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CASING MEDIA FOR *AGARICUS BISPORUS* CULTIVATION IN SOUTH AFRICA

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CASING MEDIA FOR *AGARICUS BISPORUS* CULTIVATION IN SOUTH AFRICA

by

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CHAPTER 1

INTRODUCTION

A casing medium plays an important role in the commercial cultivation of *Agaricus bisporus* Lange (Sing). Clay-loam field soil, a mixture of peat with ground limestone, or reclaimed weathered, spent compost or other alternatives like paper pulp and coconut fibre pith, could be applied as casing medium to the colonized compost. The casing medium and the environmental factors influence the mushroom mycelium to change from the vegetative phase to the reproductive phase, resulting in formation of fruit-bodies. *Sphagnum* peat neutralized with calcitic lime/calcium carbonate ($CaCO_3$) is currently the most popular casing medium used in most mushroom producing countries.

Peat originates from many kinds of organic material but mainly plant litter. Its properties are determined by the botanical composition, the soil water quality, and the extent of microbiological decomposition processes. There is a large variation in the chemical composition between different peat types and this has been correlated to the variation in botanical composition and the degree of decomposition (Bohlin *et al.* 1989). This phenomenon has not been taken into account by South African mushroom growers when using indigenous peat as casing medium.

The only natural peat available for mushroom growing in South Africa is reed-sedge peat. However, there is little information on suitable sources and no published literature on the management of the local peat in mushroom growing is available. Many South African mushroom growers import peat from Europe, Ireland and Canada. Due to the high cost of importation it is often mixed with indigenous peat. Management practices adopted in South Africa have been based on those developed overseas where fortuitously well-structured peat is used. When these practices are applied to the reed-sedge peat, poor crops often result and consequently the indigenous peat is regarded as an inferior product. Although no studies have been undertaken before, the fault may lie with management procedures which do not recognise the inherent differences between casing media. The same situation was encountered by Rainey & Cole (1987) in New Zealand.

Until recently *Sphagnum* peat sources were unknown in South Africa, but the quantities available are not commercially viable owing to its being in a sensitive conservation area (Smuts, personal communication). More information on South African peatlands such as peatland types, rate of peat formation, volumes of peat, general geochemistry and characteristics of peatlands is currently becoming available due to the mapping and characterization of the peatlands (Smuts 1992).

After a preliminary regional investigation of peatlands in Natal by Smuts (1992) (Figure 15), reed-sedge peat was submitted for trials for the production of mushrooms at the University of Pretoria. The peatlands cover approximately 9 800 ha, and peat from that area has never been tested as casing material before.

In Africa peat originates mainly from papyrus, reed and grass (Figure 7). Due to the work done in the Congo by Smuts (1993), a geologist, more than six million ha of peatlands were mapped. Some of the Congo peat is used on a very small scale to improve agricultural soil. The peat can be imported to South Africa for the cultivation of mushrooms at a lower cost than the European peat (Smuts 1992). No published reports assessing the performance of Congo peat as casing medium could be traced.

Some South African growers use a mixture of Canadian peat and indigenous peat or Euroven (imported mixture of peat and sugar beet sludge). Due to the high cost of importation of these materials, other substitutes must be surveyed in order to find replacements for the imported materials.

The objective of this study is to investigate the quality, suitability and availability of peat sources and an alternative casing medium for South African mushroom growing. Peat from two sources in South Africa (Potchefstroom and Natal) as well as from the Congo (Africa), were examined. Coconut fibre pith (Coir) from Sri-Lanka was tested as a possible alternative casing medium (Figure 1). Although few published reports of Coir on mushroom production from other countries are known, none have been published for mushroom growing conditions in South Africa. No published data on the management and performance of Potchefstroom and Natal peat under South African growing

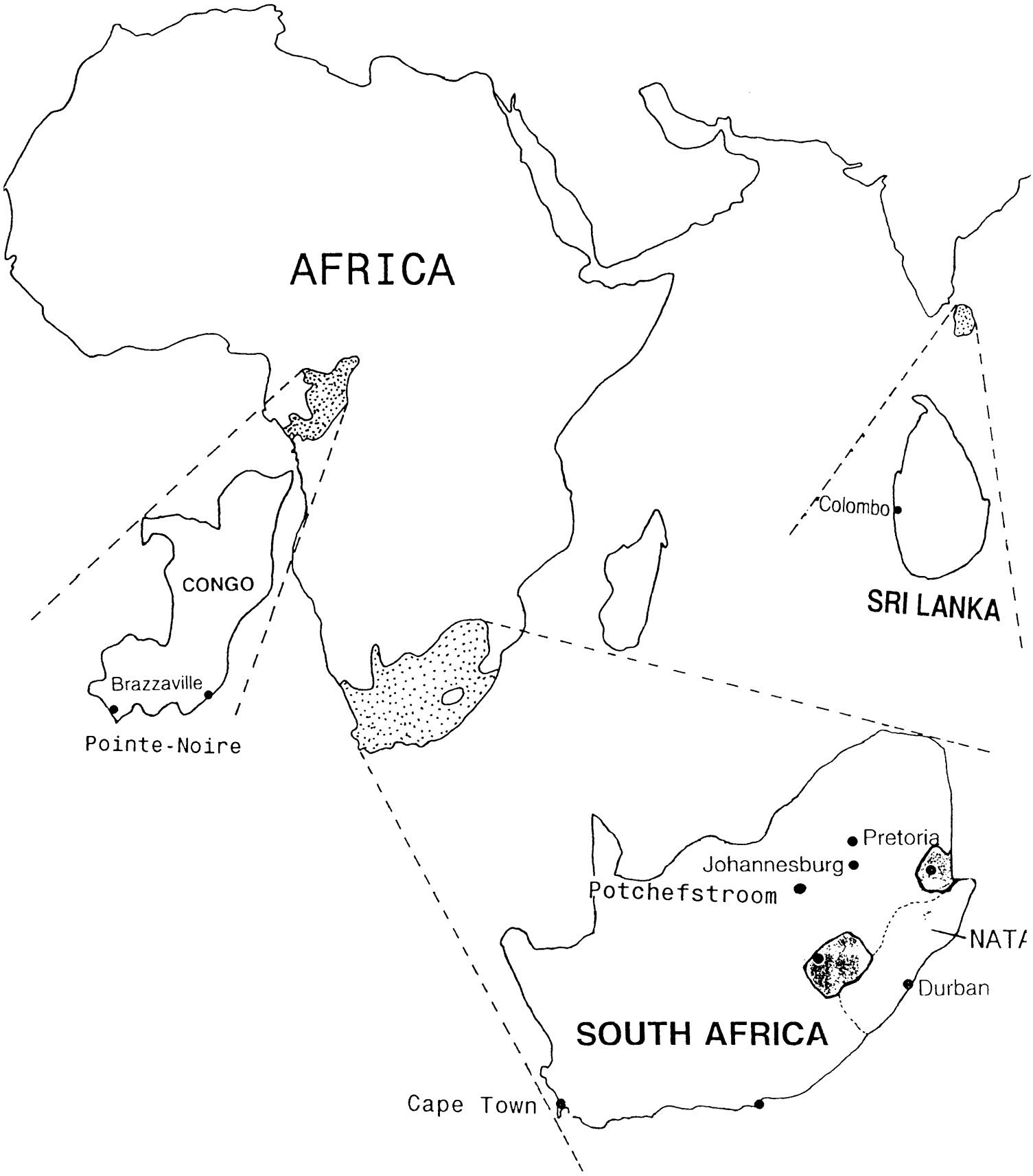

Figure 1 Land of origin of the different casing media used in this study.

conditions are available. Some physical, chemical and fungal characteristics and cropping yields of Potchefstroom peat, Natal peat, Congo peat, Bapsfontein peat, Deodar peat and Coir were investigated.

CHAPTER 2

LITERATURE STUDY

2.1 History of casing

It has been found from experience by mushroom growers that the application of a layer of inorganic material (casing) to mushroom beds is an indispensable component for the successful cultivation of *Agaricus bisporus*.

In the 1950's, systematic studies, by Flegg (1951), on a range of casing mixtures were started by Flegg and Edwards at the Mushroom Research Association (MRA), Yaxley, near Peterborough, in the United Kingdom (UK). In those days casing soil was soil dug from the surface, or preferably from at least one spade's depth below the surface. This was to avoid, or at least minimise the risk of using soil contaminated with pests and diseases. It was then far from clear what the ideal casing should be and most mushroom growers had to make the best of their local soil. Soils vary tremendously in type, texture, physical and chemical characteristics and are similarly varied in their suitability for mushroom growing (Flegg 1991). As a result of the work done by Flegg and Edwards in the UK and Bels-Koning in the Netherlands (Visscher 1988), growers in many countries began to case with a mixture of *Sphagnum* peat and lime, replacing the traditionally used soil casing. Although the use of peat mixtures for casing mushroom crops stemmed from the systematic studies at the MRA, there are reports from Pennsylvania of peat being used since the 1930's (Flegg 1991).

There are three important layers in mushroom culture, the atmosphere, the casing and the compost (Figure 2). The function of the casing which is "sandwiched" inbetween, is greatly influenced by factors in both. The compost generates gases which move into or through the casing and soluble salts and bacteria move from the compost into the casing. Atmospheric carbon dioxide and percentage relative humidity influence the formation and development of mushroom pins. The casing layer itself can also be viewed as three layers. The bottom layer is in contact with the compost which provides a strong and

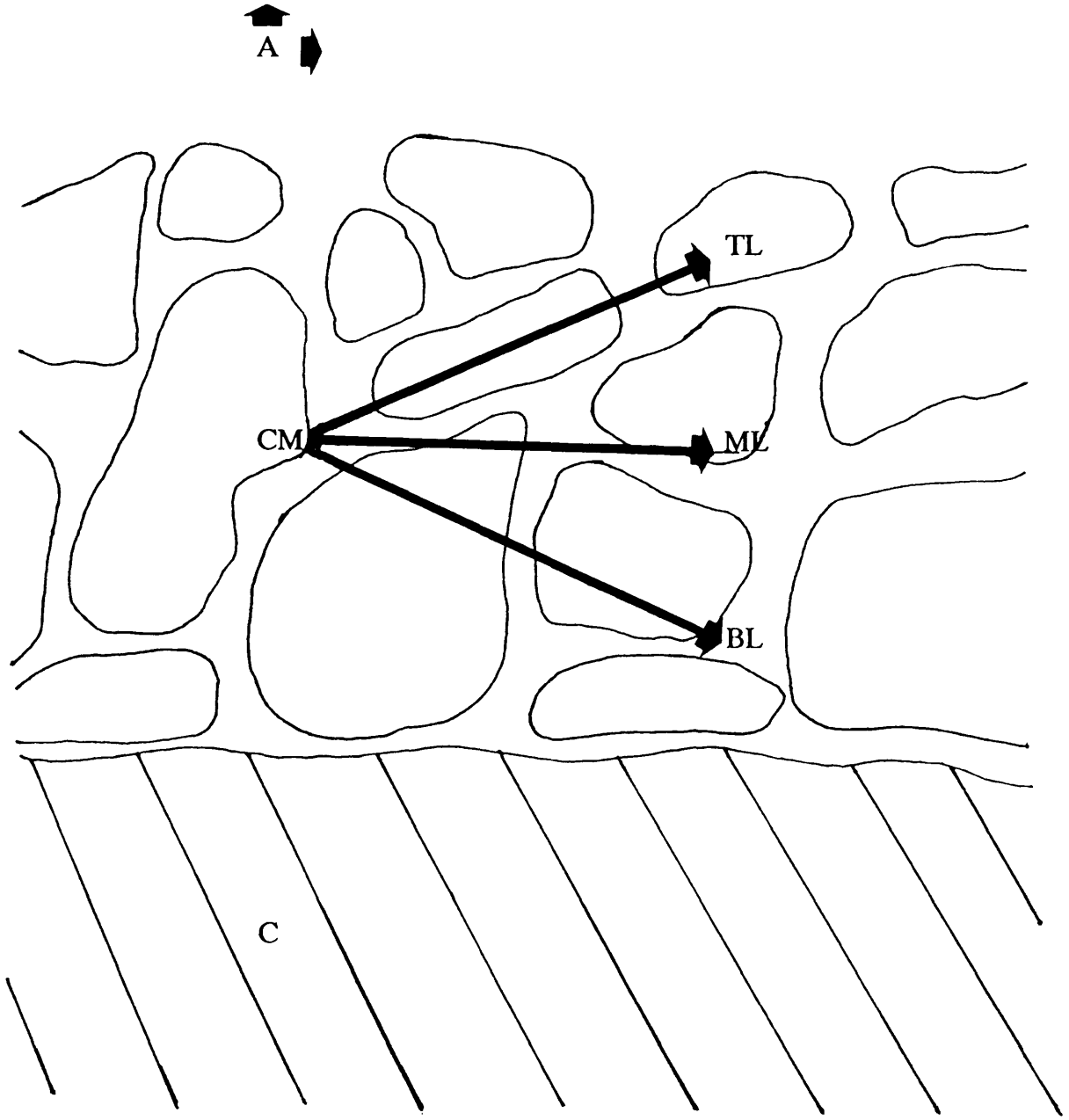

Figure 2 Three important layers in mushroom culture.
A= atmosphere, CM= casing media, C= colonized compost,
TL= top layer of casing media, ML= middle layer of casing media,
BL= bottom layer of casing media.

uniform mycelium growth into the casing. The middle layer provides the required depth to maintain adequate reserves of water and acts as a diluent to harmful salt accumulation from the compost. The top layer is critical in terms of yield and quality (Hayes 1993).

2.2 Casing characteristics: physical, chemical and biological

It is essential to case mushroom beds in order to optimise the requirements for growth and completion of the growth cycle of *A. bisporus* (Hayes 1979). The exact mechanism which initiates the change from the vegetative to the reproductive phase is not clear. Although difficulties are encountered in defining a good casing medium, there are sufficient established facts which permit at least a broad assessment of the requirements for a casing medium in order to produce mushrooms in commercially acceptable quantities. These requirements are associated with the inherent complexity of the interaction between a wide range of physical, chemical and biological variables operating in the casing medium of commercial practices. To improve the existing casing medium and develop new media relies in gaining a precise understanding of the characteristics and functioning of the casing medium (Rainey *et al.* 1986).

The physical characteristics and chemical composition of the casing medium and the macro-environmental changes (oxygen, water, relative humidity, air flow and temperature) modify the micro-environment around the mushroom mycelium. These alterations to the nutritional and gaseous environment stimulate the microbial flora, which aid in mushroom formation (Rinker 1993).

