Mushroom
PRODUCTION GUIDE
FOR COMMERCIAL GROWERS
2008/2009 EDITION

Revised 2008

Ministry of Agriculture and Lands

Published by
British Columbia Ministry of Agriculture and Lands

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Publication Information

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Cover Photo: Courtesy – Mushroom Industry Development Council.

Acknowledgements

This publication was prepared over a period of the past several months and with contributions form many individuals. Several people have been instrumental in the making of this guide. I would like to thank especially Danny Lee Rinker - University of Guelph for his contributions encouragement and patience throughout the duration of this project. I would also like to thank the BC Ministry of Agriculture Specialists: Siva Sabaratnam - Plant Pathologist, Tracy Hueppelsheuser - Entomologist and Tiffany Guan - Food Safety Specialists for their contributions. Special thanks also to Dennis Wheeler; Vaughn Paul; Toni Allardyce, Nitin Verma, Geraldine Auston and BC Mushroom Producers: Frank Moscone, Duke Tran, Harvey Francis, Mark Imahashi, Colin Lacey and Huu Quach.

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Useful Publications

The following publications are generally available through the district offices of the B.C. Ministry of Agriculture and Lands (see back cover) or from Agriculture and Agri-Food Canada (AAFC), Publications Branch, Ottawa, K1A 0C7. However, some publications may be in short supply or may even be temporarily out of stock as they are currently being revised.

F = factsheet M = manual B = booklet $ = charge for publication

Farm Management

B.C. Farm Employers' Handbook (Books 1-5) (M)

Enterprise Budgets for Various Crops (Planning for Profit) – request list (F)

Estate Planning Checklist for Farm Families (M)

Estate Planning for the BC Farmer, 1996 (M)

Farm Business Management Factsheets (F)

Preparing a Business Plan, Direct Farm Marketing Example (M)

Sources of Farm Credit in British Columbia (M)

Taxation and the BC Farmer (M)

General Horticulture

B.C. Organic Agricultural Products Certification Regulation, Operation Policies, and Farm Management Standards (M)

Industry Overviews

An Overview of the BC Mushroon Industry (F)

Marketing

B.C. Food Processors' Reference Manual (M)

Fraser Valley Farm Direct Marketing Guide, www.bcfarmfresh.com

On-Farm Processing: A Handbook for Producers, 1994 (M)

Pesticide Equipment and Use

Disposal of Pesticide Containers (F)

Disposal of Unwanted Pesticides (F)

Emergency Procedures for Pesticide Poisoning (F)

Handbook for Pesticide Applicators and Pesticide Dispensers (M)

On-Farm Pesticide Storage and Handling Facility (F)

Pesticide Applicators' Course for Agricultural Producers (M,$)

Pesticide Spills on the Farm (F)

Trouble-shooting Check List for Spraying (F)

Punjabi edition (M,$) Chinese edition (M,$)

Rodent Control on Agricultural Land in British Columbia: Central and South Interior (B,$)

Seven Steps to Managing Your Weeds (M,$)

Suppliers of Bird Control Materials and Equipment for B.C. Growers (F)

Weed Control Leaflets (F)

Soils and Fertilizer

Soil pH (F)

Food Safety

Hand Washing (Poster)

Useful Websites

Farm Business Managment – B.C.

http://farmcentre.com/resources/

USDA Fruit and Vegetable Market News Reports

www.ams.usda.gov/fv/mncs/index.htm

Ontario Ministry of Agriculture, Food and Rural Affairs - Current Minor Use Registrations, Priorities and Projects.

www.omafra.gov.on.ca/english/crops/minoruse_mushroom.htm

Pest Management Regulatory Agency - Canadian Pesticide Labels

http://pr-rp.pmra-arla.gc.ca/portal/page?_pageid=34,17551&_dad=portal&_schema=PORTAL

Infobasket –

http://infobasket.gov.bc.ca

Pesticide Wise - information about the safe use of pesticides.

www.al.gov.bc.ca/pesticides/index.htm

Other Information Sources

BCMAL Plant Diagnostic Laboratory

www.agf.gov.bc.ca/cropprot/lab.htm

Also refer to:

- Environmental Management - Further Resources - Pg 7
- Food Safety - Good Agricultural Practices - Pg 12
- References - Pest Management Section - Pg 68

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Environmental Management

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Mushroom Farm Practices

Introduction

The long-term well-being of mushroom farms in British Columbia depends on good management practices that protect the environment. Practices necessary to sustain the natural resources around a mushroom farm depend on the farm and its location within the province. Additional measures may be necessary where specified practices do not protect the environment adequately. It is in the best interest of all mushroom producers to determine the necessary environmental precautions for their specific situation.

Legislation

There are a number of regulations at federal, provincial and municipal levels as well as local government bylaws that mushroom producers are expected to follow. The following section provides a summary of legislation that protects the environmental. It is recommended that the actual legislation be consulted for the complete, precise wording. For provincial legislation refer to the Queen's Printer website: Revised Statures and Consolidated Regulations of British Columbia at http://www.qp.gov.bc.ca/statreg/default.htm . The following information is not intended to be a legal interpretation of these Acts. Please refer to a lawyer or legal authority for specific advice.

Federal

Fisheries Act

Fish Habitat Protection and Pollution Prevention - prohibits the discharge of deleterious substances (i.e. agricultural wastes and fertilizers) into waters frequented by fish.

Provincial

Environmental Management Act (formerly the Waste Management Act)

This Act empowers Ministry of Environment (MOE) to control pollution within BC. Waste is defined to include "air contaminants, litter, effluent, refuse, biomedical waste, and hazardous wastes" and any other substance designated by Cabinet. Pollution is defined in the Act as "the presence in the environment of substances or contaminants that substantially alter or impair the usefulness of the environment."

Section 6 of the Act is of particular interest to agricultural producers; Section 6(4) states that "a person must not introduce waste into the environment in such a manner or quantity as to cause pollution."

On-farm processing, handling and sale of agricultural produce may be defined as "agricultural operations" and if they generate wastes (such as waste water, cull vegetables etc.) may require an Approval Permit or Operational Certificate from Ministry of Environment (MOE).

Health Act

This Act is administered by the Ministry of Health Services. It includes regulations on farm practices that may result in a health hazard. A health hazard may occur when nutrients, contaminants or pathogens are discharged to land, water or air to pose a public health problem. Spills of potentially harmful substances must be reported to the Local Health Authority. Under this Act, the Local Health Authority must investigate any health hazard and has authority to order the hazard to be eliminated.

Integrated Pest Management Act (formerly the Pesticide Control Act)

This Act is administered by Ministry of Environment (MOE). It regulates the sale, containment, transportation, storage, preparation, mixing, application and the disposal of pesticides and their containers.

Farm Practices Protection (Right to Farm) Act

The Farm Practices Protection (Right to Farm) Act (FPPA) applies to farmers who operate in the Agriculture Land Reserve (ALR) and in other areas where farming is permitted by local zoning bylaws. When farmers operate under "normal farm practices", the Act protects the farmer against nuisance actions, court injunctions, or specific nuisance bylaws related to the operation of the farm. Protection provided by the Act specifically relates to nuisances such as odour, noise, dust or other disturbances. The right to farm is, however, not automatic. It requires that: a farm operation use "normal farm practices" (as defined by the Act) or practices as may be prescribed by Cabinet regulation. The Act stipulates that the farm operation must meet the Environmental Management Act, Integrated Pest Management Act, and Health Act and regulations under those acts. Within the Environmental Management Act and Health Act is the Agricultural Waste Control Regulation which deals with practices for using, storing and managing agricultural waste that will result in agricultural waste being handled in an environmentally sound manner.

Local Government

Under the Local Government Act local governments (e.g. regional districts and municipalities) have bylaws that deal with a number of matters. Development of farm bylaws that prohibit or restrict agricultural land use or zoning in the Agricultural Land Reserve require approval by the Minister of Agriculture and Lands. Once a regulation is in place for a particular area, it may authorize local government to enact farm bylaws, and/or require review of the rural land use or zoning bylaws. Local governments may use a variety of tools to reduce conflicts between agricultural and residential land uses. The guiding principals are enforced by bylaws including miscellaneous, odour, noise, nuisance, zoning, storm water runoff and rural land use bylaws.

Farm Practices

The three main disturbances mentioned in the Farm Practices Protection (Right to Farm) Act are odour, noise and dust. All three disturbances can be of particular concern to composting and mushroom farming practices. In addition, these operations must also ensure that all leachate created is contained and not allowed to pollute ground and surface water. Below is a summary of farm practices for composting and mushroom farm activities. Additional information can be found under in the Farm Practices section of the BCMAL Reference Guide:

http://www.al.gov.bc.ca/resmgmt/fppa/Refguide/intro.htm

or by calling the BC Ministry of Agriculture and Lands at 604-556-3001.

Compost Production Practices

There are three regulations under the Environment Management Act (EMA) administered by the Ministry of Environment (MOE) that deal with compostins:

- Agricultural Waste Control Regulation - deals with compostins associated with agricultural operations;
- Organic Matter Recycling Regulation - specifies feedstock allowed under Schedule 12 of this regulation;
- Mushroom Composting Pollution Regulation - deals specifically with production of mushroom compost.

The Fisheries Act has sections of importance to compost management including: Section 36(3): prohibits the deposit of deleterious substances into watercourses (deleterious substances could include compost materials and leachate), Section 37: requires approval for any work that may impact fish and Section 38(4): requires reporting infractions of Section 36.

The release of odours is a primary concern with composting operations. How people perceive the odour (nuisance or not) will depend on the frequency, intensity, duration and offensiveness of the odour, how well they smell and personal experiences associated with odour. Odours can cause air pollution when present in the air and cause or are capable of causing material physical discomfort to a person, or substantially alters or impairs the usefulness of the air. Under the Environmental Management Act, the release of odours from activities or facilities that cause pollution are prohibited. In addition to the provincial regulation, local or regional government bylaws may require permits or bylaw applications in order for a composting operation to be constructed or operated on the farm. Farms should check with these agencies prior to developing a composting operation to determine what approval is required.

A primary consideration when designing a compost production area is the prevention of water pollution. A composting site must be located at least 15 m from any watercourse and at least 30 m from any source of water for domestic purposes. Some situations may require distances greater than those specified in legislation. These operations must ensure that all leachate created is contained and not allowed to create pollution.

Potential odour nuisance complaints or other conflicts with neighbours, such as noise impacts may be reduced by using the following: Locate buildings and operations as far as possible from rural residences or residential areas, take advantage of unique topography or microclimatic conditions that could affect odour impacts, site buildings and operations so that prevailing winds transport odours away from rural residences or residential areas and use visual screening such as trees or berms.

Mushroom Farm Practices

Dust

Dust may be generated when fine particulate are lifted from fields, roads, buildings and yards by the stirring action of air. Dust in the air is defined as fine grained suspended particulate. Farms engage in a variety of activities that require the use of equipment or practices that will create dust. How people perceive dust (nuisance or not) will depend on the frequency, intensity and duration of the dust generating event. Dust can be a result of many farming activities and could be a source of complaint concerning farm activities.

Noise

Farmers engage in a variety of activities that generate noise. Noise is defined as any sound that is audible but judged to be an unwanted, irregular or erratic disturbance. Noise may be generated continuously or intermittently and may rise when equipment is run at high RPM.

Hearing damage potential of sound depends not only on the level but also the duration of the sound. Noise levels for workers are provided in the Occupational Health and Safety Regulation by the Workers Compensation Board, An employer must ensure that a worker is not exposed to noise levels above 85 dBA Lex daily exposures and 135 dBA peak sound levels.

Most equipment generates some noise. Good farm practices include: eliminating unnecessary noise such as truck engines running while parked, keeping noisy equipment inside buildings to buffer the noise and maintaining machinery and equipment in good working order with functional mufflers. Consider the loudness of equipment when making purchase decisions. Consider the time when noisy equipment must be used to avoid times that are going to be a nuisance to neighbours.

When building new farms, site new buildings farther away from property lines especially where neighbouring houses are or are likely to be built. Use and maintain landscaping to buffer and provide visual screening for noises.

Numerous jurisdictions in the province have drafted and implemented bylaws that regulate or prohibit noise or sounds which disturb the quiet,

peace, rest, enjoyment, comfort or convenience of neighbourhoods or person(s) in the vicinity. These bylaws most often spell out the hours during which certain levels of noise are not acceptable such as between the hours of 10:00 PM and 7:00 AM. These bylaws are now subject to the approval of the Minister of Agriculture and Lands where agriculture is impacted.

Emergency Plan

An emergency plan outlining steps to be taken in the event of a spill or leak should be posted near the entrance of every facility in which agri-chemicals are stored. Each emergency plan should include information on the location of emergency and first aid equipment, emergency phone numbers, and clean-up instructions.

Farm Buildings

Farm buildings are given separate status within the National Building Code. This is because they are subject to a low human occupancy load, are often located in remote areas, and are often special in nature with respect to the occupancies involved. Implications of the separate status afforded agricultural buildings are published in the National Farm Building Code of Canada. The Code sets out minimum requirements in matters affecting human health, fire safety and structural sufficiency. The BC Building Code requires all farm buildings within municipal districts to conform to the national code.

Large mushroom barns, composting facilities and storages areas need a management plan that addresses both the quantity and quality of storm water runoff. The plan should include drainage systems that keep rainwater separated from contaminated water, such as irrigation water containing nutrients from the mushroom growing facility. Mushroom barn roof water that is allowed to flow onto concrete slabs could create contaminated runoff. Roof water should be kept separate from contaminated water. On-site storm water detention should also be provided, to avoid overloading municipal or regional drains or waterways. The post-development storm water flow release rate from the property should be similar to pre-development flows unless other mitigative drainage measures are taken. Local government bylaws should be checked.

Fill Placement or Soil Removal

As necessary, soil removal or placement of fill is a permitted agricultural activity. For specified farm and non-farm uses, including the construction and maintenance of mushroom farm building or a composting facility, with conditions. Where the removal of soil or placement of fill exceeds 2% of the area of the parcel, a 'Notice of Intent' must be submitted to the Agricultural Land Commission. Proposals under the 'Notice of Intent' may be allowed with terms and conditions set by the CEO of the Commission or require an approval of the Commission.

Storage of Chemicals

All agricultural chemicals should be stored in a dedicated facility. Minimum standards dictate that a storage structure must:

- be ventilated naturally or mechanically to the outdoors to prevent the accumulation of toxic or flammable vapours,
- be accessible from outdoors and secured from unauthorized entry,
- have an impervious floor, typically concrete, without a floor drain and curbed to contain a volume at least equal to the largest container stored within,
- be separated from all food, feed and water supplies,
- be separated from all other occupancies either by an open space or by a fire separation wall having a fire rating resistance of at least one hour,
- be clearly identified with a sign saying "Danger", "Chemical Storage" or "Authorized Persons Only" permanently attached to the outside of each entrance,
- contain shelving that separates oxidizing chemicals from combustible chemicals and
- have an insulated and heated cabinet for chemicals requiring protection from freezing.

