Integrated disease and pest control in Irish mushroom tunnels

L. Staunton and R. Dunne
Kinsealy Research Centre

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Summary

This project set out, in the year 1999, to develop and disseminate an integrated pest and diseases management system for mushrooms. The project was a natural successor to project 4095 (Chemical and Biological Control of Mushroom Pests and Diseases). The main objective was to research and bring together information on efficient methods of control and to put this information into a suitable blueprint to enable Irish growers achieve satisfactory disease and pest control with minimal pesticide usage.

Factors identified for improved disease control include:

- Avoidance of soil contamination including dust in the growing unit
- Protection of new casing
- Good hygienic practices
- Use of spore grade filters on the air intake
- Good fly control. People and flies are efficient disease carriers

- Early detection and eradication
- Suitable procedures when emptying tunnels
- Use of steam cookout

- **Factors identified for improved pest control include:**
- Protection of newly spawned compost
- Exclusion by screening air inlets and vents
- Proper sealing of tunnels and closing doors promptly
- Early detection by monitoring
- Judicious use of approved pesticides
- Biological control methods
- Early termination of infested crops

Introduction

Most newly erected mushroom units have very little, if any, disease or pest problems for the first few crops. Then gradually the level rises and, if not properly managed, diseases and pests can become a serious problem causing big losses. Most growers however succeed in getting some control, disease and pests becoming a chronic background problem. If one were to properly measure the losses in terms of yield, quality and amount of money spent on pesticides it would add up to a significant loss in income. Many growers in Ireland are unable to have a fourth flush because of the level of disease. In many cases it is not even advisable because of the disease risk it creates for the whole unit.

The mushroom growing environment is very different from other crop production situations. After peak heating the pasteurised compost is in many ways a biological vacuum so that anything that colonises it has no competition. Some pests are actively attracted to the compost and as peak heating is pasteurisation and not sterilisation, inevitably small numbers of pests are liable to be present. Natural enemies of pests have also been reduced by the peak-heating, climatic conditions are ideal for pest reproduction and so it is not surprising that large pest populations can develop in the crop in a very short time.

Consumers and environmentalists increasingly frown on the use of pesticides in food crop production. In addition the range of pesticides available and approved for use on mushrooms is decreasing.

All the above considerations have prompted us to take a fresh look at disease and pest control methods used in mushroom production and to develop a revised strategy to help growers keep the level of disease and pest in their units at a minimum.

Users of this report will need to give a little time to read it from the beginning so that they will have a good understanding of the diseases and pests they are trying to control. Doing this will enable them to better appreciate the control measures in the strategy.

- The greatest single cause of loss of income in Irish mushroom units is DISEASE
- The greatest single cause of diseases problems is POOR HYGIENE
- Because of the layout of Irish mushroom units and the amount of movement by outside personnel and vehicles, only a concentrated and continuous effort by growers will keep disease at an acceptable level.
- In this report we have attempted to put together a strategy based on scientific research, and the best practice of existing growers, to enable the reader to benefit from the existing knowledge.

Methods

The project consisted of a combination of research, literature review and examination of practical diseases and pest problems at growing units. The experimental work was done in the mushroom research unit at Kinsealy Research and Development Centre. Compost and casing used was obtained from commercial suppliers. Growing procedures were the same as those used commercially as outlined in the Teagasc booklet "An introduction to Production of Mushrooms in Plastic Bags and Tunnels". Work at growing units was done used normal pathological and entomological procedures including the use of swabbing, spore trapping, fly monitoring and general observation.

Results and Discussion

MUSHROOM DISEASES

Causes of diseases

A specific organism, either a fungus, bacteria or a virus causes each of the mushroom diseases. Only the diseases most commonly occurring will be discussed here.

Fungal	**Cause**
Dry bubble	*Verticillium sp.*
Wet bubble	*Mycogone sp.*
Cobweb	*Cladobotryum sp.*
Greenmould in compost	*Trichoderma harzianum*
Greenmould on casing	*Trichoderma viride*
Bacterial	
Bacterial blotch	*Pseudomonas tolaasii*
Virus	

Dieback Various virus strains

Fungal diseases - primary sources

It is common that where disease outbreak occurs in a crop the grower is completely mystified as to the origin of the disease. This can often lead to the wrong conclusions being drawn and thus incorrect procedures being put in place to control it. Control measures consist of integrating very good hygiene with the minimal use of fungicides. To properly apply a rigorous hygiene programme it is necessary to have a very clear understanding of the cause of diseases, where they come from and how they spread.