2.2.1 Physical characteristics of casing

Physical, chemical and biological characteristics are all important in the productivity of the casing and interact beneficially in well-structured media. The attainment of good structure and water holding capacity (Bels-Koning 1950; Visscher 1975; Yeo & Hayes 1978) are of prime importance and understanding its inter-relationships with the growing mycelium allows the grower to exercise greater control over cropping (Rainey & Cole

1987). Qualities required from casing medium by mushroom growers can be summarised as follows: casing medium must have excellent water holding capacity; structure (= the shape and size of the aggregates when crumbled), and texture (= the relative proportion of particles of different sizes) are very important; casing must be easily rewetted between flushes and; the casing must be consistent for each delivery (Smith 1991).

The structure of a casing medium is influenced by pore space, fibre content, heat treatment, watering, mixing, liming and air-drying. Puustjärvi (1992) indicated that the overall structure of the substrate is a resultant of the arrangement and bonding of individual substrate particles into structural units, and of the arrangement and bonding of these units (Figure 3). Therefore, a complete quantitative characterization of the peat structure would involve an evaluation of the size and shape of the structural units and the size distribution and continuity of pore spaces within and between the units. Hence, peat structure is a complex phenomenon that cannot be characterized precisely by a single measurement. The pore size distribution is the most important characteristic of peat structure. Unfortunately, it can only be measured by using indirect methods.

The structure of the casing medium is determined by the size, shape and arrangement of its primary aggregates or granules. A granule is a rounded porous mass of mineral particles of varying sizes held together by humus/organic matter, clay and water attractions. A good casing medium requires a range of particle size, from very small colloidal particles, which are generally deficient in most peats, through to macro-sized particles which are abundant in peat (Hayes 1991). The voids (pores) between aggregates provide space for water, air and microbial activity and their size greatly influences the volume of air and water held by the casing. The air to water ratio, in turn, affects the rate of gaseous exchange which has a significant effect on the growth of *A. bisporus* and associated microflora.

Casing media retain water primarily within their micropores. Larger diameter pores (macropores) drain free and leave space for air which contains the oxygen necessary for the growth of *A. bisporus*. Oxygen is relatively insoluble in water and therefore the mushroom requirement must be met by the air-filled pores. In contrast, carbon dioxide

readily dissolves in slightly alkaline water and can be obtained by the mushroom from both the aqueous (bicarbonate) and gaseous phases. Dense casing materials contain a large proportion of "fines" (clay, silt and sand size particles) which pack together tightly and ensure that the pore space is dominated by micropores. Macropores predominate in light, open structured casings (Rainey & Cole 1987).

Hayes (1991) found that the greater the porosity of a mixture in the dry state, the more likely it was to produce good yields. A high pore space when a mixture is dry means there is plenty of room for water and for the passage of air and carbon dioxide. The total porosity of a peat will decrease if the decomposition level of the peat increases. Decomposition is based on a qualitative scale called the "Von Post Scale". The scale is based on the clarity of the water extracted from a peat sample: the darker the liquid, the more decomposed the peat. For example; classes H_1 to H_3 = horticulture peat/blonde peat, H_4 to H_6 = brown peat and H_7 to H_{10} = combustible peat/humus (dark peat) (Caron 1987).

Heat treatment of peat will alter its structure to a greater or lesser extent based on the duration and temperature applied. This is why users of *Sphagnum* peat moss, generally do not pasteurise the material prior to application. Over-steaming may destroy bacteria which are beneficial in mushroom formation, or result in accumulation of ammonia in amounts toxic to the mushroom (Schisler 1978; Caron 1987; Rinker 1993). Soluble salts and manganese levels may also increase after steaming (Schisler 1978).

The unique property of peat to absorb and release water is the main advantage over other possible alternatives, but the tendency of many peats to "pan" on water application, and thus prevent the required gaseous exchange between the compost and the atmosphere, is a major disadvantage (Hayes 1991; Visscher 1975). A more compacted casing medium during vegetative growth gives better yields, provided the surface of the casing medium is loosened before fructification (Visscher 1975). Casing does not need nutrients but rather acts as a water reservoir. Fine mycelium fuses together to form rhizomorphs which give rise to mushroom initials, primordia, or pins (Wuest *et al.* 1980).

The moisture content at the time of mixing and the method of mixing both have a marked effect on structure. Materials other than resilient *Sphagnum* peat become very dense (few air filled pores) when mixed in a wet state, especially when combined with a soluble lime. Mixing machines, especially those which have a grinding, compressing action, damage structure. The period of mixing also has an effect and brief mixing ensures minimal damage is done to the structural fibres (Rainey & Cole 1987).

Casing texture is the proportion of the size of the different particles, making up the mixture, and includes both peat and the added neutralising agent, lime. Clay and silt confers the "stickiness" to the casing and these small particles reflect the water retention properties. The macro-particles are important in providing the necessary spaces for gaseous exchange and for growth of mycelium and formation of rhizomorphs (Hayes 1993).

Calcium carbonate is commonly used for liming peat for pH adjustment. The fineness of limestone and its alkalinity influence pH adjustment. The rates of addition vary enormously in commercial practice. Mushroom fruit bodies are known to form over a wide range of pH (Allison & Kneebone 1962) and pH correction alone does not justify its inclusion in media above Ph 6. It may be justified on the basis that some competitor moulds, especially species of *Trichoderma* are favoured by pH's of below neutrality (Hayes 1981; Visscher 1988).

The effect of lime on the physical characteristics of the casing medium is difficult to assess. It appears that lime has a beneficial effect on open structured medium, but a detrimental effect on dense casing medium (Rainey & Cole 1987). Many different types of lime are available and range from fine and soluble to coarse and insoluble. Open media benefit from finely ground lime, whereas the structure of dense media can be improved by adding a coarse insoluble lime and/or gravel chips (addition of a small amount of soluble lime may be necessary to ensure correct pH adjustment). The amount of lime added also has a significant effect on the structure (Rainey & Cole 1987). According to Flegg (1989), more lime can be added and this lumpy lime may help to keep the mixture "open" and more porous to gases.

According to Gamayunov *et al.* (1993), peat structure depends on the high mobility of structural elements (particles). Dehydration causes irreversible changes in the microstructure of peat. These changes occur in the organic skeleton (Figure 3). This skeleton is made up by the particle framework (matrix), consisting of a spatial network of "cross-linked macromolecules". These cells have intracellular water that can diffuse freely into the external solution. Water molecules and inorganic ions are able to move into the matrix and into the particles. As a result of the aqueous-physical properties of peat and the binding of the water with the dry substrate, the structure changes significantly. The peat particles are compacted and shrinkage occurs due to compression of inter- and intra-aggregate moisture and some intracellular moisture. Removal of moisture from micro-capillaries and micro-cavities cause macromolecules in the organic part to form such strong cross-linkages that the accessible sorption sites could not react with molecules of water in the sorption of moisture.

One of the most important characteristics of peat is its ability to hold and supply large amounts of water to the mycelium whilst simultaneously it should be structurally adapted to contain large volumes of air (Abad *et al.* 1989). It should have the capacity to absorb and release water in order to maintain the required water levels for the culture as a whole, irrespective of natural fluctuation in the relative humidity of the growing house environment. According to Vedder (1978), $2dm^3$ of water is needed in the production of 1kg of mushrooms. Water holding capacity of a casing medium is influenced by its structure, organic composition, decomposition level, types of colloids, liming, soluble substances and water potential.

Peat contains a considerable amount of organic colloids. Due to their large specific surface, such colloids constitute the most important ingredients of peat. This increased surface area gives rise to pronounced surface phenomena, in particular, to the process of adsorption, which is the concentration of gas, liquid, solid or the solute, or a solvent of a solution at the interface. The colloidal state of peat depends on its water content. For example, the ability of peat to bind water decreases during drying and the peat then shrinks. Both these phenomena are seen in the structure of peat. Most of the colloids of virgin peat have an affinity for water which is the cause of the high water holding

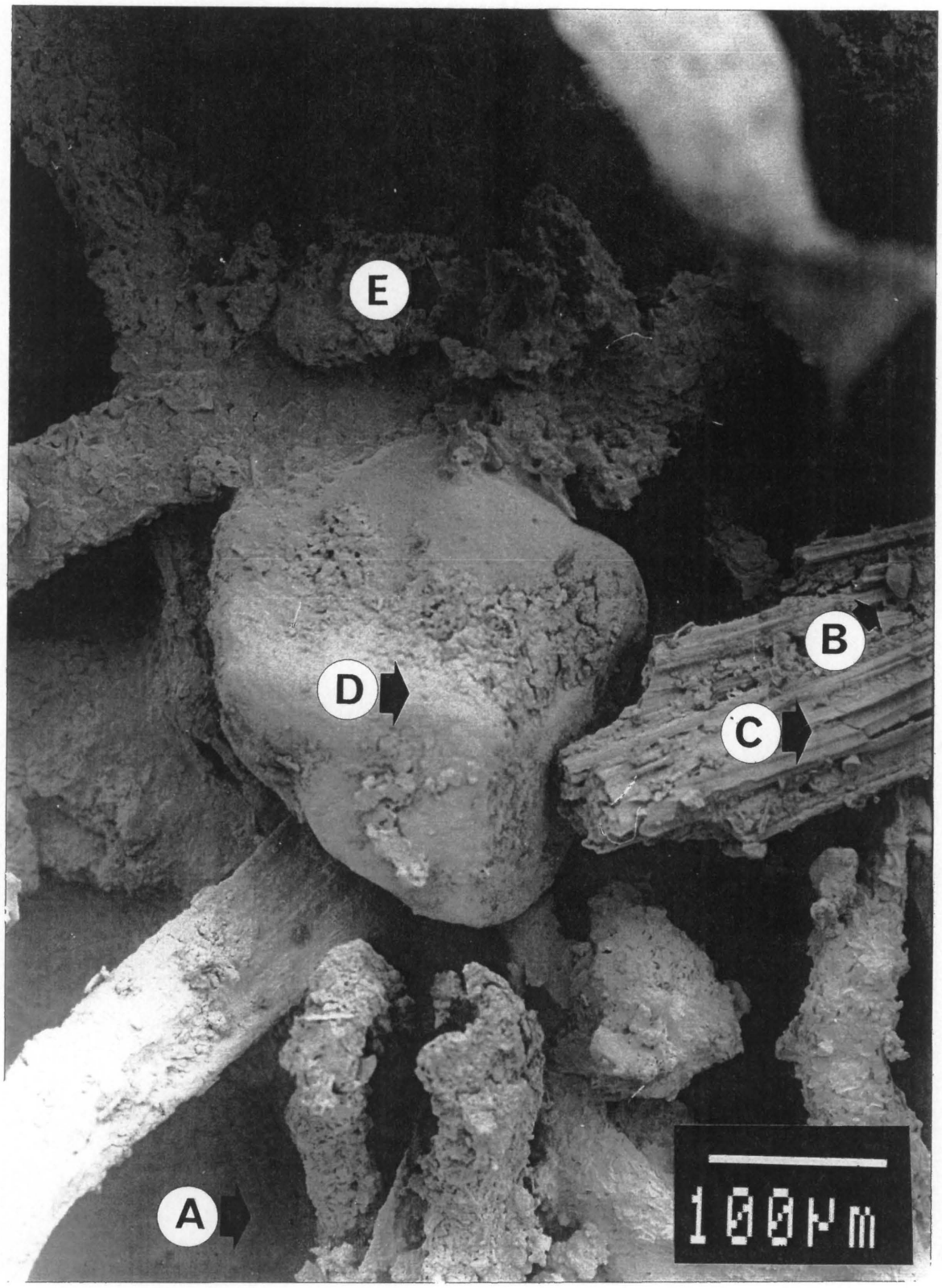

Figure 3 Organic skeleton of peat illustrating the particle framework with pore spaces inbetween. A = macro-pore space, B = micro-pore space, C = fibre, D = silica grain, E = "fines or clays".

capacity of peat. Drying has a different effect on different colloids. When, for example, the humic acids dry out, the peat hardens into coal-like clods, which are very difficult to rewet. On the other hand, the colloids of pure *Sphagnum* peat are easy to rewet after drying, provided the peat is not overdried. If it is, it cannot be rewetted. It is easy to understand that even small amounts of different types of colloids may have a significant effect on the water holding capacity of peat (Puustjärvi 1992).

Valat *et al.* (1991) found that beyond the numerous advantages of the substrates with high organic matter content, it appears that after air drying the characteristics of the organic matter upon rewetting is difficult to achieve. Dehydrated peat displays different wetting properties according to the degree of decomposition. Humic polymers found in most decomposed peat and in soil organic matter contain polar (carboxyl and hydroxyl groups) and non-polar (methyl or ethyl groups) sites; the former groups are hydrophillic and prompted to interact strongly with water, whereas the latter display a strong hydrophobic character. In the drying process, polymer flexibility allows polar functional groups to associate and to interact through hydrogen-bonds at very low relative humidities. As a consequence of the molecular orientation, non-polar groups become orientated outwards, and the organic surface displays a lower affinity for water. In the drying process peat colloidal matter becomes irreversibly aggregated. The hydrophobic character of air-dried organic substrates changes the water retention properties and consequently, forces modification of the irrigation regime.

The amount of water that can be absorbed by a casing medium, depends largely on its organic matter content (Amsing & Gerrits 1991). The moisture content (60%-90%) of a casing medium has an effect on the size and mass of the fruit-bodies (Schroeder & Schisler 1981). According to Reeve *et al.* (1959), mushroom size will decrease whenever the moisture content of the casing medium decreases. Mushroom size as well as the yield will increase with increased moisture content of the casing medium (Schroeder & Schisler 1981).

Fibre content has been shown to be related to water holding capacity, density and even energy potential. Fibre content (Figure 3), is a measure of the degree of preservation of the tissue fragments in the peat (Cohen *et al.* 1991). A long fibre peat moss (blonde peat) offers a good structure and has a high water holding capacity. Ash and fibre contents of peat are important characteristics indicative of the suitability of a casing medium. Peat is classified in three classes according to the fibre content:
class I = 0-33%; class II = 33-66%; class III = 66-99%
The peat most ideal for mushroom growing would be one that satisfies the parameters set for class II peat (Smuts personal communication).

The ash content represents the percentage non-organic/inorganic fraction of peat. Lime being an inorganic material will contribute to the increase in the ash content of the casing medium. A casing medium with a very high ash content *c.* 60% is classified as soil and may lack some of the characteristics of a good casing medium (Smuts personal communication).

A fine peat (more decomposed) will be prone to sealing if over-watered or watered too frequently. The sealing or panning of the fine peat is associated with a poor structure, although the fine peat seems to retain a relative high water holding capacity (Caron 1987). In microtome sections of different peats it was found that the lack of fibres indicated a high degree of decomposition while *Sphagnum* peat was dominated by well preserved tissues (fibres), light in colour, and high in porosity. This explains why *Sphagnum* has an excellent water holding capacity (Cohen *et al.* 1991). A decomposed peat will retain less water and have a high percentage ash content (Caron 1987). Abad *et al.* (1989), found that sedge peat with a poor, nearly amorphous structure, has a low water holding capacity. Highly decomposed organic material has small pores which hold relatively large amounts of unavailable water. Well-structured peat has a small amount of available water, due to large pores resulting in the loss of water through gravity, which then requires frequent irrigation. The voids between aggregates provide space for water held by the casing. The casing medium retains the water primarily within the micropores, while the larger pores (macropores) drain free (Rainey & Cole 1987).