A storage facility should be dedicated to the storage of full and partially full containers only. Empty containers should be triple-rinsed or cleaned to the point where they pose no threat to people, animals or the environment. If temporary storage is required, the site selected should be one that is used infrequently, does not attract public attention and, ideally, is fenced. Landfill disposal of clean empty containers is permitted. Containers must be triple rinsed or cleaned with a pressure washer. Care must be taken to ensure that rinse water does not run into storm drains, creeks or other water supplies.

To minimize the number of containers that must be disposed of, farmers are encouraged to calculate their chemical needs carefully. Chemicals that are not likely to be needed in future or whose efficacy is likely to decline before they will be used again should be disposed of in an environmentally responsible manner. Unopened pesticides can be returned to the vendor. Excess pesticide, whether diluted or not, should never be disposed of in an inconspicuous farm location or drained into the sewer system. Under no circumstances should expired chemicals or incompletely washed containers be stored in an area not dedicated to pesticide storage.

To reduce the volume of waste going to landfill sites, agri-chemical manufacturers and dealers in B.C. have initiated a recycling program. They will accept and recycle triple rinsed or pressure-rinsed plastic and metal containers. (For a list of participating dealers contact the B.C. Ministry of Agriculture and Land or the Crop Protection Institute.)

Storage of Compost and Raw Materials

Compost and other raw materials should be stored in a closed storage facility or placed on an impermeable pad and covered to protect them from the rainy weather and to prevent the production of leachate and/or runoff. Raw materials may be piled in the open for short periods of time, but precautions must be taken to ensure that no runoff enters surface or ground water supplies. Compost and raw materials also have a potential to cause odours, dust or pest problems. They should be covered or managed so that problems do not occur.

Storage of Fertilizers

Large dry bulk fertilizer storages should be sited on elevated ground with all rain, snow melt or flood water diverted away. Fertilizers must be kept dry in well-constructed facilities to prevent caking and consolidation.

Storage of Hazardous Material

Commercial fertilizers, petroleum products, and pesticides and other products may be stored on farms. Potentially poisonous, corrosive, volatile, flammable or dangerous materials or liquids must be stored in structurally sound facilities to prevent leaks and spills.

Storage of Petroleum Products

Appropriate guidelines must be followed when setting up fuel storage facilities to ensure that environmental and fire safety concerns are met. Siting and labelling regulations vary and are dependent on sizes of fuel tanks and whether storage is aboveground or underground. Disposal of used oil products and the recycling of used petroleum are subject to regulation.

Safe Use of Pesticides

Although only contractors and those using restricted-use pesticides are required to take the Pesticide Applicator Course for Agricultural Producers, it is recommended that all agri-chemicals users take the course.

Spills: The Spill Reporting

Regulation of the Environmental Management Act describes the levels of substances that must be reported when a spill occurs and who to report it to. The Regulation requires a person to report to the Provincial Emergency Program at 1-800-663-3456, any spill of pesticide greater than five kilograms, fertilizer (including manure) greater than 50 kilograms and petroleum products greater than 100 litres. Check the regulation for other specific substance and reportable quantities.

Water Management

Uncontaminated stormwater runoff from farms may enter municipal drainage systems providing that a stormwater management plan has been prepared in accordance with local government

bylaws. Wastewater or other contaminated runoff cannot be discharged to ditches or streams. Contaminated runoff or wastewater must be collected and applied to vegetated land at an appropriate time and rate or under a permit from the Ministry of Water, Land and Air Protection treated and discharged.

Handling of Spent Mushroom Substrate (SMS) and Mitigation of Environmental Concerns

Mismanagement of agricultural waste products such as SMS is typically associated with environmental problems. These problems are a result of improper handling of SMS during the storage, processing and application procedures. This section will give an overview of where environmental issues occur when handling SMS.

Leachate Generation

The primary environmental concerns with SMS is the production of leachate. Reduction of leachate generation should be the primary focus of any SMS storage or handling practices. Leachate from SMS contains high concentrations of dry organic matter and inorganic salts. The environmental concerns associated with leachate include the pollution of groundwater and/or drinking water reservoirs. Leachate has the potential to damage critical habitat for other species if it leaches into the surrounding watershed.

Storage and Handling

(e.g. further composting to add value) of SMS in areas of high precipitation should be conducted on impermeable surfaces with leachate collection system. In the Lower Mainland, where precipitation is high from October to April, it is regulated to cover piles of SMS in order to avoid environmental pollution. The best solution is to prevent leachate generation. Cover stored SMS and divert uncontaminated runoff to prevent leachate production and contaminated runoff.

Odours

Piles of SMS may become anaerobic and give off offensive odours. Odours are an indication of reduced sulphur and/or nitrogen compound emissions. Odours generate nuisance complaints from neighbours and may foster negative attention in the community where SMS is stored and processed. Odours generated from SMS may be reduced or eliminated by ensuring piles are aerated using forced aeration or turned regularly. Low C: N ratio may also increase odour generation because microbial activity is increased.

Nutrient Application

SMS may be stored on the farm and applied to crop land as a fertilizer however, for pest management reasons it is not recommended to stored SMS at the mushroom farm site. SMS is classed as a fertilizer based on the property of C:N ratio less than 30:1. Therefore, when applied to soil there are environmental concerns that one must be aware of. Land application rates should not exceed the agronomic requirements of the soil and the crop to be grown. Care must be taken to ensure that there is no runoff. Applying SMS at rates that exceed the soil's ability to assimilate nutrients may result in water or soil pollution. Application of SMS to saturated soils or during times of heavy rainfall can result in groundwater pollution. By applying SMS too close to watercourses or to soil with low infiltration rate water pollution may occur and sensitive habitat may be negatively impacted. SMS cannot be applied on frozen fields in areas or times of high precipitation or snowfall if runoff or escape of agricultural wastes causes pollution in nearby watercourses, or goes beyond the farm boundary.

There are several bodies of legislation that govern the storage, handling and use of SMS. The sustainability of any SMS operation depends on its compliance with the legislation outlined below. Efforts should be made to educate SMS handlers regarding regulations.

Environmental Management Act– Agricultural Waste Control

This Act has three Regulations that address agricultural composting on farms. The Code under the Agricultural Waste Control Regulation specifies acceptable agricultural composting activities.

Section 3: agricultural wastes must be collected, stored, handled, used and disposed of in a manner that prevents pollution.

Section 15: agricultural waste may only be composted on the farm if the agricultural waste consists only of waste produced on the farm, or if produced elsewhere, is being composted for use on the farm. The composting site must be located at least 15 m from any watercourse and at least 30 m from any source of water for domestic purposes and must be composted in a manner that does not cause pollution.

Section 19: states that the Code is not intended to prohibit various odours from agricultural operations or activities on a farm, providing such operations or activities do not pollute.

Section 30: agricultural products must be managed to prevent the escape of agricultural wastes (agricultural products include farm inputs and outputs).

***Note:** Mushroom Composting Pollution Regulation - deals specifically with production of mushroom compost.

Fisheries Act

This Act has two sections of importance to compost management: Section 36(3): prohibits the deposit of deleterious substances into watercourses (deleterious substances could include compost materials and leachate). Section 37: requires approval for any work that may impact fish. Section 38(4): requires reporting infractions of Section 36.

Farm Practices Protection *(Right to Farm)* Act

This act protects farmers from undue nuisance complaints regarding odour, dust and noise and provides a complaint resolution process.

Fertilizer Act

If SMS is to be used as an organic fertilant, the Fertilizer Act must be abided by. Applicable sections in the Act are titled: exemptions from Registration, Registration, Standards, Regulations, Guaranteed Analysis and Labelling. Depending on the operation, a permit may or may not be required.

Further Resources

Farm Practices section of the BCMAL Reference Guide:

http://www.al.gov.bc.ca/resmgmt/fppa/Refguide/intro.htm

Reference Guide: The Canada – British Columbia Environmental Farm Plan Program.

Refer to the EFP section in this guide. For information on current EFP programs, contact the BC Agriculture Council at

www.bcac.bc.ca

or Tel: (604) 854-4483 or contact the closest BCMAL office. Also

Best Environmental Practices for Mushroom Growers in Canada

http://www.canadianmushroom.com/pdf/Best_Practices_Guide.pdf

Report: Value-Added Strategies for Spent Mushroom Substrate in BC

For a copy of this report call BCMAL Abbotsford office at 64-556-3001

Environmental Farm Planning (EFP)

The long-term prosperity of British Columbia's agricultural sector is linked to its environmental sustainability. With increasing agricultural production intensity and expanding knowledge of our biological and physical environment, the need for improving farm practices has been recognized. The goal of Environmental Farm Planning is to raise awareness amongst producers and enhance environmental farm stewardship. This can be accomplished through the establishment and implementation of Environmental Farm Plans. Environmental Farm Planning (EFP) is normally seen as a voluntary, confidential, producer-driven planning exercise that uses specifically designed resource materials and technical assistance. In British Columbia, both senior governments and the agriculture industry recognize the value of EFP's, and programming is available in all agricultural regions of the Province. Between 2003 and 2008 recognized planning advisors working under the Canada-British Columbia Environmental Farm Planning Program provided Planning Workbook and Reference Guide materials to participating farmers. These materials are used to develop a farm plan that identifies on-farm environmental risks and subsequently establishes a priority sequence of action items for addressing those risks. The EFP concept has been around for over two decades. The first in North America was the Farm-A-Syst program in Michigan. This was adapted by the Ontario Farm Environment Coalition for use by Ontario farmers. The Ontario program has been in place for well over 10 years. Since 2004 all Canadian provinces have had an EFP program in place. EFP's are voluntary. There are no government laws or regulations that require a farmer or rancher to prepare a plan. However: recently, institutions such as banks, insurance companies, food processors and buyers are paying increasing attention to the impact of agriculture on the environment and are requesting some form of environmental risk assessment from their clients. Farmers may find their environmental farm plan to be a very useful tool when dealing with these other organizations.

What is an EFP?

An EFP is an agriculture-environment risk identification process. It is conducted through a comprehensive review of activities and facilities that exist on the farm or ranch with respect to their impact on the environment. The review also looks at the impact of the environment on the farm, for example impacts from wildlife or flooding. The review considers current environmental regulation requirements and beneficial management practices that should be in place on the farm. It looks at the risk of the operation to the environment as well as the risk of the environment to the farm or ranch operation.

Why do an EFP?

- To determine the standing of the farm with respect to environmental rules and regulations and the environmental risk of management practices.
- To sustain the resources used and affected by farming practices for long-term production.
- To increase public confidence that BC farmers are "doing it right" with respect to the environment.
- To improve farm/ranch profitability. Potential economic benefits include things such as minimizing cost of pesticides by using integrated pest management techniques.
- To differentiate your product(s) in the marketplace and thereby maintain or enhance marketing opportunities.
- To help plan for unforeseen contingencies such as floods, spills or fires.
- To demonstrate due diligence on the part of the producer.
- To reduce potential for new legislation/ regulation.
- To improve relationships with regulatory agencies reducing the need for further regulation.

For information on current EFP programs, contact the BC Agriculture Council at — www.bcac.bc.ca or the BCMAL office.

Food Safety —
GOOD AGRICULTURAL PRACTICES (GAPs)

2

Food Safety – Good Agricultural Practices (GAPs)

Mushrooms may become contaminated by microbial, chemical or physical hazards at various points along the production, handling and marketing chain. These contaminants have the potential to cause food-borne illness in consumers. By using good agricultural practices (GAPs) growers can minimize the risk of contamination.

Biological Hazards

Micro-organisms such as bacteria, viruses, parasites, etc. that are in high enough numbers cause food-borne illness.

Chemical Hazards

Pesticide residues which exceed maximum residue limits (MRLs).

Other chemicals such as fertilizers, fuel, lubricants, cleaning agents, etc.

Physical Hazards

Material from the environment (e.g. wood, rocks).

Foreign objects from equipment and containers (e.g. screws, glass, metal).

Personal objects (e.g. jewellery, buttons, latex gloves).

Worker Hygiene and Practices

A basic employee training program should be given to all farm employees, covering personal hygiene, hand washing techniques and good food handling practices. One person should be assigned the responsibility for training and monitoring employee's hygiene and handling practices.

Harvest workers should be instructed to remove or cover jewellery, cover wounds, report illnesses, wear hairnets, and refrain from eating, drinking, chewing gums or smoking while handling mushrooms.

Growers are responsible for providing their workers with proper washroom facilities. Toilet and hand washing units must be provided in a convenient location and serviced regularly. Toilets should be cleaned and sanitized daily. A proper hand washing unit includes clean water, liquid soap dispenser, wash basin, individual paper towel dispenser and a trash bin. Workers should wash hands before starting work, after using the toilet, before and after breaks, after handling garbage, after sneezing/coughing/smoking, before putting on gloves or anytime hands become dirty. The proper hand washing technique is to:

1 - wet hands,
2 - use soap,
3 - rub soapy hands together for 20 seconds,
4 - rinse,
5 - dry with paper towel,
6 - turn off tap with paper towel

(See ***How to Wash Your Hands*** poster at the end of this chapter.)

Other good worker practices include putting trash in covered containers, emptying trash bins daily and restricting worker movements from potentially contaminated areas and other mushroom production areas to prevent cross-contamination.

Water Safety and Quality

Water can be a vehicle for the spread of micro-organisms and chemical contaminants.

Potable (drinkable) water should be used in all operations and where water contacts mushrooms or food contact surfaces. A lot of water is used on a mushroom farm such as for preparation of compost and casing materials, cleaning and sanitizing of equipment and food contact surfaces, irrigation, pesticide applications, generation of steam, hand washing, and drinking.

Water should be tested regularly for microbial and chemical contaminant (municipal at least once per year, wells at least 4 times per year). The E. coli test is considered to be the best indicator of microbial contamination. Water is acceptable for overhead irrigation if it contains less than 77 cfu/100 ml of E. Coli. Irrigation water should be sampled at the point where it is immediately taken before contacting mushrooms.

Faucets, fixtures and hoses in production areas should be fitted with backflow-prevention devices to prevent cross-contamination of the potable water supply. Hoses should be stored properly so that they do not contact the ground to prevent contamination.

Pesticides

Harmful chemical residues will not occur if growers follow pesticide labels that include application methods, application rates, days to harvest restrictions and other pest management recommendations. Use all pesticides according to label instructions. It is essential for growers to use the right equipment that is well-maintained, calibrated and operates to ensure accurate and uniform application (See the Sprayer Equipment & Calibration sections in this guide). Good quality water must be used to ensure pesticide effectiveness and prevent possible contamination.

Pesticides must be kept in a locked, well-ventilated storage area posted with a warning sign. Chemical spills must be cleaned promptly according to the procedure outlined by the product manufacturer (See Pesticide Regulations and Safety section in this guide).

Other Chemicals

Other chemicals used on a mushroom farm include fertilizers, lubricants, cleaners, sanitizers, disinfectants, fuels, coolants, paints, and solvents. All chemicals must be labelled, used according to label directions and manufacturer's instructions and stored in a safe manner to prevent chemical contamination of mushrooms.

