PN-ABY-491
99109

SMALLHOLDER MUSHROOM PRODUCTION

IN SWAZILAND

SHORT-TERM TRAINING

IN

MALAWI

3 - 16/7/95

BY

THANDIE LUPUPA - A.O. HORTICULTURE

AND

DAUGLAS GAMA - R.O. HORTICULTURE

ACKNOWLEDGEMENTS

Thandie (a Subject Matter Specialist) and Douglas (a Research Officer) both in Horticulture, would like to extend their appreciation to the USAID Commercial Agricultural Production and Marketing Project Number 645-0229 and to the Government of Swaziland for sponsoring their study tour in mushroom production and marketing in Malawi on July 3 - 16, 1995.

They would also like to thank the Government of Malawi for allowing them to come for this training at Bvumbwe Agricultural Research Station. A vote of thanks in this institutions goes to several people, particularly the Acting Chief Research Officer, Mr Sanjama, who warmly welcomed the two officers and made everything they needed availabe; Mr A.N.Phiri for being the major contact person in making all the arrangements for the training; Mrs C.E.D. Mainjeni (the Rsearch Officer in mushroom) and Mr L.B.M. Kayira (a laboratory Technician in the Mushroom Research Unit) for giving lectures, practicals on mushroom production as well organizing"farm visits."

TABLE OF CONTENTS

	Page
Introduction	3
History of mushroom production in Malawi	4
The Biology of mushrooms	5
Mushroom spawn making in the laboratory	5
Spawn and spawning	7
Composting	8
Nutrition and growth requirements of cultivated mushrooms	12
The casing soil	13
Application of casing soil	15
Mushroom bed management	16
Mushroom diseases and their control	19
Effective pest and disease control	19
Economic Importance of the cultivated mushroom in Malawi	22
Visitations to mushroom growers in Malawi	23
Recommendations for development of mushroom production and marketing in Swaziland	26

INTRODUCTION

This training was a fulfilment of a Mushroom Project Proposal aiming at investigating possibilties of mushroom production by smallholders in Swaziland. Malawi which was reported to be advanced in mushroom production was chosen to be an appropriate place to go to for the training particularly that it is also a developing country like Swaziland.

The report on this training, which took place at Bvumbwe Agricultural Research Station on July 5-16,1995, is presented in three parts. The fisrt part is the presentation of the lecture notes which starts with the history of mushroom production in Malawi- highlighting their achievements and limilitations; the cycle of mushroom production, starting with the "biology of a mushroom". The second part deals with "farm visits" which were important in assessing the farmers' views about the mushroom production enterprise in their circumstamces in Malawi. The third part is a presentation of the Recommendation on the Development of Mushroom Production in Swazialand.

HISTORY OF MUSHROOM PRODUCTION IN MALAWI

Mushroom production under Research began in 1979 at Bvumbwe Research Station using South African strains. At that time the information was not sufficient. The research work on mushrooms was done in a mudded and grass thatched house. Spawn was being imported in the name of brown and white strains of *Agaricus* spp. of mushrooms.

Yields were very low; the highest being 5kg/m^2 of mushrooms harvested over a period of three months. By 1987, Research work was being done using Taiwan mushroom strains of Agaricus bisporus: TNS1 and TN2. The mushroom houses used were an adaptation and modification of Taiwan mushroom houses. These were of a frame work of wood covered with a heavy plastic and outer grass thatch for insulation. In the middle of 1987, the Research had produced a bumper yield. Farmers around Bvumbwe who came and saw this crop very much wanted to embark on a mushroom production enterprise.

Achievements from 1987 to date under research are as follows:

1. Investigations have proved that rice straw and maize stover are best raw materials for making compost.

2. Spawning has been reduced from 600ml to 400ml/m^2 without reducing yield and yet reducing costs of production.

3 Highest yield range of 10-15kg/m^2 over 3 months have been obtained under research.

4. Farmers not less than 50 have at least grown mushrooms and successfully obtaining an average yield of 5kg/m^2 over 3 months.

5. Bvumbwe Research Station no longer import spawn from South Africa for research purposes as the Research is now able to produce spawn for research and the excess to sell to farmers .

Whilst the above are achievements, limitations do exist in this enterprise as of now. These are as follows:

1. Low spawn production versus high demand due to limited resources.

2. Extension department have not taken up this project and so pressure on advisory remains with the Research Department.

3. Many farmers who are interested in growing mushrooms get dissappoited because they cannot easily get spawn.

THE BIOLOGY OF MUSHROOMS.

In the course, the biology of mushroom was discussed. The mushroom was defined as a fungus which lacks chlorophyll to enable it to make its own food. For a living therefore, mushrooms depend on other organisms for food. All fungi, except yeast, form what is called "hyphae" which are tiny threads that originate from the spores. These hyphae will branch out and form a mycelium. When these threads cross one another, they mate and produce spore-producing structures called "mushrooms".

By breeding, different strains of mushrooms have been produced. In Malawi, Taiwan strains: TNS1 and TN2 have been found to be very productive with yields ranging between 10 - 15kg/m^2. The *Agaricus bitorguis* strains from the Republic of South Africa were found to produce very low yields of 5kg/m^2.

MUSHROOM SPAWN MAKING IN THE LABORATORY

Spawn is a technical name for mushroom seed. The spawn is infact a pure culture of a desired mycelium. The recommmended culture medium for the three types of mushrooms: TN2, TNS1 and *Agaricus bitirquis* is prepared using the following ingredients:

1. 67g of dry corn (after removing the testa and breaking it into pieces)
2. 17g dry compost (after peak heating).
3. Distilled water (1L)

METHOD OF PREPARATION.