Water holding capacity of peat is also affected by the addition of different types of lime. Soft lime retains more water than hard lime. Hard lime particles are like ball bearings whereas soft lime has an irregular surface so water gets trapped in its cuplike indentations (Brown 1993).

Mushroom mycelium growth depends on the amount of water in the casing medium. A drier casing results in formation of finer hyphae, whereas in an over wet casing, slower developing rhizomorphs form. In a casing with enough moisture, rhizomorphs and fine hyphae develop (Flegg 1962). The mushroom mycelium absorbs water from the casing as well as the substrate. In biological systems, water can be moved by hydrostatic pressure and by water potential gradients. The water potential of a cell is the sum of the osmotic potential and the turgor pressure. The difference in water potential between the substrate and the mycelial cells strongly influences water uptake by the mycelium. The water potential of the substrate depends on the concentrations of solutes in the substrate water. This concentration is influenced by substrate additives and by solutes formed by the mushroom mycelium or by micro-organisms (Kalberer 1987). Addition of pesticides to the casing can also lower water potential and produce the same effect as salt (Kalberer 1990a, 1990b). High salt concentrations decrease the water potential, and the yield (Kalberer 1991). There are no instruments available which give *in situ* data of the availability of water in the substrate and the casing medium during cultivation (Kalberer 1991).

2.2.2 Chemical characteristics of casing

Discrepancies occur as to what is the ideal optimum level of lime, to add to the casing medium. Mushrooms seem to prefer a casing medium with a pH somewhere between 6.5 to 8.5 (Allison & Kneebone 1962; Flegg 1989). Peat alone is not an ideal casing medium. Usually it is acidic and has to be mixed with lime to counteract this acidity. According to some growers, the exact quantities of peat and lime are not that important. Usually more lime is added than is strictly needed to neutralise the acidity of the peat (Flegg 1989). Rainey & Cole (1987) found that the amount of lime added had a significant effect on structure. Hayes (1981) found that extremely small quantities of

lime are necessary in maintaining pH, suppressing excessive salt accumulation and sustaining high yields. The inclusion of lime in a casing layer is essential to maximise productivity and although it functions in maintaining pH, equally important is its contribution to lowering electrolyte activity. The role of calcium is well known in plant and microbial nutrition as an antagonist to toxic elements, but more information is required on its possible antagonistic function in the casing medium (Hayes 1981).

Since mycelium produces acidic compounds such as Ca-K-oxalate crystals around the hyphae during growth (Visscher 1988), the pH of the casing layer will drop slightly if only hydrated lime is used. Some growers use a combination of ground lime in a ratio of 1:2 on a dry weight basis with the peat, and hydrated lime [$Ca(OH)_2$ (20g/kg peat)] to obtain both the rapid reaction of the hydrated lime and the buffering effects of ground lime (Ingratta & Blom 1979).

The lime requirement of a medium is usually defined as the amount of liming material required to raise the pH of the medium to a specific value. Several buffer-ph methods, using barium acetate, ammonium acetate and calcium acetate, have been employed for estimating lime requirements for tropical peat and other soils. Chemical buffers have been widely used. A buffer is a mixture of a weak acid and a salt of the same weak acid which resists a major change in pH of a solution. The change in the pH of a buffer after reaction with the medium is an index of the lime requirement (Husni *et al.* 1994). Precise liming of a medium requires a knowledge of the type of peat used, initial pH, degree of decomposition and the volume of the peat. No published literature is available on buffer-pH methods to estimate the lime requirements of sedge peat in mushroom production to achieve a specific pH.

Electrical conductivity, like pH, is an indication of the level of anions and cations in the casing medium (Hayes 1981). Certain cations inhibit fruit-body formation while others stimulate it (Hayes 1972). Anions accumulating in the casing are chloride and sulphate ions. Due to the accumulation of potassium ions (K^+) and sodium ions (Na^+) during cropping, pH decreases and electrical conductivity increases (Yeo & Hayes 1978). According to Hayes (1981), fruit-body formation will be inhibited by an electrical

conductivity of 54 x 10^3 μmho, and a value greater than 9,7 x 10^3 μmho will reduce fruit-body formation. The size of the fruit-bodies is influenced by the K^+ concentration. At the end of the cropping cycle the K^+ concentration is high, and the mushrooms are bigger (Reeve *et al.* 1959). During the cropping cycle the K^+ and the Na^+ concentrations increase, the magnesium (Mg) concentration more or less remains constant, and the water soluble iron (Fe) increases (Yeo & Hayes 1978). A higher salt concentration results in a lower water potential and therefore water is not readily available for the mushrooms.

While growing and fruiting best in a neutral to slightly alkaline casing medium, the mushroom will not fruit well if there are high levels of soluble salts present. The compost usually contains large amounts of salts and these will slowly diffuse upwards from the substrate into the casing (Flegg 1989). The addition of sodium chloride (NaCl) to the casing medium will reduce the yield, due to the lowering of the water content of the fruit-bodies, while the total amount of dry matter of the crop will not be affected (Kalberer 1987). Beelman *et al.* (1986) obtained similar results to Kalberer (1987) and found that the addition of increasing concentrations of calcium chloride ($CaCl_2$), has a tendency to decrease yield, increase size and decrease moisture content of the mushrooms, due to decreased water uptake from the casing layer to the mushrooms. Postharvest storage studies indicated that increasing concentrations of calcium chloride in water delayed mushroom development as evidenced by cap opening. Decreased moisture content of mushrooms in the storage environment will have a less stimulating effect on bacterial growth. This will result in less tissue deterioration, and therefore enhance a longer shelf life of the mushrooms (Kalberer 1987).

Two nutrients, acetate and iron, seem to have an effect on the developmental process in mushroom growth. The former seems to be associated with compost while the available iron appears to be related to the casing medium (Hayes 1972). Hayes (1973) found acetate to be an essential requirement for the formation of primordia and suggested that the acetate units are synthesised from fats and oils contained in the "biomass" of thermophilic micro-organisms which accumulate during composting.

Abad *et al.* (1989) found that the relatively high cation exchange capacity (CEC) of sedge peat was clearly related to the high humic and fulvic acid content. Humic substances contain activated carboxilic, phenolic and some other groups which are capable of retaining cations in non-leachable forms. Certain cations inhibit while others stimulate fruit-body formation (Hayes 1972).

Hayes (1981) indicated that stimulus to fruit-body formation provided by the casing layer is related to its physiochemical and biological properties. Phyto-hormones are present in the casing medium at the time of application but concentrations fluctuate during the growing cycle. Auxin and gibberellic acid activity increase after casing but cytokinin activity decreases. The number of fruit-bodies increases when ferrous salts are added to the casing medium, but the opposite effect is obtained with manganese (Hayes 1972).

2.2.3 Biological characteristics of casing

The biological characteristics, like beneficial micro-organisms, weed moulds, pathogens and insects have an influence on the suitability of the casing medium for mushroom production.

Soon after the application of the casing medium, the mushroom mycelium begins to grow into the casing in the same way as it grows in the compost. As the mycelium reaches the top of the casing layer, the fine, hair-like mycelial growth changes. Thickened strands of mycelium form a network from which "knots or lumps" of mushroom tissue appear. Eventually some of these knots of white tissue take on a more definite rounded shape about the size of a pinhead. These "pinheads" as they are called, are the early stages of the development of a mature mushroom (Flegg 1989). The casing medium, although often regarded as an inert substrate, has been shown to support an active, aerobic bacterial flora and populations have been shown to fluctuate in a regular manner, which may be associated directly with the growth of the mushroom mycelium (Hayes & Nair 1974). Particular emphasis was given to the occurrence of *Pseudomonas* spp. which dominate approximately ten days after the application of casing medium, a time which

coincides with the important transition from vegetative to reproductive phase (Cresswell & Hayes 1978).

The precise mechanism which initiates the change from the vegetative to the reproductive phase is unknown but several theories have been presented. The most popular concept is that micro-organisms in the casing material produce metabolic products which induce a change in the lipid metabolism of the growing mycelium, resulting in the formation of pinhead initials (Ingratta & Blom 1979).

Certain bacteria which live in the casing medium are associated with formation of fruit-bodies. The bacteria first restrict the growth of the mycelium and only then do fruit-body initials start to form. The more bacteria present in the casing, the stronger the inhibition of mycelial growth and the sooner the formation of fruit-body initials begins (Eger 1962, 1972). Another explanation is that the mushroom mycelium produces a substance (or substances) which does not normally allow fruit-bodies to develop. However, certain bacteria, commonly present in the casing layer, destroy this substance and the mushroom mycelium is then free to produce fruit-bodies (Flegg 1989). The bacterial population and composting of the casing layer in turn may be influenced by the bicarbonate ion (HCO^-_3). Similarly, temperature also influences bacterial activity in the casing layer which in turn influences the behaviour of mushroom growth (Hayes 1981).

Hayes & Nair (1974) obtained a correlation between initiation of fruit-bodies and activity of *Pseudomonas* spp. in the casing layer by altering the concentration of bicarbonate ion in the medium. Lower levels of bicarbonate in the casing medium appear to stimulate the population of *Pseudomonas* spp. as well as the formation of fruit-bodies. Reddy & Patrick (1992) reported that some of the bacteria which colonize the substrates normally used in commercial cultivation of *A. bisporus* have a stimulating effect on the formation of fruit-bodies. The results are in agreement with laboratory studies reported by other investigators, who showed that formation of fruit-bodies is reduced or absent under totally axenic conditions (Eger 1972; Hayes 1981; Visscher 1978).

The presence of *Bacillus* sp. and *P. putida* in the casing layer is responsible for fruit-body formation. It may be possible that the mycelium is capable of utilizing nitrogen fixed by bacteria like *Azotobacter chroococcum*, *Rhizobium* sp. and *Azospirillium brasilens*. Additional nitrogen fixed by these bacteria may be utilized by other bacteria for their growth and multiplication. *Agaricus bisporus*, in turn, benefits from this increased bacterial growth (Vijay & Gupta 1992). Cochet *et al.* (1992) mention that several bacterial strains seem to be involved in the fruit-body formation phenomenon. During the fruit-body formation stage, calcium oxalate crystals surround the hyphae and probably act as a protection against bacterial invasion. It appears that the mycelium dissolves the calcium carbonate in the casing medium. The mushroom mycelium seems to make a selection amongst the bacterial strains. Inversely, the major part of the bacterial population is able to enhance the mushroom growth, and the cells might be used as nutrition by the bacteria. This induced mycelial autolysis due to several ultrastructural modifications of the hyphae seems to be required for fruit body formation. Potassium and iron appear on the hypha surface without crystals and that seems to favour bacterial growth and relates to the formation of mycelial aggregates. These interactions between *Pseudomonas* sp. and *A. bisporus* during primordia formation were confirmed by Masaphy *et al.* (1987) using electronmicrography. It is possible that the hyphae exude metabolites which cause the bacteria to be attracted by chemotaxis to the hyphal surfaces and to multiply there.

Visscher (1978) found that bacteria thrive on volatile metabolites from mushroom mycelium. In a more open medium, the volatiles will escape more readily to the detriment of the bacteria which will be less stimulated and consequently, fruit-body formation and yield will be lower. Bacteria associated with initiation of fruit-body formation use the volatile metabolites as carbon source. The occurrence and activity of *P. putida* in casing medium is the result of the environment created by the growing mycelium in the compost layer, and the accumulation of volatile metabolites, eg., ethanol, ethyl acetate, acetone and carbon dioxide, produced by the mushroom (Hayes 1972; Cresswell & Hayes 1978; Hayes 1981).

According to Vedder (1978), Geels *et al.* (1988) and Rinker (1993), some micro-organisms are beneficial while others can cause considerable economic losses through quality reduction.

Common bacterial diseases occurring in the commercial production of mushrooms are, bacterial blotch - *P. tolaasii* Paine, and mummy disease - *Pseudomonas* spp.

Significant fungal pathogens of mushrooms include, dry bubble - *Verticillium fungicola* (Preuss.) Hasseb., wet bubble - *Mycogone perniciosa* Magn., cob web - *Cladobotryum dendroides* (Bull. ex Mérat) Gams & Hoozem. and green mould - *Trichoderma viride* Pers. ex S.F. Gray., *T. koningii Oudem.*, *T. harzianum* Rifai. The viroid disease "La France or Die back" is in many cases so devastating that growers have to cease mushroom production.

Non-infectious diseases, termed as indicator and weed moulds of mushrooms, include lipstick mould - *Sporendonema purpurascens* (Bon.) Mason & Hughes, cinnamon brown mould - *Chromelosporium fulvum* (Link ex Fr.) M^{c} Ginty and nematode trapping fungi - *Arthrobortys superba* Corda. Casing soil may harbour some serious pests including arthropod pests such as sciarid fly, dark-winged fungus gnat - *Lycoriella mali*, cecids, gall midges - *Mycophila* spp., phorid flies - *Megaselia halterata* Wood, red pepper mites - *Pygmephorus* spp., parasitic nematodes - *Ditylenchus* spp., *Aphelenchoides* spp. and saprophytic nematodes - *Acrobeloides* spp., *Rhabditis* spp., *Choriorhabditis* spp., *Caenorhabditis* spp. The majority of insect and disease problems can be controlled or eliminated by proper manipulation of the growing materials and the production environment. Both heat treatment and chemical fumigation methods can be used to control pests (Geels *et al.* 1988; Rinker 1993).

2.3 Macro-environmental management of casing

The casing medium must be thoroughly wetted before applying it to the fully colonized compost. Depending on the casing medium used, a layer of 5-8cm is usually adequate.

Casing irrigation methods, volume of water and application times are critical for mushroom production and depend on the type of casing medium (Kalberer 1984, 1985, 1987; Rinker 1993). During the first week after casing, vegetative growth will be

stimulated if the compost temperature is kept at 25°C, and the CO_2 and relative air humidity are kept at high levels (Flegg 1989).

To change the mode of growth of the mushroom from vegetative mycelial growth to the reproductive development of fruit-bodies, a change in cultural conditions is necessary. By increasing the fresh air in the growing room, the CO_2 level will be lowered. The adjustment of the air temperature is also necessary to change the mode of growth of the mushroom (Flegg 1989).

