but on poplar sawdust if possible. In winter *Nematoloma capnoides* and *Kuehneromyces mutabilis* ought likewise to be suitable for this method. Experiments with *Marasmius scorodonius* are still in progress and seem to promise success. The fungus garden on the window sill is therefore no longer a dream of the future.

*Culture in trays*

Of course, other containers can be used instead of glasses. Plastic trays appropriate for the size of the window sill are suitable for cultivation by the same methods. While the quantities harvested from glasses are small and suffice as an accompaniment or condiment for the meal, the larger culture containers are adequate for complete mushroom dishes. Trays and cultures in plastic sacks, including substrate and spawn, can be bought for this purpose form various firms, if one wants to lighten one's work in culturing. However, one must also take care to provide a suitable place, correct temperature, good

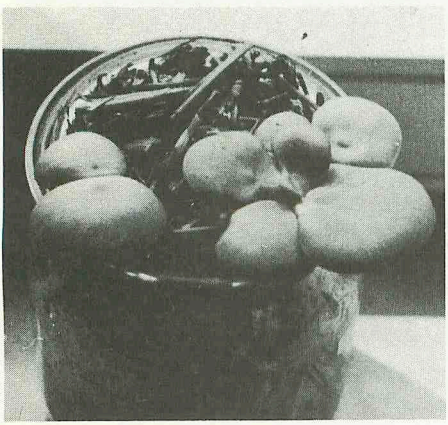


*Fig. 65. Oyster mushrooms on straw substrate*

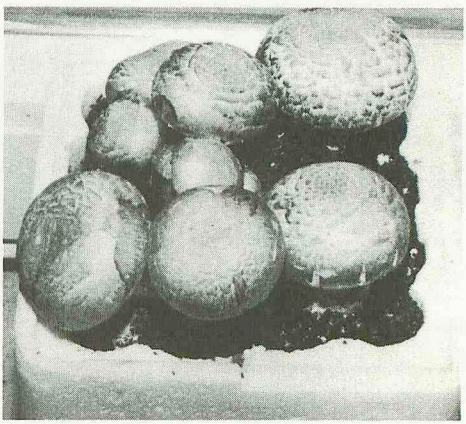


*Fig. 66. Blond Agaricus on a window sill*

aeration, necessary moisture, and sufficient light, if one wishes to obtain a rewarding yield.

*Culture on disks of wood*

Another effective method for the window sill is culture on disks of wood. To do this one uses the same methods as for cultivation on logs. Two disks about 5 cm thick are cut from a log and watered; then some sawdust and spawn are put between them and they are fastened tightly together with a nail. Afterwards they are put in a plastic sack and kept in the cellar; they are moistened from time to time until they are permeated by the mycelium. Then they are put in a shallow flowerpot saucer whose bottom is always kept moist. Drying out from the sun must be avoided. The number of fruiting bodies forming on the disks is not large, but they look truly unusual between flowers and especially ferns.