Wash the corn three times under tap water, mix it with 17g dry compost in a beaker and add 1 litre of distilled water.

Cover the mouth of the beaker with a piece of plastic (autoclavable) and autoclave at 121^{0}C for 10 minutes. Strain the liquid from the beaker through a towel three times. Take the volume of the strained liquid, and top it up to 1 litre with distilled water. Mix the 1 litre solution with 39.5g Potato Dextrose agar (PDA). Then autoclave the mixture at 121^{0}C for 30 minutes. After this step, the medium is ready for pouring onto sterile petri dishes or test tubes which have been pre-sterilized before pouring medium at 132^{0}C for 10 minutes. Inoculate after about 24 hours from pouring the medium. This is done under a Laminar Flow carbinate.

STOCK CULTURES.

Stock cultures are those cultures that have been preserved in test tubes under sterile mineral oil, e.g. liquid paraffin to

keep the fungus dormant for future use.

Under sterile conditions, using a sterile scooping loop, make a full scoop from a section of the culture in the test tube and allow excessive oil to drop back into the test tube. Open the lid of the petri dish sightly and press the scoop onto the medium with side of fungal growth facing up until the section of the medium in the scoop is slightly pushed out.

It is important that when making scoops from the test tube, the mouth of the test tube should always be over a flame of gas or alcohol fire to avoid contamination. This step is done in order to multiply the fungus. Generally the fungus takes two weeks to grow if the source of inoculum was under oil. The petri dishes should be as sources of inoculum to inoculate onto other dishes in order to multiply the fungus further.

PREPARATION OF MEDIA SLANTS IN TEST TUBES.

Instead of pouring the medium onto petri dishes as explained above, test tubes are used and the method is as follows:
Plug the required number of test tubes with cotton wool and sterilize at 132^{0}C for 10 minutes. Pour the medium into these test tubes about 1/4 way up and sterilize at 121^{0}C for 30 minutes. When the sterilisation cycle is over, take the test tubes out and put them in a slanting position such that the distance from the mouth of the test tube to the lowest part of the slant is about 1/2 the length of the test tube. Leave them in that position and inoculate after 24 hours. Cultures grow faster if incubated at 25^{0}C, but they will still grow at room temperature. Pour into each test tube a reasonable amount of oil, immersing the whole culture but not touching the cotton plug.

The cotton plug should then be covered with a piece of aluminium foil and then sterilized at 132^{0}C for 10 minutes.

These cultures can be stored at room temperature and should remain unspoiled for at least five years. This period can be extended by keeping them in a refrigerator at 5^{0}C. If stock cultures are not desired, the fully grown cultures in test tubes (without oil of course) can be used as a source of inoculum for preliminary inoculations, a step before making spawn which is the mushroom seed that will yield the actual mushroom.

Sterile wheat seed is used as the medium for spawn making.
Ingredients:

Dry wheat seed	98%
Calcium carbonate	2%

The proportions are equivalent to 20.4g of calcium carbonate to 1kg of dry wheat seed.

Method of preparation.
In a saucepan, cook clean wheat seed until it is just soft - not very soft.
Pour the seed out onto an open container, preferably a straw tray to drain excess water and also to allow it to cool down quickly. Once it has cooled, add the required amount of calcium carbonate and mix thoroughly. Pour the seed into a jar, plug off the mouth with cotton wool and autoclave at 121^{0}C for 1 hour (if contents are in excess of 1 litre autoclave for 1 hour and 30 minutes).

After the contents have cooled down, with constant flaming of the mouths, pour them into test tubes containing cultures up to a point where they will not touch the cotton plug. Close the test tubes and incubate at 25^{0}C. The wheat grains will be fully colonized by the mushroom fungus mycelium after two to three weeks. At this stage, larger quantities of seed should be prepared in jars following the steps stipulated above. Once sterilized and cooled, inoculate by pouring into the jars the colonized wheat seed from the test tubes with constant flaming of the mouths of both the jars and the test tube. Generally, one 60ml test tube will be sufficient to inoculate one jar of 1 litre capacity. After inoculation, incubate at 25^{0}C or leave at room temperature.

The seed in the jars will be fully colonized by the mushroom fungus mycelia after two to four weeks. However, tha actual period will depend on factors like size of the jar, amount of inoculum used and whether the jars were incubated or not. Once fully colonized, the jar contents are now known as spawn. This is the final product in the spawn making process and that which will be spawned or sown in the mushroom house as "seed".

The spawn can also be used as a source of inoculum for further multiplication of spawn. Flame the mouth of the spawn jar and that of the jar to be inoculated and simply pour a reasonable amount of spawn into the other jar and plug off with cotton wool. Note that all materials being used are sterile.

Caution: Never sterilize a jar or a test tube that has already or previously been inoculated as this will kill the mushroom fungus inside the jar.

SPAWN AND SPAWNING

Spawn is the technical name for mushroom seed. Spawning is the broadcasting or planting of mushroom seed onto the compost on the shelves.

Before spawning ensure that:
1. The moisture content of the compost is 65-70%
2. The compost temperature should be reduced down to 25^{0}C
3. The relative humidity should be at 75-85%
4. Spawning rate is 400ml/m^2

(planted) is initially broadcasted on the compost and is completely or thoroughly mixed into the compost up to the bottom

of the compost.

(c) Then the remaining 1/4 of the total spawn is broadcasted or spread on top of the compost and mixed lightly with the compost.

(d) After spawning the compost should be levelled

(e) Then the door should be closed and the compost temperature should be maintained at 25^0C.

Day 2. If the temperature of the compost rises above 25^0C, then open vents. Also mantain relative humidity at 75-85% after spawning.