Several processes, such as scratching (disturbing the surface layer of the casing medium) and ruffling (which is mechanically mixing or breaking up, one week after casing) the entire casing layer and thoroughly redistributing the mycelium without picking some compost up, result in reduced clustering and more uniform breaks (Flegg 1965; Rainey *et al.* 1986; Ganney 1987; Visscher 1988). These practices result in even, rapid, three-dimensional colonization of the casing medium. The process whereby the casing medium is inoculated with compost colonized with mycelium of the same strain growing in the compost, is called CACing, which is an acronym for compost added to casing (Vedder 1978; Janssen 1993; Samp 1993). The advantages, such as more rapidly colonized casing, good mycelial growth in the casing and uniformly sized mushrooms, as well as a shortened crop cycle, control over timing of the crop and better quality mushrooms, are excellent. However, several disadvantages such as introduced diseases, insects or nematodes, and excessive heat build-up during spawn run which may weaken or kill the mycelium, are encountered when using this commercial production technique. The benefits achieved by CACing are similar to spawn added to the casing (SPACing). The advantages of CACing and SPACing are similar to that of cultured casing inoculum (CCI - a product similar to spawn) (Rinker 1993), with the additional attractions of CCI being purity of mushroom strain, ease of application, reduced risk of green mould problems and technical support from the supplier (Rinker 1993; Samp 1993).

2.4 Casing alternatives

Although the peat industry argues that peatlands can be managed at sustainable levels, it recognizes that alternatives to peat must be developed to meet consumers' environmental concerns and to contend with increased regulation of peatland exploitation (Cresswell 1992; Robertson 1993). The peat industry is accused of peat extraction being environmentally damaging in a number of ways. The main one being that it irreversibly damages or destroys dwindling and irreplaceable wetland habitats. The most important fact that emerges from surveying peat substitutes and their environmental impact is that nearly all the organic materials are waste-based (Coir, spent compost, paper processing sludges). Most of the inorganic and semi-organic alternatives are either made from non-renewable resources (vermiculite, perlite, loam, sugar beet washings) or consume energy in their manufacture (vermiculite, polystyrene) or do both, and extraction of mineral-based materials leaves "holes in the ground". Some organic wastes are contaminated and may affect the environment negatively (Pryce 1991).

A wide range of materials (spent compost, vermiculite) has been tested as a possible alternative to peat (Vijay *et al.* 1987; Eicker & Van Greuning 1989), as well as paper and pulp mill by-product (PPMB) (Cresswell & Hayes 1978; Yeo & Hayes 1978; Hayes 1979; Eicker & Van Greuning 1989). Lelley *et al.* (1995) obtained encouraging results with "Champyros" - a mixture of crumbled used paper, calcium carbonate and 20% peat moss. Results confirmed that the mushrooms were as good as those originated from peat moss casing medium as regards to taste, flavour, cleanness (less soiled) and associated better quality, which allowed better grading.

Coir is a natural and renewable resource of the coconut industry. Coir is the name given to the fibrous material that constitutes the thick mesocarp of the coconut fruit (*Cocos nucifera* L.). The material is a mixture of a corky cellular material and short fibres, and has both the appearance and feel of peat (Cresswell 1992). In the Netherlands, Coir pith has been used as horticultural growing medium since the 1980's (Meerow 1994). More than a century ago Coir was introduced into English horticulture and was known as "Coir-Nut fibre refuse". Coir products are sold under different names like Coco peat

from Malaysia and Palm peat from Sri Lanka. Coconut husks are soaked in water for three months (Figure 4). The long fibres are extracted from the coconut husks (Figure 5), and used in manufacturing industrial products. The short fibres and dust (Coir fibre pith) left behind accumulate as a waste product (Cresswell 1992; Meerow 1994) (Figure 4). Coir fibre pith is similar to peat in appearance and has physical and chemical properties (Cresswell 1992; Handreck 1993) that recommend it as a peat alternative in mushroom production. Several qualities of Coir compared to peat are: High water holding capacity (equal or superior to *Sphagnum* peat); absence of weeds and pathogens; renewable resource; slower decomposition than sedge peat or *Sphagnum* peat; acceptable pH; electrical conductivity and; easier wettability than peat (Cresswell 1992; Meerow 1994). Although the qualities encountered by Cresswell (1992) are encouraging, dangerously high salt levels have been recorded in some Coir samples. Salt contamination is a potential problem with recent Coir reserves as the coconut husks are sometimes soaked in brackish water to loosen the fibres. The levels of salt in the older stock piles are not excessive due to it being leached by rain for a longer period of time. Mixtures of Coir and peat gave yields at least equal to, and often in excess of, those with peat alone (Kemp 1990; Border 1993). It is hydrophillic and rehydrates easier, produces less panning and requires less lime for pH adjustment than peat alone (Border 1993).

Coir appears to be extremely resilient, but the influence of high compression rates on the physical properties of the material after break-out (the break-out volume is the volume of loose material obtained when compressed Coir bricks are broken up) need to be investigated (Cresswell 1992).

2.5 Peatlands and peat extraction

The main *Sphagnum* peatlands in Europe and the UK are "rain-fed", being raised above the mineral groundwater limit (Barber 1993), and are distinguished from the South African reed-sedge peatlands which occur in valleys and basins, or on river floodplains and are nourished by inflowing streams and precipitation. The composition of the water may change as a result of physical, biological and chemical processes during percolation through the soil. Groundwater pollution is generally reflected by increased chloride

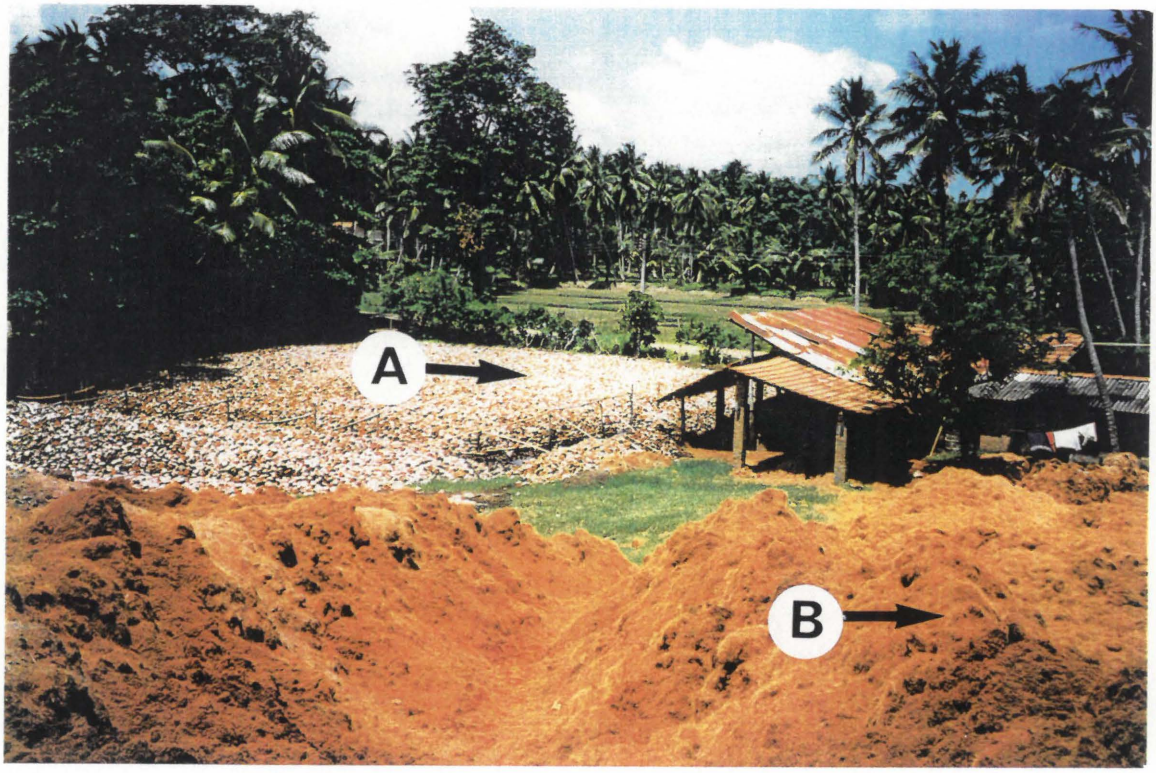

Figure 4 Coir industry in Sri Lanka. A = coconut husks soaked in water, B = Coir stock pile (some stock piles are reputed to be close to 100 years old).

Figure 5 Extraction of Coir fibres for industrial use (arrow).

concentrations and therefore chloride was used as a criterion for pollution. Polluted groundwater may lead to misinterpretation of natural groundwater composition, eg., through increased calcium concentrations from fertilizer application (Schott & Wassen 1993).

Of all the natural ecosystems, peatlands are the most vulnerable to irreversible damage. In previous centuries the use of *Sphagnum* peat in Europe and the UK has lead to its wholesale removal and irreversible landscape change (Barber 1993). According to conservationists, peatlands simply do not regenerate after large-scale interference by humans to anything like the former state. A consortium of ten voluntary conservation organizations launched the Peat Campaign in 1990. Several objectives were set, such as the ceasation of peat extraction in the UK by 1997, and to encourage the development and use of alternatives (Barkham 1993).

In South Africa reed-sedge peat extraction is monitored by the Department of Agriculture, Directorate Resource Conservation, to ensure that peat suppliers conform to adequate requirements of conservation and rehabilitation of peatlands (Act: 45 of 1983 on Agricultural Resource Conservation).

According to Barber (1993), the rate of *Sphagnum* peat growth is about 2-3cm in a season, whereas according to Smuts (personal communication), the growth rate of South African reed-sedge peat varies from 10cm and more a season. The rehabilitation period of such a peatland can be achieved in less time than the European peatlands.

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Compost

Compost colonized with mushroom mycelium, was obtained from Highveld Mushroom Farm. It was commercially prepared from wetted wheat straw, broiler chicken manure and gypsum. Composting procedures corresponded with those popularly used in commercial production of mushrooms in South Africa (Eicker 1990). Le Lion X20 or Hauser A9.3 strains of *Agaricus bisporus* were used for spawning.

3.1.2 Different casing media used in the phytotron

3.1.2.1 Control

The casing medium used as the control in the trials in the phytotron was the same used by Highveld Mushroom Farm in their commercial production of mushrooms (Figure 6). The casing medium was mechanically mixed on the farm and consisted of a well mixed, moistened mixture of two indigenous reed-sedge peats neutralized with calcitic lime and pasteurized with steam for 6-8h at 60-65°C.

3.1.2.2 Congo peat

Reed-sedge peat from the Loémé river near Pointe Noire at the coast (Figure 7), and from Mbamou island (Figure 8), north-west of Brazzaville was extracted by Smuts (1993) and local workers (Figure 9). It was partially dried on land and bagged (Figure 10), before transportation to South Africa for mushroom production trials at the University of Pretoria.

Figure 6 Casing media. A= Highveld Mushroom Farm casing mixture used as control in the trials, B= Congo reed-sedge peat.

Figure 7 Loémé river near Pointe Noire with peatland in the background (arrows).

Figure 8 Reed-sedge peat was dried near this village on Mbamou Island.

Figure 9 Manual excavation of Congo peat, and bagging prior to transporting it to the mainland for drying.

Figure 10 Mbamou peat, partially dried prior to bagging and transportation.

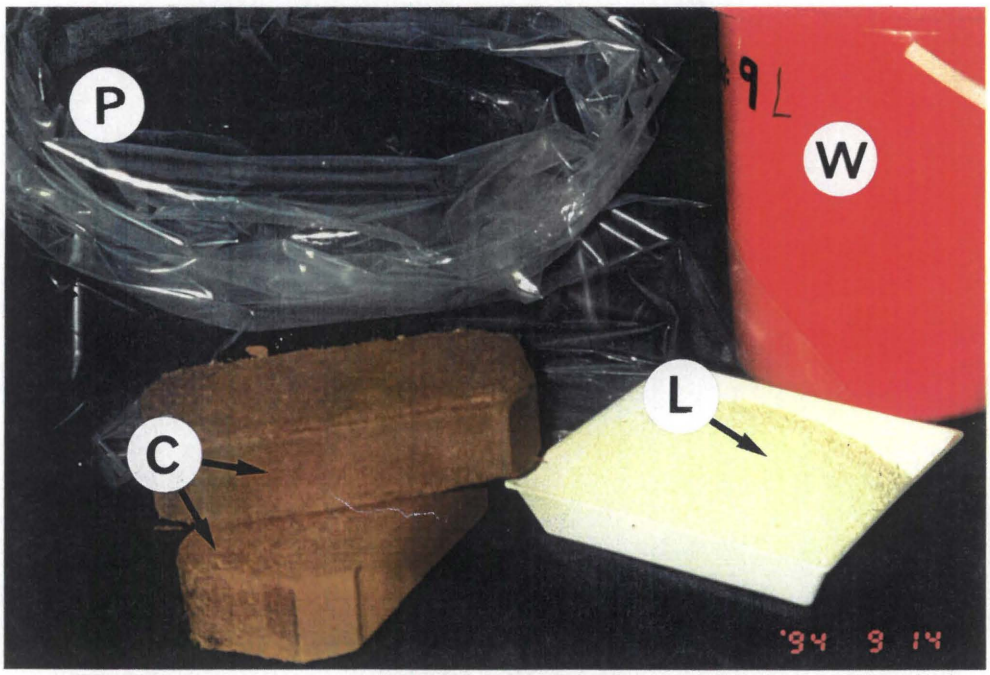

Figure 11 Compressed Coir bricks prior to rehydration and liming.
C = Coir bricks, L = lime, W = water, P = plastic bag for rehydration.

3.1.2.3 Coir

The Coir fibre pith used in this study originated from Sri Lanka and was received as highly compressed bricks (*c.* 20 x 10 x 5cm) (Figure 11), from a supplier of horticultural products. Less compressed larger blocks recently became commercially available but have not been used in these trials.

3.1.2.4 Potchefstroom peat

Reed-sedge peat from a peatland near Potchefstroom in South Africa was extracted by means of a mechanical digger (Figure 12). The peat is less decomposed and contains a large amount of fibres (Figure 13). It was bagged on the farm prior to transportation to the University of Pretoria (Figure 14).

3.1.2.5 Natal peat

Reed-sedge peat from a peatland in Natal (Figure 15) was manually excavated by Smuts from *c.* 50cm below the surface. This virgin material, not being disturbed or handled before, has an almost amorphous structure. The peat sods were not partially dried or screened prior to delivery, and this hampered the handling of the material.

3.1.2.6 Mixtures

Mixtures of Coir and indigenous peats, with the following ratios were prepared for the trials done at the University of Pretoria:

50:50 - Coir:control 50:50 - Coir:Potchefstroom peat
75:25 - Coir:control 75:25 - Coir:Potchefstroom peat
(control = Highveld Mushroom Farm casing mixture consisting of two indigenous peats)

Figure 12 Mechanical digger excavating Potchefstroom reed-sedge peat.

