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MUSHROOM-GROWING

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FOREWORD

THE first edition of this Bulletin, issued in 1931, augmented and replaced the Ministry's Leaflet No. 276, *Commercial Mushroom Cultivation*. A second edition, somewhat revised, was published in 1932. Both of these editions were largely the work of Mr. W. M. Ware, D.Sc., of the South-Eastern Agricultural College, Wye, Kent, who for some time had studied the methods employed in growing mushrooms, and the fungus diseases to which they are subject.

In May, 1934, Dr. Ware was granted a Travelling Fellowship to enable him to visit some of the chief mushroom-growing districts in the eastern states of the United States of America, and to consult with scientific workers who were carrying on research into all aspects of mushroom cultivation in that country. The 3rd edition of the Bulletin embodied a considerable amount of quite new information that had been acquired as a result of that visit. Messrs. S. G. Jary, B.A., and M. D. Austin, F.R.Æ.S., of Wye College, wrote the section on pests of mushrooms in that edition.

The 4th edition, now presented, has been entirely revised by Dr. Ware. Messrs. Jary and Austin have rewritten the pages on pests and their control, and new sections on preparation of the manure and on the value of spent compost have been furnished by Mr. N. H. Pizer, M.Sc., Ph.D., F.I.C., also of Wye College.

A list of references to relevant literature is provided at the end of the Bulletin; this should be of value to established growers, as well as to others who desire to study the problems of mushroom cultivation and diseases in greater detail. This list is not, however, intended to be exhaustive.

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September, 1938.

CONTENTS

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MUSHROOM-GROWING

CULTIVATION

The cultivation of mushrooms begins with the planting of spawn in specially prepared beds of composted stable manure. These may be situated either in a building or in the open. Mushrooms grown in the turf of fields, and not on specially prepared beds, may also be considered cultivated if they have originated from planted spawn, or if manures have been applied for the purpose of stimulating the cropping of naturally existing spawn.

Until comparatively recent times the cultivation of mushrooms was considered to be more or less of a gamble: experience, and the knowledge gained as to the causes of failures, make it possible nowadays to grow good crops with a considerable element of certainty. Even the most experienced growers, however, meet with difficulties and sometimes with failures, and the beginner is warned against embarking on mushroom-growing on a large scale on the strength of a single initial success.

For the guidance of those with no experience, it may be stated that mushroom-growing can be started with little or no capital, without employing labour, and with only a cellar, a garden frame, or small well-built shed; but under these conditions the scale of operations cannot be large, and an undertaking of this sort is to be regarded merely as a hobby or a means of learning and is likely to yield only a small sum of money in total profit. Mushroom-growing is not a means of rapidly acquiring wealth. Any expansion of operations should be gradual, because new buildings and failures of the crop are costly. The larger the scale of growing, the greater are the possible total returns, but at a certain stage, and before a livelihood can be secured, both capital and labour will be required.

It should be noted that, even with some knowledge of the causes of failures, it is still not known how to remove all those causes; such important matters as, for example, the preparation without fail of a suitable compost, and the method of prevention of attack by certain pests, are still imperfectly understood.

There are many wild species of edible fungi in this country, but the mushrooms commonly used as food and those in cultivation are varieties of *Psalliota* (*Agaricus*) *campestris* and *P. arvensis*. The life-cycle of a mushroom comprises three stages:—(i) spores, (ii) mycelium (spawn), and (iii) mushroom.

If a ripe mushroom is carefully removed from the ground, the white thread-like mycelium, resembling roots, can be seen at the base of the stalk and spreading in the ground. If now the stem is cut off and the cap laid with the gills downwards on a sheet of clean white paper and left in still air for a day, a fine, brown powder will be found to have fallen from the gills. This consists of millions of minute spores or " seeds " of the mushroom which, under natural conditions, would be thrown off and carried by the wind, probably on to blades of grass near by. When the grass, or the hay made from it, is eaten by a horse, the spores, even after taking 2-4 days to pass through the animal's body, are believed to be capable of germination in the dung. Direct germination of the spores in the soil or on manure, without previous passage through the alimentary canal of an animal, can take place under natural conditions, but the extent to which this happens and mushrooms develop in consequence in pastures is probably largely determined by surrounding conditions, including the amount of competition with other fungi encountered there.

Virgin Spawn. Germination of the spores in dung leads to the formation of a mass of white fungus threads (mycelium) which permeate it. The resulting product, probably mixed with mycelium from vegetative growth, is known as " virgin " spawn or " track ". This material is used by the makers of commercial " brick " spawn, who are able to identify it by its appearance and peculiar scent. It may occur in cattle sheds situated in meadows, about farmyards, under haystacks and in stables; and, in the days when horses were used, it was found in mill-tracks. A sufficient quantity can usually be obtained for the immediate inoculation of prepared bricks of manure, it being considered harmful to the vigour of the spawn, in this country, if the virgin spawn is propagated by being " tracked " into trenches or beds of prepared manure*. Similarly the practice of inoculating a further quantity of bricks with pieces of those first made is said to result in loss of vigour and fruitfulness. Virgin spawn should not be collected from mycelium that has already borne mushrooms.

Brick Spawn. Cow dung with litter, or a mixture of horse droppings, cow dung and loam together with the litter, and in

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* In France it has been the common practice to propagate the virgin spawn by planting it in beds of manure. When the beds have become permeated by the mycelium, they are pulled to pieces and the fragments of compost, white with the mushroom mycelium, are dried and sold as " Flake " spawn. In this country, however, brick spawn has always been preferred.

a soft condition, is well turned in an open shed, and when dry enough is moulded into bricks, each measuring about 9 in. by 6 in. by $1\frac{1}{2}$ in. These, when sufficiently dry, are set on edge for further drying and, when ready, are made into a stack with two small fragments of either virgin or pure-culture spawn firmly placed in each brick, or, more commonly, between one brick and the next. The stack, if necessary, may be covered with sacks or with dung to preserve moisture and an internal temperature of about 60° F.; the bricks then become covered with, and penetrated by, the white, mould-like growth of mycelium. Before growth goes too far, and before the mycelium becomes thread-like, the bricks are removed, slowly dried, and stored in a cool, airy, dry place, not exposed to frost in winter. They are then ready for use or for sale.

Intending growers are advised to purchase this brick spawn *rather than to depend on making it themselves* before the necessary experience has been gained.

Pure-culture Spawn. This is known also as "Sterilized* ", " Bottle " or " Carton " spawn. Its preparation entails the collection, under aseptic (i.e., germ-free) conditions, of tissue or spores from the best, selected mushrooms. The previously germinated spores, or the tissue, are transferred to prepared, bottled horse-manure, or other medium, which has been made sterile by heat under pressure. The white mycelium from the tissue, or from the germinating spores, " runs " through the sterilized material just as it does from virgin spawn into bricks. The medium thus impregnated is then used for increasing the stock and, after a second or third generation of containers (commonly quart bottles) have been " run " from the first, the material (now called spawn) is sold in the bottles or is removed from them if for immediate sale in the damp condition. Alternatively, it may be dried and kept in cool store ready for sale. Either dry or moist, it is packed in cartons to provide protection in transit.

This method of preparing pure-culture spawn was elaborated in France in 1894, and between 1899 and 1902 by mycologists of the United States Department of Agriculture. Originally the cultures were supplied to growers who used them for impregnating bricks. Certain growers in the U.S.A. then proceeded to make their own cultures from mushroom spores, and bricks inoculated from such cultures were first sold in 1917. In the following year, 1918, there began commercial production

* A most inappropriate term, for, strictly speaking, sterilized spawn means barren or dead spawn.

of the bottle spawn derived from spores and in sufficient quantity for direct use in spawning beds without resort to bricks.

Only mushroom growers who have the necessary training and equipment for the laboratory methods involved will be able to undertake successfully the making of pure-culture spawn. The outlay of a large amount of money will be required and the work is continuous. Unless, therefore, the grower is producing mushrooms on a scale larger than is commonly found in this country, it is certainly not worth while contemplating spawn manufacture for home use only.

Purchase of Spawn. It is probable that old or carelessly stored spawn has been one of the main causes of failure to grow mushrooms successfully in the past; care should therefore be taken that spawn is purchased from a reliable source. Both brick and pure-culture spawn when bought dry should not be more than six months to a year old, and they should both show the white mushroom mycelium on the surface and throughout the material. Four bricks, if they are well " run ", should be equivalent to a one-quart carton of pure-culture spawn, for, at the time of breaking up, each of these amounts will provide 40 pieces of a size suitable for planting, which will suffice for about 35 sq. ft. of bed. In practice, however, each brick is often broken into only 6 pieces, and at least 7 bricks of average commercial quality are then required for spawning the same area as can be spawned with the contents of a single quart carton. One brand of pure-culture spawn is supplied in the form of a cylinder, 7 × 4 in., which breaks into segments and is sufficient for spawning 100 sq. ft. Another is put on the market as a cylinder having transverse segments. One or two makers of spawn cater for the small grower by providing miniature packages.

There are several points for consideration in the choice of the type of spawn to purchase. Excellent crops have been, and can be, grown from good, fresh, brick spawn, but it has been found that there is more certainty of obtaining a crop, and a heavy one, from good-quality pure-culture spawn.

Cost of transport and storage accommodation for brick spawn are necessarily more than for quart cartons. After what has been said about the process of making brick spawn it will be realized that it may contain mycelium from unknown and unselected mushrooms, and the resulting crop may consist of a mixture of types showing variation, particularly in size and colour. Pure-culture spawn, on the other hand, always yields crops that are true to a selected type and colour; so that it is quite possible, for example, to grow white or brown* mushrooms along one side of a ridge bed and cream-coloured ones along the other. Very great improvement, however, has been effected in this direction by some makers of brick spawn, and crops of uniform type and colour can now be secured from this spawn also. Pure culture spawn was first imported in 1926 and it was not until 1931 that it was made and sold on a commercial scale in England. Since that time it has steadily superseded brick spawn and is now almost exclusively used.

If the grower experiences trouble with mushroom pests or diseases, he commonly suspects as the cause, not so much any of the factors under his own control, but rather the spawn, if this has been purchased. It is well, therefore, to consider what are the possibilities of the introduction of such troubles when bought spawn of either type is used. It will be realized that brick spawn, whilst being made, and even when drying, might conceivably become infected with foreign organisms derived from the air, the loam, the manure, implements or boots; also that it might contain animal life. Pure-culture spawn, on the other hand, particularly that from spores, has the advantage of being free from pests or disease; for, if it is assumed that conditions are hygienic at the time of drying and packing, only in the rather unlikely event of under-sterilization† of the medium, before it is " run ", could this spawn even be suspected. During drying and packing, however, and also when handled by the planter, pure-culture spawn is no longer under the aseptic conditions that existed inside the glass container, and spores of one of the very common green moulds may be deposited on it. The presence of the mould, if it is there, may or may not be observed when the spawn is planted, but under the damp and warm conditions of the mushroom bed, the green mould rapidly develops and will become obvious within a very few days. It is most often seen on planted fragments derived from dry pure-culture spawn after they have been in the bed for about a week; sometimes it occurs also on brick spawn. The green mould, though very undesirable, is not a fungus causing any mushroom disease, nor does its growth necessarily indicate that the spawn is dead. Probably its worst effect is in suppressing the active growth of the mushroom mycelium from the spawn fragments, for when two or more

* The brown variety that is cultivated in the United States is said to be the species *Psalliota brunescens*.

† Mushroom mycelium, with a good start, can " run " successfully in the bottles even in the presence of contaminations. Spawn whilst growing is regularly inspected and any contaminated bottles are rejected.

fungi occur together there is usually a struggle for possession of growing space and food material, and in the present instance the green mould may prevail. Any spawn, therefore, on which green mould is visible at the time of purchase may be treated with suspicion, and, if planted, will require observation before casing is done.

Both forms of spawn are obtainable from mushroom growers, nurserymen, seedsmen, florists and horticultural sundriesmen. It is essential in cold or in very dry weather that the spawn should be ready at hand when the manure is prepared and the beds just made. If the order is given some time in advance, for delivery at the estimated date, an opportunity is given for the supply of the freshest spawn.

The cost varies according to the size of the contents of the carton. Quart-size spawn is sold at prices from 4s. 6d. to 18s. If large quantities are required the cost may be less than 4s. 6d. per carton. The higher prices are charged for small orders, and more particularly by firms who offer in return instructional literature as well as special marketing facilities.

Damp pure-culture spawn is preferable to dry for the following reasons:—Not being in a dormant condition, it starts into growth more rapidly; it is not so likely to fail if subjected to bad treatment by being planted in beds that are too wet or too dry; it is almost certainly fresh. It must be removed from wrappings and used promptly, but can be kept in a cool, airy place for a few days or weeks if the beds are not quite ready. Dry pure-culture spawn is of course preferred by dealers who must hold stocks.

Choice and Preparation of the Manure. The mushroom feeds on decaying organic matter, chiefly plant remains that have passed the active stage of decomposition and reached a condition of slow change. Chemical and especially physical differences make some plant remains more suitable than others. It is not necessary that the plant residues should consist of or contain the excreta of the horse or any other animal. In the wild state, the mushroom is found in old pastures where it lives on decaying roots and other plant debris that accumulate beneath the turf. It occurs sometimes in arable fields that have been recently dunged and occasionally in soils containing leaf mould from the leaves of deciduous trees. The crop is usually cultivated on fermented horse manure. Experience has shown that composts made from horse manure are the best for commercial purposes, giving heavy crops for long periods, but good crops have been grown on composts made from other materials.

QUALITY OF THE MANURE. Fresh horse manure is unsuitable for mushroom-growing and it must first be allowed to ferment in special heaps known as compost heaps which will be described later. The highest yields and the most consistent results are obtained from composts made from fresh stable manure from hard-worked horses, fed with grain and good hay and bedded with wheat straw. Fresh manure ferments better than old, since the latter is either already partly fermented or has lost readily fermentable material, e.g., by exposure to rain. The influence of hard work lies in two directions. Usually hard-worked horses are fed well with dry foods and consequently the droppings and urine are richer. The droppings add " body " to the manure and the urine assists fermentation of the straw.

The food the horses are receiving influences the amount of heat produced during fermentation, the texture of the composted manure and the yield of mushrooms. The droppings are chiefly undigested food and fully half the dry matter in the foods commonly given to horses is excreted undigested. Dry foods that are high in protein give rise to rich manure that heats readily and composts rapidly. As the amount of protein in the food falls, the manure becomes increasingly poorer, heats less and ferments more slowly. Peas and beans produce hot manure; oats, maize, bran and clover hay produce manure of average richness; meadow hay and timothy hay produce poorer manure, while pasture, molasses and roots produce poor cold manure that ferments slowly. Manure from horses receiving large amounts of the poorer foods should not be used for mushroom-growing. Certain foods, e.g., molasses, roots, maize, bran and timothy hay and, to a less extent, meadow hay, give rise to compact, " greasy " droppings and pasty, greasy composts. These ill effects may, however, be counteracted by adding gypsum, a mineral containing calcium, to the manure.

The litter influences the quality and texture of the composted manure. Peat moss, sawdust and shavings are undesirable as litter. Though good crops have been grown when these materials have been used as litter, they are of considerably less value than straw, and unless selected or specially prepared are too variable in quality to be reliable. Most peat moss and many kinds of sawdust and shavings are excessively acid and certain woods contain resins which are reputed to be harmful. Also, they lack readily fermentable material and do not generate heat in the compost heaps. It is said that up to 10 per cent. of the bedding may be shavings, the remainder being straw.

Other undesirable kinds of litter are poor meadow hay and timothy hay which may be pulled down from the feeding racks or used for bedding. These materials, as stated previously, give rise to pasty, greasy composts which unless treated with gypsum are quite unsuitable for mushroom growing. They should not constitute more than 50 per cent. of the litter and the remainder should be wheat straw. With the exception of barley straw, which breaks down excessively, the cereal straws are all suitable as litter. Wheat straw makes the best litter. It ferments steadily but not excessively and retains sufficient rigidity during composting to prevent the manure settling into a compact state. At one time, rye straw was widely used, especially in France, and though it makes good composts, it is a little too rigid and breaks down rather slowly. Oat straw is relatively soft and results in compact manure heaps that are hard to turn and difficult to shake out. Oat straw also tends to break down to a pasty mass and become mouldy.

Manure containing disinfectants and that from horses under veterinary treatment should be avoided.

PROCESS OF COMPOSTING. Hot fermentation of the manure is necessary for the following reasons: (1) to reduce the manure to a condition in which it is suitable for free, rapid growth of the spawn; (2) to remove, to a great extent, the tendency of the manure to heat up to high temperatures; (3) to obtain an evenly mixed product that is readily moulded into beds.

Plenty of water is essential during the early stages of fermentation to speed up the chemical changes that are involved, to retain the heat that is generated and to prevent overheating leading to excessive "burning" of the manure; a certain amount of burning, shown by whitening of the manure in places, is unavoidable. A supply of air is required in the fermenting manure at all times, otherwise the rate of fermentation will slacken. Regular turning of the manure is necessary to renew the supply of air, to add water to dry parts and to mix the manure thoroughly.

Composting is a process of the greatest importance and should be carried out with conditions as much as possible under control. It is best to have the heaps protected from the weather since rain and particularly wind will damage heaps considerably. Small heaps suffer from exposure to the weather more than large ones, but even large heaps may be cooled considerably by a few hours of cold wind. A shed with a drained concrete floor and sides which may be closed after the manure has been brought in is ideal. The shed should be ventilated by an open space about 2 ft. deep, between the top of the sides of the shed and the eaves, and there should be at least 10 ft. of space above the top of the manure heap. It should be possible to open the sides during turning to assist the removal of the "steam" rising from the heaps. The size of such a shed will vary according to the size (see below) and numbers of heaps it is to contain, and there should be sufficient distance between the uprights and under the eaves to allow free access to the heaps for farm carts or lorries—whichever it is proposed to use. In sheltered situations a Dutch barn or an open shed are suitable places for compost heaps.

Fig. 1 shows a long, open shed, consisting of a sloping roof supported on posts, in which the manure for making mushroom beds is being prepared. Fresh manure has been delivered by lorry and trailer, and is being unloaded from the latter into the shed. After they have been unloaded, the heaps of manure are made up into long, flat-topped ridges about 4½ ft. high, and the ends of three such ridges are to be seen on the left of the picture, beyond the lorry. Subsequent operations, as described, are carried on in this shed.

Fermentation in a compost heap is a complicated process. The changes that go on are partly biological and chemical, depending on a supply of air and moisture, and partly physical, due to heat and water. The degrees of aeration, moisture content and temperature in compost heaps are therefore most important. The principal factors affecting these properties are the quantity, depth and compactness of the manure.

The results with heaps containing less than 4 tons of manure are not always satisfactory and the best results are obtained with 10 tons or more. Heaps are sometimes made containing several hundred tons. The volume (in the compost heap) of 1 ton of manure may vary from about 50 cu. ft. for moist manure containing a large proportion of droppings to 120 cu. ft. or more for dry strawy material.

In shallow heaps, under 3 ft. in depth, the temperature does not rise sufficiently and in heaps more than 5 ft. in depth, fermentation is very uneven. The best conditions for fermentation and heating are obtained when the depth of the manure is about 4 ft., so, to allow for settling of the manure, a height of 4½ ft. is desirable when the heap is made.

Heaps with straight vertical sides and a flat top are made. A square heap of manure has the least exposed surface and is the best for uniform fermentation but the shape is usually determined by the dimensions of the composting shed. Rectangular heaps are more common. They vary from 6 ft. to 12 ft. in width and should not be less than 6 ft.; 6 ft. is a suitable width for two men to turn.

It is best to compost sufficient manure to make all the beds in a house at one filling. The usual basis of calculation is 70 sq. ft. of 6-in. bed from each ton of uncomposted manure; 15 tons will thus fill a house with a capacity of 1,000 sq. ft.

The compactness of manure in a heap is largely influenced by the amount of straw contained in it, and the method of composting must therefore be varied according to the proportion of straw. As supplies of manure vary in character a method of composting well-balanced manure is described below and modifications of the method are given later for other types of manure. Well-balanced manure is manure in which droppings are plentiful but straw appears to be the main constituent. Strawy manure contains a fair proportion of droppings, but consists mainly of straw. Very strawy manure, in which droppings are scarce, needs special treatment as described in the section on horse-manure substitutes. The method of composting is suitable for covered, sheltered situations. Composting in exposed places is dealt with later.

Instead of varying the method of composting according to the proportion of straw to droppings in the manure, it is possible, where manure from different sources is used, to standardize the composition of the manure by blending different lots or by adding wheat straw, and to use one method of composting in all circumstances. This manner of dealing with manure has advantages when a fixed routine is desirable. *Not more than* 4 per cent. by weight of fresh straw (6 stones per ton of manure) should be added; it will ferment best if it is thoroughly wetted and put in a layer at the bottom of the manure heap and mixed well with the manure at the first turn.

In the course of handling manure in preparation for composting, salt licks, which have a detrimental effect on the texture of the manure, and any refuse should be thrown out.

COMPOSTING WELL-BALANCED MANURE. When the required quantity of manure has been unloaded at the composting site, it is shaken up loosely with a fork and the droppings and any large lumps are broken up as much as possible and mixed with the straw. The manure is then carefuly stacked, beginning at the back of the shed. Each forkful of manure is placed firmly in position. As the heap increases in length it is built up to the required height and the sides of the heap are kept regular and vertical. In the course of this process, ground gypsum is sprinkled evenly over the manure at the rate of 28 lb. of gypsum per ton of manure. If the manure is dry it is sprayed with water from a hose until thoroughly wet. It is almost impossible to add too much water at this stage. The height of the heap should be about 4½ ft. and the length should be at least a yard less than the space available in the shed in order to leave room for turning.