Day 3. Ventilation should be reduced.

Day 4. Open the vents for 30 minutes for ventilation. This should be done twice a day i.e. 30 minutes in the morning and 30 minutes in the evening to reduce CO_2

Day 7. Mycelia has now colonised the compost. Therefore ventilation needs to be increased to 1 hour to make the surface layer of the compost dry slightly to avoid contamination by other fungi. After the surface is dry, ventilation is not necessary.

It takes 12 to 14 days for the spawn to be fully grown or colonised into the compost.

Factors that affect spawn colonisation.
(a) Spawn rate and its distribution and purity.
(b) Compost moisture
(c) Compost temperature.
(d) Nature or quality of compost.

COMPOSTING (PHASE 1)

Generally, composting refers to the piling up of substrates for a certain period of time and the changes due to the activities of various micro-organisms which result in the composted substrate being chemically and physically different from the starting material.

The purpose of phase 1 composting is to mix and wet the raw materials and to begin the composting process during which the various micro organisms break down the straw. The initial substrate must have the following qualities:
. must support aerobic conditions.
. hold water without becoming water lodged.
. have a proper pH.
. have good drainage.
. free from stones, wires and garbage.

Phase 1 composting is also known as Free Heating or Outdoor

composting. In this phase , the materials are put into stacks, preferably protected and under a shelter and it is here where the chemical and microbiological processes begin and develop under

uncontrolled conditions. The duration of the process is from 14-16 days during which the material must be turned repeatedly for purposes of mixing , shortening, adding, wetting and homogenising the material. Thermophillic bacteria, moulds and the actnomycetes are responsible for improving the water holding capacity and to bring the various nutrients to a proper condition. The germs of these bacteria and moulds present in the manure, develop and multiply absorbing oxygen and producing heat, water and carbon dioxide and the fact that in a well stacked manurepile, there is little coding, compost temperature rises. As it rises from e.g 35oC it becomes too hot for the first group of bacteria, thus the work is taken over by the next group of which prefers high temperatures etc. until about 60^0C.

The compost must be turned every 3 to 4 days by separating the material between the top , middle and bottom zones to give the entire compost the desirable aerobic zone conditions for fermentation.

Generally, cultivated mushrooms grow well on compost made from straw to which small quantities of fertilzer and chicken manure as well as small quantities of waste containing protein, such as soya bean meal, cotton seed meal are added.

So far, rice straw,maize stalks and wheat straw have been tested in compost making, with rice straw giving the highest yield and wheat straw giving the lowest when the following mushroom varieties *(Agaricus bisporus)* with their cropping temperature requirements were used:

1. TNSI 16^0 - 20^0C
2. TN2 18^0 - 22^0C

Steps in Phase 1 Composting.

Compost ingredients per ton of chopped dry straw:

sulphate of ammonia	20kg
single super phosphate	30kg
calcitic lime	10kg
white wash lime	20kg
chicken manure	150kg
rice bran	30kg
soya bean powder or cotton seed cake	20kg
molasses	20kg

COMPOSTING PROCEDURE:

After the straw has been cut, the procedure is as follows:

Day 1 pre-wetting of straw
Day 2- 4 Compost is left intact in order to let it ferment
Day 5 Turn the compost. Add white wash lime, chicken manure and half the amount of sulphate of ammonia and mix thoroughly then stack the compost. The stack should at least be 1.8m in width and 1.3m in height.
Day 6-7 No activity.
Day 8 (2nd turning) Add single superphosphate and calcitic lime, then re-stack the compost.
Day 9 No activity.
Day 10 Wet and mix soya bean powder with rice bran and molasses without adding them to the compost
Day 11 No activity
Day 12 (3rd turning) Break and aerate the compost stack. Add the wetted mixture of soya bean powder,rice bran and molasses and the remaining amount of sulphate of ammonia.
Day 13-14 No activity
Day 15 Break and loosen the compost then restack it Fill the compost onto the growing shelves in the mushroom house to a height of 15cm without compressing. Compost should have a moisture content of about 75%.When squeezed, a few drops of water should just ooze out. Clean the floor and close all doors and ventilators.

The compost after free heating, filling generally, has the following characteristics:

. Smell of ammonia and manure very much apparent
. Still sticky and slimy. Hands get wet or dirty.
. Lightly speckled with white actinomycetes.
. Properly moist, about 72-75% moisture content. When squeezed firmly, drops of liquid from the manure appear between the fingers.
. Straw blackish in colour.

PRE-REQUISITS OF COMPOST PASTEURISATION

The term "Pasteurisation" is also referred to as Peak-heating or Sweat-out. Pasteurisation differs from sterilisation because the former term refers to the use of "low temperatures to kill unwanted organisms and leave some useful ones; whilst the latter means the use of high temperatures to kill all orgainsms.

The objective of pasteurisation or phase 11 composting are two folds:

1. To eradicate insects and pests carried in with phase 1 composting (out door) substances and to destroy spores of contaminating micro-organisms.

2. To bring the substrate to a uniform temperature of about 65^0 -70^0C (while air temperature is 60^0C) which promotes decomposition of the substrates by thermophillic micro-organisms.

Through this final adjustment,a more selective medium favouring the growth of mushroom is produced.

Live steam generated from a boiler is generally employed for

pasteurization. Carelessness at this stage may lead to a crop failure.