Figure 13 Light coloured, fibrous Potchefstroom peat.

Figure 14 Potchefstroom peat bagged prior to transportation.

Figure 15 Natal wetland where the peat was taken out.

The ratios of 50:50 and 75:25 were implemented to determine whether an equal or greater amount of Coir should be used to improve the porosity, fibre content and water holding capacity of the indigenous peat when used as casing material.

3.1.3 Different casing media used in a pilot trial at Deodar Farm

3.1.3.1 Control

The standard casing mixture (50% Potchefstroom peat: 25% Deodar peat: 25% Bapsfontein peat),with and without lime, used on Deodar farm acted as the control in this trial.

3.1.3.2 Bapsfontein peat, Deodar peat and Potchefstroom peat

One pilot trial was done under commercial conditions on the Deodar farm (Figure 16), to determine the influence of the addition or omission of lime on pH, water holding capacity, pore space, salt content and yield of indigenous peats (such as Bapsfontein, Deodar and Potchefstroom) used as casing material (Figure 17).

3.2 Methods

3.2.1 Physical and chemical characteristics of peat

3.2.1.1 pH

For each type of casing medium a slurry was prepared from one volume of test material and one volume deionised water (Hayes 1981) and a Crison-pH meter supplied with a glass electrode to determine the pH. Three replicates for each sample were tested.

Figure 16 Different casing media hand mixed and limed on Deodar Farm.

Figure 17 Deodar peat pile without lime.

3.2.1.2 Water holding capacity and pore space

Water holding capacity on Potchefstroom, Natal and Congo peat was determined according to the Bord na Mona (Irish Peat Board) and ASTM (American Society for Testing and Materials) Laboratory procedures adapted by Cohen (1983) and can be summarised as follows:

- dry an indefinite mass of peat for 12-24h at 105°C
- determine the mass of a given volume of dried peat eg., a small polytop with volume $4cm^3$
- submerge the peat in water and leave 6-12h
- weigh a wet filter paper
- filter the peat through the wet filter paper
- weigh the filter paper and the peat
- determine the mass of the wet peat
- determine the percentage water holding capacity using the formula:

$$\text{Water holding capacity}(\%) = \frac{\text{wet mass(g) of peat}}{\text{dry mass(g) of peat}} \times \frac{100}{1}$$

Percentage water holding capacity and pore space of Potchefstroom peat and Coir were also determined according to the method adapted by Hayes (1981).

$$\text{Water holding capacity}(\%) = \frac{\text{drained mass(g) - dry mass(g)}}{\text{drained mass(g)}} \times \frac{100}{1}$$

$$\text{Pore space}(\%) = \frac{\text{saturated mass(g) - fresh mass(g)}}{\text{drained mass(g)}} \times \frac{100}{1}$$

Percentage pore space of Potchefstroom, Natal and Congo peat were also determined using the method of Cohen (1983).

3.2.1.3 Microtome thin sections for microscopic analyses

This method is used in geological surveys for characterization (describing) of peats and provides information on the physical, biological and chemical properties of peat. The method involves preparation of microtome thin sections of the peat and making area point-counts of the slides according to Cohen (1983).

Procedure for embedding samples of peat for sectioning on a microtome:

1. An uncompressed cube of wet peat is folded in tissue paper, to minimise disintegration of the peat sample, and labelled.
2. The peat sample is placed in a "killing and fixing" solution (F.A.A) and aspirated to remove all air.
3. The sample is removed from the F.A.A. and placed in a solution of 50% distilled water and 50% ethyl alcohol for 15min.
4. Step 3 is repeated twice with fresh solution.
5. The sample is placed in a series of dehydrating solutions as follows:
   a. 50% water, 40% ethyl alcohol, and 10% tertiary butyl alcohol - 2h.
   b. 30% water, 50% ethyl alcohol, and 20% tertiary butyl alcohol - overnight.
   c. 15% water, 50% ethyl alcohol, and 35% tertiary butyl alcohol - 1h.
   d. 45% ethyl alcohol and 55% tertiary butyl alcohol - 1h.
   e. 25% ethyl alcohol and 75% tertiary butyl alcohol - 1h.
   f. 100% tertiary butyl alcohol - 1h.
   g. 100% tertiary butyl alcohol - overnight.
   h. 100% tertiary butyl alcohol - 1h.
6. The sample is placed overnight in a container with "embedding paraffin" in an oven where the paraffin is allowed to melt.
7. The molten paraffin containing the sample is poured into a "paper boat" and transferred to a tub of ice water so that the paraffin will harden rapidly.
8. After hardening, the cube of embedded peat is carefully removed from the paper and the edges are trimmed.
9. The block is mounted with paraffin on a wooden block for microtome sectioning.
10. Microtome thin sections of 15μm in thickness are cut using a sliding microtome.
11. Cutting, staining and mounting on microscope slides is done following the

standard procedures for making botanical slides.

12. The paraffin is dissolved from the mounted slice of peat with xylene. A permanent microscopic slide is prepared using a drop of Canada balsem on the slice of peat which is then covered with a glass coverslip.

3.2.1.4 "Point-count" technique

Microscopic analysis involved ten equally-spaced transects of each permanent slide made at X400 magnification. An eye piece with a grid (Kpl W 10x; 10x10 squares, each square = 14μm) was used, and the number of times an ingredient fell under a grid point divided by the total number of grid points counted equalled the "area-percentage" of the ingredient. This area "point-count" technique can be used to determine pore space (a hole between fibres or within a large cell cavity or degraded portion of fibre where no ingredients occur), fibre content (objects greater than 100 - 150μm in any dimension), organic components (plant organ types), mineral contents and texture (size, shape and arrangement of components) of peat, to name a few (Cohen 1983). Since the slides are permanent and easily stored, samples are always available for additional new analysis, or repeated analysis. For the purpose of this study only fibre content and pore space of Potchefstroom, Natal and Congo peats were determined using the "point-count" technique.

3.2.1.5 Chemical analysis

The chemical properties of Potchefstroom peat, Natal peat, Bapsfontein peat, Deodar peat and Coir were analysed by a commercial chemical laboratory. No chemical analysis was done on the Congo peat.

Peat samples with and without lime added were send to a commercial laboratory for chemical analysis. Due to the high cost involved only one replicate per sample was analyzed. Therefore no statistical analysis was performed on the results recorded in Table 1. All the peat samples (except Natal peat) were tested with and without lime. Due to an insufficient sample of Natal peat it was tested only without lime.

3.2.2 Mycobiota characteristics of casing

3.2.2.1 Isolation of fungi

Fungi from fresh casing samples prior to pasteurization were isolated using the dilution plate technique (Menzies 1957). A 5g sample of casing was suspended in 250m*l* sterile water and shaken gently for 20-30min. This dilution was 5 x 10^1. One m*l* of this suspension was diluted further by adding it to 9m*l* sterile water in a sterile McCartney bottle to obtain a 5 x 10^2 dilution. One ml of this dilution was added to 9ml of sterile water to obtain a 5 x 10^3 dilution. This procedure was repeated until a dilution series to 5 x 10^5 was obtained. One m*l* of each of the different dilution series was poured in petri dishes, covered and mixed with potato dextrose agar (PDA)-Rose bengal-antibiotic medium and incubated at 25°C. Observations of the number of colonies was recorded after 2-3d. After counting the fungal colonies on the petri dishes, individual colonies differing in morphology were subcultured on PDA, or malt extract agar (MEA) amended with Rose bengal (10m*l*.1000ml^{-1} agar medium) and antibiotic (Chloromycetin-250mg). The cultures were incubated at 25°C until sporulation occurred.

Permanent microscopic slides of the different isolated fungi were prepared using the slide culture technique (Coetzee & Eicker 1990). An agar cube (1 x 1 x 0.5cm) was placed aseptically on the lid of an inverted petri dish containing *c.* 4mm thick PDA. The sides of the agar cube were inoculated with the isolated fungus and a sterile coverslip was placed onto the agar cube (Figure 18). The petri dish was incubated for 3-4d, and later placed under ultra-violet light to enhance sporulation on the coverslip. After sporulation the coverslip was removed and mounted on a drop of lacto-phenol on a microscope slide. The sides of the coverslip were sealed with clear nail varnish. The permanent slide was viewed under a light microscope, and identification of fungi was done according to standard mycological procedures. The isolated species were identified in an attempt to determine the presence of possible competitive and pathogenic species (Figure 19).

A chemically defined selective agar medium (Rinker *et al.* 1993) was also used to screen

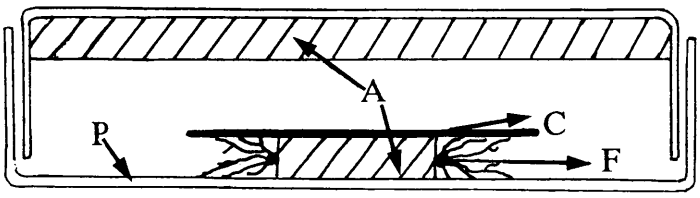

Figure 18 Diagramatic representation of the slide culture technique.
A= agar, C= coverslip, F= fungus, P= petri dish.

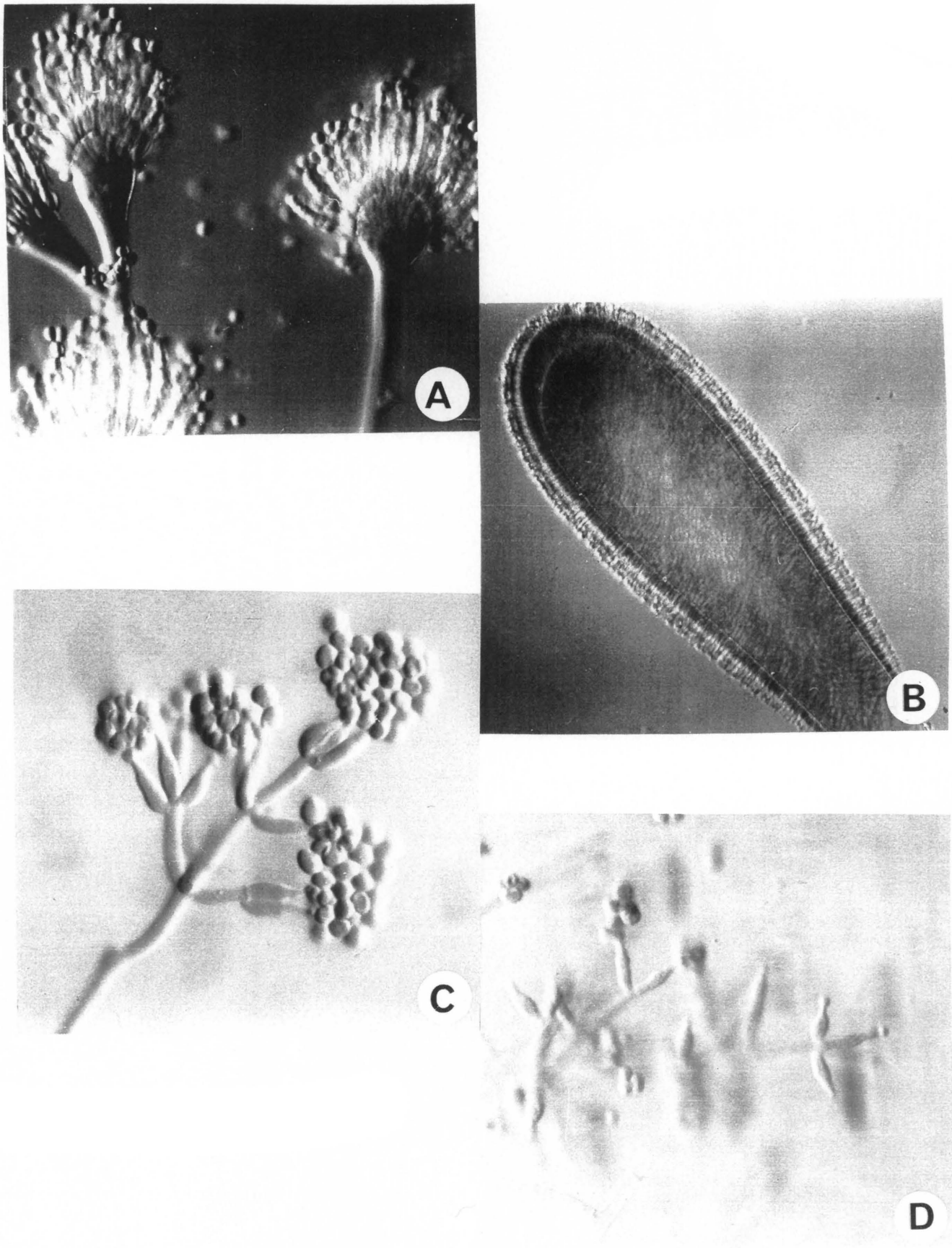

Figure 19 Examples of some of the isolated fungi from the different casing media.

A = *Aspergillus sp.*, B = *Aspergillus giganteus*, C = *Penicillium sp.*, D = *Trichoderma sp*

the casing media for the presence of *Verticillium fungicola* (Preuss.) Hasseb., a serious pathogen causing dry bubble disease.

3.2.3 Preparation and pasteurization of casing media from the raw materials for trials in the phytotron

Reed-sedge peat formation and composition is affected by underground or surface water. The risk that pathogenic spores can get through the peat into the casing soil is much greater, therefore pasteurization is necessary. During pasteurization a minimum temperature must be maintained long enough to ensure eradication of harmful organisms but minimizing damage to beneficial organisms and the physical properties.

3.2.3.1 Congo peat

Congo peat contained a great amount of coarse plant material and was first screened through a sieve to obtain a more uniform material. The peat was hand mixed with ground calcitic lime to adjust the pH to neutral, and moistened to 90% of its saturation point. Pasteurization with steam for 6-8h at 65°C was done on a commercial farm.

3.2.3.2 Coir

Coir bricks were soaked in the prescribed amount of water (one brick.4.5l^{-1} water) for 2-3h to enable water uptake by the fibres. Calcitic lime (1kg.13l^{-1} Coir) was added and hand mixed to adjust the pH. Coir was pasteurized with steam for 3h at 65°C in a converted cement mixer at the University of Pretoria (Figure 20).

3.2.3.3 Potchefstroom peat

Potchefstroom peat was hand mixed with calcitic lime per volume (8 peat:1 lime) and pasteurized for 3h at 65°C in the converted cement mixer prior to casing.

Figure 20 Converted cement mixer used at the University of Pretoria to produce a good blend of casing medium and neutralizing agent for pasteurization.

Figure 21 Wooden growing trays treated with a wood preservative solution of azaconazole.

3.2.3.4 Natal peat

Since the Natal peat arrived as wet sods with an amorphous structure, it had to be partially dried and screened. It was limed and pasteurized in the converted cement mixer as for the Potchefstroom peat.