Rapid fermentation of the manure sets in almost immediately, heat is generated and the temperature rises. In a few days the heap begins to " steam " and give off ammonia, and the temperature in the interior rises to 140°-160° F. Under certain weather conditions the heap becomes quite wet along the top, owing to condensation of water vapour rising from the interior of the heap. The heap continues to settle gradually but after about 5 days, irregular sinking is noticeable and the manure is then ready for turning. It is usual to turn heaps at definite intervals. The manure is turned for the first time 5-7 days after it is stacked and twice a week subsequently, at intervals of 4 and 3 days. Usually four turns are given, the composted manure being carried into the houses 3 days later, 21 days after the process was begun.

Turning is done by two or more men who dig into the end of the heap and place the manure a few feet behind them. A new heap is constructed in the same manner as the first heap. The manure is shaken up loosely, lumps are broken up, dry parts are watered and outside portions turned in to the centre of the new heap.

After the third turning, watering should be carefully done. Water is a product of fermentation of the manure and in the later stages of composting almost sufficient water is supplied from this source. The bulk of the water necessary for composting should be added in the early stages and thereafter only sufficient water should be added to keep the manure uniformly moist but not wet.

At each turn the physical condition of the manure should be ascertained by handling it, and any marked greasiness or tendency to form dough-like, greasy lumps noted. A greasy condition restricts the growth of the spawn and may prevent growth entirely. It may arise in any kind of manure whether plenty of straw is present or not. The easiest way to detect greasiness is to examine the droppings. In greasy manure, the droppings are usually whole and tend to deform under gentle pressure rather than break apart. Greasiness may also be detected by working the manure gently between the fingers. Strong pressure should be avoided since this destroys the structure of the material and, in so doing, may induce a greasy feel. A greasy state may be prevented as described above by adding ground gypsum to the manure, when the droppings break up as the manure is turned and mix readily with the straw. The quantity of gypsum used at the beginning of composting is sufficient for this purpose, provided it is evenly distributed, but if at the last turn greasy patches are present in the manure it is advisable to apply a further 28 lb. of ground gypsum per ton of manure (see Pizer, 1936-8).* Ground gypsum occurs mainly in two varieties, pink and white (or grey) and they are equally effective.

Manure composted in the manner described is usually suitable for mushroom-growing and should possess the following general characteristics. It should be uniform in appearance and brown in colour, and with a " sweet " smell that is quite inoffensive. Most of the droppings should be in fragments mixed evenly with the straw and what whole droppings there are should break readily. The straw should be short and have lost its stiffness and resistance to shearing and pulling, and should break into a bundle of fine threads on rolling between the fingers. A proportion of the straw should be found already shredded into fine fibres. The material should be open in texture and not greasy. It should be moist enough to hold together when pressed in the hand and should break up readily afterwards. A handful when twisted with the hands in opposite directions should come apart without great effort. If the manure appears to be rather " raw " as determined by these tests, it should be given a fifth turn and taken into the houses three or four days later. The moisture content is important. The compost should contain sufficient water to wet the hand on squeezing a handful tightly, but not so wet as to exude liquid between the fingers. Wet manure must be turned and given a day or two longer in the compost heap. Dry manure should be watered lightly before it is made into beds, especially if the houses are heated. From the last heap and while still hot, the manure should be promptly wheeled into the houses for making the beds.

The temperature of the composted manure falls if the fermentation has gone too far or if the manure contains insufficient water. Over-fermentation is improbable if the above method of composting is followed, and usually loss of heat is due to withholding water while trying to arrive at a product that is not too wet. While a high temperature of 140° F. or higher is desirable, it is not essential; good crops may be grown on manure that has lost heat and is quite cold when put into beds, provided the manure is in good condition.

There are no rapid laboratory tests which may be applied to determine whether spawn will run well in composted manure and produce a good crop. The only known test is the inoculation of a sample of the compost with pure culture spawn followed by incubation under controlled conditions, but as at

* *See* references to literature p. 77.

least a fortnight is required for this test it is of little value except in the examination of cases of failure.

The pH value of the compost, which measures the intensity of acidity or alkalinity, is of importance since spawn fails to grow in media that are more than moderately acid or more than moderately alkaline. The effect of pH on growth and productivity is discussed in a footnote.*

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* THE EFFECT OF pH ON GROWTH AND PRODUCTIVITY.—With certain exceptions, natural organic materials contain *hydrogen ions* which have a profound influence on the processes and changes effected by living organisms. The concentration of active hydrogen ions is of particular importance since it determines the reaction of the material, i.e., the neutrality or the degree of acidity or alkalinity. It is expressed by means of a number on a scale known as the pH scale, which extends approximately from 0 to 14. Neutrality is at pH 7 which is the pH value of pure water. The pH of acid materials is *less* than 7 and the lower the number, the greater is the degree of acidity. On the other hand, the pH of alkaline materials is *greater* than 7 and the higher the number, the greater is the degree of alkalinity. A unit change in pH represents a tenfold change in hydrogen ion concentration, e.g., a material with a pH of 5 is 10 times as acid as a material with a pH of 6, and 100 times as acid as a material with a pH of 7.

It has been found that living organisms grow most readily when the pH is within a given range. In the instance of the mushroom, the effect of pH on growth and productivity is incompletely known, but from the available evidence it appears that the mushroom is able to grow over a wide range of pH from 5·9 to 8·0, that there is poor growth or no growth at all outside these limits and that optimum growth is obtained when the pH is around 6·5. It is possible to criticise these conclusions and they may have to be modified when further research has been completed.

Recent investigations in the U.S.A. have shown that the growth of a number of organisms which compete with the mushroom for food (*see* page 54) is considerably influenced by changes in pH within the range that is favourable to the mushroom. Unfortunately the optimum pH for growth is in many instances too close to that of the mushroom for any control to be possible by altering the pH, but with the white plaster mould the mushroom is better able to compete when the pH of the compost is between 6·5 and 6·9. French investigators have also stated that mushroom beds remain healthy when the reaction is slightly acid at about pH 6·5.

It would appear desirable, therefore, to control the pH of mushroom composts as much as possible and to bring the pH just below 7. No method of achieving this result is at present known. During composting, the parts of the heap differ widely in pH, from 5 to 8·5, and although the differences become less marked as composting proceeds, it is not until the manure is put into beds that the pH becomes more or less uniform. The pH is largely influenced by the composition of the fresh manure, the moisture content, the aeration and temperature during composting, and the length of composting. High temperatures during composting and the presence of ground gypsum in the manure appear to prevent the reaction from becoming too alkaline. With the method of composting described on page 10 the pH approaches 7 and is usually between 6·5 and 7·2 in the beds. According to Beach (1937) the pH usually declines during the final fermentation in the beds and it is suggested that this fermentation should be prolonged by maintaining a high temperature until the pH has fallen to a favourable level. The chief difficulty in following this advice is that a low-priced, simple apparatus for the accurate determination of the pH of composted manure is not obtainable.

Composting Manure with Little Straw. Manure of this kind ferments very readily and should not be left unturned in a heap more than four days, or considerable "burning" may occur in the outer layers. It is composted in the same way as well-balanced manure except that the first turn is made four days after stacking and subsequent turns at three- and four-day intervals. The manure should be composted until the fermentation shows signs of slowing down. A composting period of three weeks is usually sufficient.

Composting Manure with Much Straw. Owing to the low proportion of droppings, strawy manure does not carry water well and tends to remain loose and open in the early stages of composting. Unless steps are taken to counteract these properties, fermentation and rise of temperature will be slow and heaps may dry out. Large heaps should be constructed about 4½ ft. high, and *if necessary* made firm by careful treading. Plenty of water should be used when the first heap is made and, between turns, the heap should be sprayed with water if it becomes dry. Owing to slow heating, the interval between turnings must be lengthened. Seven days is a suitable interval until the third turn. The manure is then considerably shorter and almost ready to go into beds. If further composting is necessary, it may be possible, if the manure heats up sufficiently in the time, to reduce the interval between turnings to four days. The ability to heat is lost more readily by strawy manure than by manure with plenty of droppings.

Composting in the Open. Sudden changes in moisture content and temperature are likely to occur in heaps of manure in the open through the action of sun, wind and rain. Under such conditions, composting is by no means an easy matter, especially in cold, wet, windy weather, and it follows that very variable results are likely to be obtained. The risks may be minimized by constructing large heaps, containing not less than 20 tons of manure, 6 ft. deep and at least 9 ft. wide, and shaping the top so that rain runs off the surface. The greater depth of manure, though a safeguard against the weather, leads to uneven fermentation and heating; the outer portions of the heap dry out and cease to ferment, a layer underneath is usually white with "firefang" and the inner core is foul-smelling owing to anaerobic fermentation. Great care is needed in turning the heap to ensure that, in the new heap, the material on the outside changes places with that from the centre. The sides of the heap should be protected with straw hurdles to minimize the effect of the wind, particularly the prevailing wind,

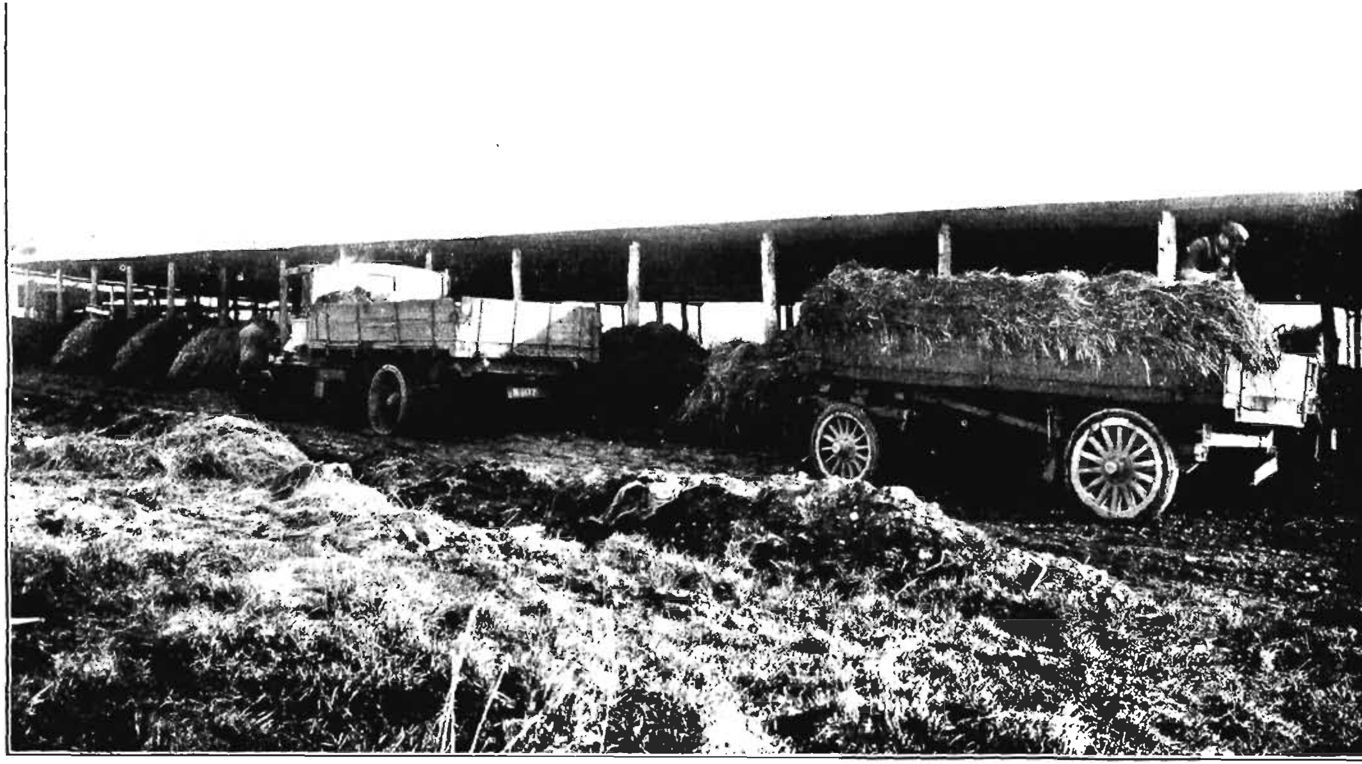

FIG. 1.—Open shed in which the manure is stacked and converted into compost (See p. 9).

[To face p. 14

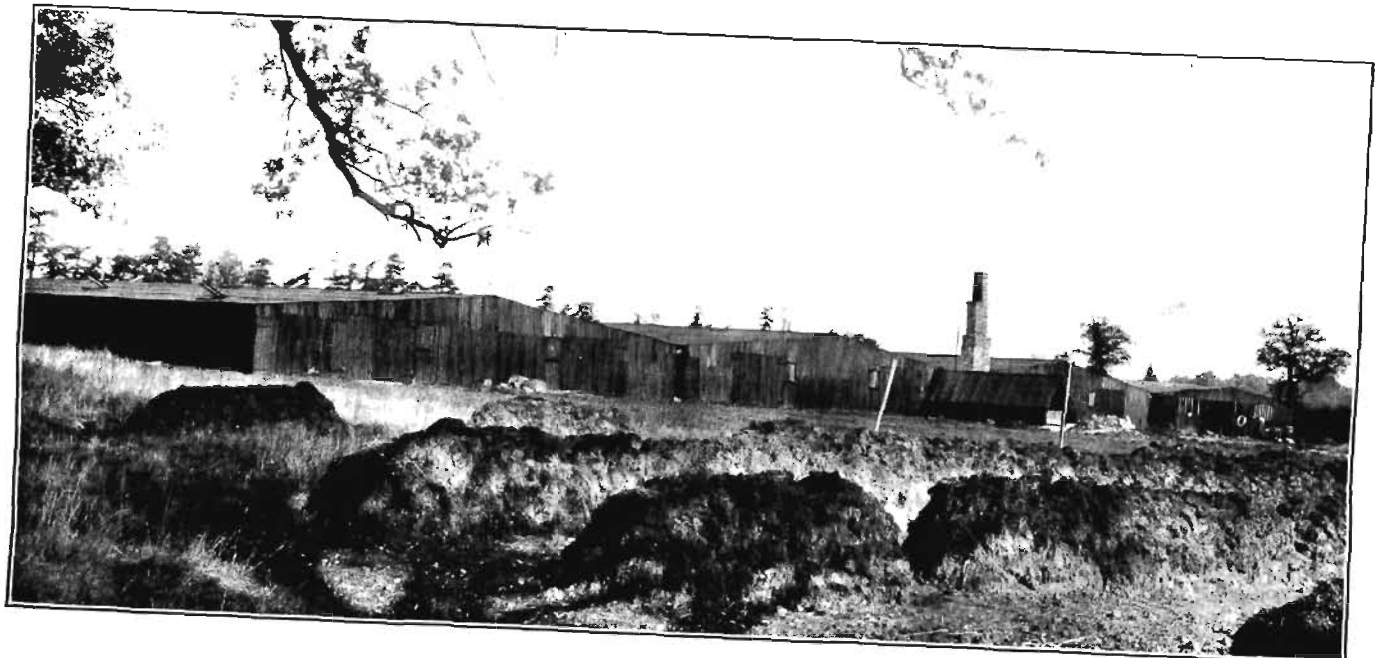

FIG. 2. -Range of English Mushroom Houses (See pp. 21 & 22).

otherwise the grower will be faced with the problem of turning a heap that has fermented on the lee side and hardly changed on the windy side. If, between turns, the heap becomes dry it should be sprayed with water. Definite periods of time between turnings cannot be given, but as long as a fortnight may be necessary, and the grower must be guided by the condition of the heap. The period of composting is longer than with heaps 4½ ft. deep under cover.

OVER-COMPOSTING. The aim of the mushroom grower is to carry manure into the houses in a slightly under-composted rather than over-composted condition. By so doing, the manure continues to ferment actively in the beds and reaches temperatures of 120° F. or higher. The increase of temperature is of value in the control of pests by " peak heat " fumigation, and when the period of high temperature has passed the warm manure is favourable for rapid growth of the spawn. If the manure is over-composted these advantages are lost; the manure may then heat up slightly or not at all.

The productivity of the manure, however, is not necessarily reduced and if the houses are heated the beds will be no slower coming into bearing. Over-composting to the extent of one or two turns is not a serious matter. Composted manure, turned occasionally and kept until almost cold, has been known to produce a heavy crop. The practice is not recommended, however. A considerable reduction in bulk of the manure occurs and less bed space is filled per ton of original manure.

USE OF SUPERPHOSPHATE. Phosphorus is essential for proper growth of the mycelium and, when it is deficient, growth is restricted. Horse manure composts contain relatively small amounts of phosphorus and it has been found in a number of instances that when a little superphosphate is added to the manure, mycelial growth is stimulated and an earlier and better crop is obtained. In many instances, however, superphosphate is not necessary and there is evidence that it may then shorten the cropping period and lower the yield. When a supply of manure is known to be good, it is unnecessary and inadvisable to use superphosphate, but with manure that gives poor results it is well worth a trial. Superphosphate is best applied mixed with gypsum, as the mixture is much more readily distributed and is better to handle than superphosphate alone. Twenty-eight pounds of the mixture, containing *not more than* 7 lb. of superphosphate, are applied per ton of original manure when the heap is given its final turn.

ACCUMULATING AND STORING MANURE. When manure for a large heap is collected in daily deliveries of a few tons each, the difference in age between the first and last batch should not be greater than nine days or it will be difficult to obtain a compost of even quality. The manure should be accumulated in such a way that the different deliveries become well mixed at the first turn. A method by which this is readily achieved is described by Bewley & Harnett (1934). Over nine days, for example, three heaps of manure of equal length are made in contact side by side, each containing the accumulation of three successive days. The heaps (4-5 ft. high and 5 ft. wide) are begun from the same end on the 1st, 4th and 7th days and when completed form a single long heap with a width of about 15 ft. in a transverse section of which adjacent parts do not differ in age by more than three days. The first composting heap is made by digging into one of the ends and mixing thoroughly as is done when turning. Manure that is dry on arrival should be moistened and made firm if necessary by treading to reduce fermentation but the main watering should be delayed until composting is begun.

Storing manure for 3-4 months, as distinct from accumulating it, is practised in the U.S.A. and may on occasions be convenient. The manure must be kept in a moist state and very compressed to exclude air as much as possible. Very large heaps are therefore made, 8-10 ft. high and containing 100 tons or more of moist, well trodden manure; the sides are supported by boards during construction of the heap to obtain tight packing. When completed, the heaps are covered with 6 in. of soil which is watered occasionally.

Substitutes for Horse Manure. As a result of the duty on imported mushrooms and the introduction from the U.S.A. of intensive methods of cultivation, mushroom-growing has increased considerably in recent years. Supplies of horse manure are gradually diminishing and in some places are costly and difficult to obtain. A substitute for horse manure is needed, that compares favourably with it in price, uniformity and productivity. Preparations are already on the market which are used directly for mushroom-growing or for making a compost from straw and/or other plant products. Results equal to those given by the best horse-manure composts are claimed for them; details are obtainable from the makers. The variable quality of horse manure has been noted previously. The age of the manure, the feeding and management of the horses—among the chief factors affecting cropping capacity—are outside the control of the grower and it is believed that there would be less uncertainty in cropping if a more uniform material were used.

Variability cannot be entirely eliminated, however, since natural materials are never uniform in composition. Some of the insect pests and diseases of the mushroom are frequently brought into houses with the composted manure and the inference is frequently made that insect pests are attracted by the manure and that a compost made without the use of manure would be relatively free from them and produce healthier crops. While this may be true, experience with manure substitutes is too limited for a definite opinion to be formed, but from what is known of the habits of some of the pests they are likely to be present in most kinds of rotting plant material.

Accounts of experimental work on horse manure substitutes come largely from the U.S.A. and France. Research has shown that horse manure is not necessary and that many natural products could possibly be made suitable for mushroom-growing. Composts made from green crops and straw have given promising results, but it seems hardly desirable, at least in this country, that mushroom-growing should be dependent on another specially grown crop. On the whole, investigators have tried partial or complete replacement of horse manure either with the manure of other animals or with straw.

It has been known for many years that manure from fattening bullocks or cows fed on cake and other dry foods may be used with straw or mixed with horse manure. One-third of the horse manure may be replaced in this way and the mixture is said to be equal to, but no better than, plain horse manure. Manure from cows fed mainly on grass and other succulent foods is cold and useless. Noble (1936) states that in Australia success has been obtained with the following mixtures:

1½-2 tons fowl manure to 1 ton of dry straw.
3-4 tons sheep manure to 1 ton of dry straw.
5 tons cow manure to 1 ton of dry straw.

The quantities are sufficient for approximately 300 to 375 sq. ft. of bed 8 in. deep. The compost heap is made up of alternate layers of straw and manure, a thick layer of straw first and a layer of manure on top. Each layer of straw is thoroughly wetted and it may be necessary to moisten the manure at least 24 hours before use. The process of composting used for horse manure is followed and it is important to make the heaps about as compact as heaps of horse manure. Though the feeding stuffs given to the poultry, etc., must have an important influence on the quality of the composts obtained from these mixtures, there is no mention of the point. Further, the physical condition of all the mixtures would be improved by the addition of ground gypsum.

Répin (1897) stated that straw will rot down to a material that is suitable for mushroom-growing if it is watered with a solution of ammonia or ammonium carbonate and composted. Hutchinson and Richards (1921) published the results of research at Rothamsted on the rotting down of straw to form a substitute for ordinary farmyard manure. The principles laid down by Hutchinson and Richards have been applied to the production of mushroom composts from straw.