To do the work on sweat-out, therefore, the following items are needed:
- Two to three drums to which 2 metal pipes are fitted in a parallel position on each drum (preferably 210 litre drum). These metal pipes should at least protrude 1m from the drum.
- A water source nearby in case of a fire out break.
- Plenty of dry firewood for heating the boilers
- A thermometer with a calibration of over 70^0C
- Horse pipe (1/2 - 3/4 inche size) which can resist high temperatures.
- A torch or lamp.
- Adequate personnel to carry out the job, including night shift.
- Properly treated manure which has undergone phase 1 of composting.
- An axe or any instrument that can be used to open the drum when refilling water.
- Strong or high temperature resistant rubber bands for tying the horse pipes on to the metal pipes.
- A well built and strong oven for the boilers and to protect the people.

MUSHROOM GROWING STRUCTURES

The type of a house in which the experiments were first carried out in Malawi was a traditional mud house. The house was a cheap one, but had a disadvantage of absorbing moisture by mud walls from the compost and the casing soil giving rise to reduced relative humidity.

Their modern mushroom house is made of wooden pole framework, plastic lined and grass-insulation all over. This house is an adaptation from the Taiwanese type of house.

ITEMS NEEDED FOR THIS TYPE OF HOUSE.

1. Poles of different sizes
2. Plastic sheet, preferrably a clear plastic.
3. Nails from 1 1/2 - 6 inches
4. Nylon screen gauze
5. Thatch grass
6. Solignum - for wood (pole) preservation
7. Measuring tape.

IMPORTANT POINTS TO NOTE

1. Plan the size of your house e.g. a mushroom house of 5m x 2.75m x 2.0m x 2.2m (gable) for a new mushroom farmer and a house

of 7m x 5m x 3.5m x 4m for progressive farmer.

2. Know the amount of plastic sheet your house will require. Also of importance is to know the width of the plastic because this will determine the space between the poles.
3. The house should face where the wind comes from.

NUTRITION AND GROWTH REQUIREMENTS OF THE CULTIVATED MUSHROOM.

(a) Temperature.
Mushroom mycelia are sensitive to changes in temperature. If the temperature is varied five or six degrees higher or lower than the optimum requirement, the growth rate is significantly reduced. Different species of mushroom require different ranges. Agaricus bisporus specifically TNS1 and TN2 require 22 - 25^{0}C during spawn run or colonisation whilst at casing and cropping 16-20^{0}C for TNS1 and 18 - 22^{0}C for TN2 is required.

(b) **OXYGEN AND VENTILATION.**

The ventilation requirements during the growth of spawn and during cropping of mushrooms differ. While the mycelium or spawn is running very little oxygen is required. Generally, a satisfactory crop is absolutely dependent upon a regular exchange of air. During the cropping period, ventilation is required to remove harmful gases such as Carbon Dioxide produced by the mushrooms.

(c) pH.

The optimum pH for the growth of different mushrooms vary. The Agaricus bisporus, TNS1 and TN2 require an optimum pH of 7.0

During growth, the mushroom mycelia produces acids which reduce the pH medium. For example, an initial compost pH 8 can lower to pH 7 when the compost is colonised by the mushroom fungus.

(d) **WATER.**

Water is required by the mushroom for its growth. At least 90% of the mushroom is water. Naturally, mushrooms are found growing in the gardens and forests soon after rainfall.

In the composting process, water governs the level of microbial activity. However, too much water leads to too little air

penetration and circulation in the compost.

MINERAL REQUIREMENTS.

(a) Major
Nitrogen. Nitrogen is perhaps the most important element for mushroom growth. Not all nitrogen sources are suitable as a foodstuff for the mushroom. Nitrogen in the form of ammonium salts is suitable. Examples include ammonium sulphate. Nitrogen strongly influences the bacterial activity of the compost.

(b) Potassium. This element is essential to all forms of living matter.An excess is toxic to mycelia.

(c) Phosphorus. This element is also required for mushroom growth.

(d) Magnesium and Calcium.
These are also required for mushroom growth. Calcium serves as a nutrient for cell growth and influences moisture content,aeration,drainage and pH of the manure heap. It antagonises or neutralises the toxic effect of certain other elements when these are present in excess.

(e) Sulphur. It is also required.

(f) Trace Elements. Trace elements such as iron, zinc, copper and manganese are also required in very small amounts for the growth of mushrooms.

CARBON REQUIREMENTS:

Mushrooms require certain organic (carbon) compounds from which it can derive energy for its growth. The chief energy food stuffs are the carbohydrates. Straw provides carbohydrates such as hemicellulose and cellulose. When hemicellulose is broken down xylose a simple sugar is released which supports mushroom growth.

THE CASING SOIL

Casing is the addition of soil to the compost after the mycelia have fully colonized the compost (12-14 days after spawning). The main purpose of application of the casing layer to the surface of the spawn running-compost is to stimulate and promote the formation of fruiting bodies. The casting soil also retains moisture needed for mushroom growth. The production of mushroom will not occur until the mycelium is covered by a casing medium.

CHARACTERISTICS OF A GOOD CASING MEDIA.

(a) Open texture
(b) Good water holding capacity

(c) Freedom from pests and diseases
(d) Low organic matter content(e.g. sub soil)
(e) Adequately aerated
(f) pH value 7.0- 7.5

Generally, clay-loam soil obtained from the subsoil layer is preferred.

pH OF CASING SOIL

Mushrooms will not grow on soils which are very acidic or alkaline. Normally, a pH value of 7.0 to 7.5 is favourable for the growth of mushrooms. In acid soils the pH should be raised by the addition of "white wash lime" which should be done at least two weeks before the casing soil is added to the compost. This period is important because it allows for the reactions to take place, thus bring the soil to a stable pH.

WETTING AND MIXING OF CASING SOIL

Casing material is usually applied to the bed as moist as possible. It should not be too wet to avoid dripping onto the compost.