Soil

Nearly all of the common fungal diseases of mushrooms originate in the soil. Thus soil is the enemy of the mushroom grower and all possible sources of contamination must be eliminated. Soil can get into the mushroom production system in many ways and the most common include:

- Wind blown dust
- Soil on the wheels of vehicles or on shoes
- Soil in water running off soil banks on to the yard
- Soil contamination of the casing as it is being prepared
- Soil contamination of the ground limestone or sugar beet waste lime

Water

The use of dirty muddy water to wet the casing can lead to disease outbreak. Trials at Kinsealy have shown that bubble spores (*Verticillium* and *Mycogone*) can readily survive in water for many months.

Peat

Peat in a bog is relatively sterile except for the top layer. If casing is a source of disease it will almost certainly be from contamination after harvest of the peat. Sugar beet waste lime (SBL) coming from the sugar extraction process in the factory is very clean, as it has been subjected to a high temperature. However if it is subsequently stored in a dirty area it can become contaminated. In plating tests at Kinsealy we have isolated *Verticillium* from contaminated SBL. This can also occur with ground limestone if there is soil contamination.

The appearance, in some crops, of considerable wet bubble before and during the first flush points to contamination of the casing.

Compost

It is extremely unlikely that properly made compost is a source of diseases, such as bubble or cobweb, as the compost goes through a pasteurisation phase in its preparation. This entails holding the compost temperature at 56 to 58^{o}C for some hours, which will kill all the fungi causing these diseases.

There is still some uncertainty and debate as to whether the green mould fungus *Trichoderma* can survive the composting process. Very good hygiene procedures in the compost yards have succeeded in reducing that disease to a very low level.

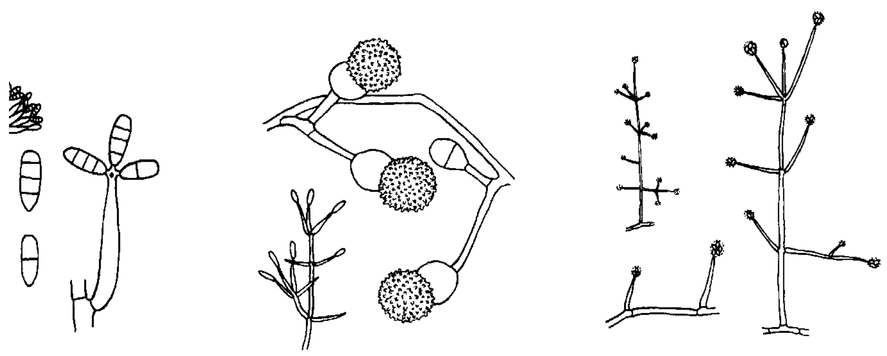
Spawn

Mushroom spawn is made in factories where surgical levels of hygiene are used so that it is almost impossible for spawn to be a source of disease. Composters putting the spawn into the compost have to very careful to avoid contamination.

Fungal disease spread

Spores are the main method of fungal disease spread. These are tiny invisible seeds produced in very large numbers by the fungi causing disease. They cannot be seen by the naked eye, only by powerful microscope. As a result, growers can be totally unaware that they are spreading disease and this is one of the main problems in control.

Fungi causing bubble and cobweb diseases of mushrooms



Cobweb **Wet Bubble** **Dry Bubble**
Cladobotryum ***Mycogone*** ***Verticillium***
(Source: H.L. Barnett, Illustrated Genera of Imperfect Fungi)

Spores have different shapes and sizes and are attached to little branches as above. Even the smallest patch of disease will produce many thousands of spores.

Primary spore spread

The spores formed on disease-causing fungi become detached from the fungus and are spread in many ways including:

- Air currents - wind
- Flies - spores stick to feet, legs and wings

- People - clothing, hands etc.
- Water splashing - this is very significant with bubble
- Equipment being moved from one tunnel to another
- Materials such as compost and casing

Secondary spore spread

Once spores arrive at an infection site, whether in the compost or casing, they will germinate to produce mycelium, which will give rise to disease and will produce large numbers of spores. Thus, from the original site of infection, rapid spread will occur. In trials at Kinsealy Research Centre we found that disease appears about 7 - 10 days after inoculation with bubble and a bit longer for cobweb. The time varies depending on the level of inoculum and the temperature and humidity. The main methods of secondary spread from an initial low level of disease include any or all of the following:

- Watering is a very efficient way of spreading disease spores
- People - including clothing, hands and equipment
- Flies, particularly sciarids, are a very good transport mechanism as spores stick to their legs, wings and bodies. Fly monitoring and early control is an essential element of an integrated disease control system.
- Air movement. Some spores such as those of cobweb are easily carried in the air. Intake air can carry spores and this is a particular danger when an adjacent disease-ridden tunnel is being emptied.