3.2.3.5 Mixtures

Mixtures of Coir:control (Highveld Mushroom Farm casing mixture) and Coir:Potchefstroom peat were prepared according to the ratios given in 3.1.2.6. The different components were pasteurized and limed separately, in the converted cement mixer, prior to hand mixing.

3.2.4 Preparation and pasteurization of casing media from raw materials for a trial on Deodar Farm

3.2.4.1 Bapsfontein peat, Deodar peat and Potchefstroom peat

Peat from Bapsfontein, Deodar and Potchefstroom is used on the farm as a casing mixture (with lime) in the ratio described in 3.1.3.1. Peat from each type was prepared and mixed by hand in plastic containers of *c.* 20*l* in volume. The amount of lime ($1l.20l^{-1}$ peat) added to the peat corresponded with the Deodar farm practice. The different casing media, with and without lime, were separately prepared and pasteurized in plastic baskets with steam for 8h at 60-65°C during a normal pasteurization cycle on the farm.

3.2.5 Cultivation of *Agaricus bisporus*

3.2.5.1 Experimental design

The experiments were conducted in a controlled environment cropping facility (phytotron) at the University of Pretoria. The treatments were arranged in a randomized block design with four replicate trays for each treatment. The number of

experiments varied depending on the availability of the casing material. One experiment with Coir:Potchefstroom peat (50:50 & 75:25), three with Congo peat, four with Potchefstroom peat, Natal peat and Coir:control (50:50 &75:25) and five with Coir were done.

3.2.5.2 Cultivation procedures at the University of Pretoria

Wooden growing trays with dimensions 0.55 x 0.85 x 17.5cm (surface area = 0,47m^2), were used in all the experiments in the phytotron. Prior to use, the trays were sprayed with a wood preservative solution of azaconazole (Figure 21), at a concentration of 2500ppm (equivalent to a 5% solution) at a rate of 600m*l*.m^{-2} (Eicker & Strydom 1990). The phytotron rooms were washed down with Panacide solution, to minimise contamination prior to stacking the growing trays vertically.

Compost colonized with mushroom mycelium was transported from Highveld Mushroom Farm to the University of Pretoria. Approximately 42kg of compost was manually compressed into each of the wooden trays (Figure 22). The compost was covered with wet paper towelling until the casing layer was applied the following day.

A 4-5cm thick layer of the various, well mixed, moistened, pasteurized casing media was applied to the compost surfaces. The environmental conditions such as air temperature and relative humidity and growing techniques in the phytotron, were comparable to those used in the commercial cultivation of mushrooms in South Africa (Eicker 1990). A light surface spray of 1% formaldehyde was applied to the casing to control surface fungi. After casing, the compost temperature was maintained at *c.* 25°C for 6-7d, air temperature *c.* 22°C, relative air humidity at 95% and a low air flow rate. The rooms were sealed to ensure a build up of a high CO_2 level. At this stage mushroom fruiting was inhibited and only mycelial growth occurred. When the mushroom mycelium reached the surface of the casing (Figure 23), pinning was initiated by reducing the CO_2 concentration level, forcing fresh air to enter the production room and reducing the air temperature from 25°C to 18°C. This stimulated the hyphae to bundle and form primordia (pins), which are the generative stage (fruit-bodies) of the mushrooms. The

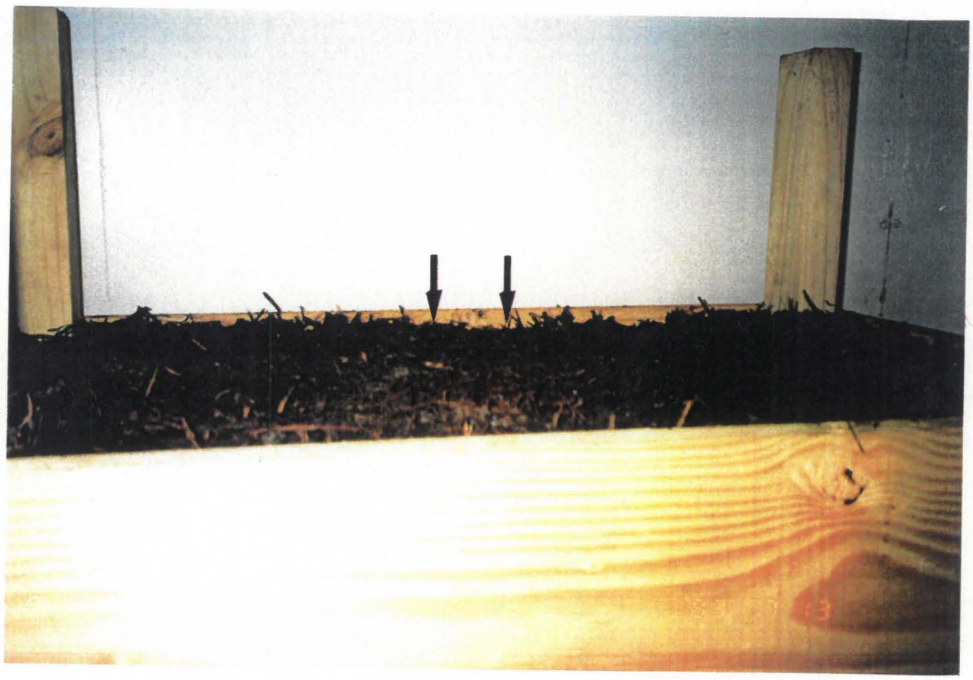

Figure 22 Compost manually compressed into the wooden growing trays (arrows).

Figure 23 Mushroom mycelium visible at casing surface (arrow).

air temperature was then fixed between 17-19°C for optimum size and yield, depending on the activity in the compost and strain requirements.

The amount of water applied to the mushroom beds depended entirely on the nature of the casing material. Sodium hypochlorite (150mg.dm^{-3}) was added to the irrigation water to minimize bacterial blotch on the mushrooms. Mushrooms were hand picked as large "buttons" (30-40mm in diameter) (Figure 24), before the veil under the cap stretched and opened (Eicker 1990). The mushrooms are loosened from the surface when given a slight twist. The stem is cut perpendicularly with a sharp knife, leaving about 2cm of stem. The mushroom crop is unusual in that fruit are produced in a series of spurts or mini-crops known as flushes or breaks. The mushrooms were harvested over three breaks (Figure 25), over a *c.* 42d period, with the first flush being picked *c.* 18-21d after casing. Yield was expressed in kg.m^{-2}. Cropping was terminated in all experiments 5-6wk after casing.

3.2.5.3 Cultivation procedures at Deodar farm

Eight aluminium growing trays with an area of *c.* 0.316m^2 each and containing *c.* 37kg of compost per tray were placed in the corridors of one of the growing rooms. A layer of *c.* 5cm of each of the different casing media was applied to the surface of the compost in the trays. These trays were subjected to the same conditions (temperature, relative air humidity, CO_2 levels and water application) applied to the aluminium shelves in the growing room of the farm throughout the cropping cycle. The mushrooms in the small aluminium trays (Figure 26) were harvested according to the standards used on the farm, and the yield over three breaks was expressed in kg.m^{-2}. The change in pH during the whole cropping cycle was monitored in the same trial (Table 4). Cropping was terminated 4wk after casing.

Figure 24 Mushroom "buttons" (*c.* 30-40mm in diameter).

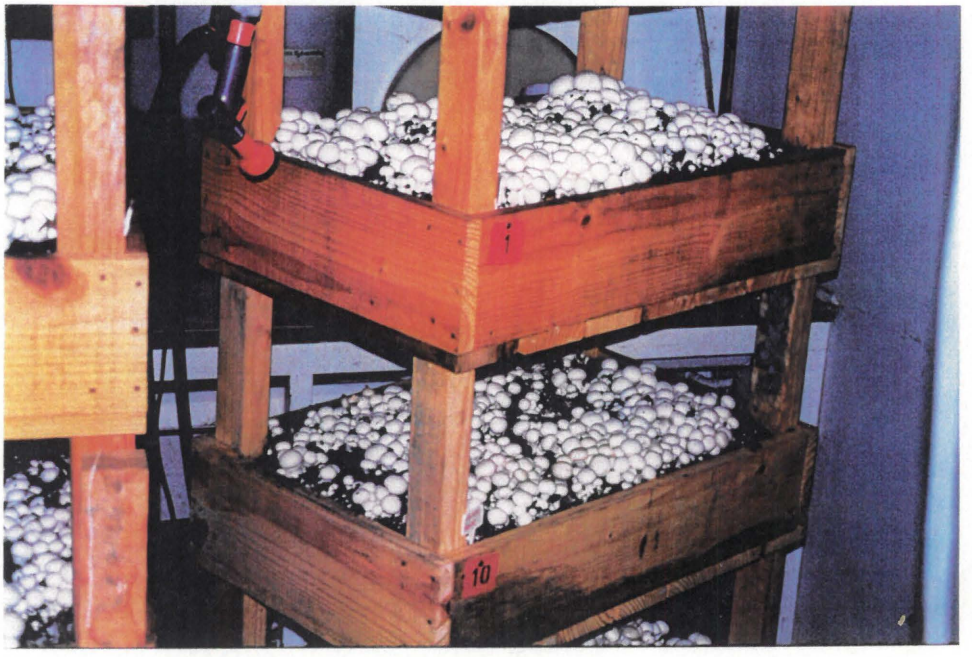

Figure 25 "First break" before harvesting.

Figure 26 Small aluminium growing trays for pilot trial in a commercial mushroom growing room at Deodar farm.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Physical and chemical characteristics of casing

4.1.1 The pH, fibre, ash and salt content as analyzed by a commercial laboratory

The initial pH of Potchefstroom peat of 6.05 (Table 1) may be an indication of the calcareous conditions in the groundwater surrounding the peatland where the peat was excavated. After liming the pH values of all the samples (except Natal peat) increased (Table 1). According to Hayes (1981), the addition of lime (as little as 2%) is beneficial in affecting the buffering capacity for maintaining pH and suppressing excessive salt accumulation. The initial pH increase of the Potchefstroom peat sample (Table 1) seems not to justify the detrimental effect it had on the ash (highest increase) and fibre (greatest decrease) content. Whereas the detrimental effect it had on the ash and fibre content of the Coir can be tolerated for the beneficial pH increase. The assumption can be made that no or little lime could be used with Potchefstroom peat as casing material because the initial pH of 6 falls within the range of *c.* pH 6-8 as suggested by Allison & Kneebone (1962) and Flegg (1989). Peats with a more acidic nature such as Natal and Bapsfontein (Table 1) need to be limed to increase the pH level and minimize the possible growth of competitor moulds such as *Trichoderma* sp. which prefer a lower pH level. Excessive liming should be avoided in the Bapsfontein peat as this can further increase the already high ash content. In comparing Natal peat with Potchefstroom peat the assumption can be made that liming will benefit the Natal peat by increasing the pH and the ash content within the range of a good casing material.

Of all the samples analyzed (Table 1), the percentage ash in the Coir without lime was the lowest while the control, Bapsfontein peat and the Deodar peat had an already high ash content prior to liming. Addition of lime to these peats resulted in a further increase in the ash content as revealed in Table 1. If the pH of the peat is not lower than 5.5-6.0 then the addition and the amount of lime must be taken into consideration

Table 1 Some of the physical and chemical characteristics influenced by the addition of lime, of different casing media as analyzed by a commercial laboratory[a]

	control[b]		Pp		C		Bp		Dp		Np[c]
	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)
pH	6.54	7.25	6.05	6.98	5.50	6.90	4.98	6.71	5.53	6.94	4.88
Ash (%)	57.00	60.25	24.00	55.00	4.00	12.00	55.00	63.50	63.25	67.50	18.25
Fibre (%)	11.85	10.72	42.72	13.37	46.25	38.37	10.42	8.32	13.0	7.27	13.95
Potassium (%)	0.16	0.17	0.13	0.10	0.72	0.67	0.21	0.13	0.14	0.15	0.10
Calcium (%)	1.70	5.31	1.80	19.52	0.22	3.62	0.52	15.96	0.49	4.83	0.49
Magnesium (%)	0.24	0.35	0.48	0.53	0.14	0.21	0.20	0.37	0.10	0.18	0.36
Sodium (%)	0.02	0.03	0.04	0.02	0.31	0.31	0.02	0.02	0.02	0.02	0.12

[a] only one replicate per sample was analyzed due to the high cost of the analyses,

[b] Deodar Farm casing mixture (50:25:25 Potchefstroom peat: Bapsfontein peat: Deodar peat)

[c] lime added not determined,

Pp= Potchefstroom peat, C= Coir, Bp= Bapsfontein peat, Dp= Deodar peat, Np= Natal peat,

(-)= lime not added, (+)= lime added.

when preparing a casing medium. The percentage ash of all the limed samples increased in Table 1. All the limed samples, except the Coir, revealed an ash content closer to being classified as a soil (Smuts personal communication).

The percentage fibre of all the limed samples (except Natal peat) decreased (Table 1) with the greatest decrease in the Potchefstroom peat and the smallest decrease in the control. A possible explanation for this phenomenon may be that the lime replaces some of the fibres per volume of peat. When a large (sometimes excessive) amount of lime is added to the casing, the fibre content may decrease further. Fibre content is associated with the organic skeleton of a casing media, which affects pore space as well as the ability to hold and release water (Cohen *et al.* 1991). A lower fibre content in the casing media will influence the pore space which is associated with the passage of air and water molecule movement and through which hyphae can grow. According to the classification of peats (see p. 11), the fibre content of all the limed samples except Coir decreased to an amount below the minimum fibre content requirements of a class II peat (33-66%).

The percentage calcium and magnesium of all the samples in Table 1 increased after liming. Lime consists of *c.* 97% calcium carbonate (according to the supplier) and the presence of other minerals such as magnesium in the lime could possibly have contributed to the increase of the magnesium. No chemical analysis of the lime was done to determine the percentage magnesium present in the delivered lime batch. The percentage sodium of the control slightly increased whereas that of the Potchefstroom peat decreased (Table 1). The potassium percentage of all the peat samples decreased except in the control and Deodar peat. According to Yeo & Hayes (1978) ions such as potassium and sodium accumulate during cropping which influences the salt concentration and results in a lower water potential. The low percentage of potassium and sodium in the peat samples in Table 1 will possibly not have an affect on the water potential of the casing material.

Although no high salt levels were recorded in the Coir in this study, it is essential for the grower to check with the supplier that the batch received complies to the requirements

of a low salt content. Coir piles less leached by rain water can contain a high salt level which can have an influence on the electrical conductivity resulting in a decrease in the yield.

4.1.2 Fibre, pore space and water holding capacity determined by using different methods

Table 2 lists the results obtained using the methods of Hayes (1981) and Cohen (1983) to determine pore space and the methods of the ASTM (1989) and Hayes (1981) to determine water holding capacity. Fibre content was also determined according to the method of Cohen (1983).