In preparing the casing soil for pasteurisation, the soil is obtained from the subsoil level because this layer contains less organic matter and it is also a bit free from pests and pathogens. Therefore, the top layer up to 10cm deep is dug and thrown away. Then casing soil is obtained from the subsoil thereafter, all clods, stones are broken or removed to leave fine soil. Some farmers prefer to sieve the soil in a big wire mesh. After sieving it is when the white wash lime is added and thoroughly mixed in the soil.

The soil is then sprayed with a fine rose of water to make the it just moist. Then the soil is covered with a plastic sheet and left intact for about two weeks. After this period, the soil is ready for pasteurisation with live steam.

PASTEURISATION OF CASING SOIL.

Since soil contains a lot of disease causing organisms and pests, it is important to pasteurize it before use. A number of materials are used as indicated below:

1. **PHYSICAL**
   - by fire or steam

- if fire is used the soil is sterilized at 60-70^{0}C for 30 minutes
- if steam is used then the soil is sterilized at 70-80^{0}C for 30 minutes (This is the method presently recommended in Malawi).

2. **CHEMICAL**

(a) Basamid (Dazonite)

10g/10kg of soil. Pour Basamid in moistened soil, cover with a plastic sheet for 1 day then remove plastic and turn and aerate the soil.

After 7-10 days the soil can be used for casing.

(b) Formalin

80cc/100kg of soil. The chemical is applied in the soil,then a plastic sheet is put on top of the soil. After 1 day remove the plastic. The soil is used 1 week when there is no odour of formalin.

(c) Chloropicrin (99%)

This is also known as Tear Gas; can be used for soil pasteurisation at a rate of 5-6cc/100kg of soil.

The soil depth should be 50cm and the chemical is applied up to 25cm deep. Soil temperature should 15^{0}C. A plastic paper is put on top for 2 days after that it is removed. The soil is used after 2 weeks.

(d)Benlate 50% WP + Mertect* 40%

* Mertect is also known as Thiobendazole. These are mixed and dissolved in water 1:2,000 parts of water and the chemical solution is applied at a rate of 40cc/m^2 on the surface of the casing soil.

HYGIENE IN THE USE OF PASTEURIZED SOIL

After the soil is pasteurized, hygiene should be practised. Utensils used to carry the soil into the mushroom house must be washed with a detergent before and after use. Thorough cleaning of the floors, boots, and shovels and the use of a clean water supply should be practiced. Pateurized soil can be kept in an enclosed storeroom or covering with a plastic sheet may be sufficient to protect the casing soil for a short duration. As much as possible, pasteurized soil should be used immediately to avoid contamination by other fungi.

APPLICATION OF CASING LAYER.

Once sufficient soil has been moistened, treated with lime and pasteurized,the procedure is as follows:

Day 1 Apply soil evenly onto the shelves 3-4cm deep. Deep casing will result in dicoloured mushrooms while shallow casing results in small mushrooms. About 30 litres of soil will be required per square meter.

Day 2-3 Open vents. Apply water to the casing to increase moisture level in the casing and this is particularly important on Day 3. The soil should stick to the finger once the finger is pressed against the soil.

Day 4 Open vents twice: once in the morning and once in the evening for 30 minutes each time.

Day 5 or 6 Scratch the casing. Scratching means disturbing the top 1cm layer of the casing using a nail-fitted plank of wood or a similar tool. This is done to break the surface compaction and to aerate the soil. At this time a lot of carbon dioxide is required and so all vents should closed.

Day 7-9 Two days after scratching , water should applied. During this period mycelia grow down the scratched surface.

Day 10-12 Open vents to introduce fresh air. decrease compost temperature to between 16 and 20^{0}C by pouring water and relative humidity should be between 85 and 90%. Application of water on the floor helps raise the humidity.

Generally, pinheads start forming from Day 16. Watering of the casing is suspended from pinhead formation. Pinheads will form at temperatures below 22^{0}C. Water may be applied using a sprayer when the pinheads have grown to the size of a pea (about 5-7 days from pinhead formation).

MUSHROOM BED MANAGEMENT

Mushroom bed management can be referred to as all the processes and activities or operations that are employed onto the mushroom beds before peak heating up to when mushrooms are harvested. Mushroom bed management is more of a pratical activity than theory. The management of mushroom beds varies from one farmer to another because of different experiences. Basically mushrooms grow under uncontrolled conditions. The regulation of Temperature, Humidity and Ventilation is the prime environmental requirement for successful mushroom culture.

When mushroom beds are managed properly both the yield and the quality of the mushrooms will be high.

This subject will be discussed in six major areas i.e. before compost is made, at filling, spawning, casing, pinhead formation and harvesting.

1. Prior to addition of compost.
The cross poles or bamboos on the beds should be close to each other to avoid later compost falling from the beds.

Sterilize the room with formaldehyde (formalin) solution at 12.5ml/litre. This is optional.

2. After filling.
Pasteurisation of the beds/house with live steam at 70^0C for 10 hours helps kill all harmful organisms and leaves beneficial ones to further break down the compost.

The surface of the compost on the beds should be level because uneveness on this layer leads to uneven casing. This also ensures that the right depth of compost is applied on the beds through out.

3. At and After Spawning.
Maintain compost bed temperature at 25^0C for fast mycelial colonization.

Level the bed for even casing at the end.

Ensure that moisture content of the compost on the bed is right 65-70% (when a handful of compost is squeezed 1-2 drops should ooze out).

Three days after spawning, open ventilators twice a day (morning and evening for 1/2 an hour) to allow the surface of the compost to dry to avoid contamination by wet fungi.