Ensure that these chemicals are stored away from mushroom growing and handling areas and that all machinery is properly maintained to prevent fluid leaks. Food-grade lubricants and fluids should be used in harvesting equipment.

Cleaners and sanitizers should be labelled for use in food production facilities. Use cleaning chemicals that are proven effective and have been approved for use on mushroom farms. Apply chemicals carefully to prevent contamination of nearby mushrooms. Clearly mark containers used to hold or store prepared chemicals or chemical solutions.

Harvest Containers

Containers that come into contact with floor may contaminate mushrooms with micro-organisms. Harvest containers should be stored off the ground or floor.

Harvesting equipment should be washed regularly and stored to prevent contamination.

Reusable harvest containers should be cleaned and sanitized before each use, using only products approved for food contact surfaces. Store clean containers in a clean and dry location where they are protected from contamination.

Prohibit harvest containers from any use other than holding mushrooms.

Growing Area Sanitation

The grounds should be regularly cleaned and maintained so they do not become a source of contamination. Keep grounds free of litter, debris, trash, standing water, or mushroom waste. Store litter, trash and mushroom waste in covered containers and regularly remove them from the premises. Growing rooms should be kept clean and uncluttered.

Buildings should be maintained to prevent entry points for pests or water. Keep doors and windows closed when not in use or install screens, plastic strip curtains or air curtains.

Building interiors should be maintained to prevent physical hazards (e.g. loose paints, shattered glass), condensates and floor splash from contaminating mushrooms.

Control of Pests and Pets

Insects, birds, rodents, dogs and cats are capable of transferring human pathogens in their saliva, feces, or on their feet to mushrooms. Keep building foundations, walls, roofs, and gutters in good conditions to minimize pest entry points. Store trash in covered containers and empty trash bins daily so that pests do not have access to food and water. Use poison bait stations only on the outside of the mushroom growing and handling areas.

Restrict pets from entering mushroom growing and handling areas.

Protection of Harvested Mushrooms

Mushrooms are at risk for contamination during and after harvesting. Growers should take action to prevent contamination of mushrooms during harvesting, when they are moved to storage areas, and when they are loaded onto trucks.

Harvest containers should not be put on the floor during packing and storage.

Containers of mushrooms in storage areas should be protected from physical hazards, condensate, and floor splash. Ensure floor splash, loose wall or ceiling materials, machinery and equipment parts, and other materials do not fall into mushrooms. Cover exposed containers of mushrooms with clean plastic or paper sheets to prevent contamination. Transport mushrooms to packing facility promptly.

Mushrooms should be loaded onto clean, sanitary and secure trucks.

Record Keeping

Growers should keep records of their production inputs including chemical list, pesticide application, water testing, irrigation and harvesting dates. Sample checklists and forms can be found at the end of this chapter

In a crisis situation such as product recall, proper records can be invaluable in demonstrating that reasonable steps were taken to prevent and reduce the risk of food borne illness on the farm.

More Information

A number of resources are currently available to assist growers in implementing on-farm food safety programs. One good resource is available at Penn State University website:

http://foodsafety.psu.edu/mush/foodsafety.htm

For more information contact BCMAL, your industry organization or packer/processor.

BC Ministry of Agriculture and Lands has a number of food safety signage available to growers in multiple languages including:

- ***On-Farm Good Food Safety Practices poster***
- ***How to Wash Your Hands sign***
- ***Remember You are Working with Food sign***
- ***Important Phone Numbers sign***
- ***Visitors Must Report to Farm Office Before Proceeding sign***

The following checklists and records have been provided for basic food safety practices:

1 - Pesticide/chemical checklist

2 - Pesticide application record

3 - Pre-harvest food safety checklist

4 - During harvest food safety checklist

5 - Toilet and hand washing station inspection checklist

6 - Food safety training log

7 - Master cleaning schedule

1 - Pesticide/Chemical Checklist

FARM NAME: _____ ADDRESS: _____

INSPECTION	YES	NO	N/A	IF NO, CORRECTIVE ACTION	COMPLETED DATE
Pesticide(s) are stored:					
- in a locked, leak proof and ventilated location, with warning & caution signs posted at the door of the storage					
Sprayer(s) & Other Equipment are:					
serviced and calibrated at least once a year					
- maintained to prevent leaks					
- cleaned & maintained in a way that prevents mushroom & water contamination					
Other:					
Spraying staff are aware of what must be done in case of a spill					
Fertilizers, fuels, oils, cleaners, sanitizers, disinfectants, lubricants, etc. are stored to prevent mushroom & water contamination					

Applicator's license:

Name: _____ Valid until: _____

License Number: _____

Attach Completed Sprayer Tune-Up/Calibration Worksheet found in Sprayer Calibration section of this guide

Attach Pesticide Re-certification Credit Sheet

INSPECTED BY: _____ DATE: _____

PESTICIDE APPLICATION RECORD

YEAR: _____

GROWER NAME: _____ ROOM NUMBER: _____

CROP: _____ TOTAL CROP AREA: _____

WATER SOURCE: _____

APPLICATION DATE	TARGET PESTS	PESTICIDE & FORMULATION	PESTICIDE RATE USED	WATER RATE USED	RE-ENTRY DATE	DAYS TO HARVEST	COMMENTS (Indicate crop area sprayed, if not all)	APPLICANTS INITIALS

3 - Pre-Harvest Food Safety Checklist

Farm Name: _____ Address: _____

INSPECTION	YES	NO	N/A	IF NO, CORRECTIVE ACTION	COMPLETED DATE
Employees					
Are trained in good personal hygiene & harvesting practices					
Good food safety practices signs are posted					
Handwashing technique signs are posted					
A supervisor is designated to monitor practices and train new employees					
Toilets and Handwashing Stations					
Are cleaned thoroughly and daily					
Sanitary supplies (dispensing soap, paper towels and trash cans) are provided					
Water					
Hoses are stored so they do not contact the ground					
Water used for irrigation & sprays is tested for *E. coli* and/or fecal coliforms (attach water quality lab test results)					
Breezeways and Growing Room Sanitation					
Floors are free from trash and mushroom debris					
Trash cans have been emptied and are clean					
Pesticides and other chemicals secured in designated storage areas					
Tools, Equipment and Harvest Containers					
Picking knives have been cleaned and sanitized regularly					
Harvest containers have been cleaned and sanitized regularly					
Harvest containers are stored off the ground and protected from contamination					
Pests and Pets					
Free of insects, rodents, birds or other pests					
Clear of pets					

INSPECTED BY: _____ DATE: _____

4 - During Harvest Food Safety Checklist

Farm Name: _____ Address: _____

INSPECTION	YES	NO	N/A	IF NO, CORRECTIVE ACTION	COMPLETED DATE
Employees					
Are trained and following safe and good hygiene & harvesting practices					
Toilets and Handwashing Stations					
Are cleaned regularly					
Are replenished with supplies					
Water					
Hoses are stored so they do not contact the ground					
Breezeways and Growing Room Sanitation					
Floors are free from trash and mushroom debris					
Trash cans are emptied regularly					
Tools, Equipment and Harvest Containers					
Picking knives are cleaned thoroughly as needed					
Harvest containers are cleaned thoroughly as needed					
Harvest containers are stored off the ground and protected from contamination					
Pests and Pets					
Free of insects, rodents, birds or other pests					
Clear of pets					

INSPECTED BY: _____ DATE: _____

5 - Toilet and Handwashing Station Inspection

Farm Name: ________________________ Address: _____________________________

Date	Facilities are cleaned	Toilet paper full	Soap filled	Water available	Disposable towel full	Trash cans emptied	Handwashing sign posted	Initial

6 - Employee Training Record

Farm Name: ________________________ Address: _____________________________

Date	Type of Training		Trainer's Name	Employee's Name	Material Trained	Employee's Initial
	Initial	Follow-up				

7 - Cleaning and Sanitizing Record

Farm Name: _____ Address: _____

Date	Time	What was Cleaned and/or Sanitized	Cleaning and/or Sanitizing Product Used	Amount Used/ Mixing Calculation	Initials


Canada
How To Wash Your Hands
Cách Rửa Tay
1
Wet
Làm Ướt Tay
2
Use Soap
Dùng Xà Bông
3
20 sec
Rub Together
Xoa Tay Với Nhau
4
Rinse
Xả Sạch
5
Dry
Lau Khô
6
Turn Off Tap
Tắt Vòi Nước
Partially funded under the Agricultural Policy Framework:
A Federal-Provincial-Territorial Initiative
Được tài trợ một phần theo Khuôn Khổ Chính Sách Nông
Nghiệp: Một Đề Xướng Liên Bang-Tỉnh Bang-Lãnh Thổ
BRITISH COLUMBIA
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Pest Management

3

Integrated Pest Management (IPM)

Introduction

Integrated Pest Management (IPM) is a system of crop production that effectively manages pests (pathogen, insects and weeds) using a combination of control methods - cultural, physical, biological, and chemical - in ways that are economical and environmentally sustainable. IPM programs consider both the crop health and pest management while minimizing harmful impacts on the environment. They aim to create conditions that are optimal for the crop but less favourable for pest development. On any mushroom farm an IPM program can:

- Help minimize negative impacts on the environment and worker health.
- Provide an ecologically-sound pest control program for the crop.
- Reduce the cost and limit dependency on chemical pesticides.
- Provide a positive public image enhancing marketing potential.

Developing an IPM program takes time. Growers, researchers and extension specialist need to work together to gain knowledge on how the pests, crop and environment affect one another. Growers can generate an effective IPM program that is suitable for their farm by using this knowledge, having good observations and keeping careful records. The aim in an IPM program is to take the necessary steps and use a combination of control methods in order to prevent a pest situation from getting out of control; rather than trying to eradicate the pest once it has established. Growers using an IPM program can anticipate possible pest increases, make timely control decisions and therefore reduce their reliance on routine pesticides use.

5 basic Steps of an IPM Program

1. Identify and Understand the Behavior of the Pests

The first step in an IPM program is to properly identify and understand the behavior of the pest, its' biology and the conditions that promote its development. Including:

- The pests name and what it is caused by.
- The life cycle of the pest.
- Conditions that favour the pest's incidence and severity.
- Where and how the pest survives.
- The pest's relationship with respect to activities on the farm.

2. Regular Monitoring for Pests

An IPM program requires regular monitoring of pests and the crop conditions. Monitoring pests allows for early detection of the presence of pests. It is essential for determining when, how and where to control pests. With this information a grower can make timely pest management decisions. Monitoring may also be used to evaluate the pest management strategies and help determine if the strategies are working or if corrective actions are needed.

Monitoring for Flies

The effectiveness of fly control measures can be assessed when it is known if the fly population is increasing or decreasing. In the early crop stages it is not always possible to detect flies without a monitor. Low fly populations especially during cool down and spawn run are of major importance. These flies are the initial infestation which results in the high populations that occur later in the cropping cycle and result in economic injury.

A fly monitor should be placed inside every growing room during cool down. Daily fly counts must start 1 to 2 days before Phase II cool down and should continue up to pin formation. Monitoring flies on cropping days also provides population size estimates and identification of the species present. This data along with knowledge on the fly species' lifecycle can then aid in estimating fly population one, two or three weeks later. Pest control choices can be based on fly counts during this period.

Various devises are used to attract or trap flies. A simple, low cost monitor may be built using a clip board and a clip on florescent light. The clip board is then lined with wax paper and sprayed with a sticky substance (such as tanglefoot.) Flies are attracted to the light and stick to the adhesive on contact. Flies counted on a particular day are squished on the sticky paper and so new flies can be counted the following day. The sticky wax paper is replaced once it becomes too difficult to count flies.

It is important to remember that a fly monitor does not catch all the flies in the room. It traps only a percentage of the flies and mostly females that have already laid their eggs. For this reason a fly monitor is not useful for controlling flies. However, it does provide a relative fly count valuable for making pest control decisions.

Monitoring for Diseases

Diseases of mushrooms can be caused by pathogenic bacteria, fungi or viruses. They can significantly reduce the yield and quality of a mushroom crop. Early detection of disease can help a grower effectively control a disease outbreak.

Diseases should be monitored at all stages of the crop and start early in the crop cycle. By recording the disease type, distribution and level of damage a grower may be able to determine the disease patterns and sources of infection. For example, improperly sanitized casing equipment may result in high levels of disease in the area where the casing crew started and high disease levels near the door entrance might suggest that the initial contamination is entering through doors ways with air flow and dust.

A disease assessment can be made by calculating the percentage of all mushrooms infected in a selected location. It is important to select a location that is representative to what is occurring throughout the farm. Visual assessment of harvested mushrooms is also recommended.

Early disease outbreaks can be effectively controlled or minimized by covering the diseased area and peripheries with a layer (at least 1 to 2 inches thickness) of coarse salt and gypsum or lime

mixtures. Covering the disease before watering and harvesting will significantly reduce its' spread. It is recommended to cover the following diseases using the following methods: Dry Bubble completely with salt and gypsum/lime; Green Mould with salt and gypsum/lime 15 cm beyond the visible colony; Cobweb with a wet paper towel first and then with salt and gypsum/lime. Ensure good thick coverage with salt pieces that are not too large.

Monitoring for Weed Moulds

Weed moulds are fungi that grow in competition or in association with the mushroom mycelium. Some weed moulds have little to no effect on Agaricus bisporus while others can inhibit the growth of the spawn and eventually the mushroom. All weed moulds compete for nutrients and may have a negative influence on nutrient uptake and growth by Agaricus bisporus.

Some weed moulds grow in properly prepared compost while others may not grow unless the mushroom mycelium is present. Indicator weed moulds, are fungi that grow in compost that has not been selectively prepared for Agaricus bisporus. These moulds utilize compounds that the mushrooms can not use. Growth of these moulds may suggest a nutrient imbalance in the compost. By recording the type, abundance and location of weed moulds a grower can determine the cause and mitigation measures.

Monitoring for Mites

Pyemotid mites, commonly called pigmy mites or red pepper mites can vector disease organisms which cause losses in marketable yield. They are also a nuisance to mushroom harvesters. They do not feed on mushrooms. They eat weed moulds such as Trichoderma species and are indicators that this disease is emerging. These mites can be transported by flies, air currents, tools and equipment from mushroom house to mushroom house. Proper preparation and pasteurization of compost usually prevent the development of large populations of mites as few weed moulds will grow which eliminates food for the mites. Proper sanitation of tools and equipment can help reduce their spread. . By recording the abundance and location a grower can determine the cause and mitigation measures.

Monitoring for Nematodes

Parasitic and saprophytic (free living) nematodes are species associated with mushroom production and are found in most agricultural soils. Parasitic nematodes are capable of drawing out the contents of a mushroom cell. Saprophytic nematodes do not attack the mushroom but in large populations may produce by-products which adversely affect mushroom spawn growth. If present in the compost they either survived phase II pasteurization or were carried over in the woodwork from the previous crop. Pasteurization of compost and wood is a key component in mushroom sanitation. The presence of nematodes may suggest a failure in the sanitation process. By recording the abundance and location a grower can determine the cause and mitigation measures.