Survival of disease fungi
Trials at Teagasc, Kinsealy have shown that the bubble causing fungi can survive more than 6 months in water. Most of them produce survival spores, which are very durable. Swabbing tests have shown that they can also survive on tunnel walls and other structures.

Bacterial Blotch

The bacteria that cause blotch are found in compost - casing - limestone - water
They grow on the surface of developing mushrooms and secrete chemicals, which cause browning. They occur in small or large numbers depending on conditions. Thus on dry mushrooms few bacteria are present and there is no disease. Wet or damp mushrooms have large amounts of bacteria resulting in blotch.

Prevention of blotch - Evaporate moisture from the mushroom surface by increasing air speed over mushrooms and reduce RH.

Virus diseases

Mushroom viruses are spread in mushroom spores or mycelium. Units producing open mushrooms, which release large numbers of spores, are particularly at risk. Such growers must watch out for virus symptoms appearing in their crops. Generally there is distortion of the mushrooms with long stipes and a tilted cap. Bare patches appear on the beds.

DISEASE CONTROL

The procedures discussed here are part of an integrated control strategy involving hygiene, structures, crop management and the use of pesticides. They are broken down into three sections; **pre-cropping**, **cropping** and **post-cropping**.
Growers who follow these instructions should be able to keep disease at a low level in their units.

Pre-cropping precautions

All sources of disease must be avoided prior to cropping. Early contamination of the compost or casing with spores will result in early disease appearance. It takes about 7 to 10 days for bubble **(***Verticillium or Mycogone)* disease to appear after spores land on the casing and a little longer for cobweb.
The following are very important points:

Avoid dust

Dust blown by air currents or risen by brushing dry concrete is a serious disease source. Doors should be kept closed as much as possible.

Use air filters

One way in which disease organisms and flies enter mushroom tunnels is through the air intakes. The synthetic filters presently in use are not designed to catch very small particles such as fungal spores. A spore grade filter is installed in a specially constructed extension to the air intake vent.

Ensure personnel are free of contamination

Any person involved in emptying bags or who are in any way in contact with mushroom disease must **shower** and **change clothing** before coming in contact with a new crop - filling - casing - watering etc.

Minimise compost transfer at lining out

It may be necessary to transfer compost between bags at lining out in order to create a level cropping surface. This should be done carefully and minimised, as it is a definite way of spreading disease from bag to bag, particularly green mould.

Protect casing

Peat from a bog is relatively sterile with no disease but it is easy to contaminate it after harvest. The main thing is to avoid any possible contamination with soil. Make sure that the limestone used in casing is clean.

When casing is delivered to a mushroom unit it must be protected from contamination. The area on which it is dumped must be scrupulously clean. Remember that power hosing alone will not sterilise an area. If the casing is not being used immediately it should be covered with a sheet of plastic, particularly if it is a windy day.

Add fungicides to casing

Sporgon is the best fungicide approved for disease control. It may be applied in one single application after casing or can be split into two or three. The former is probably the best procedure to follow. Other approved fungicides include Bravo and the carbendazim types such as Bavistin. Disease-causing fungi can easily adapt to become resistant to a fungicide. To avoid this it is suggested that fungicides with different active ingredients should be alternated occasionally. Thus for example Bravo should be substituted the odd time for Sporgon. Underdosing with pesticides can lead to the development of strains of disease fungi or insects which are tolerant to the pesticide.
A list of approved chemicals for use in mushrooms can be obtained from the Department of Agriculture

Use foot dips

A foot dip containing an approved general-purpose disinfectant can be placed inside the door of the tunnel. Please remember that it will be no use if people keep stepping over it.

Precautions during cropping

Disease control procedures during cropping are mainly based on common sense but include the following:

Do not brush a dry floor

A floor should be damp before it is brushed, to avoid producing a cloud of dust in the air, which may contain disease spores.

Detect and remove disease early

Apart from very severe cases, there is usually only a small amount of disease in the first or second flush. Failure to detect and control this low level of infection will result in a disease epidemic in the third flush. It will not be possible to harvest a fourth flush. If a few disease spots can be detected early and treated with salt (directions below) or an appropriate chemical then further disease spread can be considerably curtailed. Disease inspection should always be done before watering or picking.
If there is a large amount of disease in the third flush then it should be killed off and disposed of. To do otherwise makes it almost impossible to devise a sensible disease control programme.