A clean ordinary newspaper may be placed on top to raise compost temperature and also protect the surface of mushroom bed from contaminating spores. Dip the newspaper in methylated spirits, dry it before putting it on the bed.

At spawning maintain relative humidity at 75-85%.

4. At and After Casing.
Ensure full colonization of fungus is achieved (12-14 days from spawning).

Right depth should be maintained through out the surface of the compost. Shallow casing may result into "stroma" (mycelia grow to the surface of casing layer and forms a water proof skin). Deep casing leads to dicoloured but, big mushrooms.

Maintain high humidity in the house 85-90%

Casing soil on the bed should be moist all the time.

The casing layer should be free of weeds all the time.

Maintain compost bed temperature at 22^0C for rapid mycial growth.

Heavy watering of casing layer first 3 days, thereafter light watering.

Seven days from casing disturb up to 1cm deep the casing layer to break surface compaction and reduce carbon dioxiode levels.

Generally from casing to pinhead formation more carbon dioxide is required.

5. At Pinhead Formation
Temperature reduced for initiation of more pinheads i.e.up to 22oC.

Frequent watering of the floor and wall is required but is suspended on the actual growing beds until pea size is reached.

When pinhead have grown more than pea size watering is resumed.

Regulate supply of oxygen and carbon dioxide by opening and closing the ventilators.

6. At Harvesting.
Stop watering of the beds 1-2 days prior to commencement of harvest.

Cropping temperature requirement for *Agaricus* is 25^0C. Yields get reduced beyond this temperature.

Frequent watering of the beds should be avoided when beds are densely covered with mushrooms.

Soon after harvesting, pasteurised soil should be added in the beds, then application of water should follow and the doors and ventilators should be left open to dry the surface of mushroom and reduce the "blotch" problem.

After every flush is harvested, the doors to be closed for 1-2 days to increase level of carbon dioxide on the beds for initiation of more pinheads.

Relative humidity left at 95%.

Generally, mushrooms begin to appear in about 2 to 3 weeks after casing. The problem of management from this time forth relate to the provision of suitable conditions of temperature, bed moisture, ventilation and humidity and the increase struggle against insect and mould enemies.

Additional Information .
1. Several light sprays are preferable to one heavy one.
2. Use a fine rose spray of water on the mushroom beds
3. During unusually warm weather , restrict ventilation to the night hours.

4. Ensure that casing layer is moist all the time.
5. Ensure that the floor is always moist all the time.

MUSHROOM DISEASES AND THEIR CONTROL

1. Wet Bubble. This diseaese is caused by a fungus called *Mycogone perniciosa*

Symptoms - A large mass of tissue turns white and fluffy and eventually dark brown. A patch of white mycelia can also be seen on the surface of the casing. A brown streak forms on the stipe (stalk) and at a later stage mushroom produce brown drops of water. This is a disease of the fruiting bodies and not the mycelia.

Control: Avoid the excessive application of water. Water splash will help in disseminating spores of the fungus.

2. Dry Bubble. This is caused by the fungus *Verticillium fungicola.*

Symptoms: Brown sports (patches) appear on the mushroom cap. This disease can easily be confused with bacterial blotch. Affected mushrooms are often dry and they crack. Distortion and tilting of the cap results. Caps are affected later with circular pale brown spots up to 1cm in diameter. High temperature and humidity are conducive to the sporulation of the fungus. The disease is common in closely spaced mushrooms.

Control:
(a) Farm hygiene to reduce fly population.
(b) Reduction of humidity and air temperature.
(c) Use of resistant strains

3. Olive green mould (Chaetomium spp). The mould appears on compost surfaces soon after pasteurisation and can lead to complete failure of crop growth.

Control:
- By proper pasteurisation of compost.
- Avoid over wetness or compaction of the compost.

4. Mat (Chrysosporium spp) This disease is characterised by a creamy to yellow mycelial fungal growth on both the compost and casing soil, coating it completely. The mat impedes air and water penetration.

Control: Prevent the disease by ensuring that the casing soil is not shallow. Farm hygiene is important in reducing the

disease.

EFFECTIVE PEST AND DISEASE CONTROL

Effective pest and disease control may be defined as all the forces/efforts or activities employed on a mushroom farm to prevent and eradicate pests and pathogens in order to have an

increased yield and improve the quality of mushrooms. This subject will be summerized in five major areas:

1. Farm hygiene.
 (a) Farm disign.
 The mushroom farm should be designed in a way to prevent the flow of materials, personnel, debris from areas likely to have pest and diseases to clean areas.

(b) Peak-heat
 By introducing live steam of 70^0C for 10 hours in the mushroom house before spawning ensures the death of pests and pathogens on and in the surface layers of compost.

(c) Filtration.
 This is important to prevent the spread of virus diseases in the mushroom house.
- By using a 2um mesh filter on the ventilators and doors.

(d) Cook-out.
-The introduction of live steam at 70^0C for 10 hours ensures the elimination of all pests and diseases in finished cropped houses, shelves, boxes and all other equipment used at cropping.

2. Management

(a) Staff.
Workers on a mushroom farm need to trained to identify disorders and diseases of mushrooms and the dangers so that they can help when a problem arises.

(b) Isolation of disease
- Diseased mushrooms need to be removed as early as possible.

(c) Disinfectants.
- These can be used on a mushroom farm for exclusion and elimination of pests and diseases.
- The choice of a disinfectant should be in line with the type of pest or disease to be controlled.
- A footbath of disinfectant at the entrance can be used.

3.Chemical control
(a) Choice of pesticide.

- It should be noted that there is a limited number of pesticides for use in mushroom production.
- The instructions on the label should always be followed.

(b) Methods of application.
- use the best method with regard to the pesticide and disorder concerned.