The results have shown that while it is relatively easy to rot down straw, it is difficult to obtain a product that can be relied upon to yield a satisfactory crop of mushrooms. In the U.S., Lambert (1932) found that better results are obtained when the physical condition of the heap is made similar to that of composting horse manure and the heap is watered and aerated by turning in the same manner as horse manure. He concluded, however, that composts made from straw and mineral fertilizers involve considerably more work and expense, are less reliable and produce fewer mushrooms than horse-manure composts. More favourable results have been reported from the Station centrale d'Agronomie, Versailles, where the difficulties appear to have been overcome and a suitable method of composting evolved by Demolon, Burgevin and Marcel (1935-7). Normal cropping and good yields have been obtained on composts made from straw alone or from horse manure diluted with straw. Urea, containing 46 per cent. nitrogen in the commercial product, is the only fertilizer added to the straw, which is composted in a special manner to ensure correct decomposition, moisture content and pH. Two applications of the process are in use and are briefly described below.

THE DILUTION METHOD. This method is the more widely used in France as it enables greater use to be made of existing supplies of horse manure. As with horse manure, the rate of fermentation is greatly improved if composting is carried out completely under cover and, in fact, it appears to be essential if a set routine is to be followed and a reliable compost obtained in a short time.

On a level site, under cover, a bed of wheat straw is made and compressed by treading to a uniform depth of 20 in. The straw is watered three times, at 12-hour intervals, using about 180 gal. of water per ton of straw at each watering. After the third watering, urea is sprinkled over the surface at the rate of 11 lb. of urea per ton of straw and lightly watered into the heap. Next, a layer of fresh horse manure, equal in weight to the straw taken, is placed on top. The straw and manure are mixed and composted in much the same way as is horse manure. A heap is constructed about 4 ft. high with vertical sides and level top, and made firm by careful treading. It is turned at intervals of six days and after 30 days the compost is ready to go into beds. At each turn, dry parts are carefully watered and the new heap is constructed in the same way as the first heap except that it is not trodden down; about the same compactness as in heaps of horse manure is required. Between turns, if the heap becomes dry, it should be sprayed with water. The final product is slightly acid and has a pH of about 6·5.

In cold surroundings, the period of composting may be longer than 30 days. The compost is ready to go into beds when it resembles horse manure in physical properties and can be moulded without difficulty. In mushroom caves where conditions are very favourable and do not vary greatly the year round, the temperature in the heaps may reach 180° F. and it is possible to complete composting in 20 to 25 days even in the coldest weather.

Eleven pounds of urea per ton of straw is the minimum quantity that should be used and it may be increased to a maximum of 22 lb. if a more rapid rate of fermentation is desired. When large heaps are made the quantity of horse manure may be reduced and a mixture made of 1 part horse manure and 3 parts by weight of dry straw. Oat straw may be used instead of wheat straw; it takes up water more readily, however, and decomposes more rapidly.

Before making it into beds, the finished compost is weighed—or the weight ascertained by suitable means—and is mixed with burnt gypsum (plaster of Paris). Forty-five pounds of burnt gypsum are used per ton of compost; 56 lb. of ground gypsum could be used instead.

STRAW COMPOST WITHOUT MANURE. When the quantity of available horse manure is insufficient for the dilution method it may be replaced by an equal weight of compost from a previous process or by straw that has been rotted down with only a trace of horse manure. The latter is obtained in the following way. A bed of straw is made under cover on a level space provided with a drainage tank. It is trodden down firmly to a height of 24-30 in. and watered three times at 12-hour intervals, using about 180 gal. of water per ton of straw at each watering. A little fresh horse manure is then spread on the surface at the rate of 2-4 lb. per 10 sq. ft. and also 11 lb. of urea per ton of straw. The surface is lightly watered to wash ferments and soluble products into the heap. A rise in temperature is noticeable after two days. When a temperature of 120°-140° F. is reached throughout the heap, usually in five to six days, a fresh quantity of straw is added on top of the first and treated in the way already described except that the fresh manure is omitted. When fermentation is properly established in the bottom layer of straw it is possible to add a fresh quantity of straw every four to five days. It is advisable when watering to include the liquid draining into the tank. Five additions of straw are made, each addition being at the rate of 65-75 lb. of straw per sq. yd. In the early stages of composting, the temperature should reach 150°-160° F. and afterwards remain at about 120° F. The heap should be sprayed with water occasionally if it becomes dry and, in exposed situations, the sides of the heap should be protected with bundles or hurdles of straw to prevent drying of the outer layers. Including the period of making the heap, the time taken for decomposition is three months but a considerable reduction in time could probably be obtained by using 22 lb. of urea per ton of straw and constructing a heap 6-7 ft. high, with three layers of straw and turning at intervals of 2-3 weeks, depending on external conditions. One ton of straw will yield about 2½ tons of compost.

The above details are of the methods which are used in France; in this country growers would be well advised to make a trial of the processes described to acquaint themselves with the practical difficulties, of which one of the chief is proper wetting of the straw.

Indoor Culture. For indoor culture, light is not required, and almost any place with the necessary ventilation can be used, provided that an equable temperature of from 55° to 60° F. can be maintained and draughts excluded. Cellars, barns, stables, sheds, worked-out mines, disused tunnels, quarries, garden frames and glasshouses are all used for mushroom cultivation.

It should be realized that a constant temperature of the air in the mushroom house is greatly to be desired, but it is not impossible to grow mushrooms if the temperature during cropping is occasionally as low as 45° F. or as high as 70° F. If the manure has been well prepared it generates some heat for a few days after the beds have been made, but then gradually cools to about the same temperature as the surrounding air. The manure itself, therefore, plays no important part in providing the warmth necessary for a steady supply of mushrooms. Lightly constructed buildings, with or without artificial heat, but especially those without, should be provided with some form of insulation to avoid sudden changes of temperature.

In Fig. 2 a range of structures specially erected for mushroom-growing on ridge beds is depicted, and also the shed from which the heating-system is worked.

Owing to the difficulty of keeping an even, cool atmosphere, glasshouses are the worst possible places in which to grow mushrooms in warm weather. If they have to be used for this crop in summer, they must be kept cool by the use of plenty of straw outside. On the inner side, clay may be smeared or canvas or paper screens hung some inches from the glass. Mushrooms can be grown successfully in unshaded glasshouses occupied by other plants during the time that the temperature can be kept near 55° F. The beds, darkened by some convenient means, can be made on or under the staging, or even on the paths, if raised planks are provided to enable workers to avoid walking on the beds.

In the winter months, growing in glasshouses is a common commercial practice. The beds are laid down immediately the tomato crop is over, from the end of August to the end of September (See p. 27, Table I, Col. 8). The whole floor space is often occupied and planks on raised cross-bars are then used as movable gangways. The beds are broken up and moved out at any time from February to early April to make room for the next tomato crop. Inside shading, as described above, is provided.

Mushroom-growing in garden or nursery frames more closely approaches outdoor culture, the frame being used not for vigorous forcing but rather to provide shelter from wind, rain, and excessive heat or cold. In such close quarters, care must be taken that sufficient ventilation is provided to avoid a completely stagnant, moisture-laden atmosphere. During cold weather, unless the frames are heated, the beds are covered with straw; in any weather the sides of the frame, and particularly the glass lights, should be protected with straw or straw hurdles, to keep the temperature between 55° and 60° F. Glass lights are not essential; sheets of corrugated iron, well protected with straw, make an efficient substitute and give ventilation with little adjustment. Frame culture is particularly advantageous at times when the frames would normally be out of use. Too much heat is, as usual, to be guarded against, and the beginner is recommended, when starting with mushroom-growing in cold frames, to make all preparations at the right time to produce the crop in autumn or spring.

With sheds, it is advisable to provide an inside lining with 4 in. air space, or to cover both roof and sides with a thick thatch (especially if the sheds are constructed of iron) and to provide some ventilation. If there are windows, rough shutters or coverings are needed to exclude hot sunshine, although daylight alone, without the heat of the sun's rays, is not detrimental to mushroom growth. Large buildings such as barns or disused stables often require attention in order that draughts of air may be excluded from the beds. Suitable ventilation and some means of coping with flooding or drip-water are points to be considered before underground sites are used.

In caves and mines, special attention should be paid to means of access. While it may be comparatively easy to carry or lower compost into mines, it is sometimes much more difficult to remove it. Trucks, for example, can easily be taken down a crooked, sloping gallery, but it may require a special arrangement of the winch mechanism to draw them up again. Ventilation is essential in such places.

The statement is sometimes made that crops can be grown without trouble in any shed or outhouse, but it should be realized that when mushroom beds are put down either in old farm buildings or in sheds not specially constructed for the purpose, the grower is often working under adverse conditions, and mushroom-growing in such quarters is undoubtedly more difficult and risky than elsewhere. The cultivation of mushrooms, especially if it is to be continued year after year, is an art requiring specific conditions, e.g., of temperature, humidity, and cleanliness; and, while every care may be taken in such matters as the provision of pure-culture spawn or the correct preparation of the compost, the same care is not universally taken in the choice of buildings. While it is possible successfully to convert or adapt existing buildings, experienced commercial growers usually erect special houses (Fig. 2), and the materials and designs for them are carefully chosen. It is not possible here to give details of building construction, but certain points may be mentioned.

On large farms, the size of the house, or of each unit in a range, will depend on the manure supply and possible rate of filling, it being advisable, especially if fumigation at a given stage is to be carried out, to fill each house at one operation or at least (with floor beds) to complete the filling, spawning and casing before the first beds begin to crop. In the latter instance the necessity for a lower air temperature during cropping is the main consideration. Exact dimensions depend on whether the tier system or the floor system of growing is contemplated. For either, a smooth concrete floor is an advantage; this should be strong enough, in sheds built for floor beds, to allow carts to be brought in. The walls and roof, on the inside, should be so constructed as to ensure a more or less air-tight lining and to eliminate rough joints, cracks and crevices which, by harbouring pests, render spraying and fumigation less effective. Floors sunk below surrounding ground level should be avoided if possible, because of excessive dampness and of greater difficulty in moving materials in and out of the house. The floors and the gangways outside the group of houses, if made of concrete, are easily cleaned.

Good insulation can be obtained if houses are built of corrugated galvanized iron on 4 × 2 in. woodwork lined with match-board. Aluminium foil on asbestos paper can be used between the two to increase the insulation in the air-space. A disadvantage of match-board is that it may swell and twist or buckle when subjected to the high relative humidity of the atmosphere. Manufactured sheets of fibrous material are also a good form of insulation for lining the house but these and also asbestos-cement sheets are easily damaged on the walls. For a roof-lining, the disadvantage of asbestos-cement sheets is that moisture condenses on them and drips, hence if this material is used the ceiling must be inclined and not horizontal.

Outside building materials, better than corrugated iron, are obtainable but they are more expensive. Weather boarding or breeze blocks are preferable to hollow tile or concrete for cavity walls because moisture does not condense on their surfaces in such a way as to lead to streaming. The insulating properties of a material depend on its conductivity for heat and on its ability to absorb and radiate heat from its surface. During the time that corrugated iron is bright, the rate of absorption and radiation of heat from its surface approximates, for example, to that of corrugated sheets of asbestos-cement, but when the iron is dark the rate is much increased and of the two the iron becomes the inferior building material. The main differences between the insulating values of the two materials is in conductivity, that of iron whether bright or dull being the higher.

Whatever the roofing material may be, an inner lining with an air space for insulation is essential. For floor beds, better air circulation in the house is secured if the lining follows the slope of the roof and does not form a low horizontal ceiling. Glass roof windows can then be fitted to afford ample ventilation and the best form of lighting. They can be screened inside by wood panels or by blinds sliding over the opening in the match-board or asbestos-cement lining.

For the tier system of growing, either a ridge ventilator, with louvres, is built, or a gap is left along the whole ridge. A ceiling is constructed inside the house, and is supported 3 ft. above the top beds by the uprights that hold the beds. In order to carry away condensed moisture and to prevent its dripping on the top beds, the ceiling slopes upwards from the top of the walls (eaves) to the centre line of the building, but it need not follow closely the steeper slope of the roof. Along the centre line, a gap in the ceiling about 1 ft. wide is left, and this provides ventilation that can be regulated by a series of hinged flaps throughout the length of the gap. The ceiling may be insulated by a thin layer of shavings or sawdust over it. At both ends of the attic so made, is a ventilator door just under the ridge of the roof. The ridge, in American houses, is not level but rises 1 ft. or more in every 60 ft. to induce a better movement of the hot air. For the tier system, some form of artificial lighting is essential, and, if electric wiring is carried out, the possibility of damage from fumigation with sulphur dioxide must be borne in mind. Marine fittings (plugs and switches for detachable lights) should therefore be installed if sulphur is to be burned in the houses.

A convenient house, of the standard American pattern, is 18-20 ft. wide, and a length of 60 ft. is ample if 6 tiers have to be filled. The height to the eaves is 14 ft. and to the ridge 19½ ft. At each end, two doors, one above the other, give access to a central pathway (2½-3 ft. wide), the upper door being at the level of the fourth bed from the floor and opening on to a plank gangway on that level; on this, angle-iron rails can be laid for a trolley to carry baskets of manure when filling the lower beds and, later, the upper ones. If one end of the house is built into the side of a hill, the trolley can be run in or out at the level of the gangway; otherwise it is run up an incline. On both sides of the central pathway are the tiers of beds, usually 6 in number, from floor to ceiling. These are 5½ ft. wide, and can be approached on the further side, and the ends, by a pathway next to the walls of the house. This pathway is about 2 ft. wide, and contains the hot-water pipes, which can be nearer to the floor than is found convenient in houses used for floor beds. Water is laid on.

The details of shelf-bed construction apply also to farm or other buildings that have been adapted. The uprights carrying the shelves are usually wood, 4 × 2 in. for 6 tiers, or 2 × 2 in.

for only 3 tiers. Angle-irons or old water-pipes are cleaner and stronger, but more expensive, and the iron is liable to corrode after sulphur dioxide fumigation. The pairs of uprights (5½ ft. apart) are set at intervals of 4 ft. down the length of the house, and wood cross-bars (" bearers ") are bolted to them. The bearers are 5 ft. 10 in. long, and should be not less substantial than of 4 × 1 in. board; they are bolted or nailed to the 2 in. face of the uprights. The loose bed-boards rest on the bearers; both the side-boards (6-8 in. × 1 in.) and the end-boards stand on edge, inside the uprights, to retain the manure. The lowest bearers should be fixed so that the bottom bed-boards are raised 6 in. from the floor, and the vertical distance between bearers should be calculated with the knowledge that the bed-boards are 1 in. thick and the beds, when cased, will be 6-8 in. thick. They should be so arranged that a space of at least 18 in. is left between the top of one bed and the bottom of the next above. This space is necessary for casing operations and for picking, and may with advantage be increased even to 30 in. The making of the beds is not a difficult matter, because the bottom one is filled first, and all bed-boards above are purposely out of position. The manure is made firm by means of a special short handled tool that can be used in a small space.

The use of wood in contact with the beds is not desirable because it encourages the growth of fungi which may be harmful. In America, however, special rot-resisting Cypress or Cedar boards are used. In England, good results have been obtained by substituting new, but second grade, 8 ft. corrugated iron sheets, the outer ones of which can be turned up along the length of the bed to carry out the function of side-boards. It has been a common experience of growers, however, that iron shelving even when punctured, is associated with a wet condition of the lower part of the beds and although it may be quite successfully employed and good crops grown, it is not altogether to be recommended. Furthermore, the burning of sulphur at peak heat is precluded. Reinforced concrete shelf-bed construction, using tubular or angle-iron for the uprights and angle-iron for the framework, is to be found in some mushroom houses in England. The upper surface of the shelf is made slightly rounded and a longitudinal gutter is formed where the concrete meets the angle-iron frame at the sides. Such shelves are of course permanently fixed and are best adapted for filling transversely with the help of moulds. Trestles for a trolley line or roller conveyor are set up in the central gangway. For picking and other work, planks on hooked iron brackets are attached to the iron edges of the beds.

Side-boards may be dispensed with if the moulds are so shaped that the edges of the beds slope back.

The wet condition of the base of the compost already mentioned in connexion with iron shelves is also found, though far less frequently, on concrete shelves and floors; presumably the water results from slow decomposition of the compost and, owing to lack of ventilation between bed and shelf and non-absorption of liquid by the iron or concrete, there is not such efficient drying as there is on boards.

In England, the tier system of growing, on proper lines, has not been adopted until the past few years, partly because it involves large-scale cultivation, and partly because the advantages and the specialized nature of the method have not been understood. In the United States, where mushroom-growing is at a highly advanced stage, and where the growers have given undivided attention to this crop, the tier system is the only one employed. There are two reasons for this that are worthy of consideration by the English grower. First, the cubic capacity of the house is used to the utmost, and six times the weight of crop is produced as could be if the beds, either flat or ridge, occupied only the floor. Secondly, the shelf beds are all filled at one time and every effort is made to secure their simultaneous heating, because, at " peak heat ", fumigation against insect pests is carried out. Success may not always be met with in the lower beds, but every effort is made to drive all pests to the surface by the heat, so that they can be killed by the fumigant. With the English system, this is almost impossible, because the sheds are leaky, the very large air space above the beds makes fumigation relatively ineffective and the beds in one house are not always completed on the same day.

Indoor cultivation of mushrooms, both with and without artificial heat, should be carefully considered by the beginner. Any summer temperature exceeding 65° F. during cropping, is one of the greatest difficulties with which the mushroom-grower has to contend; and since this is likely to occur at any time in the three months July to September, it is well not to put down beds for cropping in this period. It is apparent, then, that nine of the twelve months are very suitable, but the temperatures prevailing are often so low that artificial heating has to be employed to produce the crop in the usual period of 5-8 weeks after spawning. This, however, is a favourable situation for the grower because he can exercise more or less exact

Table I.—An Approximate Calendar of Indoor Mushroom-growing, assuming the use of Artificial Heating.

Warm periods are printed in heavy type. These should be avoided by the beginner, who is advised not to carry out operations in the periods shown in Columns **2** to **7** inclusive.

	1	2	3	4	5	6
First heap made in first week of	Jan.	Feb.	Mar.	Apr.	May	Jun.
Beds made in first week of	Feb.	Mar.	Apr.	May	Jun.	**Jul.**
Spawning in mid- ...	Feb.	Mar.	Apr.	May	Jun.	**Jul.**
Spawn "runs" ...	Mar.	Apr.	May	Jun.	**Jul.**	**Aug.**
	...	...	...	...	...	...
Crop starts mid- ...	Apr.	May	Jun.	**Jul.**	**Aug.**	**Sep.**
	May	Jun.	**Jul.**	**Aug.**	**Sep.**	Oct.
	Jun.	**Jul.**	**Aug.**	**Sep.**	Oct.	Nov.
	Jul.	**Aug.**	**Sep.**	Oct.	Nov.	Dec.
Crop ends in	**Aug.**	**Sep.**	Oct.	Nov.	Dec.	Jan.
	7	**8**	**9**	**10**	**11**	**12**
First heap made in first week of	**Jul.**	**Aug.**	**Sep.**	Oct.	Nov.	Dec.
Beds made in first week of	**Aug.**	**Sep.**	Oct.	Nov.	Dec.	Jan.
Spawning in mid- ...	**Aug.**	**Sep.**	Oct.	Nov.	Dec.	Jan.
Spawn "runs" ...	**Sep.**	Oct.	Nov.	Dec.	Jan.	Feb.
	...	...	...	...	...	...
Crop starts mid- ...	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	Dec.	Jan.	Feb.	Mar.	Apr.	May
	Jan.	Feb.	Mar.	Apr.	May	Jun.
Crop ends in	Feb.	Mar.	Apr.	May	Jun.	**Jul.**

On referring to Table I above, it will be seen that hot weather is likely to cause difficulties with cropping during the periods indicated in Columns 2, 3 and 4, while, during those in Columns 3, 4 and 5, both this, and low prices resulting from the sale of wild mushrooms, are experienced when the beds are bearing. The cropping at the times indicated in Column 6 starts when prices are usually low but, in addition to this, as also in Column 7, the manure and the beds have passed through a hot-weather period before the crop is expected. The composting of manure and the management of beds during hot and dry periods require more care and attention than at other times, and for this reason also, intending growers without experience would do well not to begin operations between February and the end of July. It may be mentioned here that even mushroom-growers with long experience avoid making beds in April, May and June (Columns 3, 4 and 5).

Where glasshouse growing is adopted, and the crop alternates with that of tomatoes, the course outlined in Column **8** is followed. Otherwise, with indoor cultivation, the usual practice in England is included in Columns **1, 2, 6, 7, 8, 9, 10, 11, 12.** The effect of hot weather is clearly shown by the limitation of American practice to the periods shown in Columns **6, 7, 8, 9, 10, 11,** the beds being made to yield their crop during the cool months from late September until May or, rarely, into June.

In unheated buildings, beds can be made at any time in the winter, and, if they are spawned while still warm, the crop will appear in the spring months. If cold weather intervenes, this will cause delay, but excellent crops have been secured, even from beds that have been spawned and standing for as long as 5 months, e.g., November to April, when they were nearly frozen.

Heating a mushroom house is usually carried out by 4 in. hot-water pipes, which most effectively distribute warmth over a large area. Coal or coke stoves installed in the building are not recommended but are occasionally used; they give a localized intense heat and have to be specially jacketed with sheet-iron to obtain the best results. The chimney, instead of being vertical, can be brought on a gradual upward slope through the building in order to use some of the heat that would otherwise be wasted. Oil stoves, except those which efficiently provide complete combustion or those which are fitted with a flue, should not be employed, particularly when the beds are cropping, because the fumes of mineral oil are harmful to mushrooms. Electrical heating by bar-radiators is cheap to instal, but too costly to use; attempts have been made to control the temperature of the beds, but not of the air, by laying electric heating cable in or on them, but this method is also too expensive. The best position for the cable has been found to be on the surface of the compost, immediately beneath the casing soil. A few growers in this country who practise the tier system have installed heating apparatus by means of which a current of air is driven by a fan through a hot radiator and is carried in a duct around or through the house, some warm air being released here and there through openings in the duct. The same installation can be used in hot weather to try to effect cooling, the radiators being charged with running cold water pumped from a deep artesian well. American experience with air-cooling systems, in which use is made of well-water in coke boxes, in radiators, or in the form of a spray, has not been very encouraging. Large quantities of water are required; its temperature is usually not low enough, and the cost of pumping it and working the fans is hardly repaid. The ammonia cooling process is more satisfactory, but installation is beyond the means of most growers. Passing the air through ice compartments is another method of cooling. It is of course useless to employ these mechanical aids in buildings that are not thoroughly well insulated.