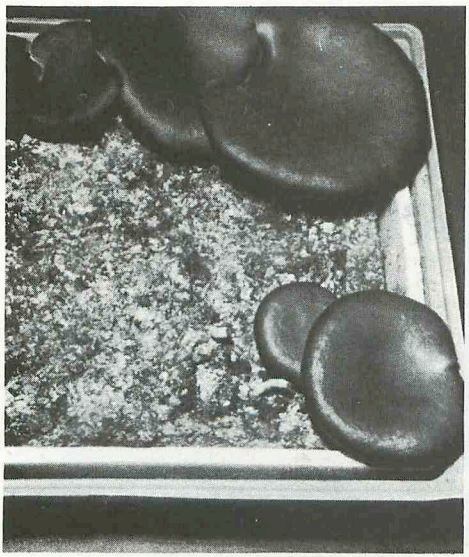


*Fig. 67. Oyster mushrooms cultivated in a plastic tray on sawdust*

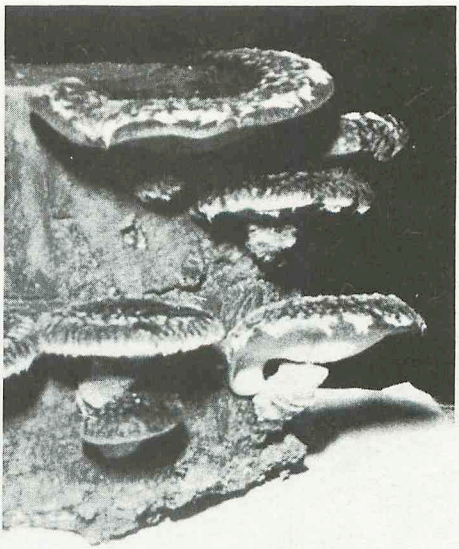


*Fig. 68. Shiitake on a disk of wood*

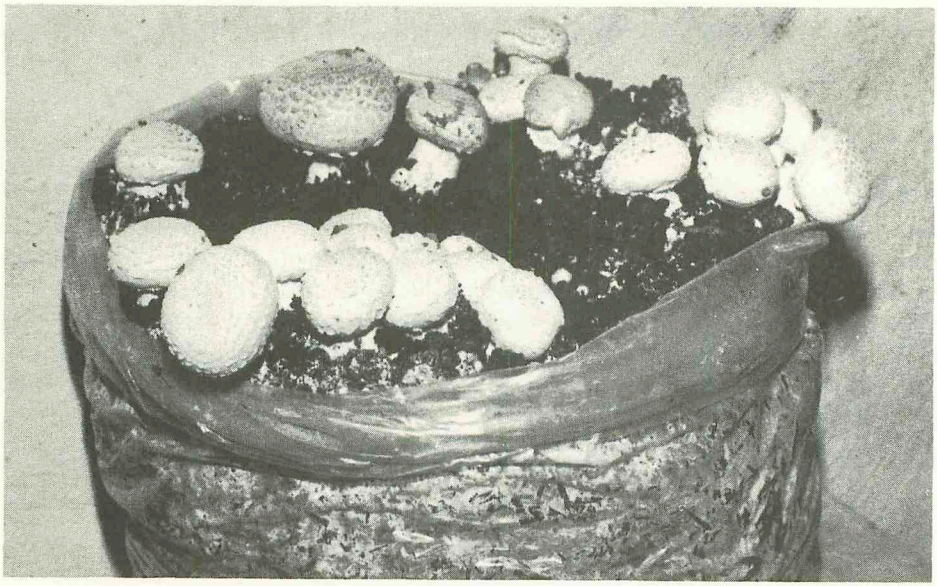


*Fig. 69. Blond Agaricus in a plastic sack in a cellar*

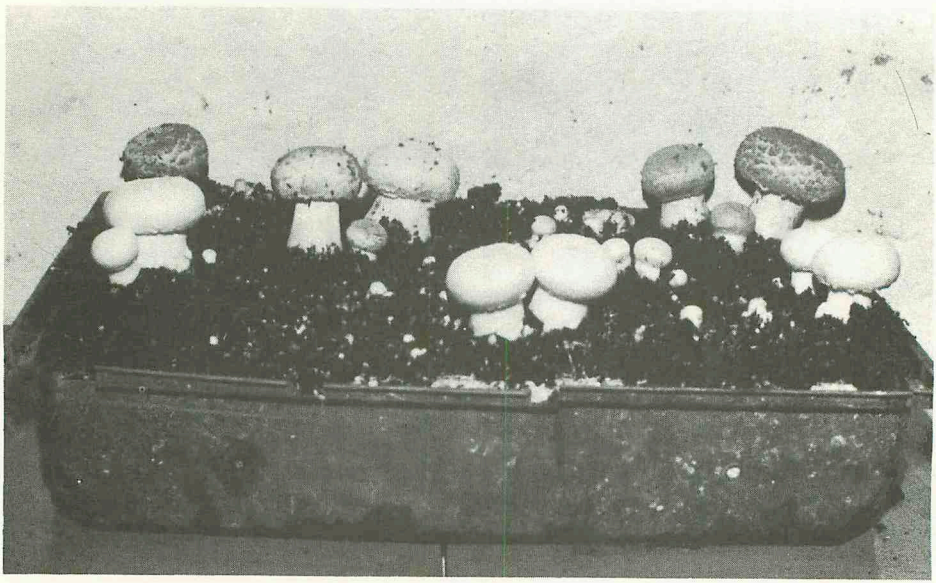


*Fig. 70. Agaricus culture in a tray in a cellar*

## Culture in the cellar

*Culture on logs*

Since the main harvest period of most wood-inhabiting fungi (with the exception of the velvet shank) ends in fall after the harder frosts in the first half of November and only solitary fruiting bodies are formed during the longer thaws, it is interesting to store in a frost-protected room logs which have not yet borne fruiting bodies but which already show very small fruiting-body primordia. A cellar room which can be well ventilated and is not harmed by dampness can be used for this. One removes suitable logs from the working area outside and sets them in plastic buckets. Wet peat is put in them to a depth of about 5 cm, and the logs are placed on it, with a part of the garden soil permeated with mycelium still attached to the lower end if possible. Around the wood is placed a layer of soil about 15 cm thick, and everything is moistened well. Then the logs are put in the cellar, the floor of which is covered with a plastic sheet which should be constantly moist. Fresh air should constantly enter through the cellar window, and the temperature should be kept at 12-15°C. Since the fruiting bodies require enough light to develop, artificial light is turned on for about 10 hours during the day; the daylight types of fluorescent lamps are the most suitable. If the stalks of the fruiting bodies become too long, this is a sign of light deficiency.

*Culture on other substrates*

In order not to have to forego a meal of mushrooms during the months when there are no fungi to harvest outdoors, one can also obtain crops on suitable culture substrates in the cellar (similar to the culture on logs).

For culturing the common commercial mushroom, plastic sacks which are provided with holes for aeration and for the exit of excess condensed water, are filled with mushroom compost which has been pasteurized (heated to about 60°C) and thoroughly mixed with grain spawn. Use 50 g of spawn for 10 kg of substrate. The sack is 2/3 filled with substrate. The upper part is folded over so that it is closed but nevertheless allows exchange of air through the fold. At 25°C the mycelium permeates the compost in about two weeks. Now a 4-cm-thick covering layer (of peat, some loam, sand, and lime, which have previously been saturated with water) is put over the substrate, and the sack is closed as before and set in a warm place until some mycelium is visible at the surface, after about 8 days. Then the plastic sack is placed on the cellar floor (which is covered with a plastic sheet), the edge is turned outward down to the level of the



*Fig. 71. Pleurotus on logs in winter*

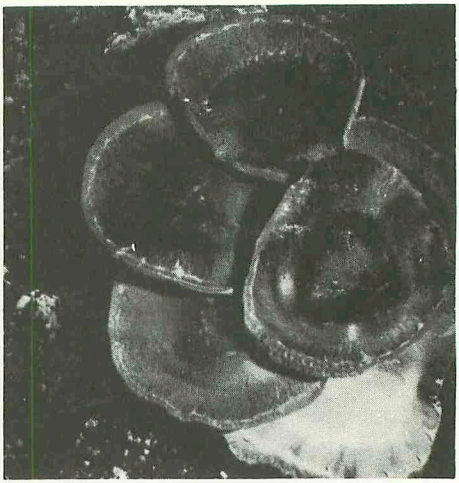


*Fig. 72. Shiitake in a tray on sawdust substrate*

covering soil, abundant fresh air is given, and the temperature is kept at only 15-20°C. Soon the first fruiting-body primordia appear, and about three weeks after the covering soil was placed one can expect to begin harvesting. Growth takes longer at a lower temperature, but the danger of foreign infections is also less. High humidity must always be provided.

For culturing *Pleurotus*, chopped straw is first shaken into a vessel filled with water, soaked for about a day, and then cooked for 2-3 hours in a large container. After subsequent cooling to about 25°C, spawn is mixed with the straw (100 g spawn in 10 kg straw substrate), and the mixture is put in plastic sacks, which are 2/3 filled. The sacks are placed in culture rooms at 20-25°C; the bottoms of the sacks are punctured to let accumulated water flow out. The room should be only slightly ventilated. At 20°C the straw will be permeated in about three weeks. Now the sacks are cut open and removed; the temperature is lowered to about 12°C, and 12 hours of supplementary light are given during the day. Abundant fresh air and moisture are necessary; therefore the cultures are constantly ventilated, and a plastic sheet laid on the floor, on which the blocks formed by the straw substrate and mycelium are placed, is kept constantly wet. After several weeks the first fruiting bodies form.

In order to retain more moisture in the substrate, one can also remove the sacks only halfway, so that the other half is protected from drying out.

It is also possible to put the straw in old bottle crates or the like in which a

plastic sheet has been laid. After the substrate is permeated, turn the sheet down for better lighting and ventilation. The crates must then be placed so that the opening is to one side, since the fruiting bodies generally form sideways on the substrate. It is advisable to fill only small sacks or boxes so as not to obtain too many fruiting bodies since they produce many spores and the wide-spread dispersal of the spores can cause allergies in sensitive people. Once six rooms in my cellar were covered with fine white dust from the spores of the fruiting bodies which were on a block 50 cm tall. In any case, abundant humidity should always be provided, and the harvest should take place while the caps are still turned under at the margin.