(c) Pytotoxicity.

- The mushroom crop can be poisoned if deviation is made from recommended means of application.

(d) Pesticide Resistance.
- It should also be noted that repeated and regular application of chemical is not good.

4.Environmental control
- By proper control of temperature, humidity, moisture content and ventilation can help reduce some of the disease problems.
- Other abnormalities on the mushroom crop appear if manipulation of ventilation is improper e. g if the carbon dioxide concentration is over 1000ppm; elongation of stalk and the cap remain small.

5. Resistant strains
There are no strains of *Agaricus bisparus* which are resistant to the common mushroom diseases. However, some are more highly susceptible whilst others are fairly tolerant. Therefore, the latter strains may be used where possible

Generally, the farm layout should be in such a way that the areas around the farm should be kept as clean as possible. For instance, the casing material store, spawn rooms are at a maximum distance from the cook-out rooms and on the windward side of the growing sheds.

POST HARVEST STERILISATION OF MUSHROOM HOUSE

WHY STERILIZE AT END OF CROPPING ?

Sterilisation at the end of cropping which is often referred to as " Cook-out is one way of reducing the pathogen and pest population and preventing their spread.

METHODS OF STERILISATION

1. Use of Live (Hot) steam

- generated from a boiler.
- Raise compost temperature to 70^{0}C for several hours.

2. Methybromide
-The chemical is administered in the mushroom house.
- Before fumigation, ensure that the house is air tight to avoid the chemical escaping from the house.

3. Formaldehyde.
- Use formalin 2-5% plus a wetter.
- Spray in the mushroom house.
-Ensure that all surfaces, the whole crop and structure are sprayed with the chemical.

ECONOMIC IMPORTANCE OF THE CULTIVATED MUSHROOM - IN MALAWI.

The cultivated mushrooms can be regarded as one of the highest income earning crops so far if properly managed.

FARMERS' INCOME.

A mushroom project was costed. From the costing it was observed that the largest portion of the cost was capital and so the farmer would not be required to spend the same amount every year. A properly constructed house with treated materials should last at least 3-5 years without major repairs. So each year the farmer would only be required to spend some money on inputs and minor repairs to the house and boilers.

At present the market for mushroom is quite open. Most mushrooms currently consumed in hotels are imported. Few of these are fresh the majority are canned. Many hotel customers had expressed their dislike of canned mushrooms. So if the farmers were encouraged to grow mushrooms,it was likely that they would get a grip of the market. Some supermarkets have lately also been importing mushrooms for resale. Some of these have going at K60 per kg.

On the current local market for locally produced mushrooms the minimum price is K30.00 per kg and the maximum is as much as K50.00 per kg. This only reflects how relieved consumers feel to pay less than they would for the imported mushrooms.

The present farmers' market for mushrooms are hotels, inns, some resturants, middlemen and consumers. Small scale farmers sell all their mushrooms direct to consumers; while the large scale farmers' mushrooms find their outlet to the hotels, inns, resturants and middlemen.

Mushroom yields achieved by farmers are generally lower than

those achieved under research. But with good management , a farmer should be able to get at least 5kg/m^2. The total yield will depend on the total shelf area whih will in turn reflect the farmer's financial return at the end of the season.

National Economy

Until now Malawi is spending a lot of money in foreign exchange importing mushrooms because they are not yet self-sufficient in the product. The local supply is so far below the demand that

mushroom importation will continue for sometime. So if farmers produce enough mushrooms to satisfy the local demand, the country will be saving the scarce foreign reserves. At the same time the country will enjoy more foreign exchange through the export market.

VISITATIONS TO MUSHROOM GROWERS IN MALAWI.

The visits were very beneficial to us (Thandie and Doug) in that we were able to hear and see some problems that the growers face in mushroom production and how they tried to solve them. Those growers visited were as follows:

1. MR MUSSA, whose farm was managed by an experienced mushroom grower by the name of Mr. Black, was visited on 6/7/95 at Njuli which was about 15km from Blantyre.

Mr Mussa was a medium resource farmer as his mushroom house was built with bricks and the roof covered with corrugated iron sheet. The walls,however, were insulated with plastic sheet and the roof with thatch grass. Electric heaters were used to raise the temperature when ever it dropped below the required minimum.

This visit gave a chance to see how mushrooms were being harvested and packed in punnets, which are plastic containers, weighed and wrapped over with a plastic cover before being dispatched to the market in Blantyre. The mushrooms were not washed but only cleaned with a piece of cloth to avoid creating conditions condusive to infections.
The punnet carrying 200g mushroom was selling for K30.00

2. MRS NAPHIYO in Pemba which is 15km from Blantyre was also visited for the first time on 6/7/95. She was a medium resource farmer growing mushrooms for the first time. Her mushroom house was built with poles, covered wit plastic for air tightness and thatch grass for insulation. The surrounding where the house was built was found clean.

For her compost,she used maize stover chopped into small pieces of about 15cm lengths. The compost was found to be well decomposed and being pasteurized. She had a problem of raising

the temperature inside the house to 60^0C because of a blockage in one of the steam pipes from the boiler. We then helped her un block the pipe.

Our second visit to her on 11/7/95 to check on her progress, we found that she had spawned after had thoroughly pasteurized the house.

3. NAMINGOMBA ESTATE was visited on 12/7/95. The technician working on the mushroom production was Mr. Omari. Here the first flush of mushrooms were just about to be ready for harvest in their neatly built thatch grass houses.

These mushroom houses were built under trees which provided shade, thus keeping the houses cool during hot days. The house surroundings were very clean indeed.