The atmospheric humidity in a house is usually regulated by watering the beds and the floor. A few American growers have installed a pipe system whereby live steam can be blown inside the building, but this is used more as a means of securing additional heat at a time when it is required to make the beds reach peak heat.

Outdoor Culture.—The selection of a site for outdoor culture is always of importance, the more so if the cultivation of the crop is to be on a large scale. Extra land will be required because it is advisable to give a rest of one or more years to any field that has carried mushroom beds. There should be, if possible, natural shelter from strong winds, and this may be supplemented by high windbreaks made, for example, of straw or faggots. It is also important that there should be an ample supply of loam or sandy-loam below the top spit of soil to provide the casing of the beds. Adequate surface drainage must be provided, and, if the ground slopes, it is an advantage to build the ridges up and down the slope rather than across it. A composting shed for the manure, a water supply for the beds and an ample stock of straw, within easy distance, will be required. To outdoor growers the warning may be given here that, on land long undisturbed and particularly on waste areas, slugs, moles and mice can cause great damage; the former spoil the mushrooms and the latter the beds by tunnelling into them. The outdoor growing of mushrooms can be done on a large scale but it is not necessarily simple. When once the beds have been made, spawned and cased, labour will still be required, particularly with the advent of spring weather, because the coverings have to be removed and replaced for inspection, watering, spraying or dusting with insecticides, and picking. The quality of the crop is usually not so high as that of one grown indoors. Outdoor beds, being well covered up, do not always receive the same care and attention as the more readily accessible beds in a house; through the tendency to neglect them, they have sometimes proved a disappointment.

Outdoor beds are usually of the ridge type, and they are made up from September to March. The first should start bearing in December and the last in June. An example may be given of late outdoor beds in the south of England, made on March 31; these started to crop on June 25 and finished at the end of August. Those made in autumn will produce mushrooms during the winter if the weather is mild enough, but the bulk of the crop will be delayed until the spring.

Making the Beds.—The most common types of beds are (i) flat, and (ii) ridge. For indoor culture where space is limited, flat beds are chiefly used, but in large sheds, tunnels etc., ridge beds are common. Each ton of the original uncomposted manure will make 60-70 sq. ft. of 6 in. bed, or 40-50 sq. ft. of 9 in. bed. Where artificial heat is available, a depth of 4½ in. may be sufficient, but where there is a possibility of low temperature, the bed may be made as deep as 15 in. The usual depth is, however, 6-9 in. Quite small beds may be made; even boxes, measuring only 2 ft. by 1½ ft. by 10 in. deep, may be used.

Before a beginning is made to lay the bed, the site that it is to occupy should be cleaned carefully and if the floor is of hard earth and not concrete, it requires special treatment if mushroom beds have been on it before. Attention has recently been drawn by Dr. W. F. Bewley and Mr. J. Harnett in the horticultural Press to the well known deterioration of cropping that occurs when beds are constantly placed on the same floor. The cause of this so-called " site contamination " is unknown, but it is stated that the best treatment known so far is sterilization of the site with formaldehyde a fortnight before introducing the beds. One gallon of 40 per cent. formaldehyde is added to 49 gallons of water and applied to 60 sq. yds. of soil because it is necessary to sterilize the top 3 in. only. Five to seven days after treatment a covering of new second-spit soil is placed over the ground to the depth of 2 in. and, after consolidating it, the compost is brought in and the beds made up in the usual manner.

For mushroom sheds with shelves, the same writers suggest that when the old beds are removed the shed should be washed down with water. Then the entire superstructure—walls, ceiling, uprights, boards and floor—is soaked with formaldehyde applied from a spraying machine with considerable force so that the solution is introduced into every crack and corner. For this purpose a solution of the same strength as for floors is used. The shed is then shut down and the temperature raised as high as possible (90° F.) with the aid of artificial heat for a period of 48 hours. After this the shed is opened up and most of the vapour disappears within 24 hours. The next step, which the authors state is of vital importance, is efficiently to flame the bed boards and supports with a blow lamp so that any projecting fibres are singed but the surface of the timber is not burnt. Limewashing walls and woodwork gives a clean appearance, but it is doubtful if it is of real sanitary value. The site should be marked out with pegs or by chalk lines on the floor, attention being paid to the arrangement of the paths, so that the most inaccessible part of any bed will not be more than 3 ft. away from the edge of a path. When marking out pathways (12-18 in. wide), allowance should be made for the space taken up by the casing of the beds; the casing soil will increase the width by about 1½ in. on each side.

After the manure has stood for 3 or 4 days in the final composting heap and has passed the tests for its condition, it is brought in and spread on the areas already marked. It should be thrown lightly off the fork and not be deposited in heavy lumps. It is spread evenly to a depth of 10 in., and beaten down with a fork as the spreading proceeds. If in good condition and not too wet, it is trodden down compactly and evenly by short side-steps taken in such a manner that every inch of the bed is covered. This will reduce the depth to 6-7 in. The compost should be slightly springy, and should rise again to some extent after being compressed by treading. Where a thicker bed is required, a further layer is added and trodden down in the same way. The amount of compression permissible is dependent on the condition of the compost. If its maturity and moisture-content are correct, it may be trodden down as described, but if not quite ready ("green") or too wet, it should be beaten with a fork and not trodden. Further heating is thus favoured, and the treading can be done later if the compost improves. To make up beds with wet, black compost is a serious fault and a waste of time, for it is almost impossible to dry it, and the spawn will not grow in it.

The sides and ends of the beds, if not protected with strips of iron, planks or bricks, should slope to the ground at an angle of about 60°, and the finished bed should have a neat and trim appearance. Flat beds should be not more than 3 ft. wide, unless raised planks are provided for convenience in picking, but if approachable by paths on both sides, they may be double that width.

The successful construction of a ridge bed requires experience. The usual outdoor ridge bed is triangular in section with the top cut off, 2 ft. 6 in. along the base, 2 ft. 6 in. high, and 6 in. across the top. The overall measurement across the ridge is thus 6 ft.* One ton of fresh manure will make enough compost for 2½ yds. length of ridge bed having a surface area of about 45 sq. ft. Narrow pathways are left between the ridges, but when marking out the ground, at least 3 ft. must be left between outdoor beds, because the thick covering of straw required will occupy about 1 ft. on each side of the path. When the base has been marked out accurately, the manure should be spread evenly over the whole length to a depth of 18 in., and firmly trodden down. A further layer 18 in. deep should then be added and trodden down in like manner. The bed should now be 2 ft. high, of tightly packed manure with loose, overhanging material on the sides. This should be removed with a fork and placed on the top, bringing the height up to nearly 3 ft. The top and sides should be beaten thoroughly until perfectly compact, smooth and even, any loose material being swept up and set aside for use in the next bed. The height at the finish will be 2½ ft.

Indoor ridge beds are usually smaller and have a base of 22 in., a height of 17 in. and a flat top, 9 in. wide; the overall measurement across the ridge is 3 ft. 10 in.,† and the cropping area on any given length is under three-quarters of that of the larger ridge bed described above. When marking out the ground, pathways at least 1 ft. wide should be provided for, and the thickness of the casing (1½ in.), which will later be placed on each side of the ridge, must not be forgotten. It is convenient to leave a 3 ft. gangway passing across the ends of all the ridges. The method of construction is the same as that already described, or the ridges may be cast in a wooden mould, shaped like a trough, with sides and ends sloping outwards towards the rim. This mould should be made of 1 in. elm-board having a smooth inner surface, and the bottom should be fixed to cross-pieces to provide a firm base and prevent tipping when a man is treading the compost. A cross-bar may be clipped across its width to prevent bulging of the sides. It should be not more than 6½ ft. long, or it will be too cumbersome to lift and invert after the compost has been pressed into it. Spaces along the length of the ridge, which will occur between the different castings, must be filled by hand.

To prevent evaporation, if the compost is dry, the beds may be lightly covered with long litter. The use of straw on freshly made beds, though essential out-of-doors, should be undertaken indoors only after experience has been gained at this stage. The beds will still be giving off moisture, and the straw may tend to make the outer inch or so of the manure very wet,

* 6 ft. 4 in., with casing in position.

† 4 ft. 2 in., with casing in position.

a condition harmful to dry pure-culture spawn. Sweating can be overcome either by opening doors and ventilators to make a strong draught, or by turning on heat. If drying-out occurs, the manure should be sprinkled lightly, but not on the day on which spawning is to be done; its dryness can be judged by its external appearance.

If the processes described have been carried out properly, the temperature of the beds should now begin to rise, and to follow the progress of the heating a thermometer should be inserted in the bed, the bulb being immersed for at least 3 in. Special thermometers reading up to 160° or 200°F. are obtainable, protected by a wood or metal case, and so constructed that the scale can be read when the bulb is buried. If only one thermometer is used, and the bed is a large one, the temperature may be gauged with a sufficient degree of accuracy by the use of several sticks or canes inserted into various parts of the bed, one being kept near the thermometer for comparison. The sticks are periodically withdrawn, and the heat ascertained by feeling them. The thermometers should be examined each day, and by the end of the second day, the temperature should have risen from about 80° F. to 120° F. or even to 140° F. The temperature of the bed should remain at about this point for a few days and then slowly fall. Should it rise above 140° F., the manure has probably been used too soon, and a number of holes must be made in the bed with an iron bar, to allow heat to escape. When the temperature has dropped to 100° F., the holes must be filled up with clean soil, preferably subsoil. After a few days, if the heating has been satisfactory, a growth of matted white moulds may appear on the surface, particularly where sweating has occurred (i.e., where moisture has condensed). These moulds need not cause alarm, but their presence may indicate that the deeper parts of the bed have heated so much that they are now dry. Should the temperature not rise, but gradually fall when the beds are made, there is still a prospect of a crop if the manure is good, and spawning should be proceeded with as described below. Lack of heating when beds have been made may be counteracted by raising the temperature of the house, but if the manure is slightly too dry, too wet, or over-composted, it will not respond.

Spawning.—There has been much difference of opinion in the past as to the correct temperature for spawning. On no account should spawn be placed in the beds if the temperature shows any tendency to rise; above 85° F. there is considerable risk that the mycelium will be killed. The warmth of the bamboo rods, or the temperature recorded by the thermometers placed in several parts of any one bed, must be observed daily (usually for about a week), and not until the temperature at 3 in. below the surface has been steadily falling and is below 80° F. should the beds be spawned. This temperature causes immediate growth of the mycelium and may hasten the appearance of the crop, but the experience of successful growers is that it is undoubtedly preferable to wait until the temperature has fallen to 70° F. The beds sometimes become cold, i.e., of the same temperature as the surrounding air, before spawning is begun, but if the temperature of the air, and consequently of the beds, is frequently below 50° F., growth will be slow and the crop will be delayed.

It should certainly be the aim, particularly in unheated houses in cold weather, to spawn when the beds are at 70° F., and for about a month subsequently, to keep the temperature of the house between 60° and 65° F. The air temperature must then be gradually reduced until, when the first mushrooms appear, it is between 55° and 60° F. The reason for this is that the mycelium in the beds requires a temperature of about 70° F. for rapid growth, whereas the optimum temperature for development of the mushrooms is considerably lower.

The spawn, whether brick or pure-culture, should not be wetted in water; if desired, it can be moistened previous to use by being laid on the beds. The brick is broken or cut into 6 or 8 equal pieces, and the fragments, each about the size of a hen's egg, are planted 10 in. apart and 1½ in. deep, care being taken that the manure is pressed firmly around them. The fragments of pure-culture spawn, about 40 from each quart carton, and therefore small in size, are planted at a depth of only ½-1 in. and again it is most important that the manure and the spawn should be in close contact. Spawn-planting should be by hand or with the help of a flat, pointed tool, e.g., a knife or mason's small trowel; cylindrical pointed tools such as a dibber must not be used for pure-culture spawn because good contact is not secured between manure and spawn. Any depressions in the surface of the beds should be filled with manure. No watering should be done just after spawning, but if the beds are drying the paths and walls of the house may be sprinkled. The spawn "runs" better in compost which is properly moist but tending if anything to a dry rather than to a very wet condition on the surface. Badly made compost, usually black in colour and wet and "greasy", will kill the spawn. In properly made compost, the start or "running" of the spawn can be seen by gently removing the half-inch or so of covering. From the edges of the spawn fragments a faint greyish-white fringe of fungus growth is to be seen after one week under good conditions. This extends and creeps on to neighbouring straw fragments, and into the manure, becoming whiter and denser as it grows. With further growth, it changes the dark brown colour of the compost to light brown, and by this it can be distinguished from the mycelium of moulds and most other fungi.

After spawning, it is advisable to allow the beds to rest for a week or ten days* before casing, to ensure that the mycelium in the spawn is starting to "run" into the dung. During this time the beds may, if necessary, be covered with damp straw or canvas to reduce evaporation; with outdoor beds the litter protecting them from rain serves both purposes and must be replaced immediately after spawning.

Casing or Soiling. The proper selection of soil for casing is probably an important matter in mushroom culture.

The richness of the soil is probably of little importance for production of mushrooms because a plentiful supply of all food requirements is present in the compost. The function of the casing soil seems to be to prevent drying of the compost, to give, especially with ridge beds, a firm foothold for the heavy clumps of mushrooms and thirdly to provide a medium which can be watered satisfactorily and from which moisture will steadily evaporate. It would seem that the mushroom mycelium, growing out of the compost and into the casing, meets with certain utterly different conditions which induce it to fructify and, of these conditions, reduction of temperature is possibly the most important. Evaporation of moisture leads to a reduction of temperature and this, with cultivated mushrooms, is brought about by periodical light waterings which are allowed to evaporate; with wild mushrooms, the soil warmed by the sun during a hot summer is cooled at the surface by showers of rain, by evaporation, and by the lower air temperature of autumn nights. An association between sudden cropping and a reduction of temperature is therefore certainly to be noted, but experimental proof is still required before it can be stated that cooler conditions are the actual cause of mushroom mycelium changing from the vegetative to the fructifying state. An observation in support of the theory is that mushroom mycelium grown in pure culture in glass bottles will produce mushrooms inside the bottles if these are removed from a room with a constant temperature of 70° F. to one with a temperature of about 55° F.

* In cold weather or with wet manure, as long as 3 or 4 weeks may elapse before the spawn starts to "run".

A casing soil should therefore be chosen which absorbs water readily, which is not so porous as to allow water to penetrate to the compost below and which will permit evaporation from its surface without becoming noticeably altered in texture when drying. Its physical state, then, when laid on the beds, is of first importance. In addition to this, its physical state before being applied to the beds must be considered. Some soils (possibly only in certain seasons) are known as " unworkable " and only those which, for example, are sufficiently friable for casing flat beds and sufficiently cohesive for casing ridge beds can be used by the mushroom grower.

To take examples, the undesirable soils are pure sands and clays. Clay soils are avoided because of the difficulty of moistening the casing, when dry, and especially on ridge beds; because of the tendency to " cake " and leave a gap between compost and casing and because they crack deeply when dry. Although pure moist sand, whether fine or coarse, is readily applied to flat beds or ridge beds, it is too penetrable, lacks cohesion and dries out rapidly. In caves where the atmospheric humidity is constantly high and the temperature low, there is little evaporation from the beds and watering is reduced to a minimum. Perhaps for this reason and because of their availability, sandy or other loose-textured soils have for many years been used with success as casing in underground sites. The best proof that soils rich in plant foods are unnecessary is found in the old-established mushroom caves in France where limestone quarry refuse and gypsum mine refuse, both in a fine state of division and sandy in appearance, have been in use for many years. In England, in the Surrey stone mines the beds are cased with Upper Greensand refuse left behind after mining operations, and in certain caves near London, sands are used that have been washed from the Thanet Beds into cavities of the chalk, far below the surface. These however, both contain a clay fraction that acts as a substitute for humus, and gives them cohesion and a certain degree of water-holding capacity.

From the above it will be seen that the best casing soil should be permeable and in all probability, for mushroom growing in places other than caves, it should contain a little humus to increase its water carrying capacity. Humus is organic matter which gives a dark colour to soils and although in nature it is associated with soils that are rich in plant foods, it is considered here solely for its use in holding and giving up water.

Top soil, whether rich or not, usually contains large numbers of weed seeds which will germinate in the casing; moreover, it is often a carrier of pests or fungi that attack the mushroom or its mycelium. Unless it is dug from an area known from previous experience to be free from the parasitic fungus *Mycogone perniciosa,* surface soil should be sterilized or it may be the means of introducing one of the worst of all the mushroom diseases. Where *Mycogone* has been reported, enquiries have commonly shown that surface soil and not subsoil has been used.

A sandy loam is the best soil for the purpose but at least 1 ft. of the surface soil should be removed before that required for casing is dug. Some alluvial deposits, such as the Valley Brickearths* are very suitable on account not only of their texture, but also of the depth of the deposit. The necessity to dig subsoil can be avoided if, by small-scale tests with mushroom beds, the surface soil is found by the grower to be free from infestation by *Mycogone perniciosa,* or if sterilization can be undertaken to make it free (see p. 56).

Trials recently made at the Cheshunt Research Station support the above theory of the value of humus in casing soil. At Cheshunt, heavy crops were grown when peat was mixed with the casing soil; in view of this it may be suggested that growers who use soil and particularly subsoil which is deficient in humus (as shown by a light colour) should try the effect of incorporating some prepared granulated peat. It may not be necessary to use large amounts and, as a beginning, a trial might be made with one part by volume of peat to three parts by volume of damp soil. This represents 25 per cent. peat by volume or 3½ per cent. dry peat by weight, assuming the soil is damp. Work in France, at the Versailles Research Station, has shown that a casing soil too rich in humus produces no greater weight of crop. The use of peat in the soil is applicable only to flat beds; for casing ridge beds the mixture would have insufficient cohesion.

It should be noted that peat commonly has an acid reaction and care should be taken to carry out a test† of the mixture. Similarly, if soil alone is used, the reaction should be tested (after the sterilization, if this is necessary) and, if acid, chalk or lime should be added. The quantity of lime or chalk required depends on the acidity of the soil (*p*H) and on its texture, more being required for heavy than for light soils.

* The larger areas, in all parts of the country, are shown in the Drift Editions of the Geological Survey maps.

† A soil testing outfit for simple determination of the reaction is obtainable for a few shillings from the British Drug Houses, Ltd., Graham Street London, N.1.

As a rough guide, from $3\frac{1}{2}$-7 lb. of quicklime or 5-10 lb. of hydrated lime or 7-14 lb. of ground chalk or limestone is sufficient for a cubic yard (about 1 ton) of soil if the mixing is carefully done. It is safer to employ ground chalk or limestone because if excessive amounts of lime are used, the casing soil will be made too alkaline. If top soil is used and sterilization is therefore to be undertaken, this should be carried out before mixing with peat; the reaction is next determined after the mixture is made and finally lime or chalk is added if the mixed soil is found to be acid. The addition of lime may alter the working of the soil, and, with ridge beds, it is advisable to carry out a few trials before making the mixture with a great quantity of the soil. A neutral reaction, expressed as *p*H 6·8 to 7·5, is required and is fortunately obtainable in a large number of instances without the use of lime. An acid reaction as low as *p*H 5·5 makes the soil useless for casing.

In Fig. 3 the digging of the casing-soil is illustrated. Here the soil is a sandy loam, and, as will be observed from the heap behind the two operators, lime is added as it is made into a heap. On the other side of the windbreak (or " lewing ") shown in the picture, and made of old hop-bines supported by poles, outdoor mushroom beds are situated (See Fig. 5).

The casing soil should be procured in advance, whilst the beds are being made. It is advisable in many instances to pass it through a very coarse riddle, to remove stones and large lumps, but it is neither necessary nor advisable to reduce it to a very fine state. It should be just sufficiently damp to bind and adhere to a ridge bed and, as a rule, it can be dug from subsoil at any time of the year in about the right condition. If, after storage under cover, it becomes dry, it should be lightly watered, but certainly not on the day on which it is to be used. When beaten down on the beds, it should not be so wet as to stick to the spade, nor should the finished surface have a shining or polished appearance, as though an air-tight covering had been put on. Although the surface should be smooth and even, the outlines of the lumps, crushed by beating, should still be distinguishable. A clean, bright spade is essential, and it should have no flanges on the shoulders.

When a ridge bed is being cased, it is best to begin by applying the soil up to a height of 1 ft. and a thickness of $1\frac{1}{2}$ in., beating it lightly with the back of the spade. This process is repeated for another 1 ft. in height, leaving only the top and a small portion on each side to be completed in a similar manner. The process requires a certain amount of skill, and if the soil is too dry, it will probably fall away just as the work is being

FIG. 3.—Digging and liming the casing soil. The wind-break in the background is to protect outdoor beds situated behind it (See p. 38).

[To face p. 38

FIG. 4.—Casing a bed (See p. 30).

FIG. 5.—Outdoor beds in January in the south-east of England (See pp. 38 & 40).