It is better to cultivate shiitake in flat boxes. A mixture of 35% straw and 65% wood chips or 35% bran and 65% wood chips serves as a substrate; the addition of soybean meal increases the yield. The substrate is mixed, saturated with water, and cooked 2-3 hours in a container. After cooling to about 25°C, the substrate is mixed with spawn and put in boxes, which are covered with a pane of glass and put in the dark until the substrate is permeated. Then abundant light, fresh air,

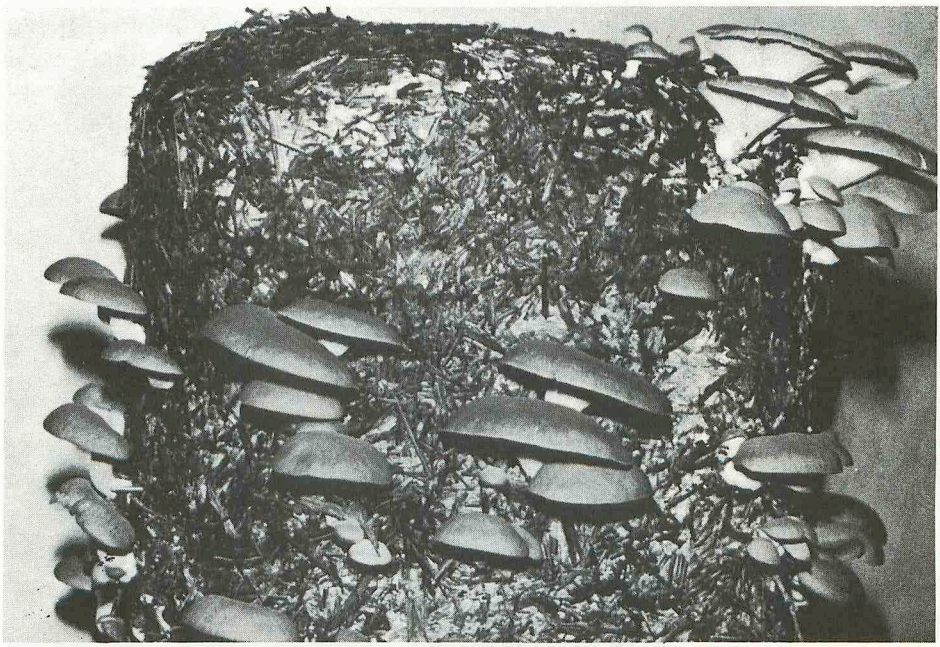


*Fig. 73. Pleurotus on straw substrate with fruiting bodies ready for harvest*

and high humidity are provided so that the fruiting-body primordia form. Success frequently does not occur with the usual spawn, since the different types of shiitake have very different requirements for forming fruiting bodies.

The shaggy mane is also suitable for cultivation in plastic sacks, boxes, or trays. Straw or mushroom compost is used as a substrate, as described in the culture of the common cultivated mushroom. Since the shaggy mane likes lime, 0.5-1 kg calcium carbonate is added to 100 kg of the prepared substrate. The substrate is put in plastic sacks or in boxes whose sides are 15-20 cm high, and pressed down. When substrate spawn is used, it is divided up into walnut-sized pieces and inoculated ca. 5 cm deep. When grain spawn is used, it is mixed with the substrate before the containers are filled. After filling, some more grains are scattered on the surface and then pressed down.

A temperature of ca. 25°C is favorable for permeation of the subtrate by the mycelium. The surface should be covered with paper (perhaps newspapers) to retain the necessary moisture. After permeation (about four weeks) a layer of soil 3-4 cm thick is put on the substrate; for this it is best to use good garden soil mixed with peat, or compost soil, which has been brought to a pH of 7.5-8 by adding calcium carbonate. The soil is thoroughly watered before being used as a covering and is kept well moistened during the culture period. At a temperature of 20°C the first fruiting bodies can appear after about 4 weeks. During cultivation, sufficient moisture must be constantly provided; the formation of a crust on the soil must be avoided in any case. During the harvest period plenty of fresh air and a room temperature of at least 15°C should be provided. Since the fruiting bodies are very delicate, they should be cooked on the day of harvest if possible.

*Stropharia* can also be easily cultivated in the cellar in boxes or sacks.



*Fig. 74. Culture of shaggy manes*

# Harvesting and use

## Edible fungi

### Harvesting

While one can control the harvest of cultivated fungi by regulating the temperature, humidity, and $CO_2$ content of the air in the culture rooms, harvest in the garden is dependent on the season and weather conditions. When cultivating the common mushroom in the usual way, for example, one can expect that harvest can begin about five weeks after introduction of the spawn to the substrate, and that it will occur in waves which follow each other at intervals of a week. The harvest of outdoor fungi, in contrast, will be determined by a large number of external influences which we cannot alter and which always upset our calculations. It is well known that years with vast mushroom harvests follow complete crop failures in which even the species which usually occur in large numbers are scarcely to be found. It is true that in the garden we can improve the prospects of the harvest a little by covering the beds with plastic sheets when the weather is very wet and by irrigating when it is very dry, as for the vegetable or fruit garden; but we can do little about dry spells, heat waves, storms, prolonged precipitation, and heavy frosts. Uniform crops, which enable one to harvest large quantities in a few days as is desirable for preserving, freezing, drying, etc., can be expected for only a few species of fungi. However, when using fresh fungi it is even desirable for the harvest to be protracted over a longer time, so that one is not forced to consume dishes made with the same mushroom in rapid succession.

Having a multitude of mushroom species in the garden makes it possible to harvest fresh mushrooms throughout almost the whole year and to be able to enjoy new flavor nuances repeatedly. After the winter fungi come morels in the spring as well as the first changeable agarics, then St. George's mushroom; with the beginning of warmer weather come *Boletus edulis*, species of *Agaricus*, *Marasmius*, *Russula*, and toward fall *Coprinus*, boletes, and *Agaricus*, followed by *Collybia*, *Tricholoma*, and *Clitocybe* until the appearance of *Pleurotus* and the velvet shank at the beginning of the winter season, to mention only a few of the most important fungi.

The fruiting bodies appear alone or in rows, rings, or groups and should not be harvested when too small, since otherwise the yield is too small and the aroma is not yet fully distinct. Mushrooms which are too large are usually already maggoty, tough, and hard to digest. One should therefore wait for the most favorable time; however one should keep in mind the fact that during hot periods after thunderstorms the fruiting bodies which suddenly shoot up become full grown very quickly. Fungi which are too old should not be harvested; when they remain they scatter their spores and ensure that fungi can be harvested in subsequent years also.

When one discovers a mushroom, one should check the surroundings painstakingly to find out whether still others are hidden in the vicinity. Fruiting bodies growing on trunks should be cut off close to the trunk; those in soil should be twisted out or cut off as deep in the soil as possible. Clusters are cut off close to the trunk, so that new primordia can develop on it. Holes caused by harvesting are carefully pressed closed; in no case should the mycelium growing just below the surface be damaged by removal of the moss or leaf and needle litter covering the soil.