Best practice following early detection
If a tiny amount of a disease such as cobweb or bubble is seen early in the first flush then it should immediately be covered with salt to prevent further spread. Best practice is to cover it with a damp tissue before salting so that the salt application does not send up a cloud of spores which are then carried in air currents and spread disease.

A diseased mushroom should never be picked off with the bare hand as this will result in very efficient spreading of disease spores.
A bag, which is very bad with disease, should be closed off.
Best procedure in picking off a diseased mushroom is to drape a damp cloth over it and the carefully place the mushroom in a container of liquid. Another method is to put a plastic bag inside out over the hand. The bag is then closed over the diseased mushroom. The area on the bed, from which a diseased mushroom is removed, should then be treated with salt as above.

Remove stumps promptly
Old stumps should be bagged and removed quickly, as they are a definite source of disease spread. So also are mushrooms, which fall between bags.

Terminate diseased crops early
It is tempting for a grower to hold on to a crop for a fourth flush regardless of the disease level. The general finding is that this does not pay and results in a disease epidemic in the unit.

After cropping

Emptying tunnels
Where there is a significant amount of disease in a unit the process of emptying a tunnel, after cropping, presents the single greatest risk of disease recycling. If bags are emptied, either in or outside the tunnel, the air can become laden with disease spores, which can then enter other crops. This is the time when many growers create a major hygiene problem in the unit. As there is no steam, for cook out, in most Irish mushroom units at this time growers must rely on chemical disinfection only. If the following

recommended procedures for emptying and cleaning are followed carefully disease levels will almost certainly drop to a tolerable level.

Killing off the bag surface

If there is some disease present, the normal procedure is to apply a strong disinfectant to the surface of the bag to kill off surface spores and mycelium. A good drenching spray is required. It must be remembered that this will only kill to a small depth and that there will be an enormous amount of disease inoculum underneath in the casing and compost. Emptying the bag in the unit will therefore release a large amount of disease spores into the air thus undoing the benefit of the disinfectant. Another option is to use steam. This is discussed in the next chapter.

Ventilate

The tunnel must be cleared of disinfectant fumes before anyone enters to load bags. Failure to do this presents a serious health hazard.

Load bags without disturbance

Ideally bags should be loaded on to a trailer without disturbance of the compost or casing. Emptying bags at this stage or outside in the yard creates a very serious disease hazard, which is difficult to overcome. If it is essential to take the bags off the compost at this stage then serious consideration should be given to using a steam cook out system.

Close air intakes

When any tunnel is being emptied the air intakes and the doors on the rest of the tunnels in the unit should be firmly closed. This will reduce the risk of spores entering clean tunnels.

Take loads downwind or cover during transport

Trailer loads of used bags of compost should be taken downwind if at all possible, but this may not be practical. If so the load should be covered with a tarpaulin or sheet of plastic.

Driving upwind with an uncovered load of bags with disease has been shown to in a large shower of spores being blown back over the entire unit.

Cleaning out a tunnel

When the bags are removed the remaining dirt on the floor must be brushed out. Dampen the floor before brushing to ensure that a cloud of dust and spores are not sent into the air. Power hosing - while good for cleaning concrete does not kill spores and may spread them.

Disinfecting tunnels

The floors and walls of the cleaned out empty tunnel should then be sprayed with one of the approved disinfectants such as Formalin or one of the phenolics. This will kill any spores or mycelium remaining.

If there has been any significant amount of disease in the tunnel then fumigation with formaldehyde is advisable. This will kill any spores in the ventilation duct or radiator or on the fan blades. The air temperature should be raised to over 15°C and the relative humidity above 50 % with the fan on full recirculation to ensure efficient fumigation.

Ventilate before entry
All fumes must be cleared from the tunnel before anyone enters, to avoid a serious health hazard. The controls should be located outside so that ventilation can take place without having to enter a tunnel full of fumes.

Disinfect equipment
Any piece of equipment, which has been used in a tunnel with disease, must be thoroughly disinfected before the new crop is started. This includes hoses, roses, trays, brushes, knives etc.

Ensure clean personnel
Anyone involved in cleaning out a tunnel with disease will be covered with disease spores, including clothes, hair, hands, shoes etc. Such persons must shower and have a complete change of clothes before coming in contact with other crops.