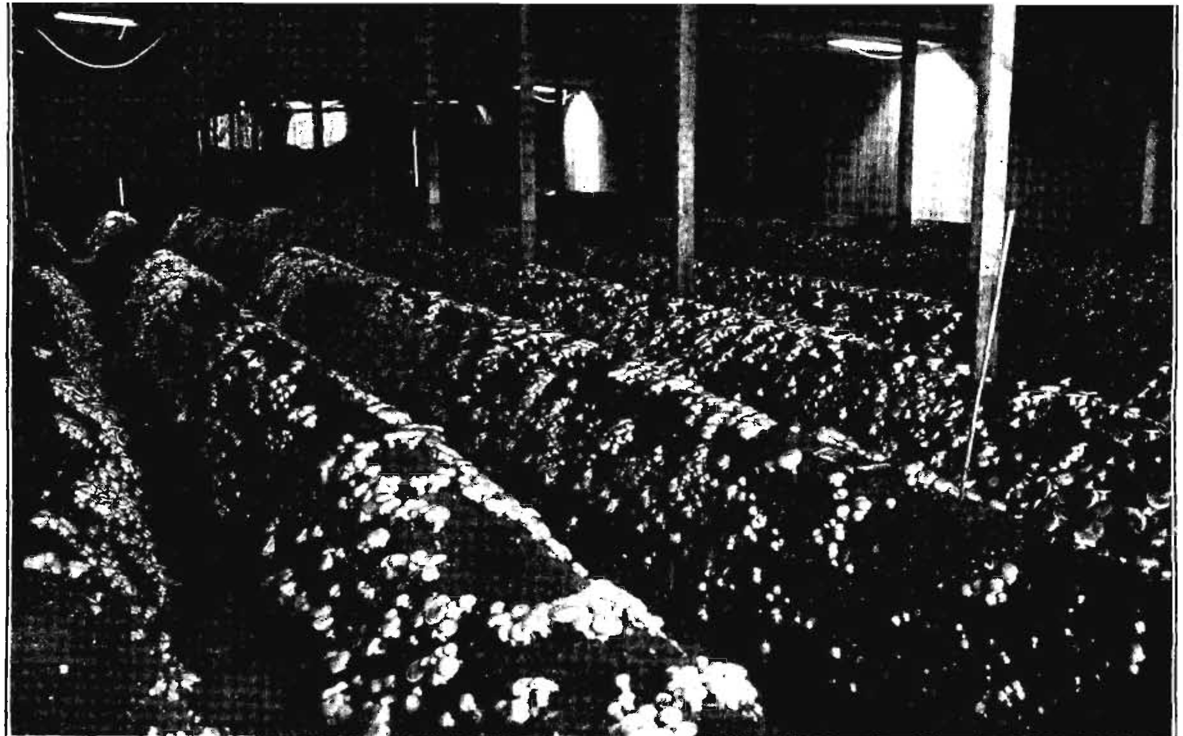

FIG. 6.—Indoor ridge beds in a house built of corrugated iron, lined with match board (See p. 30.)

completed. When finished, the bed should have a neat, smooth appearance. An alternative and somewhat labour-saving method (Fig. 4) is to lay a stout plank (12-18 in. wide) in the pathway parallel to, and having its edge $1\frac{1}{2}$ in. from the ridge. Soil is thrown down on the plank and against the ridge, to cover one half of the height of the ridge. By now using only that part of the soil which is on the plank and placing it on the upper part of the bed, labour is halved, because the lower part of the ridge was practically cased when the earth was thrown down. The plank can afterwards be moved along for the next length to be cased.

With a flat bed, the casing is a comparatively simple matter, but care should be taken to see that the soil is uniform in thickness and firmly beaten down. On shelf beds, a flat piece of wood with a handle can be used for tamping.

Fig. 4 illustrates the process of casing. The requisite prepared soil is brought in a barrow (just seen between the two men on the right), and is tipped on the planks specially laid in the pathway. Part of the soil, not yet used, can be seen in the foreground, in contact with the side of the ridge. After they had been spawned, the outdoor ridges illustrated were covered with straw, and sacks were laid on this. During casing, short lengths of a ridge are uncovered at a time and they are afterwards covered again with the material temporarily removed, which can be seen resting on adjoining ridges. The uncovered part of the ridge seen in the foreground is the spawned bed. Casing began at the far end of the ridge, behind the workers, and has been carried out as far as the spade held by the foremost of the two men applying the soil. The work was being carried out in January.

After casing, indoor beds may be covered to a depth of 4-18 in. (according to the atmospheric temperature) with straw, but this is not essential except in very cold or draughty places, or if rapid drying-out is likely to occur. It is, moreover, a hindrance in later work and provides cover for insect pests. Outdoor beds must be protected with about 1 ft. of straw, and in cold weather they will need straw mats, sacking, or hurdles in addition.

When these preparations have been completed there is nothing further to do but await the appearance of the crop. With correct temperature and moisture conditions maintained, mushrooms will begin to appear in from 4 to 10 weeks (Fig. 6). In unheated buildings in winter or with outdoor beds, a longer period may elapse. Such outdoor beds, which will bear a crop of mushrooms in the spring months in the south-east of England, are illustrated in Fig. 5. At each insecticide spraying, watering, or picking, the covering is removed and afterwards replaced.

Management of Beds. After casing and until the first button mushrooms show on the surface, the air temperature and humidity and the humidity of the casing soil are the only points for consideration. As already explained (p. 34), the air temperature should be between 60° and 65° F. from the time of spawning and should be reduced to 55°-60° F. only when the crop first appears. During this period, even with artificial heat, very little drying out occurs and it is advisable to water as seldom as possible. In defective buildings the harmful effect of draughts may be seen at this time, for the soil rapidly dries up. In glasshouses it may be found necessary to spray the casing rather more frequently, and a thin layer of straw helps to retain moisture. Atmospheric humidity at this stage is not so important as during the cropping period; it is maintained chiefly by moisture evaporated from the casing soil or from the paths.

Occasional inspection of the beds will do no harm, and is a means of gauging crop prospects. If, with correct temperature, no mushrooms have appeared after 8 weeks from spawning, a few areas of the casing may be scraped away with a knife and an examination made. The presence of white threads shows that cropping is about to begin (provided that correct temperature is maintained). On digging down to the compost, near where spawn has been planted, it should be found light-coloured and permeated with mycelium having the characteristic mushroom odour. If, on the other hand, scattered white threads are found in the casing soil but the compost is dark coloured and not permeated with the mycelium, there is reason to fear that the compost is unsuitable and a partial or complete failure is indicated. With all conditions favourable, mushrooms can be expected to appear in 4 or 5 weeks from the planting of spawn; 8 weeks is a more usual period, but, if the delay is as long as 10 weeks, the cause should be investigated. Under cold conditions, much longer periods of delay in appearance of a crop may ensue; even 5 months from the date of spawning may elapse. Just before cropping begins, it sometimes happens that deliquescent toadstools of the genus *Coprinus*, known as " Ink Caps ", appear on the beds. Their growth is taken as a good sign; they do no harm and can be brushed off the beds.

After the first few buttons have come through, rather more watering is permissible. This should be done with a can with fine rose, or with a hose, similarly fitted, if the area is large

Great care is necessary not to apply too much water, because, by so doing, a good bed can be ruined. Mushrooms thrive best in a cool, damp atmosphere and in a soil only just damp but not wet. The need for water is judged by the condition of the casing soil, because examination of the bed below the casing will usually show that the compost itself retains its original moisture throughout the whole life of the bed. The amount of water given, therefore, must be just sufficient to moisten the $1\frac{1}{2}$ in. layer of soil, and must on no account be so much as to soak through to the compost below. The casing should always be damp but not wet. In a moist atmosphere, watering may not be required more than once a week, but under drier conditions, daily watering may be needed. Lukewarm water is an advantage. Where a thin layer of straw is used and the soil can here and there be seen through it, the straw need not be disturbed when watering. If thicker layers are used, as in winter in cold sheds or on all outdoor beds, the straw must be moved before watering. In any event, a thick covering of straw should be moved and replaced at monthly intervals if there is any tendency for it to become wet. Very wet and heavy litter in contact with mushroom beds causes the mycelium to grow out of the casing, when it forms white, cushion-like masses on the surface or even grows vigorously into the litter itself. This kind of surface growth is also found in caves or mines with too much atmospheric humidity. When sprinkling the beds, it is a good practice, particularly during cropping, to water all paths and walls to keep the air moist. The relative humidity of the atmosphere should be between 88 and 90 per cent. Ordinary wet and dry bulb thermometers, to give an accurate estimate of atmospheric humidity, must be placed in a current of air moving at 10 m.p.h. They would be of no value in the still air of a mushroom house. On account of the poor sampling of air obtained when all draughts are excluded, the fixed types of hair hygrometer are liable to become inaccurate because the organic material operating them is constantly exposed to conditions of high humidity. For accurate readings, it is necessary to use a hand-operated whirling hygrometer or a more expensive apparatus which is mechanically fanned.

Ventilation is more important in houses filled to the ceiling with shelf beds, or in caves or mines, than in most houses built or adapted for floor beds. It is resorted to either when atmospheric humidity is approaching saturation and must be reduced, or to remove any accumulation of carbon dioxide.* In houses

* It has been shown by Dr. E. B. Lambert that concentrations of 5 per cent. of CO_2 in the air can prevent growth and can damage the mushrooms. Even from 1 to 2 per cent. may cause deformity in the shape of long stalks and small caps.

very closely filled with beds, it may be an advantage to provide a few ventilators at ground level as well as at the highest point along the ridge.

To sum up the work of management, the grower must have a casing soil that can be kept in damp condition by frequent light waterings and that will readily part with its moisture and so create cooler conditions on the surface of the beds. He must control this evaporation in such a way as to provide a humid atmosphere for the best development of the mushroom buttons when they have been induced to appear but, by regulation of heating and ventilation, he must never allow the atmosphere to become so heavily charged with moisture as to be saturated because, when this point is reached, water is deposited, evaporation is reduced, and conditions favourable to bacterial and fungus diseases are created.

Before and at the start of cropping, it is well to watch for any signs of insect or fungus attack and the pages of this Bulletin which describe these troubles should be read. Thus, for example, one detail of management that must not escape attention is the suppression of flies (see p. 71); if they are not kept down from the start, they increase rapidly and lead to the production of the familiar " maggoty " mushrooms, with consequent financial loss. After cropping has begun, it may be noticed that some of the very small buttons become dark-coloured and never grow beyond a diameter of about ½ in. One cause of this is the severance by insects of the mycelial strands at the base of the buttons, and a search should be made, using a 10-magnification lens, for minute fly larvae in the casing soil attached to the buttons or inside the stem itself. Other insects or mites may possibly be responsible. A casing soil which has not been sterilized may be contaminated with microscopic fungi of the genus *Fusarium* (see p. 52); it has been shown that they affect the mushroom mycelium in such a way that only small buttons or withered mushrooms are produced. On some occasions, no cause can be discerned, and the phenomenon of the production of brown, withered buttons cannot be accounted for. If, after removal of the mushrooms in course of picking, their fleshy bases are not dug out of the casing, a large number of such discoloured, soft and leathery buttons will be formed on and near the stumps. Later in the life of the beds, and especially after each heavy " break " or " flush ", discoloured buttons may become still more numerous. It is possible that in such instances breakage of mycelium has occurred, or that the trouble may be due to contraction or sinking of the compost; pressing down the casing soil over the whole bed, to eliminate any air space between it and the compost, should be tried.

The period of production depends on the management of the beds, and especially on the control of temperature in the house; from 2 to 4 months is usual. Mushrooms of the best quality are produced at temperatures between 50° F. and 55° F., but cropping and development are slow, and most commercial growers keep the temperature between 55° F. and 60° F. Higher temperatures (often unavoidable in summer) bring about more rapid cropping and shorten the period of production; the mushrooms are then of lower market value, owing to the accelerated lengthening of the stalks and expansion of the caps. In addition, increased watering becomes necessary and conditions are made more favourable for insect pests and fungus diseases.

On large mushroom farms, the *average* yield is 1 lb. per square foot, and it is usual to take this as a basis for calculations. Where full attention can be devoted to the growing, as on small farms or in single houses, the average may approach 2 lb. per square foot. A yield of more than 3 lb. is exceptional.

Mushroom bed compost, at the end of cropping, is usually acid, but it is considered unlikely that this is the cause of the bed ceasing to bear. A more probable explanation is that the mushroom, like other fungi grown on a limited quantity of medium, forms " staling products " in the compost, which at length render it unfit for further growth of mycelium. The addition of chemical fertilizers or of liquid manure* to the beds during cropping has never given results outstanding enough to cause this treatment to be adopted by growers. With the exception of lime, mixed with the casing-soil, and gypsum, with or without superphosphate of lime in the compost, no fertilizing substances are added to the materials composing the beds before these are made up. In the past, however, it has been said that 2 oz. of saltpetre mixed with every bushel of casing-soil tends to increase the yield.

When the beds cease to produce, they are removed from the houses and the compost and soil are used for manurial purposes, but care should be taken that this old bed material is not spread on land that may later be dug for casing soil.

Composition and Manurial Value of Spent Compost. Considerable changes occur in the relative proportions of the various constituents of horse-manure during composting and

* Falconer, on pp. 112–113 of his book mentioned in the list at the end of this Bulletin, recommends watering the bed, not wetting the mushrooms, with manure-water made from *fresh* horse-droppings, or sprinkling the bed with a weak solution of saltpetre (2 oz. to 8 gal. water) or of common salt (4 oz. in 10 gal. water). Sprinkling with a solution of table salt, to prevent infestation by maggots, is practised by growers in England at the present time.

the growth of the mushroom. As composting proceeds, the main constituents lost are water and readily decomposable organic matter, while the proportion of ash, lignin and organic nitrogenous substances increases. During growth of the mushroom, there is a further loss of water and all the constituents of the manure are attacked but lignin and protein are the principal materials destroyed. The net result of these changes is that spent mushroom compost is of much higher manurial value per ton than either fresh or composted horse manure. This is shown by the following figures which are calculated from the data of Waksman and Nissen (1932).

Horse Manure:	Fresh	Composted	Spent
	Per cent.	Per cent.	Per cent.
Total nitrogen	0·43	1·18	1·48
Nitrogen soluble in water ...	0·06	0·13	0·38
Organic matter	26·0	42·3	46·1
Organic matter soluble in water...	1·1	1·2	8·0
Lignin	4·7	13·5	11·3
Ash...	4·0	7·7	13·9
Moisture	70·0	50·0	40·0

The spent manure is higher in total nitrogen and organic matter and is considerably higher in ash, including the minerals potash and phosphorus; more organic matter is readily decomposable in the soil (Waksman and Allen, 1932) and the nitrogen becomes available to plants more rapidly. At the same time the spent manure contains a high amount of lignin to augment the more permanent organic matter or humus in the soil and is therefore valuable in improving soil structure.

In the U.S.A., spent manure is contracted for, dried, ground up and marketed for use on golf greens, etc., and it is recommended for this purpose in the Journal of the Board of Greenkeeping Research, 1930. There appears to be little risk of introducing weed seeds with spent compost, as these are almost certainly destroyed by heat in the compost heaps. The chances of introducing weed seeds are greater if the spent compost contains casing soil, though it is usual to use subsoil and in many instances the soil is sterilized. In this country a certain amount of spent compost is dried and sold under a trade name for use on lawns and in gardens for manuring and mulching. The dried material is correspondingly richer than the moist. Owing to lack of experimental work, the manurial value of spent manure to specific crops cannot be stated. When it is well run, spent compost has a pH of about 5·2 and it should therefore be a valuable source of organic nitrogen and humus to plants that prefer acid conditions in the soil but it might be harmful to other plants when the soil contains a low reserve of lime. Unless it has been sterilized, it should not be used for crops under glass as certain of the insect pests of the mushroom may cause damage. Since casing soil may be included with the spent compost, the latter should be bought and used according to its analysis. It may be from two to three times as rich as ordinary well-rotted farmyard manure.

Outdoor Culture in Pastures, etc. Mushrooms can be grown in pastures, lawns and meadows, but the uncertainty of gathering a good crop over a reasonable period makes this method quite unsuitable for the commercial grower. It must be understood by those who desire to make a trial of field-growing, that if, under the best conditions of commercial cultivation in beds, good crops can be obtained only by the closest attention to details, it is obviously impossible to ensure success in the open field where, for example, the temperature and the supply of moisture are beyond control.

In fields, fair results have been obtained, at least for a short time of cropping, but warning must be given that no great expenditure of money on labour, spawn and manure is warranted *if the more regular practice of indoor mushroom culture can be* followed. Field culture is to be regarded as an interesting and useful pursuit but is not necessarily a profitable undertaking.

Mushrooms in the wild state show a preference for certain fields, and the intending grower should avoid those which are wet or undrained and those which are dry and sandy; he should choose, rather, a well-drained loam. A quantity of good manure is made into compost by the method described above; and, during the months of May, June or July, when the manure is ready, turves are lifted in the selected field in places well away from the shade of trees or bushes. The turves, for convenience, are cut about 1 ft. square; about 1½ in. of adhering soil is removed with the grass and a further 4 in. of soil is dug out and may be scattered over the grass near by. The hole made is immediately filled with compost, which is firmly pressed down; in this, just below the surface, a piece of spawn is next embedded, and the turf, with as little damage as possible, is replaced in such a way that when it has been firmly pressed down it is level with the surrounding grass. Numerous plantings of this kind may be made at distances of at least 2 ft. between the turves removed.

A dry period following spawning is found to be beneficial; heavy rain, on the other hand, may damage or kill the planted spawn. With the advent of moist and mild weather in late August or during September, a crop of mushrooms may be expected to appear.

A similar method has been described in which a triangular tongue of turf, 2 in. deep, is gently prised up by cutting along two of its edges, but it is not removed. The piece of spawn is placed under the turf without manure but in good contact with the surrounding firm soil, and the turf is immediately replaced and trodden down. A third and perhaps the simplest method is to plant spawn under old, rain-washed droppings of horses or cattle wherever they occur in the field. This should be done in May or June and will be successful if the droppings are not wet at the time of planting and if the summer is warm and fairly dry and followed by a damp autumn.

Meadows spawned in any of these ways do not necessarily produce mushrooms season after season and the operation may have to be repeated each year. It is as well to begin planting operations in a field already known to produce wild mushrooms naturally.

It may be thought that, since wild mushrooms may be gathered and sold, their growth in pastures might be stimulated and a crop secured without the necessity of spawning. There is, however, no known manurial treatment that can be recommended with confidence that will ensure or certainly increase the supply in mushroom-bearing fields; grazing by horses and the application of salt and kainit have, however, been advocated for this purpose. In some parts of England, notably in the Midland counties, there are pastures that, in favourable years, provide heavy crops of wild mushrooms at any time from May to November. From 3 to 4 cwt. of kainit may be applied to them in March and 5 cwt. of salt in April. Basic slag should be avoided. Wild mushrooms are most plentiful after a hot summer, when rains falling on the warm turf, make the conditions ideal for their growth.

PICKING AND PACKING

Picking. When in full bearing, mushroom beds require picking over once a day, and at other times on alternate days. Although there is a demand for open mushrooms or " grillers ", care is necessary to ensure that the mushrooms are picked when ready, as development proceeds rapidly when once the cap has expanded sufficiently to break the membrane that connects its edge to the stem. Beds that are covered with straw should be uncovered piece by piece, each portion being covered again as soon as possible. Mushrooms should be twisted gently from the beds, and not cut or pulled. Some of the casing-soil is commonly brought away, together with the root-like mycelial threads at the base of the mushroom, and any of the solid basal part of the gathered mushroom accidentally left in the soil should be removed; otherwise it provides a medium in which flies may deposit eggs. Holes in the casing-soil made during picking should be filled as soon as possible with fresh, damp soil. Damaged mushrooms and broken pieces must be picked up and not left lying about.

Shallow trays holding one layer are convenient for picking. In these the mushrooms are placed stalk downwards. For outdoor beds, half-bushel baskets are more convenient. Where there are only a few beds, a receptacle for rubbish, as well as the picking-baskets, may for convenience be taken into the house or cellar; the mushrooms, as they are picked, are trimmed by cutting off the stalks about 1 in. from the cap, the earthy base of the stalk being allowed to fall into the receptacle provided. The mushrooms are placed, stalks upwards, in the basket.

If they have to be retained in a fresh state, mushrooms can be kept for some days under cool conditions with the temperature between 34° and 45°F., but they must not be frozen. They consist largely of water, and after drying they can be kept indefinitely. In some countries an export trade in dried mushrooms has developed. Details of a small-scale process are given in the literature quoted on pp. 75-77, notably in the books by Falconer and Lachaume. Very large canning factories exist in the United States. They are devoted entirely to mushrooms, either alone or in soups or broths, and each is capable of dealing with 3-6 tons a day. They absorb about half the output of fresh mushrooms and exert a steadying effect on prices. Mushrooms are also canned in France and in Japan.

Packing. Where a packing-shed is used, the mushrooms brought in are first trimmed by cutting off the earthy bases of the stalks and any grit or soil adhering to the caps is removed. They are then sorted and placed in baskets with the stalks upwards.

Careful grading makes for attractive packing and caters for the specific wants of different classes of buyers. To encourage the standardization of grades and packages suitable for cultivated mushrooms, statutory grades and a National Mark* scheme have

* See Marketing Leaflet No. 58, obtainable free and post free from the Ministry.

been introduced. The following are the statutory grades:—(1) *Selected Buttons* of from 1 to 2 in. in diameter, and having entire the membrane connecting the margin of the cap with the stem, (2) *Selected Cups* (*Small*) of from 1½ to 2½ in. in diameter, and (3) *Selected Cups* of from 2½ to 3½ in. in diameter, the mushrooms of both grades (2) and (3) having the membrane either entire or broken, but, if broken, with the cap still cup-shaped, (4) *Selected* (*Open*) of from 1 to 4½ in. in diameter with extended and flattened caps.

The contents of each basket should be of similar colour, and be declared as white, or creamy-white or brown.