During rainy weather harvested mushrooms are often dirty and watery and therefore keep poorly. All dirt should be removed immediately. Until they are cooked they should be stored in a cool and airy place, since when they lie piled closely on top of each other, especially in closed containers, heating and consequently rapid decomposition occur; humid warmth promotes decomposition of the protein and makes the mushrooms, like meat, sausage, and fish, unwholesome and hazardous to eat. It is best to cook mushrooms on the day of harvest and not to reheat leftovers from

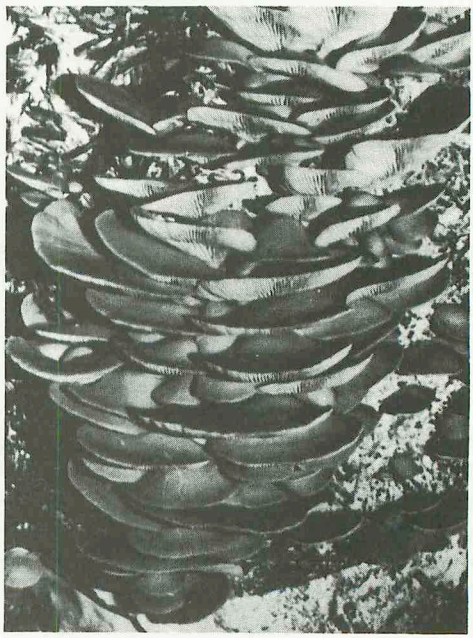


*Fig. 75. It is better to harvest Pleurotus when the margin of the fruiting bodies is still bent under*

the meal. Frozen mushrooms which are still fresh are harvested frozen and used immediately after thawing.

It is best to put the harvest in wicker baskets, trays, or containers provided with ventilation, to avoid bruises and rot.

Since sensitive people are allergic to certain species of fungi, as they are to strawberries, fish and other food, one should eat large amounts only if one knows one is not allergic to the species served.

## Nutritive value

Today an especially rich supply of mushrooms is probably especially important for sound nutrition. Since physical work is constantly decreasing, the requirement for calorie-rich food is also declining, while the percentage requirement for protein, vitamins, and minerals is increasing. Mushrooms satisfy one's hunger relatively quickly and are therefore a very suitable food. In nutritive value they correspond approximately to vegetables, but they do not attain that of lean beef, although when dry they come very near it. The protein content of mushrooms is high; it lies between 1.5 and 6% of the fresh weight. The differences among the individual species are often substantial. Thus, *Boletus edulis*, *Agaricus*, the parasol, and puffballs contain much digestible protein; chanterelles, *Tricholoma*, and most boletes contain little. The habitat and the age of the mushroom also influence the protein content; thus young mushrooms contain relatively more protein than older ones. Since the protein is stored in the cells, whose cell wall is composed of chitin and is hard to digest (but stimulates intestinal activity), it is difficult of access and is not utilized completely. The utilization varies between 70% and 90%, *Tricholoma* and chanterelles lying on the low side of this range. By careful preparation, namely thorough chopping and good steaming, as well as proper chewing of the meal, the value can be raised.

The carbohydrate content varies between 3.5% and 5% and is particularly high in *Boletus edulis* and *Russula*, low in chanterelles. Sugar is present mostly as mannose or trehalose.

Truffles, *Marasmius*, and *Boletus edulis* are relatively calorie-rich, while chanterelles and toothed fungi contain few calories, since their water content amounts to more than 90%. Young mushrooms have a higher proportion of dry matter than older ones; fat occurs only in very small quantities. The high content of minerals such as potassium, phosphorus, manganese, iron, and calcium is important. The high content of alkaline components improves the utilization of the protein present. The fairy-ring mushroom, morels, and *Boletus edulis* are rich in minerals.

Mushrooms became a desirable delicacy because of their content of aromatic substances which improve the flavor of meals; therefore many species are especially prized as flavorings.

## Value for health

Most important for health is the high vitamin content of mushrooms. They contain thiamin (vitamin $B_1$), riboflavin ($B_2$), pyridoxin ($B_6$), pantothenic acid, folic acid, nicotinamide (all three in the vitamin B complex), ascorbic acid (vitamin C), ergosterol (provitamin $D_2$), and biotin. Folic acid should be emphasized especially, since it occurs in only a few kinds of vegetables (for example spinach) and is good for a series of anemic conditions. Vitamin $B_{12}$, present according to Japanese statements, is of great importance, since deficiency can lead to pernicious anemia. Vitamin C, which is present in practically important quantities only in vegetables and fruits, is also found in various amounts in mushrooms.

*Vitamin C content* (after Schuphan; mg % of the fresh weight)

| | | | |
|---|---|---|---|
| *Macrolepiota procera* | 4 mg % | *Suillus luteus* | 14 mg % |
| *Boletus edulis* | 5 mg % | *Boletus leucophaeus* | 7 mg % |
| *Boletus badius* | 4 mg % | vegetables (average) | 34 mg % |

*Vitamin D content* (after Schuphan; expressed as the ergosterol value in vitamin D; γ = 1/100 mg)

| | | | |
|---|---|---|---|
| morel | 12.5 γ % | indoor-grown *Agaricus* | 2.1 γ % |
| chanterelle | 8.3 γ % | butter | 4.0 γ % |
| *Boletus edulis* | 8.3 γ % | cow milk | 0.2 γ % |
| outdoor-grown *Agaricus* | 6.3 γ % | | |

Green vegetables contain only extraordinarily small amounts of vitamin D. The dependence of vitamin D formation on light is clearly recognized in *Agaricus*, since outdoor-grown mushrooms contain about three times as much as those growing in dark rooms. Experiments with artificial lighting of shiitake, which Dr. T. Ono carried out by illuminating them for 20-40 minutes with fluorescent lamps, brought about a four-fold increase in the conversion of ergosterol into vitamin $D_2$. Irradiating the mushrooms' lamellae proved especially effective.

Substances in mushrooms which lower blood cholesterol are especially significant. Since accumulation of cholesterol can lead to arteriosclerosis, it seems that a diet containing mushrooms is worth recommending for avoiding or improving diseases of the heart, liver, and brain based on it. In Japan experiments on this subject were carried out by Tokita, Shibukawa, Yasumoto, and Kaneda. Rats were fed food containing cholesterol (1%), which was supplemented with various species of mushrooms (5%), in comparison to feeding without mushrooms and without cholesterol. They showed that the plasma cholesterol level of the rats which had received cholesterol-containing feed and mushroom supplement was in all cases lower than the cholesterol content of those fed without mushrooms; in the case of shiitake "Donko" and *Agaricus* it was even lower than in those fed a cholesterol-free diet. The reduction in cholesterol with the variety "Donko" appeared especially promising. The principal compound with a hypocholesterol effect, $C_9H_{11}O_4N_5$ (eritadenine), and a second compound, $C_9H_{11}O_3N_5$, were isolated from dried shiitake.