Cookout with steam

In the tray or shelf production systems used in the UK and the Netherlands it is standard practice to "cook out" houses at the end of cropping using steam. The steam is fed into the closed house so that the air temperature is raised above 70⁰ C over a 10-hour, or more, period. The bed temperature gradually rises towards 70⁰ C and is held there for some hours. The cropping structures are designed to withstand this temperature without structural damage.
In the Irish plastic bag and tunnel units the heating system is based on hot water circulation and no steam is generally available. However many growers are now looking to the possibility of using mobile steam boilers for cook out.

Thermal death points
This is the temperature at which spores or mycelium of pathogens are killed when held at a given temperature for a specified time. There are various reports in the literature of researchers measuring thermal death points. Some of these are set out below.

A. van Zaayen and A. A. Rutjens, 1981. Mush Sc. X1. 393-402

Fungus	Thermal death point °C (30 mins)
Agaricus bisporus (mushroom)	54
Verticillium fungicola (dry bubble)	39
Mycogone perniciosa (wet bubble)	48
Cladobotryum dendroides (cobweb)	43

__ Wuest and P.J. Moore, 1970. Phytopathology 60: 1274-1275

Mycogone, *Trichoderma viride*, *Verticillium* and *Agaricus* were eliminated when infected soil was treated at 54.4 ^{o}C for 30 minutes.

"Cookout" in practice

Our trials have shown that cooking out tunnels, with bags of compost on the floor, is more difficult than with trays or shelves. It is almost impossible to get to the kill temperature required in the compost in the bag particularly that near the floor. This may not be so important for bubble and cobweb, which are on the casing surface, as for green mould, which is deeper seated.

In our studies we found that if the air temperature in the tunnel is raised to 65^{0}C for about 5-6 hours this is sufficient to kill bubble and cobweb diseases on the top 5cm of the casing.

Cookout is more expensive than disinfectant but is worth it particularly for a grower with a chronic disease problem.

INSECT AND OTHER PESTS

Several types of insects can attack mushrooms but the major pests belong to three families of flies. Some mites and eelworms can also be damaging. Insects are common 6-legged animals, the adults being usually winged. Females lay eggs on the compost or casing. Eggs hatch to give larvae that are the main feeding stage. As larvae increase in size they shed their skin and it grows again. When larvae mature they change into pupae, a resting stage, from which the adults emerge.

Mites are minute animals, more closely related to spiders than to insects. They never have wings but spread by adhering to insects.

Main Pests

Common name	**Scientific name**	**Source**
Sciarids (fungus gnats)	Sciaridae (*Lycoriella* sp.)	common in nature
Phorids (hump backed flies)	Phoridae (*Megaselia* sp.)	common in nature
Cecids (midges)	Cecidomyiidae (*Heteropeza* sp.)	local/compost/casing
Tarsonemid mites	Tarsonemidae (*Tarsonem*us sp.)	local/compost/casing
Pepper mites	*Pygmephorus* sp.	local/compost/casing
Predatory mites	*Parasitus and Linopodes* spp.	compost/casing
Eelworms (nematodes)	Rhabditida	compost/casing

Sciarids

These are the main mushroom pests. Larvae kill pinheads and pea-sized mushrooms, and tunnel in stalks and caps. Adults are the main culprits in disease spread. They are small black flies longer than broad and have long antennae. They are attracted to compost for egg laying immediately after cool-down and throughout the life of the crop. Larvae have a distinct black head and their gut contents can be seen through their body wall.

A generation takes about 5 weeks to turn over so that eggs laid early in the spawn run give rise to adults at about the first flush. It is the offspring of these that do most damage. Sciarids are mainly inhabitants of the casing, where they do most damage.

The key to good sciarid control is exclusion during spawn run by having well sealed growing tunnels.

Phorids

Adults phorids are much smaller and shorter than sciarids and tend to fly less. They are actively attracted (often from considerable distances) to compost or casing in which spawn is running. The life cycle takes 2 weeks at 25oC and 5 weeks at 18oC. Consequently eggs layed early in the spawn run give rise to adults soon after casing and these reproduce again to give very high populations of adults 4-5 weeks into cropping.

The adult flies are not as significant in disease spread as sciarids but are a great nuisance to pickers. Larvae are pointed at one end and blunt at the other. They do not have a black head. They feed on mushroom mycelium. The key to efficient phorid control is exclusion during spawn run.

Cecids

Cecids are unusual in that mature larvae regularly split to give many daughter larvae thereby dispensing with the adult stage in the interests of rapid population increase. This means that they have the potential to reach huge numbers in a short time and the consequence of this is large-scale contamination of mushrooms, bags etc and easy spread between crops. Larvae also carry bacteria that cause browning of the stalks of mushrooms. Adults are rarely seen. Larvae live mostly in compost and suck the contents from mushroom mycelium.