But despite the neat houses, clean surroundings and good management practices being employed, there were fungal contaminations observed on the mushroom beds. These had to be eradicated immediately to avoid their spread to other parts of the beds.

4. MR SULANI, a low resource farmer, was visited on 12/7/95 in the Bvumbwe location. His mushroom house was poorly built with poles, old plastic sheet and thatch grass. The house surrounding was dirty.

Inside the house the mushroom mycelia, which had begun colonizing the maize stover compost, were showing some fungal contaminants. He was advised to eradicate these contaminants.

When Mr Sulani was asked what problems he encountered in mushroom production, he cited the following:

1. Difficulty of getting spawn from Bvumbwe Agricultural Research Station.

2. Inavailabilty of firewood for the heating of the boilers. Instead he resorted to burning old tyres.

3. Sometimes he would have difficulties in marketing his mushrooms due to glutting.

5. MR MASIYE, a manager for a white farmer, was visited on 12/7/95 at Chigumba Township of Limbe. Here the pasteurizing system was of high technology designed by engineers for ease of water refilling of the specially made boilers. The mushroom houses were insulated with aluminium foil, double folded.

Mr Masiye was an experienced mushroom grower. His only problem was the difficulty of getting spawn from Bvumbwe Agricultural Research Station.

6. MRS KALUMBI, medium resource farmer in Limbe Township, was visited on 12/7/95. She had the recommended mushroom house built with poles, covered with plastic and insulated with thatch grass. The surroundings were clean.

Inside the house there was nothing growing because she could not get the spawn from Bvumbwe Agricultural Research Station.

7. MR TRINNDADE, a high resource farmer, growing mushrooms for the first time, was visited on 13/7/95.
His house structure was made of planks, lined with plastic and

air conditioned. His boiler was so designed that water refilling was gravity fed. The floor was cemented for ease of cleaning. The beds were segmented to minimize the spread of disease along the whole bed.

His compost of maize stover, however, was poorly prepared as the chopped pieces were rather longer than is recommmended.

When asked what problems he was experiencing in mushroom growing, he cited the following problems:

1. Rodents coming in to barrow the beds,

2. The difficulty of reaching the required pasteurisation temperature of 65oC due to air leaks in the house structure of his kind.

8. Dr. KHONGA, a lecturer at Chancellor College of the University of Malawi in Zomba which is 35km from Blantyre, was visited on 14/7/95. He was carrying out research on Oyster Mushroom spp. which are quite different from the Button Mushroom (Agaricus spp) grown at Bvumbwe Agricultural Research Station. Oyster Mushrooms are hardy and are not as highly perishable as the Button Mushrooms.

His experiments consisted of comparisons of different mushroom varieties for yield performance, evaluations of responses of different mushroom varieties to different types of fertilizers and levels as expressed by their yields. All these experiments were carried in plastic bags hung on racks in the house. Each plastic bag with a growing medium weighed 1kg.

From these experiments Oyster Mushrooms appeared to have a higher potential than Button Mushrooms in that the Oyster Mushrooms do not need the following conditions as Button Mushrooms:

1. composted substrate

2. pasteurized house

3. casing soil

4. fertilizers in the compost

5. plastic lining of the walls to stop moisture migration from the beds to the walls.

RECOMMENDATIONS FOR DEVELOPMENT OF MUSHROOM PRODUCTION AND MARKETING IN SWAZILAND.

From the lessons learned in Malawi, which applies equally well to Swaziland conditions, mushroom production is dependent on the availabilty of the market. In Swaziland the extent of the market has not been established even though mushroom are consumed in the hotels and are sold in some suprmarkets. Therefore before research is done on mushroom production a survey is necessary to quantify the size of the market and to determine the demand and supply curves. This needs to be carried out by the Socio-Economic Section of the Agricultural Research Station.

If the mushroom market proves to be viable in Swaziland, the question of firewood and thatch grass scarcity must be solved first. In Malawi the pasteurization of the mushroom house takes a lot of firewood. To our estimate 15 tons of firewood may be needed to keep two boilers in operation for 10 hours as recommended for pasteurising a mushroom house of a standard size. Such large quantites of firewood may not be obtainable in many parts of Swaziland. An alternative source of heat energy that may need to be investigated is "coal" as this this type of fuel will avoid deforestion that can take place with the use of firewood..

In the production of mushroom, the need for a supply of spawn to the farmers is a necessity. To do this the following laboratory equipments, which are not available at Malkerns Research Station, are necessary :

1. An autoclave capable of carrying at least 40 heat resistant bottles of 500ml size.

2. Incubator capable of carrying at least 40 bottles of 500ml size

3. Laminar Flow system consisting of a fan, a duct, filters and the laminar flow hood.

4. 500ml Heat resistant bottles or heat resistant plastic bottles

5. Heat resistant test tubes

6. Bunsen Burner

7. Refrigerator

SOURCES OF SPAWN.

If mushroom production proves to be a viable proposition Taiwan and South Africa will have to be contacted for the the supply of mushroom cultures for experimentation at Malkerns Research Station so that any variety that proves to be superior in yielding its spawn can then be produced for sale to the farmers.

It is evident from Malawi expirience that mushroom production needs some capital injection to start off the enterprise. As such it is suited to the middle and high resource farmers because they have the capital to build the necessary growing structures, buy the necessary equipments and inputs such boilers, plastic sheet, the spawn, composting fertilizers.

Mushroom production being a new technology in Swazialand will require intensive training of the Extension Staff in order to disseminate the recommendations to the farmers. This requires devotion on the part of Extension since this crop needs close supervision for success.

If this technology is well received by farmers, the spawn supply has to be adequate. This can be achieved by engaging a commercial spawn supplier who will solely devote his/her time to it.