Monitoring for Abiotic Disorders

Abiotic disorders are caused by non-living organisms and are distinguished from other pests that are caused by living organisms such as viruses, bacteria, fungi insects etc. These disorders may result in physical or chemical changes in a mushroom and the affected mushroom may differ in appearance when compared to healthy mushrooms. Abiotic disorders cannot be transmitted. Some abiotic disorders are easy to identify but others are difficult or even impossible. Most damage caused by abiotic disorders is not reversible once it has occurred. They are generally caused by external factors such as excess spawn growth, shallow casing material, watering practices or environmental conditions such as diesel and paint fumes. To help in identifying physiological disorders it is important to keep a good production record to determine if there has been a lack or excess of any element that supports or interferes with the normal mushroom growth.

3. Deciding When to Control Pests

In an IPM program the decision when to control pests is made by using the information gathered in steps 1 and 2 above and using knowledge on how the pest, crop and environment interact with one another. Most pests have a developmental stage when control measures are most effective. In an IPM strategy, the grower tries to time control measures with the pest most susceptible stage.

Ideally, pests are controlled just before they reach a level that causes unacceptable economic damage; otherwise known as the economic threshold. However, these thresholds are often farm specific and have not been determine. In these situations, the use of IPM information and past experiences can help make control decisions.

4. Choosing Control Methods

The different types of control methods used in an IPM system include cultural, physical, biological and chemical. These control methods are to be used with pest monitoring and timely management actions.

Cultural Control

These methods include growing techniques that make the environment less supportive of pests and more supportive for the crop and beneficial organisms. Cultural controls methods for mushroom farms include:

Proper preparation of phase I and phase II compost so that the growing material is selective only for *Agaricus bisporus* production. If the material is not selective for mushrooms competitor organisms will quickly take over. Ensure a consistent high quality phase I compost taking in account the changes in the raw materials. Ensure proper phase II pasteurization and conditioning using representative average temperatures.

Maintain an environment that favours mushroom growth over its competitors with proper temperature and relative humidity.

Do not stretch the growing cycle beyond acceptable crop capability. Correct timing of final harvest shortens the time for pathogens and pests to reproduce. For example, going from 4 to 3 or even 2 flushes can help reduce the number of flies, pathogen spores, mites etc, by reducing the time they have to develop.

Obtain adequate post crop steam-off temperatures and time. Steaming of the compost and wood is the key component in mushroom-farm hygiene. Do not take short cuts between crop cleanups.

Physical Control

These methods prevent the pest from reaching the sites where it can cause damage. Physical control methods for mushroom farms include:

Maintain the integrity of the building by filtering air before it enters the room, and sealing walls and cracks to prevent the entry of pests. Keep a regular maintenance/repair program as part of the prevention management. This would include changing air filters and repairs.

Create barriers to prevent the introduction of pests. Keep doors closed during spawning and casing operations and minimize the number of times that theses rooms are open. Keep doors closed in harvesting rooms. Restrict the number of access door into the mushroom barn and keep these doors closed as much as possible.

Cover the compost with plastic after spawning. This keeps out flies and diseases.

Prior to watering and harvesting generously cover all diseased mushrooms with salt (Na Cl) or a 50:50 mixture of salt and gypsum or hydrated lime. For cobweb disease place a wet paper towel over top of the disease prior to adding the salt or mixture.

Biological Control

These methods provide the mushroom grower with natural tools to control mushroom pests. Natural enemies of insect pests are predators and parasites. They are also called beneficials. Predators eat pests. Parasites live in or on a pest. Specific nematodes, fungi, and bacteria species are important for controlling certain insect and disease. Some biologicals are “self-maintaining” and continue to work as long as the target pest is present. This reduces the need for repeated applications of biological control agents.

The advantage of biological controls over chemicals controls include:

- Biologicals have a specific host range.
- Biologicals leave no toxic residues, no crop re-entry periods.
- Biologicals have little or no risk for exposure to workers.
- Biologicals are less likely to develop resistance.

Biological controls require the support of an IPM program to create the conditions under which they can be most effective. For example, biological controls for sciarid flies may not control the adult stages and therefore require applications when the immature fly stage is predominant. By monitoring fly populations a timely application can be made. The effectiveness of biological controls can be reduced by some chemicals and it may be necessary to withhold biocontrol applications until pesticide residues have dissipated. Consult labels before biocontrols are implemented and time their application appropriately. Biologicals that may be used in mushroom production include:

Pteromalid wasps - This wasp is an effective biocontrols agent for controlling house and stable flies at the compost wharves. These tiny wasps are parasites that attack the immature pupa stage in the fly's life cycle. The wasps are nocturnal and do not sting.

Steinernema feltiae - This nematode species carries bacteria that are deadly to the sciarid fly larva. These nematodes target older larvae and young pupae. Thus, monitoring and knowledge of insect biology are very important. Once the nematode is inside the fly larvae, the nematode makes its way into the body cavity of the insect and releases the bacteria. The bacteria rapidly kill the insect host within 48 hours. The nematodes reproduce and are released after consuming the host. These nematodes are somewhat mobile and can seek out their host pest. Beneficial nematodes can be applied to the casing material or later in the crop production.

Hypoaspis miles -This is a beneficial mite that feeds on the larvae stages of sciarid and phorids flies. These mites do not suppress mushroom yield nor are they found on the mushrooms. The advantages to using mites are that: they are mobile and can easily search for prey, mushroom production is suitable for their reproduction and they can live for several weeks without food. Despite their low use in commercial mushroom production thus far, predatory mites have potential for successful integration into bio-control of mushroom pests. They are widely used in the greenhouse industry.

Bacillus thuringiensis var. israelensis (Bti) - This is a bacterium that is used widely in biocontrol. This bacterium produces a protein crystal that once eaten by the fly larva, the crystal degrades in the insects gut and the larva becomes paralyzed. Death occurs within 48 hours. It is most effective on young sciarid larva, so monitoring and knowledge of insect biology are very important. Research trials have found compost application provide up to 85% control and casing applications 70% of sciarid flies. Bti applied to the casing in excess to label recommendations may create excessive mycelial growth and reduced yields. Currently there are no registered products for mushrooms in Canada.

Chemical Control

This section includes pesticides and insect growth regulators. For detergents, sanitizers and disinfectants refer to farm hygiene section in this guide. Pesticides are an important part of any IPM program, but they also have drawbacks and should be used as last resort and after all other controls are put in place. If pesticides must be used, use the most appropriate one; apply evenly using the correct rate at the right time and under the right conditions. As part of an IPM program pesticides are used with monitoring of pests and established thresholds suited to the individual farm. Avoid routine use of pesticides during times of the year when the pest pressure is low for example during winter and early spring. Consider the effects on beneficial organisms in the timing of pesticide applications.

The availability of the types of chemical controls is changing rapidly. Mushroom growers need to keep up with these changes. There are very few chemical controls for fungal and bacterial diseases and no chemical controls for virus diseases. Disease control emphasizes need to concentrate on good sanitation and cultural controls practices.

There are a limited number of chemical controls for insect pests. These range from broad-spectrum materials that have activity against a wide range of insects to growth regulators which have a specific target to fly larva. The two classes of mushroom insecticides include nerve poisons - resulting in immediate knockdown and death and growth regulators - resulting slow death of larvae and a reduction in the emergence of adult flies.

The two chemical application techniques used to control flies on mushroom farms include predictive and preventative. Predictive application requires monitoring fly populations and temperatures and applying knowledge and timely chemical applications. Preventative applications serve the same role as physical exclusion, such as filtering air and sealing walls and cracks but are not as effective as physical exclusion. A preventative chemical is used as a backup if some entry points have been overlooked. This chemical barrier is applied in an attempt to kill the fly before it gains access to the growing room. Common uses for preventative sprays include application to the outside of the building and to enclosed areas outside of the actual growing area such as hallways and lofts. Preventative applications also include prophylactic or routine application to the growing materials or growing room atmosphere. These are often applied out of habit or 'fear' rather than knowledge of pest populations. Any preventative chemical measures should be regularly evaluated. Dependence on preventative chemical techniques leads to over dependence on chemicals, pesticide resistance and probable pest problems.

Consider the following when using pesticides

Economics: Compare the economic benefit expected from the pesticide application with the costs of control. To estimate the benefit of control, predict the crop loss if no pesticide is used. This can be difficult to determine. Direct costs of a pesticide application include the pesticide, sprayer and protective equipment, labour and clean-up. Indirect costs include potential hazards to humans and the environment.

Registration: Make sure the crop and pest are listed on the pesticide label. Use only the rate on the pesticide label.

Effectiveness and Pest Resistance: Choose the most effective pesticide. To help prevent pest resistance, use alternate pesticides. Use pesticides with different modes of action and only use pesticides when needed. Make sure the rate used kills the pest. Do not use less than the recommended rate.

Impact on the Environment: Pesticides can contaminate surface or ground water. The risk of leaching is greater with pesticides that are highly soluble in water (above 30 ppm) and with pesticides that breakdown slowly. Avoid using pesticides that persist in the environment.

Impact on Non-target Organisms: Protect non-target organisms. Use pesticides with low toxicity when natural enemies of pests are present. Do not use broad spectrum insecticides unless there are no other alternatives.

Timing of Pesticide Application: For the most effective control, base application timing on the crop stage, susceptible of pest, presence of beneficial organisms, environmental conditions and estimated threshold levels. Ensure pre-harvest intervals, minimum number of days before harvest that an application can be made, so that no residues are left on the crop.

Application Method: Know where the pest is and aim the pesticide application in that area. Use the appropriate spray technique which will give you the best coverage. Maintain and calibrate spray equipment.

Worker Safety: Ensure employees have application training and that they understand the label requirements of the chemical used. Ensure safety equipment and clothing is worn and re-entry restrictions are enforced after pesticide application.

5. Evaluating the Effectiveness of the Program

Keep good records. They help to evaluate the IPM programs. Records should include the regular monitoring records plus information gathered on pest control methods, weather conditions, cropping practices and yields. Once the cropping cycle is over, review this information to decide how to improve the IPM program for the next growing cycle.

Farm Sanitation

Introduction

Farm sanitation is an important part of an Integrated Pest Management Program.

Mushroom pests (insects and diseases) are easily spread by: people (feet, hands, and clothing), animals, insects (flies and mites), tools, machinery, water and airflow

Sanitation covers all measures that are necessary to prevent mushroom pests (insects and diseases) from entering, developing and spreading on the farm. It is important to understand the pest's life- cycle including the time in which infection takes place, the size of the initial population and the rate of development. To be effective meticulous attention to detail is required.

"Clean" and "Dirty" Areas

The key factor in a successful sanitation program is to identify "clean" and "dirty" areas on the farm where pest organisms would normally occur.

"Dirty" areas include older production rooms, areas where compost is being produced or delivered and personnel cross-over areas such as offices, lunchrooms, lockers, washrooms or time clocks.

"Clean" areas include storage areas for equipment, packaging etc. and sensitive growing areas such as spawning, casing and new production rooms.

Movement between the "dirty" and "clean" areas needs to be restricted. Keep farm workers for each operation separated (such as loading compost, spawning, casing, picking and cleaning).

Farm Worker Hygiene

Good farm worker hygiene helps prevent the contamination of healthy mushrooms from diseases. Spores of virus diseased mushrooms and fungal pathogens such as dry bubble, wet bubble and green mould can be spread by workers.

A farm worker hygiene program can be put into effect by developing procedures which include who, what, where, when, how and why hygiene is needed. Hygiene procedures include daily cleaning and sanitizing practices (job duties and steps) that are easy to follow and understand. An employee training program will help farm workers understand what is required and why it is necessary. Once a hygiene program is established, the procedures need to be consistently followed and validated for their effectiveness.

Farm workers should follow a regular daily sequence of work starting work with the youngest (cleanest) rooms and ending the day in the oldest (dirtiest) rooms. Control movement of work from clean to dirty areas; do not allow crossing back.

Farm workers should wear clean clothing and foot wear to work each day and follow hygiene practices such as regular and frequent hand washing. Pickers may need to change clothing and footwear if work has been carried out in a heavily diseased growing room. Work in these rooms should always be done as the last job of the day. Clothing must be washed in sufficiently hot water to kill spores.

Provide clean coveralls for clean jobs (spawning, filling of grown compost, supplementing, casing and raking.) Different coloured coveralls can be used for different operations and can help ensure that employees are kept separated. Disinfect boots or other footwear prior to starting clean jobs.

If latex or nitrile gloves are worn, hands should be cleaned prior to putting on gloves. Dispose of used gloves regularly and replaced them with new clean gloves to prevent contamination. Do not allow farm workers to wear used gloves around the premises of the farm.

Allow time in work shift for daily housekeeping duties. Clean and disinfect common areas frequently including washroom facilities and lunchrooms (tables, chairs, fridge, sink, kettle, microwave etc.), door handles, light switches, picking platforms and ladders.

Outside

Debris and long grass around the farm provides hiding places and protection for flies. The grass should be mowed regularly. Areas around growing rooms, tunnels and other sensitive areas should be kept clean and free of dirt and other debris.

Dust around the farm should be controlled as it is an excellent carrier for disease spores. Roads to and around the farm should be paved and during dry weather water can be applied to minimize dust.

Do not store spent compost on the farm.

Tunnels for Phase III Compost

Hygiene is of primary importance for tunnels that mass produce fully colonized or phase III compost. One person should be responsible for the constant attention to details that are required. Workers involved in the tunnel operations should not be allowed to cross over or work in growing areas.

After the tunnel is emptied, thoroughly clean the netting, walls, the slatted floor and any ventilation ducts. The plenum area should also be cleaned. Any compost residues or mycelia left behind may be a source of contamination, especially green mould or virus disease.

Tunnels used only for mycelium growth should be steam disinfected after being emptied by maintaining a temperature of 70°C for 6 hours. This may not be necessary for tunnels where pasteurization and conditioning are carried out because the combination of the high temperatures and ammonia produced may be sufficient. However, the high temperatures alone are not sufficient to eradicate virus or green mould. Thus, it would be prudent to routinely steam disinfected the netting and empty tunnel.

Critical times for contamination of fully-grown compost occur when emptying tunnels, transporting and filling growing rooms. Transport grown compost in closed truck or container or by properly screened conveyer belts. Prior to filling, clean and disinfect filling machines, winding mandrel and nets and disinfect growing rooms, beds and floor. Clean and disinfected all trucks, containers, equipment and machinery after use. Discard any compost spilt on the ground.

Casing Preparation and Storage Area

Start with clean casing material such as bailed peat moss or disinfect local soil casing material. ***Refer to Table 3-1: Time of Application – Casing and Pre-Production in this guide for detailed information on disinfection of casing material.*** The purpose of disinfection is to destroy nematodes and Verticillium and Mycogone spores.

Unloaded casing material in a well sheltered location away from sources of contamination. Foreign materials such as soil and other particles are a major source for disease. Windborne dust from spent mushroom substrate is an even greater source of infection than soil.

Store and mix casing material in a well cleaned and disinfected area. Mix casing material under a covered roof and on a concrete slab or in a container.

Prepared casing material should be covered with a clean sheet of plastic until it is required.