Tarsonemid mites

These invisible microscopic mites can occur in vast numbers in crops and their feeding causes reddish-brown discoloration of the base of the stem. Badly anchored and off-colour mushrooms are also symptoms of their feeding on mycelium. The key to their control is good between-crop hygiene.

Pepper mites

These minute brownish mites sometimes swarm in huge numbers on the casing surface and mushrooms. They do not feed on mushroom mycelium but on weed moulds particularly green mould, their occurrence being a symptom of its presence. The huge numbers disappear after a few days and there is no yield loss.

Predatory mites

Robber mites (*Parasitus* sp) can occur in large numbers. They are predators of the other small organisms present e.g. fly larvae, mites, eelworms. They can reach numbers that annoy pickers. Long legged mites (*Linopodes* sp) behave similarly. These are beneficial mites as they are natural enemies of mushroom pests. *Parasitus* has been used experimentally at Kinsealy to control sciarids.

Eelworms

Rhabditid nematodes or eelworms are bacterial feeders and their presence on the surface of compost or casing indicates some deficiency in the compost, which has resulted in bacterial decomposition. As they do not feed on mycelium, their presence does not necessarily result in yield loss.

PEST CONTROL

Growers must broaden their concept that pest control simply involves total reliance on synthetic pesticides to reduce pest numbers and consider the steps they can take to reduce pesticide use by adopting non-chemical control measures.

Chemical control - Killing the pests with synthetic chemicals.
The traditional method of control, it is simple, relatively cheap, but is now the focus of consumer resistance while problems of pesticide availability are becoming increasingly more acute. Two insecticides are currently the mainstays of pest control in mushrooms – diflubenzuron (Dimilin) and sulfotep (Bladafum). Dimilin is either incorporated in or drenched onto the casing. Bladafum is used as an insecticidal smoke to control adult insects. Other products are also permitted – see appendix. A current EU review of pesticides, scheduled to end in 2005, may result in further curtailment of existing permitted chemicals.

Biological control - Using natural enemies of the pests to control pests.

As chemical pesticides fall into disfavour, these organisms will be the control methods of the future. The only biological control currently used is insect parasitic eelworms, sold as “Nemasys” , “Nemasys M”, or “Exhibit SF-WDG”. These nematodes are drenched onto the casing soon after casing. In experiments at Kinsealy they have given 60 to 65% control of naturally occurring sciarid populations, compared with over 90% control with Dimilin. The degree of control of artificially created fly populations has been higher. As the nematodes are not very persistent, the growing tunnel must be extremely well sealed from incoming flies. They are rather ineffective against phorids.

Cultural control - Using all possible physical steps to reduce pest levels in the crop and thereby the need to use chemical pesticides as extensively. Good on-farm hygiene, preventing adult flies from entering the crop etc. are examples of cultural pest control.

Integrated control - Using primarily biological and cultural methods to achieve adequate pest and disease control with the occasional use of benign pesticides to restore any imbalances that occur. The basic concept is that control is non-chemically based. This is integrated pest management (IPM) and although not possible with our present state of knowledge, is the ultimate aim of the future.

ICMS - As integrated pest management is not currently feasible, the present compromise production system is an integrated crop production systems or ICMS. Its application is retailer and consumer driven and it involves growing crops in as an environmentally friendly a manner as possible. This involves minimal use of all pesticides, the disposal of crop remnants, spent compost, plastic bags, run-off water etc in an environmentally conscious way. This results in reduced pesticide costs and a reduction in consumer concern about how the crop is produced.

ICMS IN PRACTICE

Over a series of experiments at Kinsealy and observations on growers mushroom farms, a number of factors relevant to production in an ICMS system have been established. Growers should put as many of these into practice as possible and the result will be a saving in pesticide costs, greater fuel efficiency and a generally more sustainable crop production system. Attention to these details will start to show dividends at the first flush.
The most important practices recommended are as follows:

Protecting compost in transit
Ensure that compost is protected from the moment of cool-down after peakheating and spawning. While much of this period is not under the control of the grower, it is important that compost is protected from sciarids while in transit to the mushroom farm. When it reaches the mushroom farm, the

compost should be transferred to the growing tunnel as quickly as possible to avoid access to egg-laying flies.

Hygiene
Good hygiene in the tunnel is essential to avoid transfer of pests from one crop to another. This is particularly important with cecids and tarsonemid mites, as these will survive in tunnel structures and crop debris. Containers, utensils, even hoses must be kept clean and not shared between houses. Always work in newer crops before going into older ones, as pests are easily transferred between crops. Discard spent compost well away from the mushroom farm and preferably upwind from it.