The methods used in Table 2 have advantages and disadvantages. The method of Cohen (1983) needs to be done in a laboratory and requires a certain degree of training and skill in the use of the equipment (such as microtome sectioning) whereas the methods of the ASTM and Hayes (1981) require less skill. The advantage of the permanent microscope slides is that it represents a permanent record of a peat sample from which data can be obtained that is precise, statistically reproducible, and comparable with data from other sources. It is possible to assess the pore space more accurately with this method provided the sample is fresh, correctly handled and not compacted, in which case it would have a detrimental effect on the organic skeleton of the peat (Cohen 1983). The results of the percentage fibre differed between Table 1 and 2 due to different methods of determination. The chemical laboratory treated the peat sample with an acid and then an alkali. The sample was then incinerated and the loss in mass indicated the fibre content (Mr. May, Outspan Laboratory, personal communication).

Transmitted light photo-micrographs of microtome sections (method of Cohen 1983) of Potchefstroom peat (Figure 27) and Natal peat (Figure 28) indicate the presence of many fibres and many pore spaces inbetween which water and gases can move. Potchefstroom peat (Figure 27) had less charcoal than Natal peat (Figure 28). The accumulation of charcoal particles in the Natal peat may be due to a fire prior to sampling. The charcoal may have contributed to the black stickiness of the Natal peat.

Table 2 Determination of percentage fibre, pore space, water holding capacity of Potchefstroom peat, Natal peat, Congo peat and Coir using different methods

	Potchefstroom peat	Natal peat	Congo peat	Coir
Fibre (%)[a]	48	40	50	nd
Water holding capacity WT(%)[c]	410x	459.3y	457y	nd
Water holding capacity (%)[b]	86 (-)y 80 (+)x	nd	nd	90.75 (-)z 87.5 (+)yz
Pore space (%)[a]	35y	28x	37y	nd
Pore space (%)[b]	41.33 (-)x 54.0 (+)y	nd	nd	43.91 (-)x 55.67 (+)y

[a] microscopic analysis according to the "point count" procedure of Cohen (1983),

[b] according to the method of Hayes (1981),

[c] according to the ASTM procedure,

WT= weight, (-)= lime not added, (+)= lime added, nd= not determined.

Values within a row not followed by the same letter are significantly different ($P = 0.05$) according to Duncan's multiple range test.

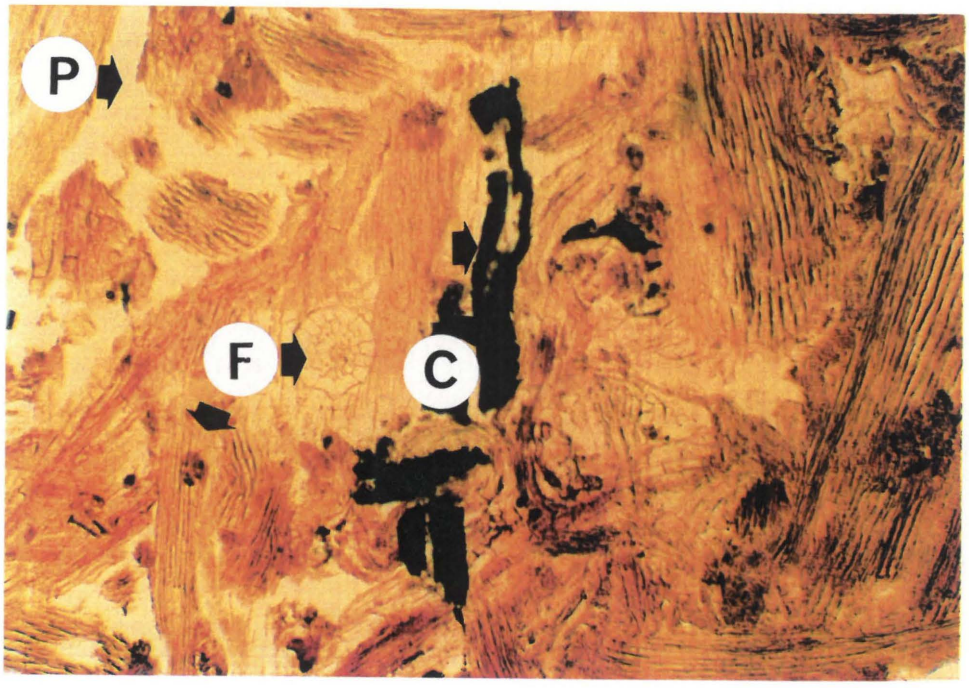

Figure 27 Transmitted light photo-micrograph of a microtome section of Potchefstroom peat. F = fibre, P = pore space, C = charcoal.

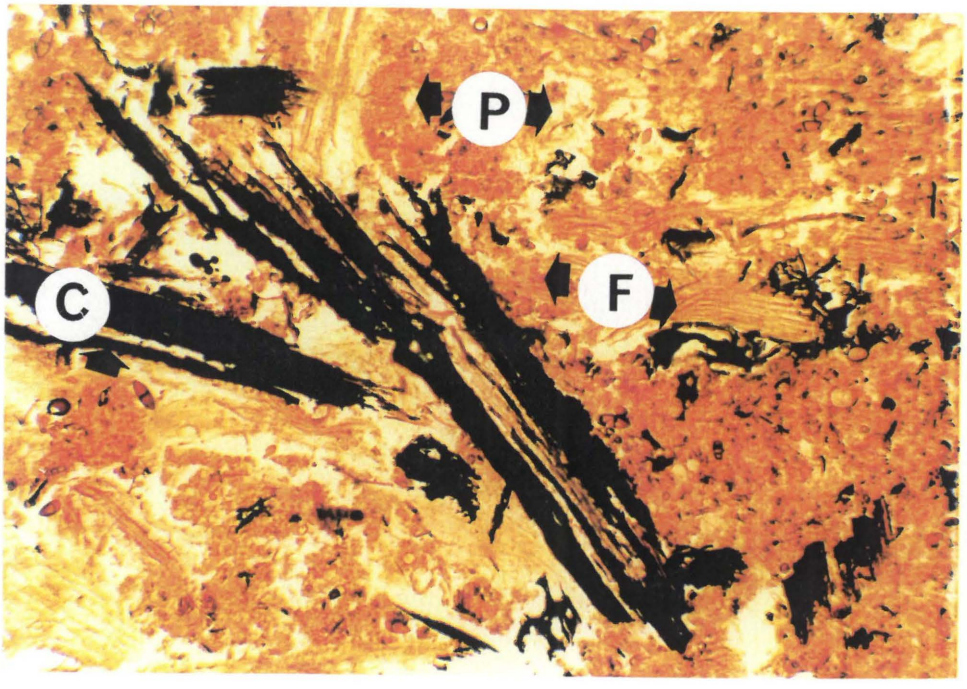

Figure 28 Transmitted light photo-micrograph of a microtome section of Natal peat. F = fibre, P = pore space, C = charcoal.

This problem can be eliminated by excavating at greater depths.

A coarse lime was used in the liming of the Potchefstroom peat and Coir (Table 2) and could have contributed to the improvement of the pore space as determined with the method of Hayes (1981). According to Rainey & Cole (1987), a coarse lime may improve the structure of a medium. An increase in pore space therefore indicates an improvement of the casing structure in relation to pore space.

The water holding capacity [Hayes's (1981) method] (Table 2) of the Potchefstroom peat decreased significantly when lime was added. This may be due to some of the water in the external solution of the organic skeleton being unavailable as it is adsorbed by the lime. Some of the lime particles may also be incorporated into the pore spaces of the organic skeleton (Figure 3) which in turn may have an effect on the water holding capacity. No significance between the water holding capacity of the Coir with and without lime was found. There was a significant difference in the water holding capacity [Hayes's (1981) method] between limed Potchefstroom peat and limed Coir (Table 2). The water holding capacity [ASTM (1989) method] of the Potchefstroom peat differed significantly from the Natal and Congo peat but there was no significant difference between the Natal and Congo peat (Table 2).

The pore space percentage using Hayes's (1981) method (Table 2) of Potchefstroom peat and Coir increased significantly after liming probably due to the lime particles "opening up" the structure of the casing material as found by Flegg (1989). The pore space percentage [Cohen's (1983) method] of the Natal peat differed significantly from the Potchefstroom peat and Congo peat (Table 2), due to the Natal peat not being screened prior to sampling.

4.2 Mycobiota characteristics

The different fungi isolated from the four different casing media before pasteurization are listed in Table 3. Among all the fungi listed in the table, potential competitor green moulds such as *Aspergillus* spp., *Penicillium* spp. and *Trichoderma* spp. were predominant

Table 3 Different fungal species isolated from the different casing media.

Fungus species	Congo peat	Potchefstroom peat	Natal peat	Coir
Aspergillus sp.	x	x		x
A. flavus Link:Fr.				x
A. fumigatus Fres.				
A. giganteus Wehmer	x			x
A. glaucus group	x			x
A. niger V. Tiegh.				x
A. ochraceus Wilhelm				
Chrysonilia sitophila (Mont.) V. Arx.	x			
Fusarium sp.		x		x
Geotrichium sp.		x		
Penicillium sp.	x	x	x	
Trichoderma sp.	x	x	x	
T. harzianum Rifai			x	

in all the samples. According to the results listed in Table 3 the Coir sample contained mainly species of *Aspergillus*, while *Trichoderma* sp. occurred in Congo, Potchefstroom and Natal peat. It is known that species of *Trichoderma* produce toxic substances which inhibit mushroom development or cause deformation of the mushrooms. Only three species of fungi occurred in the Natal peat sample. A possible explanation may be that Natal peat is a virgin peat which means it was extracted from fields which have never been used for agricultural purposes or mushroom cultivation. The risk that it contains spores of for example *Mycogone* sp. is nearly excluded. *Verticillium fungicola* which causes "dry bubble" was not isolated from any of the casing media during these trials. During the cropping cycles only a few replicates had insignificant small patches of green moulds on the casing surface towards the end of the cycle. The virtually mould-free casing surface during the cropping cycles, can be an indication of a good quality compost received from the farm and a correct hygiene program in the phytotron.

In addition to fungi, bacterial blotch occurred towards the third break due to water on the caps after watering which favoured bacterial growth.

4.3 Cultivation of *Agaricus bisporus*

4.3.1 Mushroom yield with different casing media

The yield obtained using Natal peat did not differ significantly from the other casing media (Figure 29). This implies that Natal peat could be considered as a new casing source for a possible casing media. Although the Natal peat was partially dried and screened, it still had a rigid structure resulting in a more denser casing which was difficult to mix in the small equipment and apply to the compost surface. The initial screening of the Natal peat presumably did not produce enough pore spaces, which may have resulted in this peat not being porous enough and that may have affected the yield adversely.

Potchefstroom peat yielded significantly more than Coir, 50:50 Coir:Potchefstroom peat mixture and the 75:25 Coir:control peat mixture. There was no significant difference

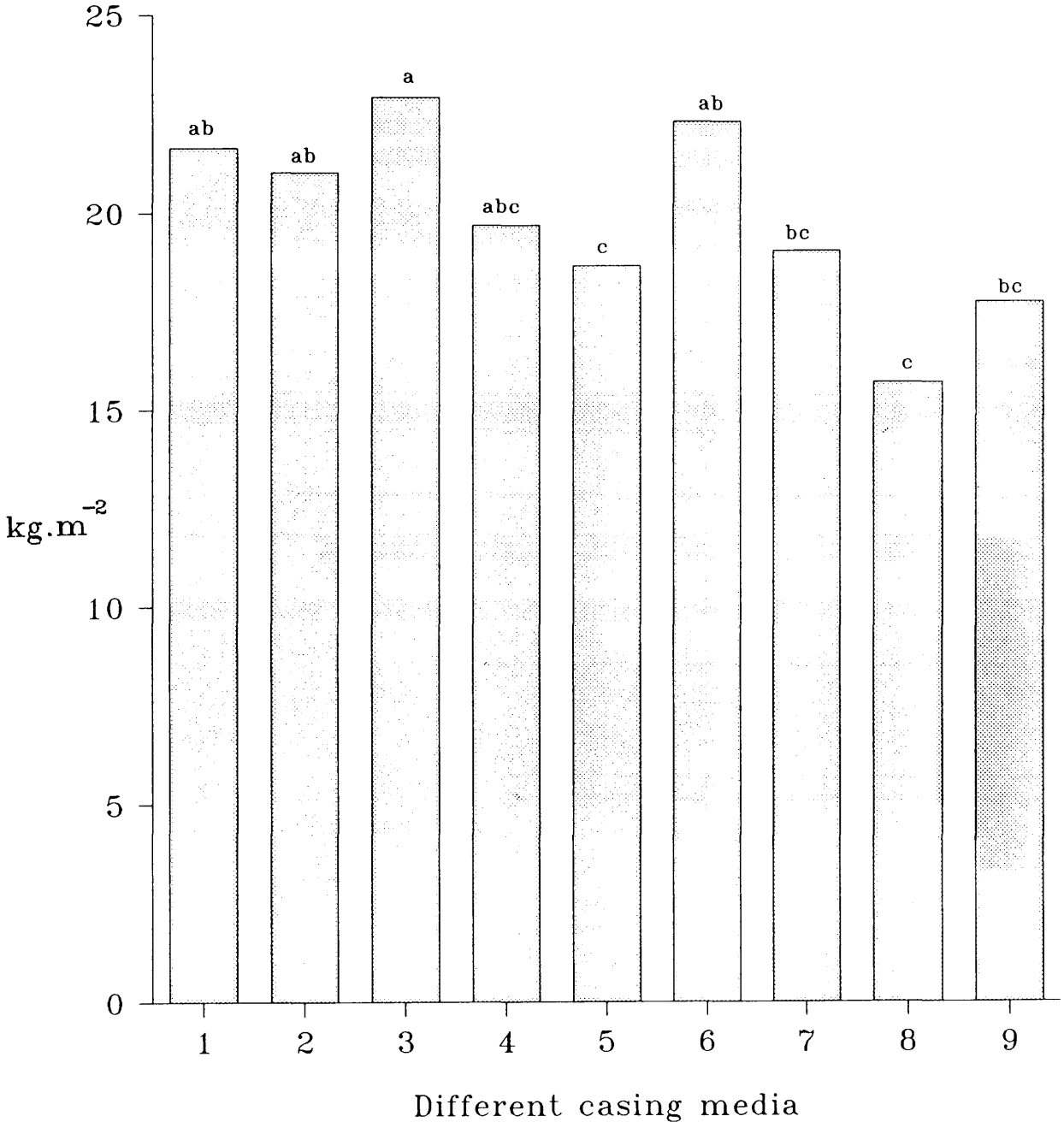

Figure 29 Yields of *Agaricus bisporus* at the end of three breaks. 1 = control (Highveld Farm peat mixture), 2 = Congo peat, 3 = Potchefstroom peat, 4 = Natal peat, 5 = Coir, 6 = 50:50 Coir:control, 7 = 75:25 Coir:control, 8 = 50:50 Coir:Potchefstroom peat, 9 = 75:25 Coir:Potchefstroom peat. Different letters above bars indicate significant differences (P = 0.05) according to Duncan's multiple range test.

between the yield of Potchefstroom peat, the control, Congo peat, Natal peat and 50:50 Coir:control peat mixture (Figure 29).