Thoroughly clean and disinfected all equipment used on the casing material after use.

Do not allow outside traffic to cross over into the casing area.

Crop Termination

Steam heat treatment (cook-out) of completed growing rooms is the backbone of a sound sanitation on a mushroom farm. Pest (spores, eggs and larva) that develop during production are a source of contamination for the next crop. Virus disease and infected mushroom mycelium may have grown in wooded boards. Used compost and casing soil must be cooked-out before the growing room is emptied.

Cook-out old growing rooms by steam heating and raising the compost temperature to 60 °C to 70°C for 8 to 24 hours. If the previous crop had a high disease incidence (i.e. green mould) then cook out at 65°C for 24 hours and re-steam the empty room and its netting before refilling at 65 °C to70 °C for 12 to 24 hours. Steam pasteurization of wood racks is best done at 75 °C for 6 to12 hours. Confirm that all surfaces (e.g. floors, ceiling and compost) reach the desired temperature. Monitor temperatures with temperature probes at various locations in the compost and air.

Old growing rooms should always be emptied down wind from newly loaded rooms. Never empty a house while filling compost or casing adjacent rooms. The concrete outside of the mushroom barn should be washed down each time a room is filled or emptied. If a known disease was present, the removal of debris in the 'fill area' is exceptionally critical. Remove any spent mushroom compost away from the farm as quickly as possible.

Growing Room Preparation

Production rooms must be thoroughly cleaned between crops and after all of the compost has been thoroughly removed. Once the growing room is emptied, the compost floor, racks, wood, nets, growing room floor, spore filters must all be cleaned and disinfected. Follow recommended procedures. Replace broken wood racks with alternate materials (aluminum) when able. Replace ventilation poly tubes between crops with new tubes. Check drains are flowing properly and that there is no build up of debris. HVAC equipment is often a concern for carry over of disease from crop to crop. Regularly clean and disinfect the coils and ducts of air handling equipment.

Building doors, air intake, windows and foundations must be sealed and made free from cracks especially at points of entry for electrical wires and pipes. Extreme conditions such as such as humidity, heat and water created during pasteurization and crop steam-off cause stress on joints, pipes and walls creating cracks. After crop turnover check outside walls, inside doors, insulation and other entries to make sure new cracks in previously sealed areas have not developed. Concrete is porous and can develop pits and holes after heavy power washing.

Inspect air filters on incoming and outgoing air to ensure they are thoroughly secured so that disease and insects can not enter or leave the growing room. Spores of virus infected mushrooms, other pathogens and competitor moulds can spread by drawing in outside air and from venting air from growing rooms. Insects must be prevented from entering or leaving growing rooms to prevent infections. Filters with good barrier action can trap disease and mushroom spores. Disease spores can be small as 2 microns.

Change filters on a regular basis (depending on the type of filter used) and after each crop if needed. Filters may be cooked-out with the growing room contents by placing them on the center of a bed before the steam is turned on.

Make sure the intake air flow is sufficient for the type of filter and the filter used can withstand the production conditions. Follow manufacturers' recommendations for total intake fan operation hours. Higher efficiency filters will require more filter surface area.

Spawning and Casing Operations

These are the most sensitive operations on the mushroom farm. They should be the first operations completed in the day. These jobs should be fully completed prior to the workers taking a break or leaving the room. Keep the doors closed and minimize times that the rooms are open.

Spawn and casing crews must not have contact with compost, spent compost or diseased mushrooms (production areas) before working in this stage. Keep spawn crew separated from other workers and do not allow cross over of workers from different duties into the spawning area. Provide a separate washroom and lunch room facilities for these workers.

Spawn and casing crews should wear clean new gloves, washed or clean disposable coveralls, washed boots that have been dipped in disinfectant.

Keep spawn in a separate cooler from harvested mushrooms.

All tools and equipment used for spawning and casing needs to be thoroughly cleaned and disinfected after use. Store in a clean area separated from other operations.

Cover the compost with a clean sheet of plastic after spawning to keep out flies and disease. The most critical time for fly control is during cool-down through spawn run. Flies are carriers of disease and mites and need to be controlled at all times and particularly during the months of May to October when the populations are the highest. Good farm sanitation practices help to eliminate breeding locations for flies.

Production Rooms

All but one entrance in new growing rooms should be sealed as quickly as possible. Strict quarantine should be enforced and only qualified farm workers should be allowed to enter these sensitive areas. Accidental entrance into these "clean" rooms can be avoided by putting up signage noting restricted entrance.

Coarse salt spread at the doorway entrance of new rooms or chemical foot dips can help reduce the spread of diseases into new growing rooms. Salt

is corrosive and should be placed into a plastic container rather than spread on the floor.

Keep doors to all production areas closed during worker activity, especially at harvest. If moving supplies into growing areas from outside, first move into building; close outside doors and then move materials thru growing area doors.

Do not allow workers to stand on side boards. Remove stumps, trash and diseased mushrooms from the production surface and the farm premises daily. Stumps provide a pathway for green moulds, Verticillium, cobweb and bacterial blotch. Removal should be done by a clean-up crew rather than pickers. Debris should be placed into plastic bags or containers and removed from the farm as soon as possible. Clean and disinfect waste containers after their use.

Keep an inventory list of all small tools and equipment used in the production areas, for example: casing rings, harvesting knives, watering equipment, hoses, baskets, ladders, picking platforms, portable lights and air conditioners. Develop a check list to ensure that all tools and equipment are thoroughly clean and disinfected prior to use and before being moved on the farm.

Only bring in the required amount of packing material into the picking room so that excess material is not moved from room to room.

Do not drag hoses from one room to another. Use hose reels on wheels. Provide separate hoses for each room.

Keep records of pest outbreaks as early as possible. Train farm workers to be on the look-out for new pest outbreaks. Map and record where pests first occurring. By doing this the source of contamination may be determined.

Cover all diseased mushrooms generously with salt (NaCl) or a 50:50 mixture of salt and gypsum or hydrated lime prior to watering and harvesting For cobweb disease place a wet paper towel over the disease prior to salt or mixture.

Terminate badly diseased crops early to reduce the spread of disease and an epidemic from developing.

If potability of irrigation water is unknown regular water testing should be part of the hygiene and IPM programs. A reputable lab can test water for numerous bacteria, pH and provide a total analysis of chemical content. If water requires treatment consider methods that are safe for the mushroom environment and end product (food safe). Low amounts of calcium chloride and hydrogen peroxide have been tested and shown to reduce overall “browning” of mushroom tops and to extend shelf-life of the mushrooms.

Corridors

Keep corridors clean at all times and disinfect at the very least once a week and daily if possible. Follow recommended cleaning and disinfecting procedures.

Keep picking boxes and other stored equipment raised above the ground level for ease in cleaning and ensure that residues from cleaners and disinfectants are not left on mushroom packing material.

Maintain a slightly higher positive pressure in the corridor to prevent disease spores from leaving the growing rooms.

Equipment

All tools, hoses and other equipment should be dedicated to growing operation, marked accordingly (colour code all equipment and tools for each production area) and thoroughly cleaned after use and before being moved to another location or being stored.

Use different or clean and sanitized equipment (conveyors) for filling new beds and room cleanout.

Detergents Sanitizers and Disinfectants

Introduction

Detergents, sanitizers and disinfectants are an essential part of hygiene program that helps to reduce the spread and/or destroy disease microorganisms. There are many products on the marketplace that can be used on hard inanimate surfaces on the farm and for cleaning hands, disinfecting footwear, tools, equipment and machinery.

Detergents and soaps are synthetic or organic materials that can emulsify oil, hold dirt in a suspension and act as a wetting agent. Soaps are less versatile than detergents as they form a scum layer when used with hard water or in acid conditions. The purpose of using a detergent or soap is to remove soil and organic matter that can support the survival and growth of harmful microorganisms.

Disinfecting Surfaces

Disinfecting surfaces may be achieved through heat, chemical or ozone treatments. Heat treatment such as post-crop steaming is a common practice used on mushroom farms.

Chemical products used to disinfect or sanitize a farm require registration either as a pesticide (PCP) or as a drug (DIN) number. The terms "Sanitizer" and "Disinfectant" are often used interchangeably but differ in that sanitizers meet a less exacting standard of "destroying 99.9% of specific test bacteria in 30 seconds. Both sanitizers and disinfectants can destroy or inactivate viruses, bacteria or fungi. They are oxidizing agents that can kill spores and mycelium of mushroom pathogens, like Trichoderma and Verticillium as well as mushroom spores and mycelium fragments that may contain virus disease.

There are a many chemical sanitizers and disinfectants available in the marketplace. Some common chemicals used on farms include alcohols (e.g. ethanol, isopropanol), halogens (e.g. chlorine bleach), peroxides (e.g. Hyperox®, Virkon®,), and quaternary ammonium (e.g. Chemprocide®, Virocid®, Verticide, Noriquat). All of these products are fast-acting, broad spectrum and low toxicity biocides. Wood treatments, such as PQ – 57 and Safetry P may also be used between crops. Formaldehyde is registered for use on casing and surface disinfectant in empty growing rooms, concrete slabs and mushroom growing equipment. Formaldehyde is classified as a probable carcinogen; information on the label provides proper use and required personal protection equipment. (PPE).

Refer to Table 1: Sanitation of Non-porous and Non-food Contact Surfaces, Table 2: Between Crops - Wood Treatment and Table 3-2: Time of Application – Casing and Pre-Production Up to Pinning in this guide for detailed information on disinfectants.

Quick Dip Disinfectant Treatments for Tools/Cutting Knives

Tools and cutting knives must be immersed in a disinfectant for at least two minutes to ensure thorough disinfection. Ensure the disinfectant used is approved for food-contact surfaces for tools and knives used around the mushroom crop. Rinsing with potable water may be required. Quick dips disinfectants may be achieved by using 70% alcohol, a peroxide or quaternary ammonia or 10% household bleach.

Disinfectants for Staff and Visitors

Hand washing station and foot bath should be placed at the main entrance onto the farm. If the foot bath is placed outside it should be covered with a lid to reduce evaporation and to prevent pets from consuming the disinfectant solution. Extra foot dips should be placed before entering critical growing areas

Secure a sign on the entrance door reading "Strict Biosecurity Measures in Effect – Please Disinfect Foot Ware and Sanitize Hands before entering these Premises." Everyone entering the farm should be encouraged to use these measures prior to entering the farm.

Hand washing stations should also be placed in easily accessible locations throughout the farm. Farm workers should be encouraged to wash their hands frequently, including before starting and returning work after taking breaks, using the

washroom and in between moving to a new room. Soiled hands require proper washing prior to being sanitized.

The use of antimicrobial hand sanitizers (for example: OneStep®, Purell® or Hand Sanitizer) may be substitute for full hand washing (washing with soap and warm water over an extended period) as long as the hands are not visibly soiled. Antimicrobial hand sanitizers save time as they usually contain alcohol in a quick-drying gel formulation and can be readily placed in convenient locations.

Foot baths can be purchased from a number of local agriculture suppliers. Common products used include Virkon® (1% or 10 g/L) - change weekly; test strips used to measure disinfectant activity, Chemprocide® (1.5% or 15 g/L) - change biweekly; test strips used to measure disinfectant activity, Hyperox® (0.8% or 8 g/L) - change solution daily or when solution becomes soiled. The disinfectant solution needs to be maintained regularly to ensure its effectiveness. Footwear should be exposed to the foot bath solution for at least 30 seconds. The foot bath will not be very effective on soiled footwear. Maintain regular cleaning of foot dips and refresh with new solutions. Make sure concentrations are mixed according to label instructions.

Factors to Consider when Selecting a Chemical Sanitizer or Disinfectant

When using any chemical product, such as sanitizers or disinfectants, every effort must be made to ensure that the product is used correctly and safely. Product labels provide information on the conditions for use and personal protection equipment (PPE) required. Additional information can be obtained from the chemical supplier. The following six factors are to be considered when selecting a chemical sanitizer or disinfectant.

1. **Location:** Use around the crop is the first consideration. Some products may be allowed for use on food contact surfaces while other products may only be used on non-food contact surfaces. A food contact surface includes any surface where the consumable food products is placed and stored. Products used on equipment or containers used to harvest, store, package, or weigh the crop should have a "food- contact" designation. Some products may require an extra step of rinsing with potable water after use. Surfaces that are non-food contact include air-handling equipment, spawning and casing equipment, bed-boards, trays, floors, walls and hallways. All sanitizers and disinfectants are not be used in any manner if the chemical can contact the crop as chemical residues may be left on the mushrooms.
2. **Cost:** The cost to achieve an effective working solution should be considered rather than the cost per litre of the concentrated product. A higher cost concentrate may provide more protection.
3. **Effectiveness:** Data for the relative effectiveness of a product is not always available. Reported results are often from laboratory testing and don't always reflect cropping conditions. All products to some degree lose their effectiveness as the organic matter load increases and therefore their effectiveness is often related to cleanliness. It is important to use the correct label rate and its conditions for use. Some products are only effective given a minimum treatment time and narrow temperature ranges. Reduced effectiveness or resistance to chemicals can be avoided by rotating the chemical options available. Records should be kept on the product used, application method, frequency of use and its' effectiveness.
4. **Corrosiveness:** Corrosiveness of the product is an important consideration. Over time continuous use of corrosiveness products can cause damage to metal and moving parts. The extra step of rinsing equipment thoroughly adds cost to the disinfecting process but may be required to protect equipment.
5. **Water Quality:** Water quality is generally not a concern. The pH of the water may need to be adjusted for chlorine products to be effective. Chlorine products are only effective at a pH 7 or less.
6. **Worker Safety:** Chemical sanitizers and disinfectants can irritate eyes, skin and/or mucous membranes. Use safety equipment recommended on the label when mixing, loading and applying disinfectants. Never mix bleach with ammonia or acidic solutions because this mixture will produce toxic chlorine gas.

Table 1: Factors to Consider when Selecting a Disinfectant.

PRODUCT	FACTORS THAT REDUCE EFFICACY	CORROSIVE	RESIDULE ACTIVITY	BENEFITS
70% Alcohol	• organic matter (alcohol does not readily penetrate organic matter) • not sporicidal • VOC emissions • flammable	• no	• low	• broad spectrum • quick drying • no residue
Bleach and other chlorine compounds	• bleach is unstable and efficacy is reduced by organic matter, sunlight, water pH > 7, and temperatures below 20°C	• yes (to metals)	• low	• hypochlorites and chloramines more stable than chlorine alone • moderately sporicidal
Peroxide	• organic matter- good pre-cleaning required • sunlight and temperature sensitive	• moderate (to soft metals)	• limited	• sporicidal
Quaternary Ammonium	• not sporicidal • hard water (>400 ppm Ca^{+2}) • affected by incompatible chemicals	• no	• good (9-day _-life in soil	• broad spectrum • many registered • non-ionic forms are good cleaners
Stabilized Formaldehyde	• leaves a residue	• no		• good disinfectant • sporicidal
Phenolics (Lysol)	• disposal issues • activity affected by other chemicals • may not be sporicidal			• those with anionic surfactants are good cleaners

Cleaning, Sanitizing and Disinfecting Procedure

There are seven steps in a hygiene procedure when using detergents, sanitizers and disinfectants. Some of these steps may be omitted or combined, for example a sanitizer may act as both a detergent and disinfectant. However each step and the sequence in which it occurs are very important to the final effect. Each step should be carefully considered when implementing a hygiene procedure.