The mushrooms should be packed stem up, and in orderly layers to within not less than 1 in. of the top of the container, to allow room for expansion. Stems should be cut reasonably short; the lengths permitted, which vary according to grade, are prescribed in the Scheme. The standard packages for mushrooms are:

(1) *No. 6 Taper Chip Basket*, holding 4 lb. of buttons or 3 lb. of opens.
(2) *No. 4 Standard Mushroom Chip Basket*, holding 4 lb. of cups.
(3) *No. 12 Taper Chip Basket*, for opens only and holding 5 lb.
(4) *No. 2 Chip Basket*, to hold 1 lb. of cups or buttons, or ½ lb. of opens.

Paper lining of chip baskets, although optional, helps to prevent bruising during transit. Covers, secured by rubber bands, may be of paper, wood or cardboard, but the last two offer the greater protection to the mushrooms.

The National Mark label or grower's own covers are printed or stamped with the name of the grower, the net weight when packed, the grade and the colour of the mushrooms, and, for Selected (Open) the size description, i.e., small, medium or large.

DISEASES

The mushroom, itself a fungus, is liable to be attacked by other fungi. These parasites, or the diseases they cause, must be kept in mind by the grower, and every care taken to avoid them. Their presence in mushroom houses is a source of trouble and may lead to serious loss; there is no doubt that they have been an important cause of failure in mushroom-growing in the past.

The first, known simply as "Mushroom Disease," or as "White Mould", "Bubbles" or "*Mycogone* disease", becomes evident when the bed is coming into bearing, and persists until cropping is finished. Some mushrooms may be infected (commonly on the gills) without showing deformity, but the disease is quickly recognizable by the fact that whole clumps of young mushrooms grow into shapeless masses, which become covered with a close white, fungus growth. If a single diseased mushroom be examined, it is seen to be covered with the whitish, mould growth; the stalk is short and much swollen and the cap is scarcely developed. As a result, the diseased mushroom may assume various shapes, (Fig. 7) but it commonly resembles a puff-ball in appearance. After being in this condition for a few days, affected mushrooms quickly decay and emit a disagreeable odour. The attack may be local or it may involve all the beds in a house. The cause is the fungus known as *Mycogone perniciosa,* but similar symptoms can be produced by *Cephalosporium Costantinii* and by *Verticillium Malthousei.* With the two last-named fungi, however, there is no rapid decay as there is with *Mycogone.*

A disease of mushrooms which, however, only makes its appearance occasionally is caused by a fungus, *Dactylium dendroides.* It is probably a soil inhabitant and is introduced with the casing soil for it is now and then to be found attacking wild mushrooms in the open in places devoid of the dung of the larger animals. It grows over single mushrooms or over whole clumps and covers them with a thick weft of white mycelium often having a pinkish or rosy tint, particularly where it comes in contact with the earth. The mushrooms completely rot away and disappear under the dense fluffy covering of the *Dactylium* mycelium. The fungus spreads over the surface of the casing soil and its spores are disseminated by currents of air, by watering and by human and insect agencies.

Another fungus disease, known as "Gill Mildew", to which the growers' name "Flock" probably applies, is caused by the fungus *Cephalosporium lamellaecola;* it is not very common and not often serious. In it the gills become joined together and more or less covered with a white, mould-like growth. The species of *Verticillium* previously mentioned, as well as *Mycogone,* may affect the gills in the same way. Lastly, a brown blotch of the caps, due to a bacterial parasite, *Bacterium Tolaasi,* is of occasional occurrence, and must be distinguished from the greyish spotting caused by *Verticillium.* The source from which the bacteria come is unknown, but it is certain that the blotch is worse in the presence of abundant moisture. Where it occurs, the atmospheric humidity should be reduced and, after each sprinkling of the beds, ventilation should be given with sufficient draught to dry the mushrooms without drying the beds.

Damage to mushrooms sometimes occurs through non-parasitic agencies. Mineral oils or the fumes resulting from their combustion can cause deformity of the whole mushroom. The caps become distorted, small mound-like outgrowths being formed on their surface and they are sometimes cleft. Gill formation may take place on the top of the cap or in the clefts. As a result, the top of the mushroom somewhat resembles the " rose " comb of fowls and the deformity has therefore been given the name of Rose Comb (Fig. 8).

A malformation of the gills of cultivated mushrooms is sometimes encountered but the cause is not known. Although the cap and stalk may develop perfectly or be slightly under-sized, the gills fail to grow out and are pale or nearly white in colour. Sometimes they are almost rudimentary and are represented by a white pad under the cap, the pad being nearly smooth or only slightly corrugated.

Fungi invading the Beds. By competition with certain other fungi growing inside the beds, the spread of the mushroom mycelium may be retarded or prevented. One such invader, which forms large colonies in the manure of the beds, is the White Plaster Mould, *Monilia fimicola* (sometimes called *Oospora fimicola*), deriving its name from its very powdery appearance. A second is the Brown Plaster Mould, *Papulaspora byssina* (also described as *Myriococcum praecox*), which first appears as white, fluffy, or matted patches of mycelium on the compost. Within a few days the centre of each patch turns brown with the formation of a powdery mass of granules which, under the microscope, are found to be " bulbils " of the fungus. When the bed is cased the fungus penetrates the soil and forms new patches on the surface. For a time, these are brown with a white fringe, but finally they become completely brown and powdery. Another invader is the Mushroom-bed sclerotium, *Xylaria vaporaria,* which in its later stages forms large, black, fleshy, irregularly branched resting-bodies measuring from 1 in. to 6 in. long, reminding one of fragments of blackish seaweed (Fig. 9). The white mycelium of the Xylaria occurs in the manure, but the branched and tangled sclerotia are formed in the casing-soil. The sclerotia have a strong and rather unpleasant odour, resembling that of crude castor oil. A fourth invader found in this country is *Clitocybe dealbata*. This is a white toadstool growing from the casing in large clumps and having a cap with very wavy margins; when fresh, it has a distinctly sweet scent. It is chiefly harmful in that it fills the beds with a coarse white ıycelium which prevents the growth of mushrooms. It seems ; be persistent when once introduced into a mushroom house.

Another competitor with the mushroom is a small white toad-;ool, *Clitopilus cretatus,* which commonly has the stalk attached ıther to one side of the cap. It is only ¼ to 1¾ in. in diameter, 'ith a slender and short stalk; its shape has given rise to the ame " Cat's Ears ". It grows in densely crowded tufts on ıe casing soil and its mycelium penetrates the compost.

One of the worst mushroom invaders, *Pseudobalsamia ıicrospora* (" Truffle disease "), known in the U.S.A. since)29, was recorded in 1936 in England. The circumstances of s occurrence were such as to lend support to the view that it as introduced to the mushroom bed by way of the casing soil. s cream-coloured mycelium grows in the compost and in or n the casing soil where it forms a dense mat of strands in hich the fruiting bodies are abundant but evanescent. These :e cream-coloured to reddish brown, sub-spherical when sub-ıerged to discoid when on the surface, and irregularly lobed; ıey are ⅛ to 1 in. in diameter and their appearance has been kened to that of calves' brains. They are formed on the ırface of the bed or in cavities in the compost. The fungus very persistent and, after it has once appeared in a house, reat care must be taken to clean thoroughly and disinfect the hole interior as well as composting grounds and other)ntaminated places.

American experience is that during the early stages of the :op the yield of mushrooms in infested beds is usually normal, ut the Truffle reduces the yield during the second half of the :opping period. According to Beach (1937), the *p*H range ɪr Truffle extends from 7·5 to 4·5, with the optimum at ·8. In comparison with the mushroom, Truffle tolerates less .kaline but much greater acid reaction. Spawn will start ɔove *p*H 7·5, at which Truffle is inhibited. This mould ɔubtless is favoured by the acidifying effect of spawn growth, ence it develops after the spawn has run. The usual very 'kaline reaction of fresh manure does not permit the growth f Truffle, hence it is impractical to determine whether ıanure is contaminated with the spores of the fungus when :ceived. It is possible that Truffle grows in stored manure, nce acid regions may develop within certain parts of a pile.

The Truffle is favoured by very warm houses, 83° F. being s optimum. Damp manure favours its start and rapid spawn rowth seems to stimulate it. Beach (1937) states that the riginal source of the Truffle is apparently infested manure hich contaminates the composting ground. The spores survive the higher temperatures of fermenting manure, as shown by experiments where cultures were kept at 115°-120° F. for 16-24 hours. The spores survived but the mycelium was killed. At the Pennsylvania State College, compost heaps and beds (at the time of filling) were inoculated with the spores of the Truffle. The fungus came to full development during the mushroom bearing period although a temperature of 136° F., continuing for two days, had been reached by the compost. Other beds in the same house, but not inoculated, remained free. Whether the spores survive sulphur or formaldehyde fumigation has not been definitely proved. There is little likelihood of new centres of Truffle infection being started by picking, watering, air currents or insects because the spores are not readily released. Spread depends rather on the dispersal of spores through the compost heaps at turning or during the filling of the beds. It is possible that casing soil becomes contaminated in a similar way. Beach (1937) points out that some unknown condition of the compost which may be an alkaline reaction occasionally inhibits growth of the Truffle.

A condition of mushroom beds commonly met with in the south of England and described by growers as " damping off " has been investigated by Wood (1937). The compost may be well " run " with mycelium but little or no mushroom production results. On the other hand mushrooms may be formed and there may be a good first flush but the crop rapidly degenerates into small, withered, brown and undeveloped mushrooms or buttons which remain on the beds without rotting. In a normal or heavy crop, some of the mushrooms are found to be dry and pithy inside the stalk; they are of rubber-like texture and are usually brown internally. Mushrooms of the brown variety have the caps shining as though burnished whereas healthy ones show a matt surface. Sometimes the trouble is localized in patches or is confined to one or more beds in a house.

Wood (1937) succeeded in isolating from the soil in proximity to affected mushrooms several species of the genus *Fusarium* and of these *F. martii,* with white mushrooms, and *F. oxysporum,* with brown mushrooms, were the commonest. By inoculation of casing soil, Wood was able to reproduce the symptoms. *Fusarium sp.* may therefore be taken to represent a seventh form of competition with the mushroom for by growth of these fungi in the casing soil not only may symptoms of disease be produced but crop failure may also result. These fungi are microscopic and it is only by making laboratory cultures from the soil that their presence can be detected. The ymptoms must be distinguished from those induced by the ırvae of *Sciara* and *Phorid* flies.

More detailed descriptions of the fungi mentioned may be found in the literature to which reference is made at the end of this Bulletin.

Control. The diseases described above as attacking the mushrooms themselves, and especially that due to *Mycogone perniciosa,* when once established, are difficult to eradicate. For this reason, and as a precautionary measure against site contamination, where land and accommodation are available, a complete change of position for outdoor beds may be made every year. With indoor growing very strict cleanliness, ventilation, humidity and temperature control and close attention to the beds are essential. Diseased mushrooms as they appear should be removed, together with their " roots "; they should be collected in buckets and burnt, and any that fall from the ridges should be picked up and not trodden in. Waste heaps of diseased mushrooms, whether exposed or in sacks, should not be left in the vicinity of the beds or houses. The temperature, if possible, should be brought down to 50° F. This is known to reduce the spreading power of *Mycogone* and also lessens the activity of insects that carry fungus spores. Reduction of atmospheric humidity has a greater effect on the *Verticillium* disease than has reduction of temperature. Sprinkling should not be done until after diseased mushrooms have been removed. Hands, clothing, baskets and tools should be clean when houses free from disease are entered, particularly if contact has been made with diseased mushrooms.

With *Mycogone* and *Verticillium,* removal of infected mushrooms is only useful in the early stages and there comes a time when the casing soil is heavily contaminated by spores of the parasitic fungus. They are carried by water or they fall mainly on the surface, and they act as an infection layer through which any subsequently formed " pinhead " mushrooms must pass in the course of growth. Many infections, leading to deformity, probably occur in this way and it has been stated by Beach (1937) that a promising method of dealing with mass infection by *Verticillium* on the surface of the soil is to spray the casing with dilute Bordeaux mixture (1:1:50). This should be done between flushes, after hard picking, and after the beds have been cleaned and the surface scarified; watering may follow soon afterwards. Slight russeting may result but the spraying seems worth carrying out where a large crop is in danger of being ruined by disease and especially if it is accompanied by every effort to improve all other conditions. Beach states that the greatest value is in cleaning up or checking occasional or local occurrences of *Verticillium* disease.

Localized treatment by watering the beds within 1 ft. radius of diseased patches with 1·5 per cent. lysol or 2 per cent. formalin has in the past been suggested where the disease is only just starting, but this is likely to kill the mushroom mycelium and would be difficult to apply to ridge beds.

Mites and flies have been observed to distribute the spores of *Cephalosporium*, *Mycogone* and *Verticillium* from diseased mushrooms, and it is evident that the suppression of animal life (insects, etc.) in the house is of the greatest importance for the control of disease.

The above methods directed towards the control of different diseases when they have once appeared cannot, for obvious reasons, be applied to the control of invaders or competitors in the beds. These are really fungus "weeds" and any alteration of conditions designed to harm them is likely to harm also the mushroom mycelium growing in the beds with them. In spite of this difficulty a certain difference in the growth requirements of the mushroom and of one at least of the competitors, i.e., White Plaster Mould, has been found and so consequently has an indication for treatment of invaded beds.

Experiments by Beach (1937) in America showed that if the compost happens to be alkaline (*p*H above 7·0), advantage is given to the White Plaster Mould and it tends to overrun the mushroom mycelium. Under more acid conditions (*p*H below 7·0), the White Plaster Mould is checked and the mushroom becomes dominant. In England, laboratory culture experiments by Williams (1937) at Cheshunt had shown that very acid conditions (*p*H below 5) prevented growth of White Plaster Mould, and this author, in company with others, announced in the horticultural Press in August, 1937, the following treatment for infected beds:

1. Remove carefully the infected casing soil, placing it without spilling in a paper lined box near at hand. Then remove the surrounding casing soil until the compost below is uncovered slightly beyond the white infected area.
2. Remove the white infected compost and fill up gradually with acid peat, moistening it thoroughly with dilute acetic acid applied from a small syringe or similar instrument. The acid solution is prepared by adding one part of $33\frac{1}{3}$ per cent. acetic acid to seven parts of water by volume. (1 quart in 2 gal.).
3. Finally recover with fresh casing soil. The treatment must be applied as soon as the first infection by the White Plaster Mould appears on the surface (usually about 12 days after casing) to bring about

FIG. 7.—Mushrooms attacked and deformed by the *Mycogone* disease (See p. 40).

[To face p. 54

FIG. 8.- Deformity of mushrooms, due to mineral oil, and known as "Rose Comb" (See p. 50).

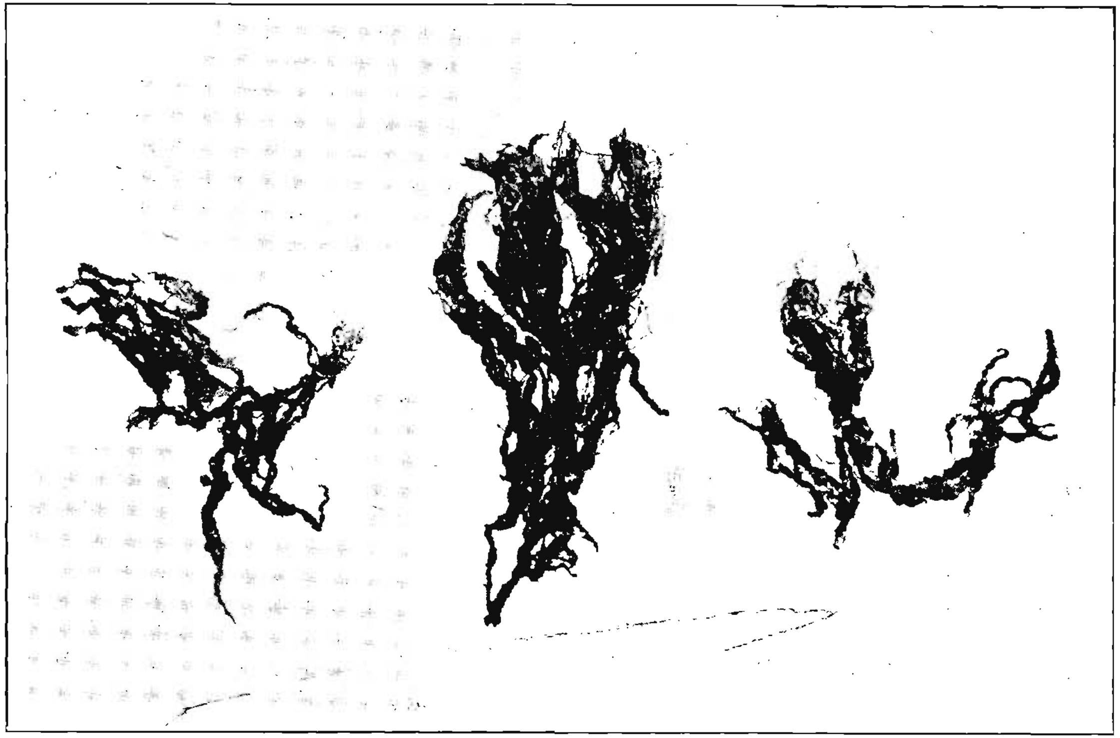

FIG. 9.—Sclerotia of a mushroom bed invader, *Xylaria vaporaria*, removed from the casing (See p. 50).

INJURY CAUSED BY SPRINGTAILS (*Hypogastrura armata*)
(See p. 63).

FIG. 10.—Holes in stalk caused by Springtails. Nat. size × 1½.

FIG. 11.—Longitudinal section of the same button as Fig. 11, showing tunnels extending inward and upward. Nat. size.

INJURY CAUSED BY SPRINGTAILS (*Hypogastrura armata*)
(See p. 63).

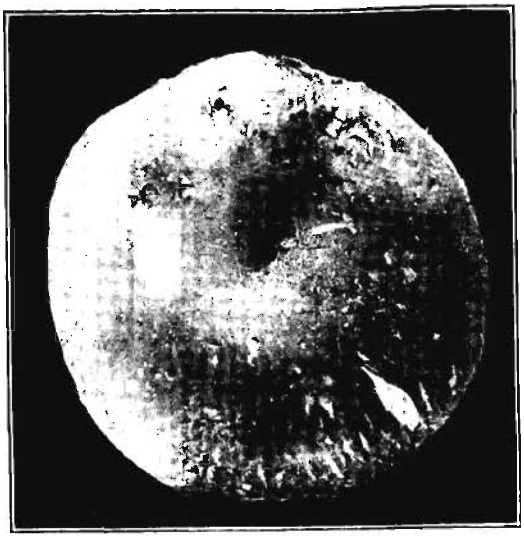

FIG. 12.—Mature mushroom showing holes in cap. Nat. size.

FIG. 13.—The same mushroom as in Fig. 12. Splitting of stalk as a result of tunnelling. Nat. size.

INJURY CAUSED BY MITES (See pp. 64 & 65)

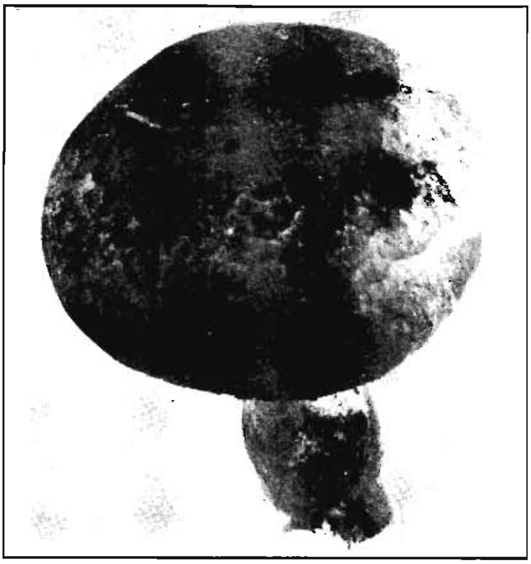

FIG. 14.—Pits in cap and stalk caused by the mushroom mite, *Tyroglyphus dimidiatus*. Nat. size.

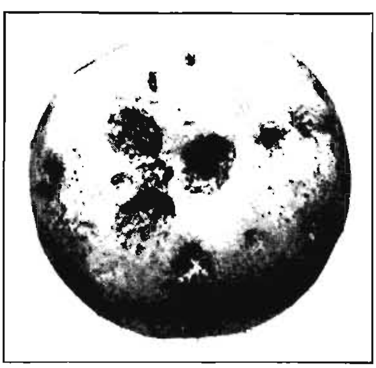

FIG. 15.—Severe injury caused by *T. dimidiatus* to the cap of a large button. Nat. size.

FIG. 16.—Mites (*T. dimidiatus*) and eggs in one of the cavities shown in Fig. 15. Magnified × 12.

INJURY CAUSED BY FLIES (See pp. 68 & 69).

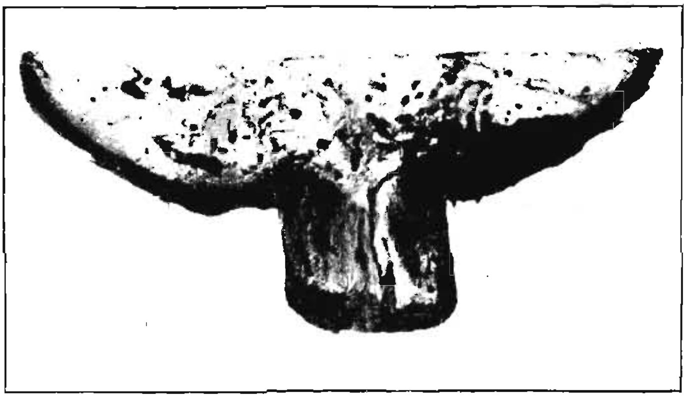

FIG. 17.—Section of mature mushroom showing tunnels made by larvae of a Phorid fly, and similar to those caused by Sciarid larvae. Nat. size.

FIG. 18.—Section of button showing tunnels made by larvae of a Phorid fly. Nat. size × $1\frac{1}{2}$.