Mushrooms are reported to contain substances which reduce the blood-sugar level, as experiments by Italian researchers have proved. Japanese and Bulgarian scientists also ascribe an influence on diseases of sugar metabolism to a few species of mushrooms. The shaggy mane is supposed to have these properties

A field that especially deserves to be studied more closely is the utilization of substances in mushrooms which have a cancer-inhibiting effect. Thus, the Nobel Prize winner Prof. Dr. Albert Szent-Györgyi found in his investigations of substances which inhibit or promote cell growth that in mushrooms the inhibitor (retine) exists in a high concentration and the promoter (promine) is in small quantity. The two substances have almost the same chemical and physical structure, so one suspects that a converter may exist in nature which can form a cell-growth promoter out of an inhibitor by altering its structure slightly. It was determined that the substance "retine" was a methylglyoxal derivative. The carcinostatic effect of such a derivative is well known. Szent-Györygi assumed that various cancer-producing substances hindered the production of "retine". In his experiments a negative effect on cancer was apparent. He traces the high concentration of "retine" in mushrooms back to the fact that they live on dead and rotting materials and are exposed to the attack of numerous parasites against whose growth they are protected by "retine".

In propagating fungi from pieces of tissue one can establish that mycelium from pieces of tissue of the same sort fuse together, while the mycelium of different sorts and species show antagonism; therefore they have an inhibiting effect on foreign tissue.

According to the investigations of Dr. N. Ishida, Tohoku University in Japan, spores of the shiitake cause organisms to form antibodies which inhibit the

growth of tumors and are reported even to cure them. At the present, experiments are being done with the most poisonous mushrooms, the Amanitas, to make it possible to use the effective substances in them for medicinal purposes (combating tumors).

That substances effective against diseases are contained in various species of fungi is shown by the success of penicillin, streptomycin, and other medicines. In antiquity and the Middle Ages fungi were already being used as medicines. Thus, for example, the spores of puffballs were used for healing wounds which were reluctant to close, the gout morel for curing gout, and the jew's ear for inflammation of the eyes and sore throats. The substance clitocybin in *Clitocybe* is supposed to have antituberculotic properties.

Nowadays, psychoactive substances in fungi are being discussed. In Siberia drinks are prepared from fungi, which are supposed to release energy temporarily when one is in a kind of intoxicated state and so enable a person to overcome unusual fatigue. In Mexico mushrooms of the genus *Psilocybe*, which occur in mountain regions around 2000 m high, are used to evoke hallucinations which are supposed to lead to spiritual expansion. The psilocybin they contain

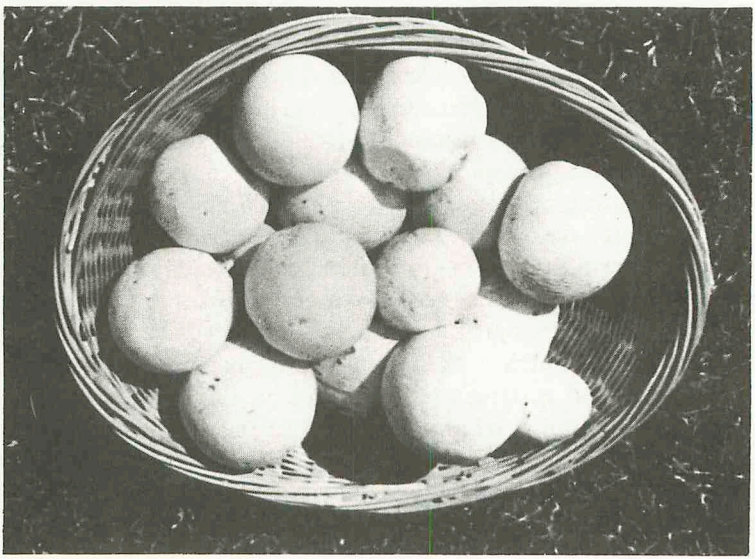


*Fig. 76. The "eggs" of stinkhorns develop underground at first, but soon break through the surface*

has been used in small quantities in psychotherapeutic research. A member of the genus contaning a similar substance is native here also and is described as slightly poisonous. In his book "Growing wild mushrooms--a complete guide to cultivating edible and hallucinogenic mushrooms", Bob Harris describes several species of *Psilocybe* growing in America.

In order to increase the utilization of the valuable substances in fungi, the Japanese produce mushroom drinks (Foresterin and Super-Foresterin). These drinks, sold commercially and enriched with effective mushroom substances, are drunk like lemonaid or fruit juices.

In Taiwan hot mushroom drinks are served. They use the jelly fungus (*Tremella* spp.) for this purpose. Hot water is poured over it, the water is sweetened somewhat with sugar, small pieces of pineapple and perhaps cherries are added, and, after they steep for a short time, the water is drunk. The pieces of mushroom and fruit floating in the cup are pierced with a toothpick and eaten as the liquid is being drunk. In Germany a mushroom schnaps made of forest mushrooms is produced in Franconian Switzerland (northern part of the Franconian Jura, Bavaria, West Germany).

### Preparation and cooking

Only young and blemish-free mushrooms are used for cooking. They are thoroughly cleaned without using more water than necessary. The top of the cap is washed off well under flowing water and then the underside is briefly rinsed. The surface is peeled off if it comes off easily. Only soft lamellae and pores, or those attacked by maggots, are removed; tough stalks are not used. After the mushrooms have dripped dry, they are cut into strips, slices, or pieces if they are not going to be cooked whole.

With few exceptions, it is better not to use mushrooms raw. Even for salads it is better to boil them briefly and prepare them for the salad after they have cooled. Only firm-fleshed species are suitable for use in salads.

The especially flavorful *Boletus edulis*, parasol mushroom, oyster mushroom, *Russula* species, cauliflower fungus, and perhaps also *Lycoperdon gemmatum* are fried. They are best left whole, and are cooked either breaded or unbreaded in an open pan over medium heat. A surer method for many species is to fry them first in an open pan and then to steam them for about 10-15 minutes.

For stewing, mushrooms are cut up, seasoned with steamed onions etc., and then stewed in their own juice for about 20 minutes. Mushrooms which are good mixed with others are commonly stewed; milky caps are unsuitable.

For mushroom soups and sauces, particularly aromatic mushrooms such as the changeable agaric, *Agaricus*, *Boletus edulis*, and the shiitake are used.

*Boletus edulis*, puff balls, and the shaggy mane, among others, are suitable for making mushroom pies. They are washed, cut up, and then steamed. After the addition of flour and seasonings, they are boiled again and put in pie shells. For mushroom omelets, the mushrooms are boiled briefly and then chopped with onions or parsley. The mixture is stirred into an omelet batter and then fried.

Mushrooms which contain bitter or distasteful substances, such as *Clitocybe nebularis*, are boiled for 5-10 minutes, then drained, before cooking. *Russula* species with a sharp taste and the sulfur shelf are cut into pieces, soaked for a few hours, boiled for about 10 minutes, drained, and then cooked.

Various methods are available for preserving large harvests which cannot be used fresh. The oldest method is drying. Sound, blemish-free mushrooms are cleaned and cut into slices unwashed, while small ones are left whole. Then they are strung on threads and hung up, or dried in an airy spot on a grate covered with paper, and afterwards preferably dried further on a radiator or oven. When they are fully dried they are put into tins or screw-top jars, in which they keep for a long time. Changeable agarics, the common cultivated mushroom, *Boletus edulis*, and *Tricholoma* species are examples of suitable mushrooms. Dried mushrooms can be ground and used as a mushroom powder for soups and sauces.