During the cropping trials, the fibrous nature of Coir had a tendency to produce dirty mushrooms with dry fibre particles stuck to the caps. Overpinning also occurred. Fluctuations in environmental conditions such as temperature could have caused mushroom initiation deeper in the casing resulting in these dirty mushrooms (Noble 1991). The Coir surface dried out quicker than the control and it tended to result in surface hardening or "panning". This may be attributed to the lack of clay particles and the greater porosity of the material, resulting in more macropores through which the irrigation water drained. This may have resulted in the significantly lower yield compared to the control (Figure 29). Overpinning, overdrying and "panning" occurred to a lesser extent in the Coir mixtures, and may be as a result of the presence of colloidal particles originating from the indigenous reed-sedge peat used in the mixtures.

The yield of the 50:50 Coir:control mixtures were significantly higher than that of the 50:50 Coir:Potchefstroom peat mixtures (Figure 29) probably as a result of the control casing media being screened on the farm prior to mixing and application to the mushroom beds. The control consisted of peat from two different localities which could also add to the higher yield obtained with this peat. There was no significant difference between the yield obtained with 75:25 Coir:control and 75:25 Coir:Potchefstroom peat. Both these yields did not differ significantly from the yield obtained with the 100% Coir casing. This may be an indication that more than 25% of other peats should be added to the 75:25 Coir:control and Coir:Potchefstroom peat mixtures.

The Potchefstroom peat had a significantly higher yield than the Coir:Potchefstroom mixtures (Figure 29). The Coir:Potchefstroom mixtures (Figure 29) yielded less than the Potchefstroom peat and may be due to the fact that the Potchefstroom peat contained a visibly higher percentage of fibres. The fibre content of the mixture was increased by the inclusion of the Coir and could have had an adverse effect on the yield as a result of the higher porosity and tendency to dry out quicker.

The cumulative yields of *A. bisporus* using different casing media and different casing mixtures are represented in Figures 30 and 31, respectively. On day 23 (*c.* after the 1st break), 33 (*c.* after the 2nd break) and 42 (*c.* after the 3rd break) Potchefstroom peat had the highest yield of 9.38, 18.63 and 22.38 $kg.m^{-2}$, respectively. The lowest yield over the three breaks was with the 50:50 Coir:Potchefstroom peat mixture with yields of 5.48, 13.96 and 15.72 $kg.m^{-2}$, respectively. According to the results obtained from the graph in Figure 31, the mixture of 50:50 Coir:control performed similarly to the control. The 50:50 Coir:control casing mixture could have benefitted physically and chemically due to the presence of colloidal particles originating from the control, and the high fibre content from the Coir.

4.3.2 Influence of lime on mushroom yield and pH

The results listed in Table 4 obtained from the commercial trial done at the Deodar farm indicated that the addition of lime to the different peats resulted in a decrease (with the exception of Potchefstroom peat) in the mushroom yield over three breaks. A slight increase in the pH of all the casing media was found towards the end of the cropping cycle (Table 4), as previously reported by Visscher (1988). According to Visscher (1988), the mycelium growth in the casing medium seems to reduce the pH slightly by the formation of Ca-K-oxalate crystals around the hyphae, but the pH then rises slightly through the watering process. The assumption is made that calcium ions are released from the lime source through the water, and that they are flushed through the peat and fixed. In this way the pH is raised to *c.* 7.

Potchefstroom peat without lime (Table 4) yielded more than when lime was added. It seems that although the lime addition increased the pH of the Potchefstroom peat and the other casing media, it resulted in a slight decrease in yield of all the other casing media. The addition of lime to indigenous peats and the influence on mushroom yield needs to be investigated further.

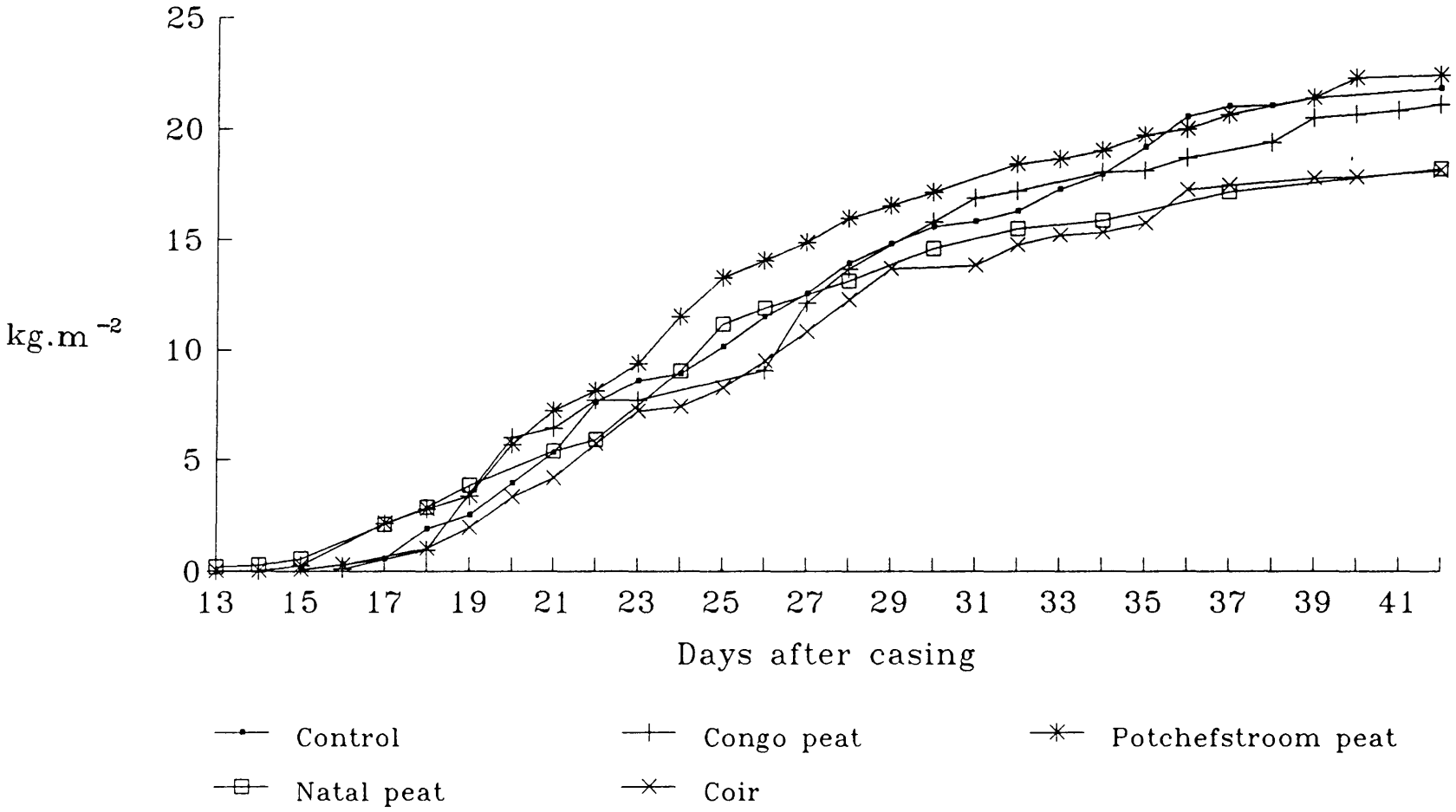

Figure 30 Cumulative yields of *Agaricus bisporus* using different casing media.

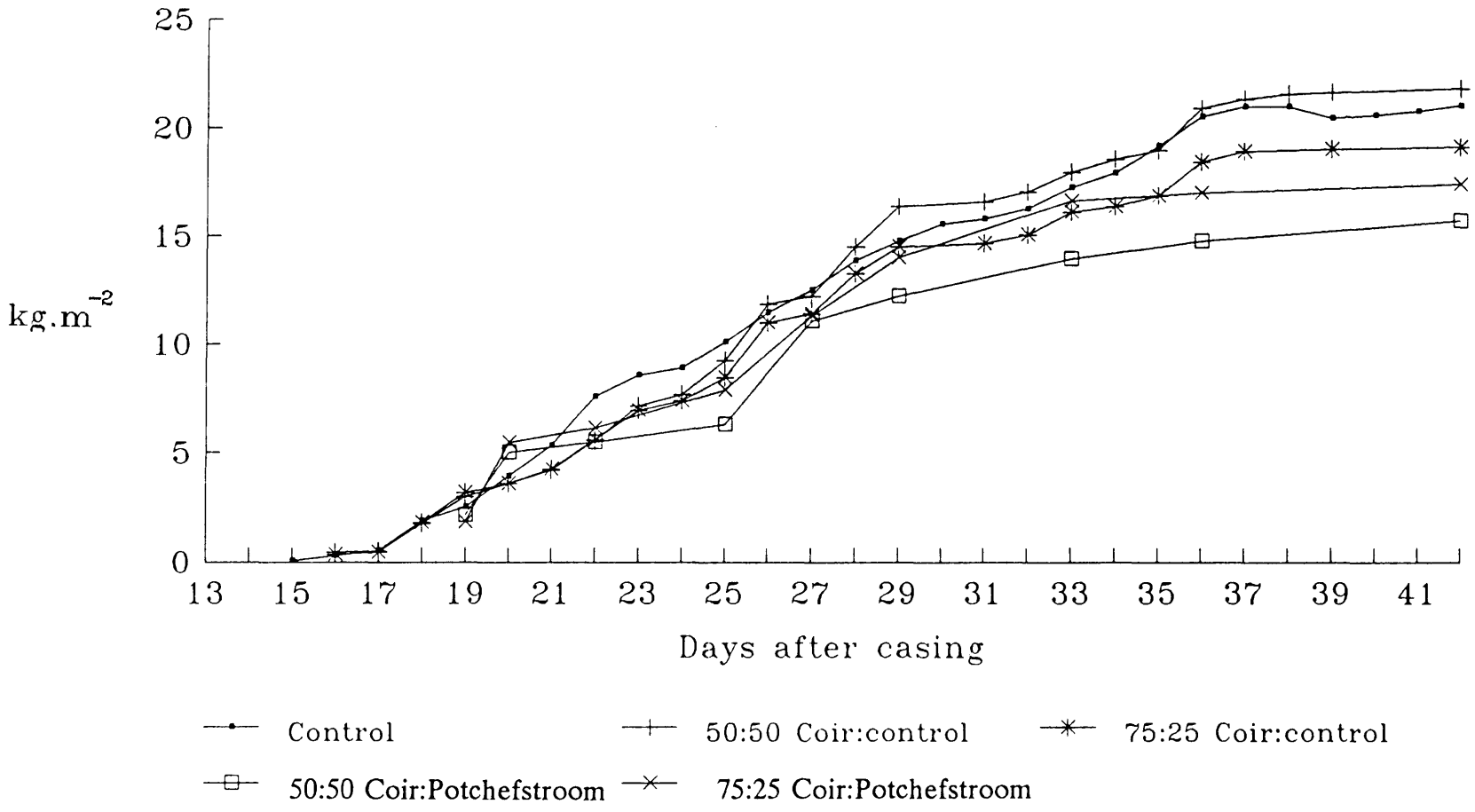

Figure 31 Cumulative yields of *Agaricus bisporus* using different casing mixtures.

Table 4 Influence of lime on mushroom yield over three breaks, and pH change using different casing media at a commercial trial at Deodar Farm[a]

	control[b] (+)	control[b] (-)	Pp (+)	Pp (-)	Bp (+)	Bp (-)	Dp (+)	Dp (-)
Yield ($kg.m^{-2}$)	27.06	23.99	24.58	25.08	22.44	19.96	24.21	21.20
pH [c]	7.25	6.54	6.98	6.05	6.71	4.98	6.94	5.53
pH [d]	7.34	6.69	7.58	7.21	7.28	5.89	7.33	6.01

[a] only one trial was done and no statistical analysis was made,

[b] 50:25:25 Potchefstroom peat: Bapsfontein peat: Deodar peat,

[c] pH before pasteurization,

[d] pH at end of cropping cycle,

(+) = plus lime, (-) = minus lime, Pp = Potchefstroom peat, Bp = Bapsfontein peat, Dp = Deodar peat.

CHAPTER 6

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ABSTRACT

The quality, suitability and availability of peat sources and an alternative casing media for South African mushroom growing was investigated.

Reed-sedge peat from Africa (Congo), South Africa (Potchefstroom, Bapsfontein, Deodar and Natal) and coconut fibre pith (Coir) from Sri-Lanka were evaluated as casing media for *Agaricus bisporus* Lange (Sing).

Physical properties such as water holding capacity, pore space and fibre content were determined using two different methods. Chemical properties (pH, fibre and salt contents) were analyzed by a chemical laboratory. Cropping trials were conducted in a phytotron and a commercial trial was done on a mushroom farm. The yields indicated a significant difference between the control and some of the Coir:peat mixtures but not between the indigenous peats. The influence of the addition of lime indicated a decrease in the water holding capacity, the fibre content and a slight decrease in the yield.

OPSOMMING

Die kwaliteit, geskiktheid en beskikbaarheid van veenbronne asook 'n alternatiewe deklaag medium vir die groei van sampioene in Suid Afrika is ondersoek.

Riet-biesieveen van Afrika (Kongo), Suid Afrika (Potchefstroom, Bapsfontein, Deodar en Natal) asook klappervesel (Coir) van Sri-Lanka is geëvalueer as deklaagmateriaal vir *Agaricus bisporus* Lange (Sing).

Fisiese eienskappe soos waterhouvermoë, porie-spasie en veselinhoud is bepaal deur van twee verskillende metodes gebruik te maak. Chemiese eienskappe (pH, vesel en soutinhoud) is deur 'n chemiese laboratorium bepaal. Kweking van sampioene is in 'n fitotron gedoen en 'n kommersiële eksperiment is op 'n sampioenplaas uitgevoer. Die opbrengs resultate is beduidend verskillend tussen die kontrole en die Coir:veenmengsels maar nie tussen die opbrengste van die inheemse veen nie. Die invloed van kalsitiese kalksteen byvoeging tot die deklaae dui 'n vermindering aan in die waterhouvermoë, veselinhoud asook die opbrengs.