Pest exclusion during cropping
Exclude pests from a new crop especially during spawn run and when spawn is running in the casing. This involves fitting an appropriate screen on air inlets and exits (at least 16 apertures per cm) and install well sealed doors. The door seal should be similar to that on a domestic refrigerator. Routinely inspect seals from inside a dark tunnel and carry out repairs if necessary. Caulking of poorly sealed houses between crops may be advisable. Very few growing tunnels are properly sealed. Perfect seals are of little value if the doors are needlessly left open.

It is advisable to put a stainless steel fly filter in front of a dust or spore filter to prolong the life of the spore filter. A typical specification for a suitable fly filter is:

Stainless steel woven wire (or nylon mesh),
Material AISI 316,
Mesh No. 39,
Wire diam 0.25 mm,
Mesh opening 0.40 mm,
Open area 38%.

Generally the area of the filter should be about twice the area of the air intake so that there is little resistance to air intake created.
The filter should be brushed down regularly to prevent blockage.

Rapid spawn run
Ensure a rapid spawn run so that the compost is quickly colonized by the mycelium, thereby taking up moisture and nutrients so that they are not available to undesirable organisms. Use spawned casing also for the same reason.

Pest monitoring
Pest populations can double in a day or decrease at a comparable rate, consequently, routine estimates of population size should be made. Monitoring adult fly numbers gives information on what pests are present,

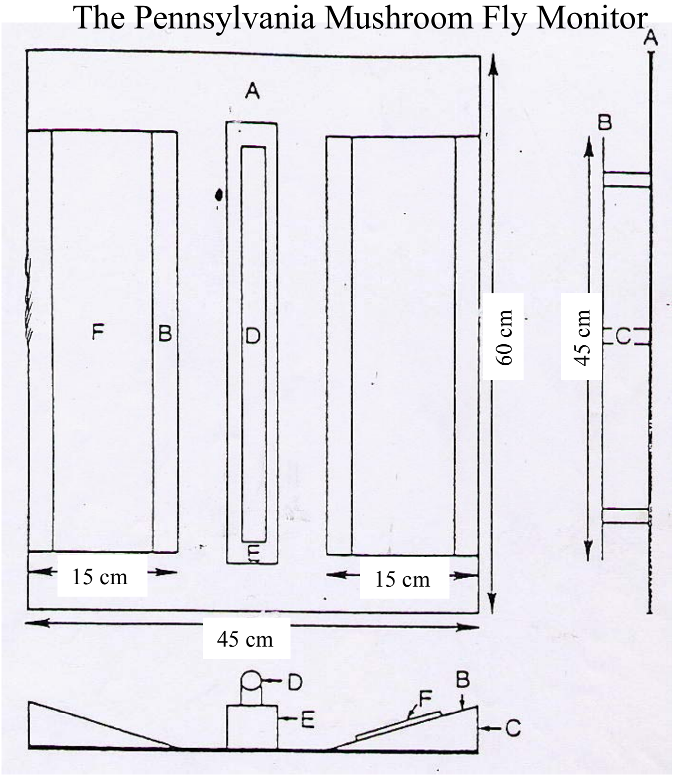
when they appear, and whether their numbers are increasing or decreasing. The necessary action taken is based on the information gathered.

Various devices have been used for monitoring adult fly numbers. Sticky fly paper hung beside a light bulb is an old method while more modern "Insectocuter " type devices commonly used in food shops are also useful. The Pennsylvania Mushroom Fly Monitor (see sketch) is an easily made and cheap alternative.
An advantage of a standard trap is that fly numbers in different locations and on different mushroom farms can be compared.

After a period of use, it should be possible for a grower to recognise pest levels that will lead to problems later in the life of the crop. It is particularly important to monitor fly numbers during spawn run and take the necessary action if appreciable numbers are detected. As high numbers of flies can enter a tunnel during casing, it is important to check these and use an insecticidal smoke on the night after casing.

It is important to remember that flytraps are only useful for monitoring and have little influence on reducing fly numbers.

The Pennsylvania Mushroom Fly Monitor



A: Bottom board 60 × 45 × 1.2 cm   D: 45 cm, 15 Watt blacklight bulb
B: Side flaps 15 × 45 × 0.6 cm   E: Fluorescent light
C: Spacers 14 × 45 × 2.5 cm   F: 10 cm White strip of stickly paper

Figure 2. Fly monitoring

Pest identification
One person should be given responsibility for pest control and this person should be trained in the recognition of pests and their symptoms. An essential requisite for this work is good lighting equipment, preferably mobile, and an appropriate magnifier such as a good-quality glass hand lens. Crops should be monitored by checking the mushrooms at random throughout the house, paying additional attention to possible "hot spots" such as near doors, along walls, and corners.