For canning in jars, the mushrooms are cleaned, put in the jars, and cooked for 1 ½ - 2 hours, or first precooked, then put in the jars, sealed, and re-cooked. Sometimes, for safety's sake, they are cooked again two days later for another hour. In any case, the jars must be checked after a few days to see that they are well sealed; the contents of open jars are no longer usable.

For deep-freezing, the mushrooms are thoroughly washed, cut up, and blanched for 3-4 minutes. After cooling them quickly in ice water and letting them drip dry, put them in plastic bags for freezing. They can be kept for several months this way.

Mushrooms can also be preserved in salt or vinegar; however, canning in jars and deep-freezing are usually preferable. Mushroom extracts are prepared from flavoring mushrooms and put in as small bottles as possible.

### Some recipes

*Mushroom soup from 1900*

The mushrooms are first boiled in their own juice for a half hour, removed with a skimming ladle, and chopped fine. Meanwhile the mushroom water is mixed with approximately an equal volume of boiling water, in which the mushrooms, after they have been fried with butter, finely chopped parsely, and

some pepper until they are light brown, are boiled another quarter hour. The soup can also be thickened with brown flour; also an egg can be added. If meat stock is available, it can be used instead of the water.

*Spread with mushrooms and hardboiled eggs*

Chop 3 onions very fine, brown them in oil or butter, add 300 g mushrooms chopped very small, cook, remove from the heat. Crush 3 hard-boiled eggs with a fork, mix them with the cooked onions and mushrooms, add salt, and finally add a grated raw onion if desired.

*Spread with mushrooms and tomato puree.*

Chop 3 onions very fine, brown them in oil or butter, add 300 g mushrooms chopped very small, 2 bay leaves, and salt, cook for a few minutes, then add 3-6 tablespoons of tomato puree.

*Spread with mushrooms, marjoram, and cream*

Chop 3 onions very fine, brown them in oil or butter, add 300 g mushrooms chopped very small and 1 teaspoon marjoram, cook, then add salt and sour or sweet cream. If the mushrooms release too much liquid, thicken the mixture with flour.

*Mushroom soup*

Brown 1 small onion, chopped very fine, with a little butter, add 300-500 g mushrooms chopped very fine or cut in slices, dust them immediately with flour and quench them with water or meat stock, let them boil only a short time so that the mushrooms remain crunchy (the soup can be enriched with egg yolk).

*Mushroom Schnitzel*

Oyster mushrooms are very suitable for this. Take large flat mushrooms, cut away the stalk (perhaps use stalks in soups or vegetable dishes), put them in milk, roll them well in flour, then roll them in a beaten egg and bread them with crumbs, then fry them like schnitzels.

*Mushroom goulash*

Coarsely chop numerous onions, brown them in a little diced bacon fat, add mushrooms, cook for 10-15 minutes, add a few tablespoons of sour cream. If desired, season with paprika, tomatoes, or herbs.

*Liver with mushrooms*

Brown onions in butter, add mushrooms and liver chopped into small pieces, cook, bind them together with sour cream and possibly some flour, season to taste, perhaps also add a few tomatoes.

*Mushroom salad*

Small *Agaricus* are well suited for this. They only need to be trimmed, washed, and, after washing, allowed to drip dry briefly while spread out on a dish towel. Meanwhile a diet mayonnaise is prepared. For 500 g of mushrooms one takes 250 g low-fat cottage cheese which is beaten with low-fat milk until smooth. The seasoning must be done very subtly, perhaps with grated onions, chopped herbs, or grated horseradish, or even prepared seasoning may be used. If one wishes, one can improve the flavor with a few raw egg yolks. Finally, the mushrooms are carefully mixed with the mayonnaise.

*Mushroom pastries*

Mushrooms are outstanding to use as a filling for pies, turnovers, and crescents. Chopped mushrooms, mixed with onions and/or minced meat, perhaps bound with eggs, are suitable as a filling. It is seasoned according to one's taste and the garden herbs available; tomatoes, paprika, celery, leeks can also go into the filling.

*Herrentorte*

One bakes a simple *salty* yeast dough in a torte or cake pan, and after it cools it is cut into 3-4 layers. The filling is prepared from well-chopped mushrooms; it can be varied with all the other vegetables and herbs in the garden. All ingredients must be chopped and cooked enough for the mass to be easy to spread. It can be enriched with smoked ham and any other kind of meat. Before putting on each layer of filling, vegetable or mushroom juice is trickled onto the dry breadstuff so that the whole torte does not become too dry. The top is decorated with small mushrooms, tomatoes, paprika, cucumbers. This torte can be the center of a cold buffet.

It cannot be task of this book to serve as a recipe book for using edible mushrooms; but the few recipes included as examples are intended to suggest how mushrooms can be used to improve the most varied dishes.

The housewife should not confine herself rigidly to particular recipes, but should invent new combinations depending on the possibilities offered by the

garden, according to her (and her husband's) taste. Mushrooms go well with beef, veal, and pork, are suitable as an accompaniment to poultry, game, and fish dishes, and can be combined well with eggs.

Frequently, at the very beginning of harvest only a few mushrooms are available. Then one should not only mix them with the other available mushrooms, but use them in vegetable side dishes such as carrots, peas, cauliflower, asparagus, and kohlrabi to improve the aroma, or add them with onions and herbs to sauces and soups. Like parsley, tomatoes, and radishes, mushrooms are well suited as edible decorations for a meal, and solitary individuals are especially effective.

One should have the courage to use mushrooms also where it is generally not yet customary. One can serve them flambé or in curry sauce with fowl along with fried bananas and pineapple. As a change from meat and onions, paprika, tomatoes, and mushrooms can be put onto toothpicks, and as appetizers one can use not only pieces of cheese, cucumbers, paprika, pineapple, bunches of grapes, cherries, and olives, but mushroom caps can be combined well with them also.

## Fungi for decoration

Fungi have long been used as decorations. Unfortunately they are mostly mushrooms of various sizes made of wood or plastic, generally in imitation of the fly agaric. That the poisonous fly agaric of all things is supposed to bring luck is truly a paradox, even when it is in a pot filled with beautiful green moss. Yet real fungi are also used for decoration. These include principally the very durable species of polypores, mostly imported from northern regions, which find their places in arrangements. These also occur in our country in manifold, frequently odd forms, which are outstandingly suited for this purpose. One can find them especially abundantly in forests on old tree stumps, especially if they are largely protected from drying by surrounding shrubbery or thick fern growth.