Step 1 - Gross Cleaning

Gross cleaning is the initial clean-up where mushroom material, soil and compost are removed from surfaces. Inadequate gross cleaning is the single biggest reason for poor or inconsistent hygiene results as it is often neglected or incorrectly carried out. Any left over debris or organic matter is a source for contamination and will reduce the effectiveness of sanitizers or disinfectants used afterwards.

Do not hose down soiled surfaces with a high pressure stream or water. This wastes water and time, creates excess effluent and produces aerosols that can be moved by air flow and remain suspended in air for a period of time before becoming deposited back onto cleaned surfaces. Remove all sources of dirt, debris and organic matter thoroughly from the area being cleaned by hand picking, scraping, or using a squeegee or shovel.

Step 2 - Pre-rinsing

Pre-rinsing removes organic deposits which were not easily removed by the gross cleaning. Rinsing should occur from the top down with high volume

low pressure water. Low pressure rinses avoids blasting particles high on walls, onto the lower growing beds and into the ventilation and other areas that are not easily cleaned and reduces the production of aerosols.

Step 3 - Detergent Application:

Detergents may be applied manually, by brushing and scrubbing surfaces or mechanically, by applying spray or foaming solutions. All surfaces should be completely covered, top and bottom. Textured surfaces will require additional cleaning. When applying detergent manually avoid contaminating the solution by repeatedly re-dipping dirty cloths or brushes. Change the solution frequently or rinse off the cloth or brush frequently in clean water before putting back into the detergent solution. Frequent changing of the solution may be needed when using a combined detergent/disinfectant as heavy organic matter loads in the solution will decrease the effectiveness of the disinfectant.

Step 4 - Post-rinsing:

Post-rinsing eliminates left over residues from detergents that can interfere with the effectiveness of sanitizers and disinfectants. Low pressured high water volume rinsing is recommended as mentioned above. The best water temperature for post rinsing is < 50°C. Temperatures above 50°C can cause excess steam and aerosols. After the post-rinsing, surfaces should be free of visible particles or residues left over from the detergent. Pools of water should be removed so they don't dilute the following application of the disinfectant/sanitizer.

Step 5 - Disinfection:

Disinfection should only be carried out on visibly clean surfaces that are free of excess water. Treatments may be applied on hard surfaces manually by cloth brush or mechanically by spraying or fogging. Extra precautionary measures are needed when fogging disinfectants to ensuring safety of the farm employees. Employees should be kept away from the treated area for the re-enter period given on the label. To get the best result from the disinfectant/sanitizer, follow product label directions and consult with your chemical supplier.

Step 6 - Terminal Rinsing:

Terminal rinsing is needed when using corrosive disinfectants such as chlorine in order to minimize damage to equipment, tools and other materials. Rinsing may be required if disinfectants are used on food-contact surfaces.

Step 7 - Drying:

Drying is normally a passive process that takes place over time. Disinfected surfaces will maintain a hygienic state longer if they are allowed to dry. Alcohol based disinfectants will dry more rapidly. Leave doors and vents closed during the drying phase to avoid unwanted contamination.

Diseases of Mushrooms

BACTERIAL DISEASES

Bacterial Blotch

Common Name: ***Bacterial Blotch, Brown Blotch, Bacterial spot***

Scientific Name: ***Pseudomonas fluorescens biotype G***

Outdated Names: ***Pseudomonas tolaasii, Pseudomonas tolassi, Bacterium tolaasi***

Introduction

Bacterial Blotch is the most common bacterial disease of commercial mushroom production. The yield may not be adversely affected; however, the disease may cause serious economic losses through quality reduction, unmarketable product and post-harvest quality problems. Bacterial blotch is most commonly found in production areas that have been wet for the longest time and may be widespread in wet, humid mushroom houses with large numbers of buttons or mushrooms in close contact with each other.

Symptoms on Mushrooms

Pseudomonas fluorescens biotype G is the pathogen that causes the formation of lesions or blotches on the mushroom tissue. Lesions are most commonly seen as pale yellow spots on the mushroom cap that later turn golden yellow, yellow-brown or chocolate brown. This discoloration is superficial, no more than 2 to 3 mm in depth and the underlying mushroom tissue may appear water soaked and grey or yellow-grey in colour. If the moisture conditions favour the disease, the spots enlarge and coalesce, sometimes covering the entire mushroom cap. The mushroom cap may crack as it expands if very dry conditions occur after the blotch has developed. In serious attacks, the pinheads turn completely brown and no longer develop. Brown streaks on the stem (stipe) may be seen. Occasionally, mushroom caps can show a dingy off-colour which results in rapid post-harvest discolouration and deterioration.

Bacteria blotch usually appears during the early button stage but can appear on mushrooms at any stage of mushroom development. The blotches may appear in the first flush but generally are more noticeable in the 2nd flushes. As there are fewer mushrooms left on the shelf at 3rd break fewer blotches may be seen at this time.

Typically the lesions are first seen near the edge of the mushroom caps where two mushroom caps contact each other or where there are tight clusters of mushrooms that remain wet after watering. Blotches may also appear on harvested refrigerated mushrooms and harvested mushrooms covered with a watertight film.

Bacterial Blotch symptoms can sometimes be confused with Verticillium disease or spotting caused by Trichoderma spotting.

Disease Cycle and Spread

Bacterial blotch pathogen is a common bacterium found in most soils. Peat and lime used in casing mixes and air-borne dust are the primary sources of the pathogen into a production house. The pathogen can also colonize in the compost at an early stage and after peak heating. Compost that is too dry at spawning (approximately 62 %) with a prolonged wet period after casing favours the development of the disease.

The occurrence of the disease is associated with moisture conditions rather than the population size of bacteria in the casing material. Mushrooms that are not dried within two or three hours after watering or as a result of condensation can show symptoms within a few hours. Given these moisture conditions, the bacteria can rapidly reproduce, doubling in number in less than an hour. The entire mushroom cap may be covered with bacterial blotch within 12 hours.

Infections can easily arise when the relative humidity of the outside air is high or during the summer months when dust is more prevalent. Temperatures above 20°C with relative humidity greater than 85% are ideal conditions for bacterial blotch development. Once the disease develops, the bacteria spreads by splash dispersal and can be spread over the entire bed through watering the crop. Bacterial blotch can also be carried on machinery and other equipment, tools, picker's hands, flies and mites. Bacteria blotch can survive on structural surfaces between crops.

Disease Control and Management

Bacterial blotch disease is strongly influenced by environmental and surface moisture conditions. Disease control requires inhibiting multiplication of the bacteria on the mushroom surface. Prevent bacterial blotch from developing by managing the environment to ensure quick drying of the mushrooms during and after watering and during condensation. Prevent conditions where the mushrooms remain moist for more than two to three hours.

Add additional ventilation and air circulation after watering to ensure quickly drying of the mushrooms. Increasing the total airflow by 10-15 % encourages quicker drying and lowers the humidity to below 85%. During colder weather, such as during the fall and winter months, the air temperature can be raised a few degrees immediately after watering to aid in drying.

Avoid temperatures above 20°C with relative humidity greater than 85%. If these conditions occur avoid fluctuating temperatures even by a few degrees during cropping. Keep the air temperatures no higher than that of the growing beds. Water vapor from the air will only condense onto the casing material and mushroom surfaces when theses surfaces are cooler than the air temperature or when the water vapor equilibrium in air has been exceeded.

Warm air holds more water vapour than cool air and will dry the mushroom surfaces if it can hold the additional moisture caused by high humidity and moisture created by transpiration from active mushroom growth. Heating the ambient air will reduce the humidity and will dry the mushroom surfaces if it can hold the additional moisture.

At times of the year when both the outside air temperature and relative humidity are high there is a risk from moisture coming in from the ventilation and condensing on the colder casing material and mushrooms. In this case less water must be given. If the outside air remains high in humidity, it may be necessary to cool then reheat the intake air to the beds.

Watch out for excessive wet areas in the casing and check to see if there are any “dead zone areas” where there is little air circulation over the beds. Cold spots in the bed may indicate uneven heating. Air temperature can be kept uniform through good air circulation.

Monitor for disease frequently with trained workers. Note areas where the disease first appears and reference the watering cycles and environment controls to try to determine the cause. Flag the infected area and keep records where an outbreak first occurs. Decide if the mushrooms in the surrounding areas can be harvested. Harvesters should be very familiar with the disease and trained not to pick symptomatic mushrooms. Provide clear instructions to workers to know what should be done. Monitor the shelf life of suspect mushrooms for early deterioration and discoloration.

Adding chlorine (sodium hypochlorite) to the irrigation water at 150 ppm will help control blotch providing the mushrooms are kept dry. Management of the air flow after watering, humidity and air and bed temperatures are still necessary to ensure a good drying. The disease will be better controlled from oxidation of the chlorine but if the mushrooms stay wet chlorine will have little effect. Be sure there are no traces of formaldehyde in the casing that may react with the chlorine and cause a dangerous vapour.

Addition of calcium chloride to the irrigation water will assist in drying and reduction in bruising. Use 0.3% (active ingredient) of a food grade calcium chloride. Some farms have mixed chlorine and calcium chloride solution together.

Use good hygiene practices when preparing and applying casing material. Ensure workers are wearing clean clothing; use the foot bath prior to entering production areas and use clean and sanitized tools. ***Refer to the Worker Hygiene and Farm Sanitation section in this guide for further information.***

There are no pesticides registered for controlling bacterial blotch.

Mummy Disease

Common Name: ***Mummy Disease***

Scientific Name: ***Pseudomonas spp.***

Introduction

Mummy disease is caused by several species of Pseudomonas bacterium that are related to the bacteria blotch pathogen. This species of bacteria are a normal part of the mushroom compost microflora. The disease occurs when conditions favor this bacterial growth to populations of infectious levels. The effects of this disease can be devastating since mushroom mycelium infected with mummy disease will stop producing saleable mushrooms.

Symptoms on Mushrooms

A noticeable delay of mushroom pins during the first break is the first symptom of this disease. The mushroom pins that have not appeared are stuck in the casing material. Typical mummy symptoms appear in the second break. Mushrooms infected by the disease are characterized by curved stems with often distorted tilted caps. The stems are often thickened at the base and are covered with a fluffy edge of mycelium. Internally the mushroom stems often have colourless, translucent, water soaked longitudinal streaks. These streaks terminate as dark spots in the mushroom cap tissue and turn brown as the disease progresses. The mushrooms become mummified, tough and spongy or leathery dry. When the infected mushrooms are harvested a cracking sound is made and a large amount of casing adheres to the base of the stipe. If the stem is cut open, a creaking noise is made and the cut surface shows a reddish brown colour. Mummy disease can also occur at later stages during the crop development. During the late infections, normal pinheads are formed and the above mentioned symptoms are exhibited.

Disease Cycle and Spread

This disease does not appear to be influenced by seasonal changes in the year or any obvious component in the mushroom growing production system. Mummy disease can be epidemic for some farms which suggests that the growing practices influence the development of this disease. For most farms the disease appears without prediction. It can appear in a growing room where the production appears to be coming along strongly. When this occurs the harvest from the room can still be good despite the bare patches on the growing bed surfaces. After the initial development, the disease spreads through the mycelium within the casing. The rate of spread can be 10-30 cm per day and can eventually affect the entire bed.

As with other *Pseudomonas* spp. moisture management is the crucial control factor. Insufficient evaporation from spawned compost and casing over wet spawned compost may induce the disease. These practices can also result in water stressed mushrooms. It is important to know the difference between mummy disease and water stressed mushrooms especially when growing off-white strains of button mushrooms.

Disease Control and Management

Ensure good quality control in compost preparation. Good sanitation and hygiene is important when preparing compost. A correct balanced growth, during phase II compost production allows for the growth of microflora necessary to produce an adequate competitive environment.

Prevent mummy disease from developing by proper moisture management that promotes evaporation from the compost. Compost moisture should be examined after peak heating. Covering of spawned compost with plastic may increase water accumulation on the plastic underside. Remove the plastic two days before casing to allow moisture on the compost surface to dry. Promote evaporation after watering and do not allow casing to become saturated. The goal is to increase the total airflow by 10-15 % after watering, lowering the humidity to below 85 %. For further information on moisture management refer to bacterial blotch section in this guide.

Wet areas on compost surfaces at casing or uneven dry areas on the casing should be monitored for disease development.

Where the mummy disease is present, dig a trench across the bed and remove a 20 cm wide

section of compost at least 1.5 meters from either side of the of the symptomatic mushrooms. The exposed netting and shelves can be treated with formaldehyde and the surfaces covered with plastic.

Strict sanitation at spawning and casing plus good post-crop pasteurization of wooden surfaces are the only means of preventing the spread of the pathogen from crop to crop.

FUNGAL DISEASES

Cobweb Mould

Common Name: ***Cobweb Mould***

Scientific Name: (***Cladobotryum dendroides or Dactylium dendroides)***

Introduction

Cobweb disease generally occurs infrequently. However, it can occasionally be widespread and a destructive problem on individual farms. In the early 1990s, epidemic outbreaks of cobweb disease occurred in the United Kingdom and Ireland. Some areas have experienced significant problems with fungicide-resistant strains.

Symptoms on Mushrooms

The initial symptoms of cobweb infections can be seen on mushroom pinheads onwards. Spotting first appears on the mushroom tissue as light fleshy to yellowish brown (blotch-like) colour. Patches of white coarse webby fluffy mycelium growth covers dead and healthy mushrooms. Colonies are usually circular and growth is rapid under moist and humid conditions. The cobweb mycelium may change to pink or red colour as it ages. Affected mushrooms turn brown and rot. Spotting or blotching of mushrooms may also not be seen until after harvest resulting in a post-harvest condition.

Disease Cycle and Spread

This pathogen is a soil-inhibiting fungus and can be introduced into the casing with soil, cobweb mycelium or spores. If the casing soil is contaminated with cobweb mycelium then severe disease symptoms can occur during the first break. If the casing soil is contaminated with cobweb spores then symptoms may not be seen until later breaks or post harvest.

The pathogen thrives under warm moist conditions and grows rapidly under ideal mushroom growing conditions. The disease develops easily in relative humidity of greater than 90% at temperatures above 18°C. Spore germination and growth occurs quickly in the 20-25°C range. Optimal spore germination temperature is 25°C with relative humidity greater than 97%. Under these

conditions, the pathogen can germinate and grow in 7 days. Water condensation also encourages the growth of cobweb. The fungus profusely sporulates when in contact with mushroom tissue.

Casing moisture and evaporation rate are closely related to disease development. Higher casing moistures and/or lower evaporation rates will provide better conditions for disease development. Heavier casing may require increased water applications, therefore may encourage the spread and development of the disease. Changes in casing management or materials, for example heavier casing material, can increase disease occurrence or development.