When to use pesticides
Establish the need to make a pesticide application before treating a crop and never apply pesticides routinely. It may be possible to establish that it is not necessary to make pesticide applications at certain times as a result of good monitoring. Always evaluate the effectiveness of a treatment for example by placing dishes containing water and a little detergent around the house to catch dead flies.

Crop termination

Terminate severely infested crops early thereby so that they do not act as a serious source of pest infestation in other crops. Before termination, take steps to curtail the movement of flies out of crops by giving a knock- down treatment at the end of the crop. Never delay casing or cropping as pests will continue to build up in the compost.

Making pesticide applications

♦ If preventative pesticide applications have to be made (e.g. Dimilin drench after casing), do not neglect to do so.

♦ Select the most appropriate pesticide to control the pest. This involves using only those approved by the Pesticide Control Service of the Department of Agriculture.

♦ Apply the pesticide at the correct rate, at the correct time and frequency and under the correct conditions. Always read the label and comply with any restrictions listed on it particularly the interval between application and harvest.

♦ Ideally, only use pesticides to augment cultural controls such as good hygiene, exclusion of pests and good growing practices. The ideal is to use pesticides as infrequently as possible and always use the most environmentally benign products.

APPENDIX

Provisional list of PPP's registered for use in Mushrooms – 2001 (DAFRD)

Product Name	PCS No.	Active Substance	Content	Marketing Company
<u>Fungicides</u>				
Amitan E Super	90054	Zineb	80%w/w	Unichem Ltd
Bavistin DF	90220	Carbendazim	50%w/w	BASF plc
Bavistin FL	90221	Carbendazim	500 g/l	BASF plc
Bravo 500	00198	Chlorothalonil	500 g/l	Syngenta
Bravo 720	00687	Chlorothalonil	720 g/l	Syngenta
Carbazol 500L	90366	Carbendazim	500 g/l	Unichem Ltd
Hymush	91728	Thiabendazole	60%w/w	Hygeia Chemicals Ltd
IAWS mbc	91740	Carbendazim	500 g/l	Power Seeds & H/W
Sporgon 50 WP	91288	Prochloraz	50 %w/w	Aventis Crop Science
Fumigants				
Agarifume Smokes	90031	Permethrin	3.5 g/unit	Sylvan Spawn Ltd
Bladafum	90296	Sulfotepp	10 g/unit	Bayer Ltd
Nicotine 40% Shreds	90786	Nicotine	40 %w/w	DowAgrosciences
Insecticides				
Apex 5E	91925	Methoprene	600 g/l	Syngenta
Bladafum	90296	Sulfotepp	10 g/unit	Bayer Ltd
Dimilin WP	91647	Diflubenzuron	25 %w/w	Syngenta
Dimilin WP – 25	91648	Diflubenzuron	25 %w/w	Uniroyal Chemical
Nemasys M	92079	Steinernema Feltiae	-	Microbio Ltd
<u>Disinfectants/Sterilants</u>				
Deosan Red Label Hypochlorite	91619	Sodium Hypochlorite	79 %w/w	Diversey Ireland
Disolite	91891	Ortho Phenol Phenol	23 %w/w	Progress Products Ltd
		Ortho benzyl Chlorophenol	-	
Diversol BX	91657	Chlorinated Trisodium Phosphate	99.5 %w/w	Diversey Ireland
Environ	90559	Sodium O Benzyl p Chlorophenoxide	9.3 %w/w	Sylvan Spawn Ltd
		Sodium Ortho Phenyl Phenol	11.3 %w/w	
		Sodium p Tertiary amyl Phenoxide	2.3 %w/w	
Formaldehyde	90613	Formaldehyde	38 %w/w	National Agrochemical Distributors Ltd
Iosan Mushroom House Disinfectant	91745	Iodine	24 g/l	Novartis Animal Health
Potassium Permanganate	90862	Potassium Permanganate	99 %w/w	C. Tennant & Company Ltd
Prophyl	90879	2 Benzyl 4 Chlorophenol	50 g/l	J.F. McKenna Ltd
		Chloro 4 Methyl 3 Phenol	100 g/l	
Steriform	91311	Formaldehyde	38 %w/w	Unichem Ltd
Sudol	91349	Tar Oils	50 %w/w	J.F. McKenna Ltd