FIG. 19.—Injury to bases of stalks caused by *Linopodes antennaepes*. Nat. size (See p. 65).

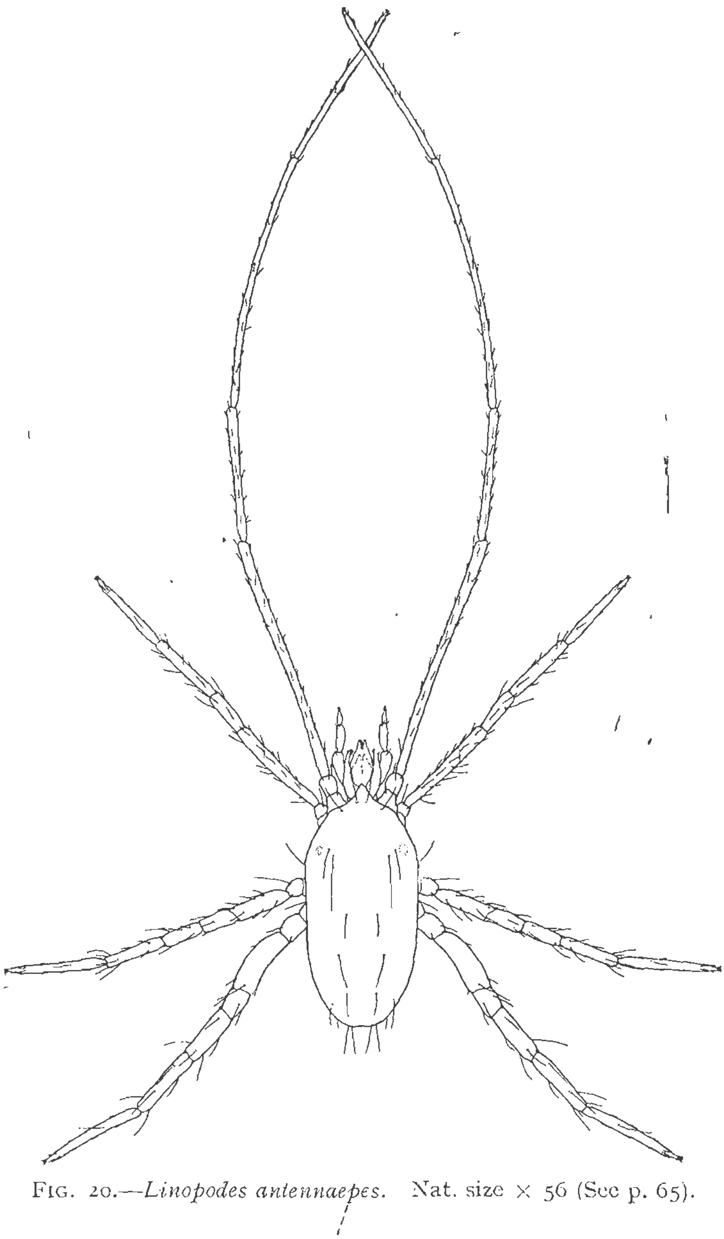

FIG. 20.—*Linopodes antennaepes.* Nat. size × 56 (See p. 65).

an early check and to make it necessary to remove only the minimum of compost. With shelf beds, it is suggested that a thick covering of paper may be placed on tbe bed beneath to protect it from acid which, under some circumstances, might drip and damage the crop below. A second and third treatment may be required if the whole of any infected patch was not properly removed at the first operation.

In connexion with White Plaster Mould, growers have reported that since they have used gypsum in composting, the fungus has been of much less frequent occurrence. One of the effects of gypsum appears to be to keep the reaction of the compost near neutrality and to prevent its becoming very alkaline (see footnote p. 13).

Prevention. Turning now to possible preventive measures for fungi invading beds as well as for those causing disease, there is at present no known method of adjusting the reaction (*p*H) of the compost so that, at the outset, it could be made exactly suitable for the mushroom and unsuitable for fungus " weeds ". Prevention, as distinct from treatment, therefore consists in having a thoroughly clean environment for the beds (see below) so that possible infection from such places as bed boards or floor is eliminated.

Further work is required before it can be stated with certainty how many of the different harmful fungi are introduced with the compost and how many with the casing soil. When this is known, prevention will perhaps be easier and more completely successful. Thus, recent research by Lambert (1930) showed that *Mycogone perniciosa* is sensitive to prolonged exposure to moderately high temperature and, under certain conditions, it is unable to survive even 6 hours at a temperature of 108° F. In England, Ware (1933) showed that *Verticillium Malthousei* behaves similarly. These important facts make it appear improbable that either disease can be brought into the house with the manure if this has been properly fermented at a temperature above 140° F., and especially if that temperature is again reached when the beds are first made up. If the ordinary strict precautions of cleanliness have been taken, if pure culture spawn has been used and if the manure has been properly prepared at high temperatures, it would seem, in the light of this research, that the casing soil is certainly the chief means of introducing both these diseases to mushroom houses. With Mycogone, this conclusion is supported by the results of earlier work, for Smith (1924) first showed that infected casing soil could be made harmless by treating it with a 2 per cent. solution of formalin, a result afterwards put to use successfully by Beach in the disinfection of fresh casing soil, with consequent elimination of *Mycogone,* in commercial mushroom houses in Pennsylvania.

As a precaution, therefore, against *Mycogone, Verticillium, Fusarium* and perhaps *Dactylium,* it is better to use soil dug from below the top 9 in. or, where trouble has already been experienced with a source of supply, to try to devise some method of warming the casing soil (in preference to chemical treatment) before use.

Partial sterilization of the casing soil by steam is carried out by an increasing number of growers in this country. One method is to place the soil in a wooden box about 5 ft. square and 6 in. deep and cover it with a sheet metal lid which fits inside the box. The steam is injected, with a boiler pressure of 50 lb., by a pipe fitted in the lid and is turned off only when the temperature at the bottom of the box has reached about 140° F. Beach (1937) describes a "bin" fitted with a false bottom; it is built on the ground and is constructed with planks. The false bottom consists of boards with wide cracks or with holes to permit the passage of steam which comes from a perforated pipe inserted beneath. The false bottom is advantageous in facilitating removal of soil with spade or shovel, in permitting drainage of excess moisture and perhaps in checking overheating. The soil in the bin is covered with wet sacks or with tarpaulin. The bin is chiefly useful in conserving heat. Such equipment is preferable to the box described above in that steam is more easily driven upwards than downwards, especially after the upper surface has become wet. As a result, with the box equipment, only a shallow layer of soil can be treated or there is risk of overheating the wet upper surface. Good boiler pressure is essential to secure proper heating and to avoid wetting the soil too much. The depth of soil in the bin may be 12-15 in. and steaming is continued until the whole of the upper surface has reached a temperature of 130°-140° F. Beach states that if possible the bottom temperature should not be allowed to exceed 180° F. The size of the bin will depend on the capacity of the boiler but it would be useful to have two, side by side, each large enough to take a cartload.

An alternative, for small-scale work, is to use one of the portable steam sterilizers such as are made by Jones and Attwood, Ltd., Titan Works, Stourbridge, or by Leale, Ltd., Guernsey. With these there is little or no pressure of steam in the boiler. They are mounted on wheels and are provided with a firebox over which is a container for water so that steam passes through the soil from below. An outfit costing £15 and taking 10 cu. ft. of soil will heat it to 125°-140° F. in about 3 hours.

For work on a larger scale the usual horticultural equipment, necessitating a large boiler and steam " grid ", is used. Full information on soil sterilization by all the above methods as well as by baking and by the use of chemicals is contained in the Ministry's Bulletin No. 22, " Practical Soil Sterilization ".*

With the methods already described, the steam and soil are not under pressure in the soil container as they are with autoclaving. This process, using specially made apparatus such as converted tip-trucks from a railway, has very occasionally been carried out by mushroom growers although the higher temperatures obtainable are not necessary. The chief advantage is that the humidity of the soil is hardly altered.

An alternative and more recently introduced process of soil sterilization is by the use of electrodes which are placed at intervals in the soil. Heating is brought about by the passage of the current. Apparatus suitable for quantities of soil from 40-50 lb. up to 1 ton is made by firms who specialize in such work and even the one-ton sterilizer can be of the portable or movable type. The soil leaves the sterilizer in dry and friable enough condition to be used for casing whilst still warm. The apparatus can be arranged to work on any A.C. or D.C. supply system, the consumption being 36 units, or thereabouts, per ton of soil, depending on the electrical resistance of the soil. This consumption is for raising the temperature to 212° F. (in 1 hour, 30 minutes), but for the lower temperatures required for mushroom casing soil it would doubtless be less.

A clean environment, to which reference has been made above, is of course essential if a reasonable chance is to be given for fresh beds to produce a clean crop. If care is taken in every other direction, including for example the use of pure culture spawn and sterilized casing soil, it is obviously foolish to lay down the beds in a place not made free from infection, and hygienic measures are usually taken whether or not disease has been previously apparent in a house or on a site chosen. An exception to this is where an absolutely new house with concrete floor or with tier beds is to be used for the first time.

When, at the end of cropping, the old beds are taken out, all materials should be cleared away from the vicinity of the houses and, with an earth floor, a layer of the top soil should also be removed. For reasons of cleanliness, some growers

* Bulletin No. 22, *Practical Soil Sterilization*, by Dr. W. F. Bewley. Obtainable through a bookseller, or from H.M. Stationery Office. Price 1s. od. (by post 1s. 1d.).

purposely lay down on the pathways ashes or some such material which holds moisture and which is easily scraped away when the house is cleared. Infected bed material must on no account be used for manuring ground that may at some subsequent time be required for obtaining casing soil for, although it is applied to the surface, it may lead to contamination of the lower parts of a pit dug in it. An exception to this is to be found on crowded nursery premises where, however, steam sterilization of the soil is the customary practice. All implements used, as well as boots, clothing and hands of workers who have removed badly infected beds, are likely to carry disease to other houses.

The empty structure should next be sprayed with formalin, using a power machine, at a minimum pressure of 70 lb., and with guns or lances such as are employed in commercial fruit plantations. A 2 per cent. solution of formalin* is used and this is made by mixing 1 gal. of commercial formalin with 49 gal. of water.

The whole of the inside, including floor, walls and roof, is treated in such a way that all crevices likely to harbour fungus spores receive some of the fungicide. Ventilators and doors may be open during this operation to secure penetration of the fluid to parts of the framework often covered. Goggles and rubber gloves are an advantage. When the floor is of concrete no further special treatment is required but when of earth it may be specially dressed, on the recommendation of Dr. W. F. Bewley and Mr. J. Harnett, with the same strength of formalin solution and using 50 gal. on every 60 sq. yds. of soil. This comparatively wide distribution of the 50 gal., as explained on p. 30, under the section on " Making the Beds ", is to sterilize the top 3 in. only. Five to seven days after treatment a covering of new second-spit soil is placed over the ground to the depth of 2 in. and, after consolidation, it is ready to receive the new beds. Such treatment of the soil should be done at least a fortnight before the new beds are to be made up.

Houses built for the tier system of growing are cleaned with water first, preferably with spray guns, and are then sprayed as above described.

After the spraying has been done and the floor soaked (if of earth) the house is shut down and the temperature raised as high as possible (up to 90° F.) for 48 hours. It is then

* " Formalin " consists of a 40 per cent. solution of the gas formaldehyde in water.

opened up to allow the vapour to escape. In houses constructed for shelf beds, the last precaution, stated to be (see p. 31) of vital importance, is to flame the bed-boards and supports with a painter's blow-lamp or, preferably, with a blow-lamp of larger size. The flame is moved quickly over the wood so that projecting fibres are singed but the surface of the timber is not burned.

An alternative spray fluid is a 1 per cent. solution of copper sulphate (1 lb. of finely crystalline "bluestone" in 10 gal. of water). This solution is cheap, penetrates well and has a lasting preservative effect on wood. After it has been allowed to dry it has no harmful effect on mushroom growth, even if used on the bed-boards themselves. The disadvantage is that iron or galvanized vessels must not be used in which to make the solution and only spraying machines with a wood tank or those, such as *knapsack sprayers, with a tank made of brass* or similar alloy can be employed without damage to the tank.

Another alternative is a 2 per cent. solution of crude carbolic acid. This contains a mixture of cresols and is also known as cresylic acid. One gallon of pale straw-coloured cresylic acid (97-99 per cent. pure), together with 8 lb. of pure potash soap, is heated in a bucket over a brisk fire for about 10 minutes to dissolve all the soap. One part of this mixture is dissolved in 50 parts of water and is used for spraying the interior. The house is then closed for 4 days and finally opened for ventilation.

Lime-sulphur, at a strength of 1 gal. of the concentrate in 15 gal. of water, is another good fungicide and probably kills some insects and mites; it cannot be used in copper or brass spray tanks unless they are specially lined or made of special alloy.

Goggles and rubber gloves should be worn when spraying with any of the above fluids. Formalin is probably the most useful of them all because the 2 per cent. solution can be employed for disinfecting both house and soil. It differs from lime-sulphur and copper sulphate in that its active principle (formaldehyde gas) vaporizes very readily and it has not therefore the permanence of, for example, copper sulphate sprayed on woodwork. Disinfection, however, is quickly performed.

INSECT AND OTHER PESTS

A considerable number of insects and similar creatures are known to attack mushrooms but there are relatively few which are of great importance when the crop is grown in modern mushroom houses, though most growers sustain appreciable loss at times from them. Most of the creatures concerned are very small and difficult to identify with certainty so that the destructive species can only be differentiated from harmless or even beneficial ones by careful examination. Growers are often concerned at the large number of flies and mites commonly seen around compost heaps and on beds, fearing that serious attacks on mushrooms will result, but this is by no means always so. Stable manure is attractive to a great variety of forms of animal life, because, directly or indirectly, it provides food for them. It is, for instance, a substance on which many fungi grow, so that creatures which feed upon fungi might be expected to congregate on it. On the other hand, it attracts many small forms of life that require only decomposing animal and vegetable refuse and are not directly concerned with fungi. The fungus-feeders may eventually attack mushrooms but the others may be disregarded from this point of view. Finally, as usually happens, numbers of carnivorous and parasitic mites and insects congregate in any such medium, because it supports a population of creatures on which they prey. For all practical purposes, all but the fungus-feeding forms may be disregarded and it is with such that the following account is concerned.

It is convenient to classify the pests into three groups; but this classification is a very rough one, for insufficient knowledge has been gained as yet about the way in which some of the attacks arise and the means by which pests gain access to the beds. It is adopted only because it gives some indication of the possible sources of infestation, and thus enables a clearer view to be obtained of the success likely to be achieved by various control measures. The three groups suggested are as follows:

1. *Creatures normally inhabiting buildings and situations used for growing mushrooms;*

2. *Creatures that may be introduced with manure, soil or straw litter used for covering beds;*

3. *Creatures that are specific to fungi,* i.e., they are attracted to growing mycelium or mushrooms. Such creatures, although they may occur in manure (2 above) may also be attracted into mushroom houses even if they are not brought in with manure.

1. Creatures normally inhabiting Buildings and Situations used for growing Mushrooms. In nearly all instances these are not true insects, but are other animals which commonly frequent semi-dark, moist situations, especially where there is old wood and brickwork in which they can shelter and an accumulation of dust and debris of an organic nature. They appear to feed chiefly upon such organic matter or upon the fungi growing on it, but they turn their attention to mushroom beds when these are present, for from the very nature of its composition, a prepared mushroom bed provides them with suitable conditions and food supply. On the other hand, these animals are not usually numerous in the compost itself when it is brought in, so that unless they are already present in the building concerned, they are not likely to become sufficiently prevalent to be harmful. It follows then, that the repair of structural woodwork and masonry and attention to general hygiene are essential for successful control; unless this is done, the results obtained from the application of other measures may be disappointing.

WOODLICE. These familiar "pill-bugs" or "monkey-peas", as they are called locally, normally inhabit decaying wood and several species* have been recorded as injurious to mushrooms. Some roll themselves up into a ball when disturbed, but in others this characteristic is not so apparent. They spoil the appearance of mushrooms by chewing holes in the caps. This damage is done at night, for they hide in the day beneath straw covering on beds, or in crevices in soil or walls. When attacking ordinary glasshouse crops, they can be controlled by poison baits composed of 1 lb. Paris Green to 25 lb. coarse bran, or 1 lb. Paris Green to 56 lb. dried blood. The use of an arsenical poison like Paris Green is undesirable, however, on mushroom beds but an effective control can be obtained by the use of Pyrethrum insecticides, which have the advantage of being non-poisonous to human beings. Pyrethrum in dust form is particularly useful, since it can be blown into crevices where woodlice hide and scattered lightly over beds and along the bases of walls. Woodlice walking over the dust are killed and attacks can be kept in check in this way.

SLUGS. Slugs are essentially inhabitants of damp situations and most frequently attack beds near the walls of a house but they are particularly important on outdoor beds. They eat large pieces out of the caps and stalks, sometimes devouring quite half a mushroom. The file-like "tongue" with which slugs tear off their food gives the attacked mushrooms the appearance of having been eaten by rats or mice. The presence of slugs is, however, generally betrayed by slime marks. Hand

* For example, *Oniscus asellus* L., *Porcellio scaber* Latr., and *Armadillidium vulgare* Latr.

collection is the most effective method of dealing with attacks, for slugs are usually few in number and large enough to be seen easily. Moreover, they are so fond of mushrooms that they eat them in preference to some poison baits. A few collecting visits at night with the aid of a good light is sufficient to keep attacks in check.

Careful use of meta-fuel bait is worth consideration. A suitable mixture can be made by incorporating 1 part of powdered meta-fuel with about 50 parts of bran, by weight. The mixture should be placed in small heaps, not more than half a handful each, the heaps being covered with pieces of tile or board sufficiently raised to allow slugs to crawl beneath. Meta-fuel is poisonous to human beings. The bait heaps should never be placed on beds, but along the bases of walls. In all probability a cellar or building can be cleared of slugs most effectively before mushroom beds are laid down, though measures might need to be more protracted out of doors. One small heap of bait every three or four yards should be sufficient.

MILLIPEDES. These are elongated creatures with very numerous legs, and many of the species curl up into a spiral, spring-like form when disturbed. Three species* are known to injure mushrooms. They are all rather less than $\frac{3}{4}$ in. in length when adult, but immature forms are much smaller. *B. guttulatus* is very pale in colour, with a row of red spots along each side; the others are pale fawn or brown, with a row of darker brown spots along each side. *C. britannicus* is more than twice as stout as the other two. Injury occurs at ground level and takes the form of holes eaten in the stalks, sometimes extending deeply into the tissue. Crops growing in glasshouses seem to be most frequently attacked. Damage can largely be prevented by the use of the nicotine sprays mentioned below for the control of fly attacks.

SPRINGTAILS. These minute insects, which are entirely wingless, derive their name from their marked power of jumping. They normally live in soil, particularly if it has a high humus content, and, like millipedes, frequently occur in glasshouses, where severe attacks sometimes occur. It is not improbable, however, that under some conditions they are present in appreciable numbers in the manure itself. The most injurious species† by far is a tiny insect about $\frac{1}{16}$ in. in length, and it varies from silvery-grey to dark-bluish-black in colour. Another

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* Viz., *Blaniulus guttulatus* Bosc., *Choneiulus palmatus* Nemec., and *Cylindroiulus britannicus* Ver.

† *Hypogastrura* (*Achorutes*) *armata* Nic.

species* is often found in smaller numbers. Masses of the insects are sometimes to be seen on beds or assembled near walls, and they are often referred to by growers as " gunpowder mites ". They are able to penetrate into the beds, where they attack the spawn and destroy the young buttons just as they are breaking through the casing soil. In extreme cases, total failure of crop may result, but this is rare and the more usual type of injury takes the form of small holes bored into the stalks, which connect with tunnels extending deeply into the mushroom (Figs. 10 and 11). These may be continued right through the cap and splitting of the stalk often results (Figs. 12 and 13). The tunnels are usually drier than those made by fly maggots and, of course, where springtails are entirely responsible for the injury, fly maggots are absent. Nicotine sprays and dusts are useful in preventing attacks and it is probable that Pyrethrum insecticides are also effective. Nothing is known about the conditions that induce the very severe attacks which sometimes occur, but possibly the state of the compost is largely responsible. Springtails seem to be killed readily by the high temperatures reached during fermentation and, according to observations made in the U.S.A., they are more susceptible in this respect than many other insects.

2. **Creatures that may be introduced with Manure, Soil or Straw.** When true subsoil is used for casing, it may be assumed that no insects are introduced with it, for such forms of life are rare in subsoil. Surface soil, on the other hand, may contain springtails and millipedes, and should not be used unless previously heated. Stable manure is known to contain many forms of life, and there is little doubt that some of the creatures responsible for injury to mushrooms are part of its natural fauna. The number of insects found in a heap of stable manure decreases with successive turnings, probably because the manure is gradually brought into a condition less suitable for them, and also because many of them are killed by the heat produced during fermentation, hence the belief, largely supported by experience, that efficient composting is one of the primary points in successful mushroom growing. The outer layers of a fermenting heap, however, always remain more or less at atmospheric temperature and the rise of temperature internally is slow enough to enable some proportion of the more active stages of insects and mites to migrate to regions where suitable conditions obtain. Eggs and other stages incapable of such migration are probably killed, though little is known

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* *Proisotoma minuta* Tulb.

about the temperatures that are fatal to many of the species concerned.

MITES. Mites are very common creatures, although by reason of their small size they usually attract little attention unless present in large numbers. Many species occur in organic debris, among animal and vegetable refuse and on straw and grain. Some are predatory in habit, feeding upon other mites and insects, while others consume decaying plant or animal tissue or fungi growing upon it. Broadly speaking, predatory mites can be distinguished from others by reason of their much more rapid movements. They usually occur in numbers in stable manure and often upon mushroom beds but their presence is simply an indication that other forms of life, which are suitable food for them, exist there. The majority of predatory mites that the grower is likely to observe belong to the family *Gamasidae* (*Parasitidae*). They are pale in colour when young, but become a darker yellowish brown as they become adult.