The pathogen is spread via air-borne spores, workers and infested equipment. Cobweb spores are dry and easily dislodge and become airborne when disturbed. The spores are readily distributed in air currents and may be carried a considerable distances. Cobweb spores and mycelium can also be spread by flies, people and equipment. Even the simplest of cultural operations, such as watering or salting an infected area could result in the distribution and spread of this pathogen. Changes in ventilation that would influence the evaporation rates in areas of the room or increase air speed or volume could promote spore dispersal.

Disease Control and Management

Good farm worker hygiene, farm sanitation practices and fly control are essential for control. Attention to sanitation practices during casing material preparation and handling is most critical since contamination at the casing stage is the primary source of infection. Refer to the Farm Hygiene and Sanitation section in this guide for further details.

Cobweb disease can be easily controlled but it is capable of causing large losses if neglected. It is important to understand the cultural and environmental conditions in order to avoid conditions that favour disease development.

Prevent the disease from becoming established by maintaining good watering practices and environmental control to prevent wetness on the casing surface and on the surfaces of mushrooms. Keep temperatures at optimum for mushroom growth at 18°C and relative humidity below 90%. Drier air desiccates the cobweb spores and does not allow them to reproduce.

Identify disease symptoms early, not only the obvious web/mildew but also the initial cap spotting. Know your enemy! Daily inspection of the bed and twice a day during epidemic situations will ensure that the disease patches are spotted and treated as they develop. Check the beds for the presence of disease prior to harvesting and watering.

Responding quickly and as soon as cobweb is seen is the most effective way to achieve disease control. Proper treatment is necessary to prevent further development and spread of cobweb. It is very important to cover the affected bed area very carefully with a damp paper towel or with an alcohol drenched paper towel before covering with salt. Treatment is best done at the earliest development of the disease. If small amounts of cobweb are seen during the first flush then it should immediately treated to prevent further spread.

An alternate procedure is picking off a diseased mushroom using a plastic bag. Carefully drape a damp paper towel over the diseased mushroom as above. Then carefully place a plastic bag inside out over a gloved hand and close over the diseased mushroom. The area on the bed, from which a diseased mushroom is removed, should then be treated with salt as above. Close the bag tightly and discard in another closed plastic bag. A diseased mushroom should never be picked off with the bare hand as this will result in spreading of disease spores.

Once the disease is present the main focus should be to contain the spread. Since very little air movement will dislodge the spores, air flow can affect the spread quickly. Workers and overhead watering will disturb the spores and spread them easily.

Keep doors closed during harvesting to prevent spores from blowing to breezeways and transferring to newer beds.

Filter exhaust air (a 5 micron filter is needed for this pathogen) to prevent the spread of airborne spores around the farm.

Consider changes in ventilation system which could effect the distribution of air within a crop and around the farm which would aid in spore dispersal.

Consider casing material and changes in casing materials. Muck soils or heavier wet peat may increase the risk of cobweb. Growers who prefer to use these types of soil should consider casing treatment e.g. pasteurization of the casing. Heavier or wetter casing material requires a greater evaporative capacity. Environmental systems that are not adequate for the evaporative demand often result in epidemic develop of cobwebbing and cap spotting. A change to heavier casing material can therefore have a large effect on the disease incidence.

Post-crop cookout is the most effective treatment and particularly when all patches are covered at the time of crop termination. The thermal death point of spores in soil is reported to be 30 minutes exposure at 50°C.

When the disease pressure is severe, for example heavy infections during the 2nd or early 3rd breaks, it may be necessary to terminate the crop early to reduce the spore load on the farm.

For pesticide recommendations refer to the Disease Chemical Control Recommendations in this guide.

Dry Bubble

Common Name: ***Dry Bubble, Split Stipe, Verticillium Spot***

Scientific Name: ***Verticillium fungicola***

Introduction

In North America, Verticillium fungicola is one of the most significant fungal diseases of commercial mushroom production. Its severity is not restricted to a specific time of the year or to any specific type of casing material. None of the commercially grown *Agaricus* strains are resistant to this pathogen. Significant yield losses can occur when this disease is present.

Symptoms on Mushrooms

Verticillum fungicola causes disease symptoms on mushrooms known as Verticillium spot, Dry Bubble and Split Stipe.

"Verticillium spot" is the most common symptom which describes infections that occur on the maturing mushroom cap. Cinnamon-brown spots (necrotic lesions) develop on the mushroom cap and enlarge and coalesce as the cap enlarges. If infection occurs when the mushrooms are at the button stage, depressed necrotic spots often develop on the edge of the cap. Large dead brown spots or small pinhead spotting are all caused by infections later in the pinning process. These infections may be an indicator of carry-over from other growing area or by transfer of spores by workers after handling diseased mushrooms. Most lesions develop a grayish colour which is evidence of the Verticillium spores.

Sometimes Verticillium spot can be mistaken for other mushroom diseases. Various *Trichoderma* species can attack the mushroom cap showing a reddish-brown or purple-brown colour. When Verticillium lesions coalesce, most of the mushroom cap will be brown which may be incorrectly diagnosed as bacterial blotch. Bacterial blotch lesions are generally shinier than those caused by Verticillium. The dry leathery state of the mushrooms, without any ooze of droplets and without an unpleasant smell, can distinguish Verticillium dry bubble from *Mycogone* wet bubble.

"Dry bubble" is the second major symptom group and is where yield losses occur. It is characterized by a puff-ball like mass where the developing mushroom should be. These infections occur during the earliest development of mushroom primordium which disrupts the growth causing it to form a ball-like mass of 0.5-1.0 cm in diameter. A dull gray-while bloom of Verticillium spores.

"Split stipe" describes infections on the stem (stipe) which causes the infected cells to stop growing. The non-infected cells continue to elongate which cause the stem to bend towards the infected side, the mushroom cap tilts slightly and the splitting or peeling back of the stem occurs. These infections occur in mushrooms at the button stage.

Disease Cycle and Spread

The optimum temperature for disease development is about 20°C. At this temperature dry bubble and split stipe symptoms will develop in 10 to14 days after infection. Higher temperatures and humidity in the summer months may promote faster development reducing the time to 7-10 days. Verticillium spots can develop within 48 hours after infection. Reducing air temperatures from 20°C to 14°C and relative humidity from 90%

to 80% can delay the spore germination time. However, changing the environment may also affect the timing of harvest.

If disease symptoms appear on the first break mushrooms, infection likely occurred at pinning and the disease may have been blown in, carried by flies or have come in with the casing material. Symptoms seen on the third break mushrooms arise from infection at the time of the first break.

Verticillium spores may persist in dry conditions and in water for up to six months. The spores can also survive outside in winter conditions under covered debris. Verticillium also causes disease of wild mushrooms which can be found outdoors and around the farm during the summer months. The fungus does not grow in the compost, but comes into the mushroom house with the casing material, dust, flies and equipment.

Verticillium spores are produced in sticky clusters which enables them to attach to dust, flies, mites, debris, tools, insects, workers clothing and hands. Movement is also through air currents and water droplets. Casing material and dust are the primary sources of contamination for early infections.

Verticillium may be spread on the hands and clothing of workers within and between crops. The sticky spores cannot be removed by washing hands in hot soapy water.

Watering the crop can distribute the spores through splash and runoff to lower shelves and floors.

Insects and mites feed on Verticillium spores and can easily move the pathogen within and between crops. Flies can be the major source of distribution within and to other crops.

High concentrations of Verticillium spores can accumulate on floors because of dropped mushrooms, infested casing material, etc. These spores can then be redistributed into the air and onto the beds or by washing down floors with high pressure water or heavy sweeping.

Non-harvested mushrooms or portions of mushrooms left on the casing are also reservoirs of inoculum.

Disease Control and Management

Start monitoring for Verticillium at pinning with trained workers. One key to Verticillium control is recognizing that 10-14 days will pass from time of infections before symptoms appear. Map out the dry bubbles in a growing room to determine the source and time of infection. For example: disease appearing during first break may point to poor sanitation in casing preparations or growing room, high overall counts suggests high incoming fly populations; dry bubble near a doorway indicates dust entering a doorway or traffic from workers carrying in the disease and disease occurring in later flushes point to harvesting, watering equipment, or workers. When the disease is found decide if the mushrooms surrounding diseased areas should be picked.

The amount of spores on a farm or in an area on the farm does not always indicate the probability of disease infection or severity. However, use of Vineland Verticillium Medium can help detect the weak link in the sanitation program or source of infection. This media can be prepared on the farm without sophisticated equipment or provided to you from your suppliers. For more information on ingredients and use of this selective medium download the following files.

(1) www.uoguelph.ca/~drinker/reprints/vvm1.pdf,

(2) www.uoguelph.ca/~drinker/reprints/vvm2.pdf

(3) www.uoguelph.ca/~drinker/reprints/vvm3.pdf

Prevent infecting healthy crops. Follow strict sanitation practices to prevent introducing the disease. ***Refer to the Farm hygiene and Sanitation section in this guile for detailed information.***

Carefully treat casing soil and ensure strict sanitation practices during preparation and handling of casing.

Minimizing the dust created from wind outside or by sweeping dry concrete inside or outside. Avoid using high pressure washes that may redistribute spores from floors.

Use properly maintained air filtering system.

Control fly population and prevent flies from entering the rooms by physical and chemical

means. Disease spread can be significantly reduced by controlling fly populations during the cropping period.

Prevent the disease from spreading within and between crops. Losses during later breaks can be reduced if infected first break mushrooms are removed or isolated. Prior to watering and harvesting generously cover all diseased mushrooms with salt (Na Cl) or a 50:50 mixture of salt and gypsum or hydrated lime.

Train pickers to be familiar with the disease symptoms and do not allow them to touch or harvest diseased mushrooms. Provide clear instructions to workers so they know what should be done. Work flow should always move from the newest or cleanest rooms to the older or most diseased rooms.

Clean and sanitize tools and equipment after use before moving into other growing areas. If possible avoid moving tools from one growing room to another.

Keep doors closed during harvesting to prevent spreading spores through air movement and flies.

Ensure good post crop cookout.

If disease is severe, terminate crop early and before the next break.

Bravo (Chlorothalonil) is the only fungicide approved for use against Verticillium-disease, which can only be applied on the casing and pre-production stages. ***Refer to the Disease Chemical Control Recommendations in this guide for detailed information***.

Green Mould

Common Names (non-aggressive): ***Trichoderma spot, Trichoderma blotch, Trichoderma mildew, Green Mould, Casing Green Mould***

Scientific Names: ***Trichoderma species***

Common Name: ***Aggressive Green Mould***

Scientific Name: ***Trichoderma aggressivum f. aggressivum (= T. harzianum, Th4), T. atroviride***

Introduction

Natural populations of green mould (Trichoderma spp.) can be found almost everywhere including in forest and agricultural soils, bogs, marshes, seeds, grains, debris, wood, bark or sawdust. Green moulds are opportunistic fungi which are naturally present in compost or casing materials. Infection can occur at any time.

There are several *Trichoderma* species that may be associated with *Agaricus* mushroom production. Identification of the different green moulds species can be difficult. However, green moulds affecting mushroom production can be grouped according to their rate of growth and management as either non-aggressive or aggressive types.

Non-aggressive green moulds, from a management perspective, can be further divided into two groups; those that begin in the compost and those found in the casing. These green moulds grow on incomplete composted or unconverted plant materials in the compost such as straw or hay or on other forms of carbohydrates found in the casing material. Generally, most green moulds have been isolated from both compost and casing.

Aggressive green moulds can look similar to non-aggressive green moulds; however their growth is much more competitive. They aggressively attack and colonize the compost, casing, and mushrooms. *Trichoderma aggressivum* f. *aggressivum* is of particular concern. This species was identified in the 1990s in Canada and USA and has caused severe crop losses in *Agaricus* mushroom production in North and South America. A variation of this species, known as *Trichoderma aggressivum* f. *europaeum* (= *T. harzianum*, Th2), is found in Europe, Africa and Australia.

Symptoms on Mushrooms

Green mould is identified by dense white fluffy mycelial growth at its early stages which turns green as the spores are produced. Other moulds that are green but should not be confused with *Trichoderma* green moulds include: *Gliocladium, Cladosporium, Aspergillus, Penicillium* and *Chaetomium*.

Non-aggressive - Compost Green Moulds

A number of *Trichoderma* species have been isolated from compost. The intensity of the green colour of the spores or the density of spores may depend on the species. One common feature of all is that green mould is competing against *Agaricus* mushroom for nutrition and usually its presence indicates a 'problem' with the compost either in Phase I, II or both. Usually, the grower may not be aware of its presence until production.

Trichoderma viride appears as a dark green mould on the casing at any time during crop production. *Agaricus* mushrooms growing in the infected area die and show signs of the dark green sporulating fungus. Reddish-brown or purple-brown colouration develops along the stem (stipe) and non-coalescing, dry sunken lesions form on the mushroom cap. The lesions are deep and usually penetrate into the mushroom. The pathogen then grows into the dead tissue and sporulates on the discoloured tissue. These symptoms may be confused with Verticillium spot.

Trichoderma koningii appears as a greyish white cottony growth on the casing which turns olive-green from the centre outward as it ages. It normally appears later in the harvesting cycle towards the 3rd break. The growth starts on dead mushroom tissue and engulfs and rots mushrooms as it grows over the casing material. It can spread rapidly over healthy mushrooms at a rate of 3 to 4 inches per day. Soon after infection, the *Agaricus* mushrooms develop a soft rot (become watery and soft.) Clusters of sage green spores can be seen on the mushroom surfaces. If *Agaricus* mushrooms become infected during the first flush, they may develop superficial purple-brown spots with dry cracked surface on the caps of the first break mushrooms. These symptoms may be visible without signs of mould growth or sporulation.

Non-aggressive - Casing Green Moulds

Non-aggressive - casing green moulds primarily occur on the casing material after the first break and rarely grow into the compost. They appear as limited green patches on the casing or compost. The growth is slow and the visible green areas are generally small and seldom coalesce. They are usually visible as milky-light-green in colour which doesn't disappear over time. Mushrooms can be seen growing through the green mould. The different species of casing green moulds have unique symptoms on mushrooms. They generally affect the mushroom quality by leaving spots on the mushrooms during production or post harvest. Some species produce symptoms that resemble cobweb mildew, Verticillium disease or blotch.

Aggressive Green Mould

Trichoderma aggressivum f. *aggressivum* may first appear similar to the other green moulds; however it is much more competitive. This species is able to aggressively attack and fully colonize the compost, casing, and mushrooms. Black circular patches can be seen on the compost or casing where there is no mushroom growth. The white fluffy mycelial growth of the aggressive green mould turns dark green when the spores are produced. Sporulation can be observed within 10 days of infestation. After some time, a few mushrooms may be seen growing in the "dead" centre but mushroom yield is greatly reduced. This disease can also cause spots the mushrooms leaving them unmarketable.

Disease Cycle and Spread

Common factors for all Trichoderma green moulds

Trichoderma spores are sticky and can easily be spread mechanically or on dust in air currents, through splashing water, flies, mites, and people. Spores are readily found in soil, organic matter, debris, wood, bark or sawdust etc. Infestation can occur in the compost and/or casing at any stage of mushroom production.