These species can also be established in the garden to decorate tree stumps, wood serving as borders and well margins, and used as perching places at bird baths, or logs used as a group of seats in the shade. For use in flower arrangements, Advent decorations, or decorations for graves, etc. either the fungi available in the garden can be used, or they can be cultivated like the edible wood-inhabiting fungi on logs. When mature polypores are harvested they can often be kept for a whole year to be used at any time. They are outstandingly effective as the base of an arrangement built upward from them with fir branches, holly, or flowers. Flat compositions of fruiting bodies of various

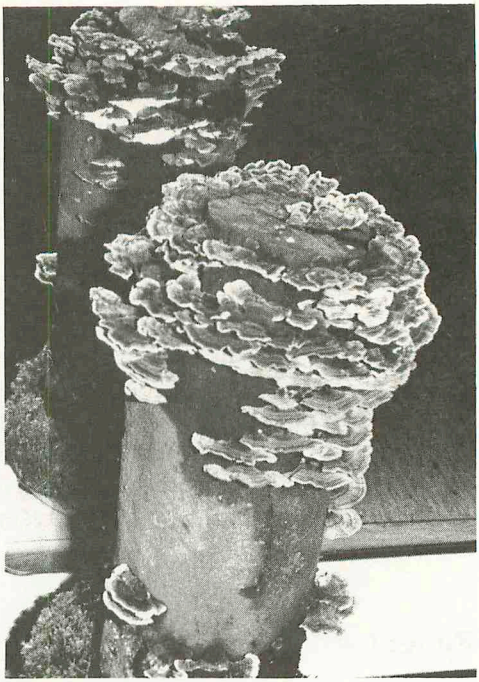


*Fig. 77. Tree stumps as hall decoration*

colors and forms can be especially effective as a grave decoration. In Advent arrangements these fungi provide an effective contrast to the upwardly directed bright red, yellow, or violet candles. Because of their outstanding ability to keep, polypores can be installed in flowerpots, particularly when they are put in the pot with the disk of wood on which they are growing so that they can continue to be provided with moisture from the soil; the addition of some moss and ferns brings a bit of forest into our room.

The easily perishable species cannot be used like the long-lasting resistant polypores. However, other wood-inhabiting species, such as *Pleurotus* or shiitake, which are also very decorative, can be incorporated in flower arrangements as additional decoration, if they are cultivated on disks of wood. For mushrooms which are very sensitive but stand out because of their bright colors, such as the wood blewit (*Lepista nuda*), *Tricholoma irinum*, or the amethyst deceiver (*Laccaria amethystina*), one should inoculate the mycelium on a suitable substrate and cultivate it in a glass container about the size of a marmalade jar until the fruiting bodies form, and then bury it in the soil of a flowerpot and arrange it with mosses, green plants, and flowers. In doing this one should always keep in mind that mushrooms usually need high humidity.

In a Japanese mushroom book written at the beginning of this century, the suitability of unusual mushroom forms as decorations was described with examples, and the writer Sterne praised "mushroom flowers" in 1906 as "the apex of the plant kingdom". They had caps like latticed balls of sealing-wax red or resembled flesh-pink carnations or vividly colored corals. As long ago as 1895 Alfred Möller praised *Dictyophora phalloidea*, native to Brazil, which begins to open in the afternoon and reaches its full beauty at midnight.

It seems time to remember the value of fungi as decorations and to grant them their proper place as ornamental plants.

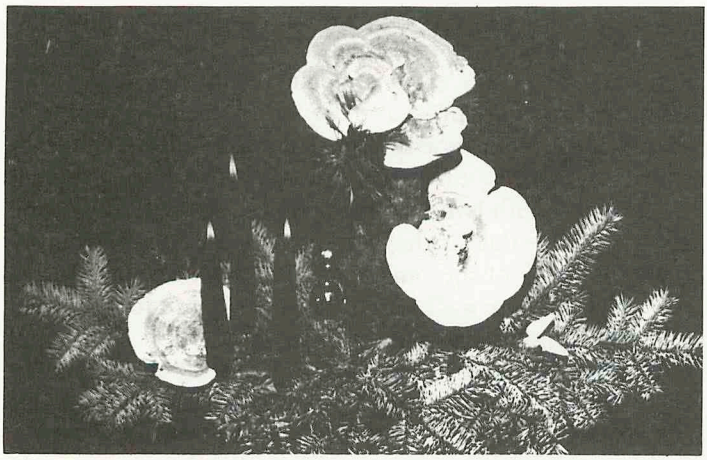
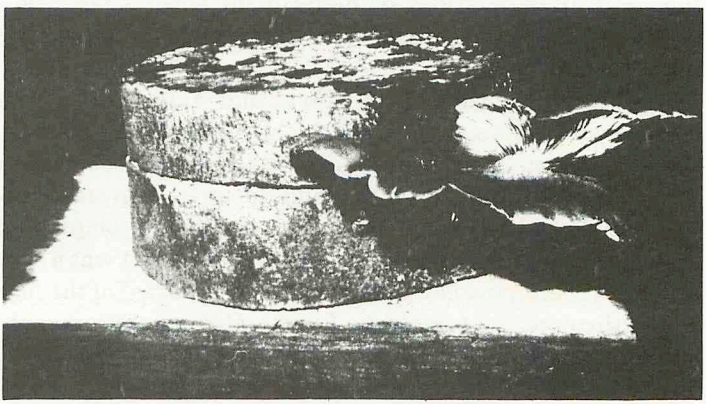


*Fig. 78. Advent arrangement*

*Fig. 79. Disks of wood with oyster mushrooms*



# The mushroom as a symbol

The mushroom has always been a symbol of things shrouded in mystery. It is suddenly there without previously giving a hint of its coming and disappears in the same way. There is no green plant to be seen which could have formed these fruiting bodies, and yet the mushrooms must take up the nutrients necessary for their structure, although they cannot nourish themselves like animals. In many years mushrooms are present in abundance; the next year in the same place perhaps scarcely one mushroom can be found. Mushroom enthusiasts, once they are engaged in cultivating mushrooms in the garden, will soon be no longer contented with two or three species, but will always be trying to introduce new species. To do this they will have to occupy themselves with the structure and way of life of mushrooms. Those who look for new species for the garden will be alert during walks in field and forest for possible discoveries of other suitable fungi and will have to be intensively concerned with the interaction of habitat, climate, and the plant world. They will widen their field of view, recognize the mutual dependence of all life, and thus also better understand the importance of protecting the environment.

The forester also should ponder why many species of mushrooms can scarcely be found any more. Departure from monocultures, from the monotonous forests in which only pines, only spruces, or only beeches grow, to forests which make the natural associations of many plant species possible. Mushrooms which promote the growth of the trees and bring joy to people on walks should be introduced here again.