From the point of view of injury to mushrooms, only those species that feed upon fungi need be described. Many other species, such as those that infest grain and stored food products, occasionally occur accidentally upon mushroom beds, having been introduced in some way, but they do not attack mushrooms. Most of the fungus-feeding mites belong to the family *Tyroglyphidae*. They are minute, soft-bodied, pale, translucent creatures, sluggish in habit and inconspicuous except when congregated in numbers. They are not, as a rule, plentiful in stable manure, but there is evidence that they become much more numerous in manure that is left undisturbed and partially dries out. Very little is known, however, of their habits and distribution, and the sudden appearance of large numbers on mushroom beds just beginning to crop has not been satisfactorily explained. These mites are usually all referred to as "the Mushroom Mite": actually at least two and probably three or more species are generally concerned, but they all cause much the same type of injury, holes of various sizes being made in the caps and stalks (Fig. 14). One of the most common species, *Tyroglyphus dimidiatus* (*longior*) is well known on grain, stored foodstuffs and cheese and it often abounds in hay and straw, from which latter source it probably gains access to mushroom beds. It is, however, widely distributed and is common on old leaves, among debris in glasshouses and has been recorded as attacking various glasshouse plants. Only during the past few years has it been recognized as one of the species injurious to mushrooms. Another species, *Tyroglyphus* (*Caloglyphus*) *mycophagus*, which has long been known to cause damage to mushrooms, seems to be essentially associated with fungi, while another very closely related species, *Caloglyphus* (*Cosmoglyphus*) *kramerii*, has also been recorded as destructive. One other species in this family, *Histiostoma rostroserratum*, often occurs in mushroom beds and upon over-ripe mushrooms, especially under damp conditions. It is not regarded as directly injurious in this country, but *Histiostoma gracilipes*, which occurs in America, is looked upon there as a serious pest.

While further investigation is needed on the question, it is almost certain that infested manure or straw is the main source from which mites are introduced. All the injurious species mentioned above have been found in manure and refuse from stables and it seems likely that they are not all killed during the composting process. Should any survive, the temperature and moisture conditions existing in a mushroom bed are such that they breed very quickly, for, under those conditions, the life cycle can be completed in about three weeks. Infestation of beds may, however, come about in another way. Most of the Tyroglyphid mites give rise, at one period in the life cycle, to a minute stage known as the hypopus. This is a non-feeding stage, adapted for the purpose of clinging to insects and other creatures and so being transported to a new locality. After a varying period in this stage, generally a few days, the hypopus becomes transformed again into a typical mite. Should several hypopi be carried to a suitable site they may form the nucleus of a new colony. The hypopus of some species is often to be found clinging to other mites, millipedes and flies, so that these creatures, if they are able to gain access to a mushroom house from some outside source where the mites are present, may be the means of introducing them. In *Tyroglyphus mycophagus*, for instance, the hypopus very commonly occurs, but the hypopus of *Tyroglyphus dimidiatus* is not known, so that the latter species is probably not distributed in this way.

A certain number of mites which do not belong to the family *Tyroglyphidae* occasionally cause some injury to mushrooms. One of these, the Long-legged Mushroom Mite, *Linopodes antennaepes* (*motatorius*), is a very pale yellowish fragile mite, capable of extremely active movement. The front pair of legs, which are about three times the length of the body, are not used for running but are carried out in front in the manner of " feelers " and are usually waved about vigorously. Both in this country and the U.S.A. this mite is known to attack mycelium in the beds and also to sever mycelial strands at the bases of mushrooms (Fig. 19), causing them to slow down in growth and eventually to fall over. A reddish-brown coloration at the bases of the stalks is typical of the attack; indeed this is often the first indication of the presence of the mites. This species has been found commonly in damp straw in stack-yards and is almost certainly introduced to beds on such material. It occurs also on outdoor beds.

At times, large clusters of very minute reddish-brown mites are seen on beds and on mushroom caps. These belong to the family *Tarsonemidae* and their relation to mushroom culture is not known. They are probably not fungus feeders and are closely related to a mite which is known to be predatory upon certain insects infesting stored grain. When present in large numbers they render mushrooms unsightly, but no direct injury has ever been traced to them.

A small, hard, dark reddish-brown species, *Oppia nitens*, has occasionally been recorded as injurious. It bores tiny galleries in the stalks and caps, but is seldom numerous and usually of little importance.

Control of Mites. Until more is known of the factors governing infestation of beds by mites, it is impossible to make definite recommendations for the prevention of attacks. The fact that injurious species of Tyroglyphids occur commonly in stable refuse suggests that the manure itself may be infested and it must then be assumed that some proportion of the mites present persist throughout the composting process. It appears, however, that growers who obtain supplies of fresh stable manure are seldom if ever troubled by mite attacks and it is not improbable that infestation of manure only becomes serious when it has been stored for a period and becomes partially dried out. The presence of any appreciable quantity of accumulated dry debris from stable floors would also be likely to increase the mite population considerably. In this connexion it may be significant to note that attacks by *T. mycophagus* and *C. kramerii* have become less prevalent in the past few years, the most common injurious species during that period being *T. dimidiatus*. There is reason to think that the two species first mentioned are chiefly found in stored manure and debris and, if the demand for manure has resulted in the clearing up of old accumulations, the relative absence of these two species may be explicable. *T. dimidiatus*, however, is known to be a very widespread species, which is certainly not associated with manure alone, and attacks may easily arise from other sources. The possibility that flies and other creatures, through introducing hypopi, may be partially responsible for the incidence of attacks by some mites must not be overlooked, though it would seem that this factor is not always of importance, since flies are prevalent in most mushroom houses, whereas mite attacks are much less general. Hypopi could only be introduced, in any case, if flies and other creatures first visited mite-infested material before entering mushroom houses. Attacks by the Long-legged Mushroom Mite are almost certainly related to the use of infested straw, especially when this is used for covering beds.

Until further knowledge is obtained, little definite action can therefore be taken to prevent attacks. Probably the most important step is to avoid the use of old, partially dried manure; general hygienic measures, especially the destruction of debris, must be stressed, notably where crops are grown in glasshouses. Efficient composting and the subjection of all parts of the heap in turn to high temperatures probably does much to reduce the numbers of mites that may be present in the manure.

Nicotine sprays and dusts have no effect upon them and Pyrethrum dust is also ineffective. Pyrethrum sprays seem to give some degree of control, possibly because of the oil they contain. Oil-containing sprays are, however, apt to cause serious injury to mushrooms, as they sometimes produce a typical deformity and render the mushrooms unfit for sale. The conditions governing the damage caused by oil sprays need further investigation, for instances have been observed where no injury has resulted and a good control of mites has been obtained. Oil sprays not containing Pyrethrum have also been employed and are sometimes applied warm, at a temperature of about 100° F., to beds during cropping. Under such conditions, enhanced control of mites seems to be obtained, but growers are advised to proceed carefully with such sprays and to test them first on a small portion of a bed.

On the assumption that mite attacks arise from individuals present in the compost, certain oil emulsions have been used for treating this, the spray being applied as the heap receives its last turning. A good control of mites seems to have been obtained in some instances, and the treatment is said to have no harmful effect on cropping or upon the mushrooms themselves.

In America,* fumigants are regularly employed for the control of both flies and mites, hydrocyanic acid gas and sulphur

* These remarks apply to the shelf-bed system of growing, which is general in America.

dioxide gas being the two substances used. Hydrocyanic acid gas is not regarded as giving as good control of mites as does sulphur dioxide gas, though the former is quite effective against flies and springtails. Fumigation with these gases is practised only at two periods, first, when the houses are empty or are being cleared of old beds, when heavy dosages are given, and second, when fresh beds have been laid down and have reached their highest temperature ("peak heat"). The high temperature then reached drives insects and mites to the surface layers, and weakens or kills many of them. Fumigation with sulphur dioxide gas at this stage is said to result in reasonable freedom from attacks. The gas is produced by burning sulphur in iron pans in the houses. When the houses are empty, 5-6 lb. of flowers of sulphur per 1,000 cu. ft. are burned, but when new beds are laid down and peak heat is reached, the dosage is reduced to 1½-2 lb. per 1,000 cu. ft. The house is closed for about 6 hours, after which it is ventilated. Sulphur dioxide gas is very destructive to active spawn and to mushrooms, so that it cannot be used if there is any chance of gas escaping into adjacent houses where beds are either spawned or cropping. The treatment is applicable only when a house is filled with beds at one time, for it is essential to have all the beds at peak heat during the operation. The gas is lighter than air and tends to rise, so that beds nearest the floor are not subjected to such intensive fumigation as those at a higher level. Moreover, beds nearest the floor do not as a rule attain as high a temperature as the upper beds and any attacks that occur after fumigation are generally found on the lower beds. Leakage of gas is a serious factor and, as an appreciable time elapses after igniting the sulphur before the maximum gas concentration is reached, some form of apparatus for distributing the gas is often installed. The gas is sometimes introduced from the outside by a blowing device which causes air to pass over burning sulphur. Considerable corrosion of metal fittings, such as fans and electric wiring, commonly occurs, and difficulty seems to have been experienced in getting a type of sulphur that will burn satisfactorily. Liquid sulphur dioxide might prove suitable for the evolution of the gas.

FLIES. Many different species, belonging to various families, are injurious to mushrooms, the actual damage being caused by the feeding of the larvae or maggots. They may be found in the pieces of spawn after these are planted, or attacking the mycelium growing out from them. When cropping begins, the mycelial strands at the bases of buttons may be severed, causing them to turn brown and preventing further development;

Tunnels are made in the stalks and caps, rendering the mushrooms quite useless.

Probably the most important family of flies concerned is that known as the Fungus Gnats.* They are dark in colour, about $\frac{1}{8}$-in. long, and are often to be seen running actively over the beds. Though quite capable of flight, they do not readily take to the wing, and often concentrate around windows. Five species†, all belonging to the genus *Sciara*, have been bred from larvae attacking mushrooms, and of these *S. fenestralis* seems to be the most common. This species lays eggs at the bases of stalks and on the casing soil, and the larvae, on hatching, work their way into the beds or tunnel in the mushrooms. The whole life cycle occupies 4-6 weeks. On mushroom beds, there is always overlapping of generations, and all stages of the flies may be found at any time. The larvae of all species of *Sciara* are creamy-white, legless maggots having a small, hard, black head, and when fully grown they are almost $\frac{1}{4}$ in. long. Attacks by these flies often result in the appearance of numerous small, brown buttons, and if these are plentiful a search should be made around them for the larvae. Such brown buttons, however, may be produced from other causes, and it is safe to attribute the trouble to flies only if their larvae can be found. In larger mushrooms evidence of attack is usually seen when the stalks are trimmed. In severe cases the whole mushroom is reduced to a sponge-like mass (Fig. 17).

Phorid flies‡ are small dark flies, about the same size as Sciarids, but with stouter bodies and shorter wings. Only one species§ seems to attack mushrooms to any extent. Phorid larvae may be distinguished at once from Sciarids by the fact that the Phorids do not possess the definite black head which is easily seen in the Sciarids. The head end, in the Phorids, is more pointed than the tail, and contains the jaws, which are visible as obscure, dark structures embedded in the body. These larvae frequently occur in the compost, especially around pieces of spawn, on which they feed, and the mycelium growing out from the pieces is also attacked. Buttons are tunnelled in the same manner (Fig. 18) as with Sciarid larvae. Attacks by Phorids are more common during the summer months, while Sciarid attacks continue throughout the year and may occur on crops grown during the winter in heated buildings.

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* *Mycetophilidae.*

† *Sciara fenestralis* Zett., *S. umbratica* Zett., *S. agraria* Felt., *S. vivida* Winn. and *S. auripila* Winn.

‡ *Phoridae.*

§ *Aphiochaeta* (*Megaselia*) *albidohalteris* Felt.

Midges* are slender, fragile flies, the adults seldom being seen in mushroom houses although their larvae often occur in great numbers. The latter sometimes swarm in the compost or on the surface of the casing soil, especially after damping down. They are about ⅛ in. in length, yellowish or orange in colour and their bodies are more or less pointed at each end. They have no definite head and resemble the Phorid larvae in this respect. They possess, however, a small dark structure, known from its shape as the " anchor process ", which is often visible with a lens, and is situated on the underside of the body just behind the head end.

Many of these midge larvae are remarkable in that they are capable of reproduction, giving rise directly to other similar larvae, and the normal life cycle, involving the production of adult flies, is often not followed for long periods. Thus, a few midge larvae may, in a short time, increase very greatly in numbers, and this remarkable increase has often been commented upon by growers. The difficulty of obtaining adult flies makes the certain identification of species very difficult, but two species† have been bred, and there are probably others.

The injury caused by the larvae is of a more or less superficial type. They collect in layers on the stalks or beneath the gills, seldom penetrating to any great depth, and cause a " stringy " appearance of the skin. Beds frequently become covered with masses of the larvae after damping and, as the soil dries again, they go below the surface, where they probably feed upon the mycelium and the bases of the stalks. It has been observed that unsatisfactory crops are often produced on beds where these larvae are plentiful.

Numerous other small dark flies, belonging to the family *Borboridae* (*Sphaeroceridae*) are often to be seen in mushroom houses and around manure heaps. They are not unlike the Phorids in superficial appearance, but, though the larvae of some of them live in manure, they are seldom found attacking mushrooms. The larva of one species‡ has occasionally been found causing injury similar to that caused by Sciarids and Phorids, but no serious attacks have been recorded. Somewhat larger flies, of the family *Drosophilidae,* also occur, and their larvae have been found in decaying mushrooms, but not in those of marketable quality. Flies of this family are known to breed in damaged and decaying fruit and similar substances

* *Cecidomyidæ.*

† *Mycophila speyeri* and *Miastor* sp.

‡ *Leptocera heteroneura* Hal.

and they probably do not lay eggs upon mushrooms until these are beginning to decompose. Much larger flies, resembling house flies, are also to be seen in mushroom houses. They arise from larvae which feed in manure but are in no way destructive to mushrooms.

Control of Flies. It is clearly important to know to what extent flies in various stages are introduced with the compost, and on this point there is, as yet, insufficient information. Larvae of *S. fenestralis* have been found in considerable numbers in both fresh manure and compost, and larvae of Phorids have also been found occasionally in similar situations. It is stated in America that larval and other stages of both Sciarids and Phorids occur in compost and may be taken into the mushroom houses in this way. Efficient turning of the manure, including the breaking of all lumps, which results in the exposure of the whole heap to relatively high temperatures, is therefore likely to exert some control. More information, however, is needed before it can be stated what temperatures are fatal to the various stages of these flies. Larvae of some of the non-injurious flies have been found in parts of a manure heap where the temperature was 150° F., apparently living quite normally, but it is most probable that the outer layers, which remain at very little above atmospheric temperature, contain most of the active stages of flies.

Flies can be controlled to a large extent by fumigation with hydrocyanic acid gas or sulphur dioxide gas, as described above for the control of mites. Such a fumigation is often carried out as a routine measure at peak heat and sulphur dioxide is never used after spawn is planted. It must never be forgotten that sodium cyanide, calcium cyanide, and hydrocyanic acid gas are all deadly poisons, and that, although with reasonable precautions they can be safely employed, nevertheless carelessness may lead to a fatal accident. The Hydrogen Cyanide (Fumigation) Act, 1937, enables regulations to be made prescribing the conditions in which fumigation with hydrocyanic acid gas (and other poison gases) may be carried out. The fumigation of agricultural and horticultural buildings not forming part of any building " used for human habitation " is exempt from the regulations already issued under this Act, and in order that this exemption may be justified in future it is of the utmost importance that growers should take every precaution when using cyanides. When hydrocyanic acid gas is employed, up to 1 lb. of calcium cyanide per 1,000 cu. ft. is used, but occasionally another fumigation is given with a lower dosage after spawning. In the latter case, up to 1½ oz. calcium cyanide per 1,000 cu. ft. is employed, the beds being in a relatively dry condition at the time. A stationary or slightly rising temperature should also be maintained during the operation to prevent condensation, since the gas dissolves readily in moisture, and severe injury, as well as loss of effectiveness, may result.

Regulation of temperature plays an important part in the control of fly attacks, probably because relatively low temperatures considerably retard the rate of development of the various stages and may prevent egg-laying. Thus, at temperatures around 55° F., attacks are generally slight, and though cropping at this temperature is relatively slow, better mushrooms are produced. Some growers adopt the practice of maintaining rather higher temperatures immediately after spawning, to induce rapid running of the mycelium, and then lower the temperature somewhat as cropping commences. Phorid fly attacks especially seem to be associated with higher temperatures, for trouble with these flies is seldom experienced except in the summer months.

Attention to general hygiene is always necessary. Over-ripe mushrooms should not be left on the beds, but should be burnt, along with all discarded mushrooms and cut stalks, since such material both attracts flies and provides a suitable breeding place for them.

Insecticides in liquid and dust form can be used with advantage to supplement other control measures. Sciarids can largely be kept in check by periodic watering or spraying with nicotine, but such treatment must be started early and carried out as a routine measure, so that there is no chance for large numbers of flies to become established. Nicotine (98 per cent.) at the rate of 1 fluid oz. to 10 gal. water, makes a suitable spray for this purpose, but soap should not on any account be added to it. The spray is harmless to mushrooms and may be used at any period, but, when cropping is in progress, it is best applied after a heavy picking of all saleable mushrooms for it sometimes causes discoloration of the caps of white varieties. Fumigation with nicotine can also be practised at any time for the purpose of killing adult flies and, as with nicotine spraying, it is most satisfactory at temperatures above 60° F. Recent experience has shown, however, that insecticides containing Pyrethrum extract are more satisfactory than nicotine for the control of flies. Proprietary extracts are available for use with a small atomizer, which distributes the liquid in the form of a cloud of minute droplets. The liquid should be directed into the air, so that the cloud fills the house; it is not necessary or desirable to apply it to the beds themselves since some discoloration of the caps may result from the use of certain extracts. Treatment of a house can be carried out more rapidly than when nicotine spraying is employed and the amount of moisture which the beds receive is also more readily controlled. Persistent nicotine spraying, especially on flat beds, may cause them to become unduly wet. About a pint of a suitable Pyrethrum extract is sufficient to treat a house which normally requires about 6 gallons of nicotine spray. As with nicotine, the effect of Pyrethrum is most marked on the adult flies. Periodic applications should therefore be made, commencing immediately spawn is planted, with the idea of preventing a large population of flies from becoming established. Up to the commencement of cropping, an application may be necessary every 3-4 days, but once cropping has started, weekly applications will probably be found satisfactory. The frequency of treatment can at all times be adjusted according to the number of flies seen in the house. It is unnecessary to maintain a relatively high temperature when using Pyrethrum fluid.

3. Creatures that are Specific to Fungi. Probably the majority of mushroom pests should, in reality, be included under this heading, with the exception of slugs, millipedes and woodlice. Those pests, which, as suggested previously, may be introduced with manure, soil and straw, are almost certainly present in such substances only because fungi grow there and any other material on which fungi grow might equally well prove a means of introducing them; even springtails and woodlice which are plentiful in some soils and in decaying woodwork of damp, dark buildings, may live there because fungi also grow under such conditions. Excluding slugs and to some extent millipedes and woodlice, most mushroom pests ought probably therefore to be regarded as "specific to fungi". They have been included in the two former groups as well in order to indicate the manner in which they may be introduced into mushroom houses; the purpose of this third group is to point out that, if they are specific to fungi, they may also attempt to gain entrance to mushroom houses when beds are present and attacks may develop even though the houses themselves and the materials taken in were previously quite free from pests. Although there is evidence that some stages of flies, for instance, are introduced with the compost, it is unlikely that attacks are entirely brought about in this way; similarly, various mites may be attracted to beds once spawn is planted. On the whole, the greater the creature's range of action, the greater is the probability that it will migrate to suitable food material and the winged insects are therefore most likely to be of importanc in this respect. They may also, as previously suggested, b a means of introducing mites.

Once beds have been spawned and covered with casing soil there would seem to be less chance of insects and mites work ing their way into the compost than during the period whicl precedes casing. In practice, beds must be left uncased fo several days after they are laid down and, if a " peak heat ' treatment is not carried out, pests may readily become estab lished then. Most minute insects and mites are, however, cap able of penetrating a thin layer of soil and it is doubtful i casing soil provides any real protection to the spawn or origina growth of mycelium from it; moreover, as soon as myceliun penetrates the casing soil and buttons appear, food become available near the surface.

It is difficult, even in properly constructed houses, to preven immigration of insects and mites and it is almost impracticabl in converted buildings. Some degree of protection may b gained by screening ventilators and other openings with cheese cloth or similar material, but it is easily torn and needs frequen renewal. When houses are being built, the use of fine mesl wire gauze is worth consideration for, though the initial expens is greater, its effective life is much longer than that of cheese cloth. The best protection is afforded, however, by the routin use of insecticides, but it is important to realize that sucl measures must be commenced early in the life of the beds. B the time the first mushrooms appear, insects and mites ma have become firmly established for they are able to feed jus as readily upon mycelium as upon mushrooms. Measure should therefore be commenced immediately after plantin spawn and should be continued at intervals. If " peak heat ' fumigation has been carried out, however, there may be rather longer period of freedom from infestation. Periodi fumigation or spraying with nicotine is sometimes practise for the control of flies, but the atomization of Pyrethrum spray as described above, is probably the best procedure for gener purposes. The value of light traps and sticky paper traps doubtful; many insects may be caught on them and they a of service in showing whether flies are becoming numerou but probably they are best regarded as useful in this way rathe than as an effective means of control.