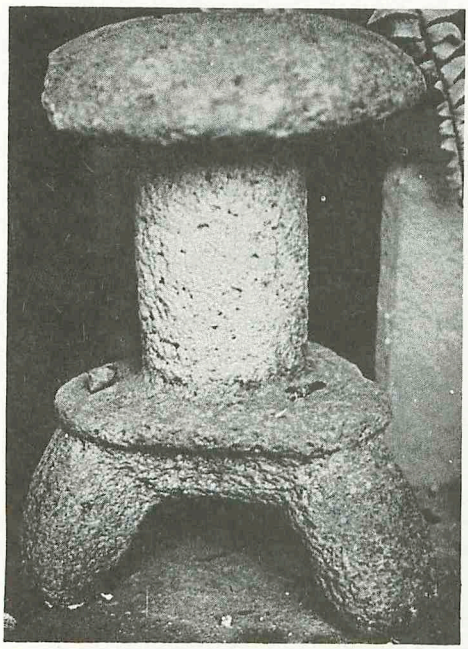
As early as the time of the Mayas and Aztecs, the mysteriousness of mushrooms made them a symbol, a link between gods and people, as the sculptures of that time show. By eating certain species of mushrooms, people were translated into a state of intoxication in which the gods answered their questions. In our folk beliefs and folk tales the mushroom was the origin of the tales of the little man of the forest, of dwarves, elves, and fairies. It was a symbol of shelter, since under its sheltering cap gathered the "creatures" of the forest. Now during our walks through the forests we find shelter-mushrooms which invite us to rest and offer a refuge during rain and shade on hot summer days.

The giant mushrooms of stone which are found in Anatolia are reminiscent of

monuments of sunken cultures. However, they were not created by human hands but are a performance of nature and originated by weathering of the stone.

Since the mushroom, with its numerous odd forms and beautiful colors contrasts with everyday things, people have even granted it a place on stamps; especially interesting mushrooms are pictured on Chinese stamps. In recent times the mushroom has become a symbol of menace; the atomic mushroom cloud threatens the annihilation of mankind. It is to be hoped that this mushroom "species" will soon go extinct.

Thus the mushroom is a symbol of the good and the bad, just as there are wholesome edible mushrooms and life-threatening poisonous mushrooms. It will lie with us whether it will become in the future only a symbol of good. When it grows in the garden as an edible or ornamental mushroom, when it gives us enjoyment, improves meals, and helps us become healthier, then it can become a good luck symbol, a "lucky" mushroom.





*Figs. 80 and 81. "Mushroom stones" of the Maya in Guatemala*

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**Sources of figures**

Rose Marie Dähnke, Hornberg: cover photograph.
Heinz Schrempp, Oberrimsingen: figs. 7-18.
All other photographs by the author.
Drawings from the author's sketches and from the botanical literature by Roland Zahn, Stuttgart.

# Sources of mushroom spawn

## European sources

| | |
|---|---|
| "Agri-Truffe"<br>Domaine de Lalanne<br>Saint Maixant<br>33490 Saint Macaire | young oaks and hazels inoculated with truffles |
| Joachim Blechschmidt<br>6200 Wiesbaden-Bierstadt<br>Rostocker Str. 4 | commercial-mushroom spawn |
| E. Mangelsdorf<br>435 Recklinghausen<br>Postfach 1680 | brown and white commercial mushrooms (*Agaricus*)<br>oyster mushroom (*Pleurotus*), summer and fall<br>*Agaricus edulis*<br>velvet shank (*Flammulina*)<br>cultivated *Stropharia* |
| Eberhard Hullen o. H.G.<br>336 Osterode am harz-Beierfelde<br>Postfach 1331 | commercial mushrooms<br>oyster mushroom (summer, fall)<br>*Stropharia*<br>shaggy mane<br>shiitake<br>velvet shank<br>changeable agaric |
| Schubert und Hauser<br>6457 Maintal 4<br>Hessenring 21 | brown and white commercial mushrooms (*Agaricus*)<br>*Agaricus edulis*<br>oyster mushroom |

| | |
|---|---|
| Hornberger Pilzlabor<br>7746 Hornberg/Schwarzwald<br>Werderstraße | various species of mushrooms |
| Mykofarm Ges. für Pilzkultur mbH.<br>2 Hamburg 1<br>Ballindamm 35 | changeable agaric<br>*Nematoloma capnoides*<br>oyster mushroom<br>shiitake<br>velvet shank<br>and permeated substrates |
| Les Miz Holland B.V.<br>Knapenstraat 15<br>Geleen/Holland | commercial mushrooms<br>*Agaricus bitorquis*<br>oyster mushroom<br>changeable agaric and others |
| Erdinger Pilzsubstrat Ges. b. R.<br>Rotkreuzstr. 3<br>D 8058 Erding | substrate permeated with mycelium of the commercial mushroom, in plastic packets |
| Nettetaler Champignonzentrale<br>H. u. W. Geurtz<br>Berg 17a<br>4054 Nettetal 1 - Breyell | prepared mushroom compost<br>mushroom culture trays<br>substrate inoculated with the commercial mushroom, in plastic sacks |
| Burbacher Pilzfarm<br>Kurt Schöler<br>Am Denkmal 14<br>5909 Burbach-Holzhausen | wood inoculated with oyster mushroom, changeable agaric, velvet shank, shiitake |

## North American sources

| | |
|---|---|
| Rick Kerrigan<br>Far West Fungi<br>P.O. Box 763<br>Watsonville, Calif. 95077 | spawn and growing kits for shiitake and other mushrooms |
| Mushroompeople<br>P.O. Box 158<br>Inverness, CA 94937 | oak and hazel seedlings inoculated with truffle mycelium<br>shiitake spawn plugs (summer, winter types)<br>*Agaricus bisporus* spawn<br>oyster mushroom and other kits<br>books, media, supplies |
| Mycotech Biological Laboratories<br>Box 1465<br>Chico, Calif. 95927 | Petri dishes, media, mushroom growers' equipment and supplies |

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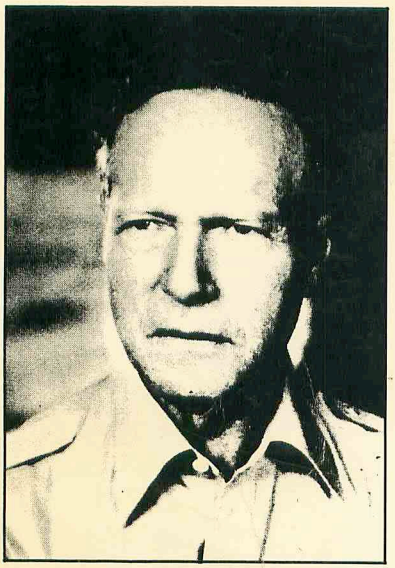
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Today people everywhere can raise their own edible mushrooms— in the kitchen garden, on the compost heap, in cold frames, even in the lawn or under ornamental trees. Culturing fungi which live on wood is at least as popular and even more interesting than growing them in the ground. Today, as in earlier times, the cellar is also a favorite place for culturing many delicious fungi.

Hellmut Steineck is a practical man. He has been concerned with problems of mushroom culture for many years and has tested nearly every method of cultivating mushrooms in his own garden and home. From preparing the substrate to harvesting and using the bountiful mushrooms for food and decoration, he describes clearly all the tested methods and technical details of growing one's own mushrooms.

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