The optimum temperature for Trichoderma growth is 22 to 26°C. Sporulation can be observed within ten days of infestation. Trichoderma grows particularly well when the pH is below 6. In later breaks, a humidity of 90% or greater favours

development of spores on the surface. These are the same conditions that favour bacterial blotch.

Trichoderma will not normally develop in fully colonized compost where the mushroom mycelium has established. However, a high level of infection with a large number of *Trichoderma* spores can overrun compost already colonized by *Agaricus* mushroom.

Trichoderma can quickly colonize compost at spawning or casing when supplemented with carbohydrates such as ground soybeans, cotton seed meal, etc. Some strains can colonize on a clod of supplement that is not uniformly distributed at spawning.

Trichoderma spores are a preferred food of the red pepper (Pygmy) mite. The presence of these mites can reduce the quality of the harvested mushrooms and spread the disease. If red pepper mites are present then it may be assumed that *Trichoderma* is also present, even though the green mould may not be visible.

Trichoderma may become establish on untreated wooden surfaces, such as bedboards, ladders and interior doors. High humidity favours *Trichoderma* growth.

Non-aggressive - Compost Green Moulds

These green moulds are indicators of compost quality and their growth is related to compost formulations and procedures. If the compost produced is not selective for *Agaricus* mushroom growth, due to an imbalance in the compost formulation or problems associated with the composting procedures, residual *Trichoderma* green moulds can grow. These green moulds can grow rapidly and out-compete *Agaricus* mycelium and other beneficial bacteria present in the compost. The incomplete composted or unconverted plant materials in the compost (such as hay or straw) are the food source for the green mould growth.

The growth of *T. viride* and other *Trichoderma* species in the compost can be viewed as indicator moulds when excess carbohydrates are available or when the compost is not supplemented with enough nitrogen. Composts pH below 6 and a carbon: nitrogen ratio of 22:1 favour their development. Normal compost at spawning should have a C:N ratio close to 15:1. *T. viride* excretes a toxin into the casing material which kills the mushroom tissue.

Non-aggressive - Casing Green Moulds

These green moulds grow on carbohydrates found in the casing material under acidic conditions. They are naturally found in casing materials and their abundance can vary depending on ingredients used in the casing mixture. A farm may experience varying challenges with these green moulds which depends on the casing ingredients used, crop age, debris and contamination on the farm.

Aggressive Green Mould

T. aggressivum f. *aggressivum* is an alarming pathogen that reduces yields by preventing growth of *Agaricus* mycelium. The pathogen gains entry into the growing rooms primarily through contaminated personnel and equipment, insect and mites, compost or carryover in rooms that were not sufficiently cooked-out, cleaned and sanitized.

At spawning time the crop is very vulnerable to *T. aggressivum* f. *aggressivum*. When mushroom beds are spawned, the aggressive green mould rapidly spreads and interacts with *Agaricus* mushroom growth. The spawn grains are a source of carbohydrates and provide food for green mould. Browning of *Agaricus* mycelium and death of small pins is visible macroscopically at the advancing edge of the green mould. The interaction between the *Agaricus* mycelium and aggressive green mould is not fully understood but it is thought that enzymatic degradation of the *Agaricus* mycelium is occurring. Un-spawned compost will not support high levels of aggressive green mould growth. Fully colonized compost with *Agaricus* mushroom is less vulnerable and infection through the casing from the top down to the compost is not easy.

Once this aggressive green mould has colonized the compost it will grow from the compost and infest areas on the casing. Large circular colonies appear on the casing and turn bright forest green in several days. The pathogen can be detected earlier by turning on the lights in the growing room 2 days before casing. This will help the pathogen to produce spores that quickly become green.

Besides *T. aggressivum* f. *aggressivum*, *T. atroviride* has also been found to be aggressive on one farm in Ontario about ten years ago and has recently been a problem in Europe. Normally, this species spots the mushroom and is classified as a non-aggressive casing green mould.

Disease Control and Management

Different strategies are required for controlling the non-aggressive and aggressive green moulds. It may be possible to identify non-aggressive from aggressive green moulds on the mushroom farm. However if there is any uncertainty then proper laboratory identification should be used. Wrong identification can result in no control to the disease being out of control which can result in large economic losses. Aggressive green mould (*T. aggressivum* f. *aggressivum*) can be identified at the Plant Diagnostic Lab, B.C. Ministry of Agriculture and Lands, Abbotsford Agriculture Centre, Tel: 604 556-3001.

Non-aggressive - Compost Green Moulds

Properly balanced and selective compost for *Agaricus* production will reduce these green moulds. Ensure careful preparation of compost to achieve a carbon:nitrogen ratio near 15:1 at spawning. Adjust compost formula or schedule to ensure that there is a good ammonia odour at the end of Phase I. If the ammonia concentration is too low and if green mould is present in the compost, tunnel or shelf, there is a much higher risk of green mould spores surviving Phase II.

Ensure quality control throughout the compost making process. Ensure there is adequate mixing of compost pile. Patchy random patterns of green moulds in the production room point to inadequate cross mixing of compost during phase I.

Fill phase I compost as uniformly as possible. Pasteurize compost at 60°C for at least 3 to 4 hours. Higher temperatures will not solve the problem.

Supplements should be thoroughly mixed to avoid clumping.

Non-aggressive - Casing Green Moulds:

Casing Green Moulds grow best under acidic conditions; provide an 'unfavorable environment' by maintaining pH at about 7.5. Green mould may appear with different sources or raw materials. Maintain good sanitation practices during storage and preparation of casing material and avoid contamination. ***Refer to the Worker Hygiene and Farm Sanitation section in this guide for further information.***

Chemical fungicides are not permanently registered for application to control casing green moulds. Thiophanate methyl (Senator®) has an emergency registration use until October 31, 2009. One application as a drench to the casing material is allowed; read the label carefully for use pattern and restrictions. Bravo used for controlling Verticillium has little effect on casing green moulds. ***Refer to Chemical Control Recommendations section in this guide for further information.***

Aggressive Green Mould

Management of Aggressive Green Mould greatly depends on good quality compost, thorough farm sanitation and worker hygiene practices, and good insect and mite control. Sanitation and hygiene practices should be maintained inside and outside of the mushroom barn. Particular attention to sanitation and hygiene is required during the cool down, spawning, early spawn run and during post crop cook-out and spent compost clean-up. ***Refer to the Worker Hygiene and Farm Sanitation section in this guide for detailed information.***

As with the non-aggressive green moulds, a balanced and selective compost is critical. A strong smell of ammonia is important at the end of Phase I. If the ammonia concentration is too low and if green mould is present in the compost, tunnel or shelf, there is a much higher risk of green mould spores surviving Phase II.

Prevent contamination. Remember green mould spores are sticky and can easily be spread by workers hands, feet and clothing, by animals, mice, pets, flies, mites, tools, machinery, picking equipment and on dust in the wind.

- Ensure adequate post crop cook-out and removal of spent mushroom substrate.
- Ensure growing rooms are thoroughly cleaned and sanitized before used.
- Clean the area from which any stage of compost (Phase I, II or III) will be filled into the production room. Phase I compost dumped on concrete slabs outside should be filled immediately. For some farms this area is totally enclosed to prevent dust from blowing onto the compost or casing; others have constructed a portable enclosure for the equipment and filling area.

- Remove and discard all spilled compost or spawn immediately. *Trichoderma* can grow rapidly on spilled spawn.
- Wash and sanitize all filling equipment prior to and after use.
- Filter fresh air during Phase II, ideally to retain 2 microns spore size.
- Personnel management is crucial in preventing and reducing an aggressive green mould problem. Restrict personnel access to the Phase II room during the cool down period, spawning and during spawn-run. The spawning and casing crew should wear protective clean clothing and be isolated from the rest of the farm workers during the spawning and casing operations.

Provide barriers to infection.

- Don't let the disease organism get into the crop!!
- Tightly seal-up growing rooms.
- Keep doors closed during harvest.
- Filter incoming air.
- Use foot dips or coarse salt at entrance of rooms.
- Minimize dust and debris inside and out.
- The casing preparation area should be located in a separate building that has filtered air and is able to be sanitized. Equipment used for casing should be cleaned and sanitized regularly. Store peat and lime used for casing in a protected manner. Properly dried and baled peat is not a source of *Trichoderma* green mould.
- Storage of spawn should be in a pest-free area and separate from harvested mushrooms. Clean and disinfect all spawn handling equipment, including hydraulic or other hoses that are pulled along the floor from room to room. Use optimum spawn rates to achieve as rapid growth of Agaricus as possible.
- Keep supplement bags clean and stored in clean area.

Maintain good insect and mite control. ***Refer Insect sections in this guide for further information***

Maintain good cultural practices.

- During spawn run, optimal temperatures are important. If the temperature is too low the Agaricus mycelium will grow slowly, allowing the growth of pathogenic organisms, including green moulds, to overtake the mushroom. High temperatures will weaken or kill the mushroom growth and allow heat resistant organisms to take over.
- Ensure uniform filling of beds and good air circulation to avoid "hot spots" or "cool spots" in the beds.
- A rapid crop cycle of three breaks or less reduces the development of diseases as well as insects and mites that spread it.

Monitor the disease by counting the number of green mould infections and mapping the locations in a growing room.

- Crews that are involved in casing, leveling or watering should be considered as a disease monitoring/scouting crew. They need to mark/flag the diseased areas and notify the appropriate personnel and do not disturb it.
- Disease patterns can make it easier to detect the sources of infection. Ventilation problems will be apparent by the appearance of diseases near doors due to dust or air movement. High incidence of a disease in one area can indicate contamination by the spawning crew or contaminated (improperly sanitized) spawning tools. Overall high counts of disease throughout the room will indicate that the disease is spread by high fly populations.

Cover the diseased areas. Once green mould has developed, some control can be achieved by securely covering the diseased areas prior to watering and harvesting.

- Generously cover all diseased areas including 15 cm (8 inches) beyond the visibly infected area in a circular fashion with coarse grade salt (NaCl) or a 50:50 mixture of salt and gypsum or hydrated lime. Use good salt size and thickness.
- By turning on the growing room lights, 2 days before casing, the pathogen will produce spores and quickly become green so it can be detected and covered up earlier.

Under high disease pressure.

- Avoid supplementation at spawning.
- Avoid top spawning during a green mould outbreak.
- Steam off the crop prior to emptying at a compost temperature of 65°C for 24+ hours. And even at this temperature and duration some spores will survive.
- It is critical to remove all debris inside the room.
- Thoroughly clean, sanitize and re-steam the growing room before new material is introduced.
- Clean outside area before the next batch of compost arrives.
- One gram of spent compost could have one million *Trichoderma* spores. Remove spent compost from the farm premises immediately. Do not store the spent compost on the slab and allow run-off of "dirty" water. This can recycle green mould on the farm.
- If necessary, steam off the crop early.

Brown strains of *Agaricus* mushrooms are more tolerant against *T. aggressivum* f. *aggressivum*.

Wooden bed frames may harbor green mould from crop to crop. When renovating a room replace all shelving and uprights with metal. Once the production beds are washed down and all organic debris removed, wood can be treated with propiconazole (Safetray P) or Copper-8-quinolinolate (PQ-57). Read labels for proper rates of application. ***Refer Chemical Recommendations section in this guide for further information.***

Regular chemical fungicides are not available for controlling aggressive green mould. Currently, there is only one chemical that is effective. Thiophanate methyl (Senator®) has an emergency registration use until October 31, 2009. The Senator application is only to treat spawn, coverage of every spawn-grain is very critical. The emergency use is limited to mechanical means of applying the Senator treated-spawn to the compost. Hand spreading of treated-spawn is not allowed in any manner. No fungicide stops an infection once it is started.

Wet Bubble

Common Name: ***Wet Bubble, La Mole***

Scientific Name: ***Mycogone perniciosa***

Introduction

Wet bubble disease occurs from time to time on mushroom farms; however, it is not considered to be a serious disease in Canada. It is similar to Verticillium (dry bubble) disease but is more easily managed and thus it may be a little less threatening. The disease occurs wherever mushrooms are grown and can cause significant crop losses by reducing the numbers of harvestable mushrooms.

Symptoms on Mushrooms

Mycogone-infected mushrooms become malformed with swollen stems (stipes), have reduced or deformed caps, or masses of undifferentiated tissue. The mycelia mass masses become necrotic and a wet soft rot may follow. An offensive odour may develop.

The disease is best recognized by the large cauliflower-like distortion of mushroom tissue. The coral-like mass can measure up to 10 cm. Under high humidity conditions, amber to brown drops of liquid form on the white fluffy surface.

Appearance in the early stage is visible as large swollen lumps of tissue coming through the casing layer before mushrooms are harvested. The stem of a mature mushroom can also be infected, showing a brown discolouration and eventual white, fluffy mycelium growth on the stem surface. The gills can be infected with white fluffy mycelium and the liquid drops may also appear.

Wet bubble (Mycogone) may have similar symptoms to that of dry bubbles caused by *Verticillium fungicola* at the early stage of pin infection. Also, under dry conditions wet bubble can become desiccated and resemble dry bubble. The two diseases may be distinguished by their size and colour. *Verticillium* (dry bubble) do not get as large and do not turn brown like *Mycogone* (wet bubbles). Dry bubble ranges in size from that of a pea to a large grape. Wet bubbles range from one half the size of a golf ball to as large as a grapefruit.

Disease Cycle and Spread

Mycogone perniciosa is commonly found in soils and grows well in casing soils and in peat. It survives apart from the mushroom crop on other fungi, such as wild mushrooms, or in a dormant form in field soils. *Mycogone perniciosa* may also been found on live mushroom debris in cracks and crevices, or in the wooden bedboards.

Mycogone perniciosa produces two types of spores; one is a small spore that is easily dispersed by water. The small spore produces a white felt textured mycelium. The other spore type is a larger, thick walled dormant spore that can persists in the environment for a long time. The larger spore causes infected mushroom to become tan coloured. Spores may survive on structural surfaces and in crop residues.

The optimum temperatures for growth of the disease is between 23 -25°C. As the disease progresses, drops of amber / brown liquid containing bacteria and spores appear on the infected mushrooms. The small spores can develop in 3-7 days and the large spores as in 7-10 days. Wet bubble diseased spreads by spores and mycelium. Infections of mushrooms occur when the mushroom initials (pins) begin forming at the casing surface. Following infection, the pathogenic fungus grows into and over the mushroom. The pathogen takes 10 to 14 days to form its' distinctive mass.

Contaminated casing material is the primary source of the pathogen. The spores are light in weight and are easily air-borne. Thus, early infections can also result from dust or soil blown in from around the farm. The disease is later spread by water splash and runoff to lower beds, harvesters, tools and equipment. Spores found in dust on floors and from traffic on outside roads is another source of contamination. Insects and mites are suspected to be carriers of the pathogen but there is no firm evidence of this.

Disease Control and Management

Employ strategies indicated for dry bubble (*Verticillium fungicola*) disease.

Disease control can be best accomplished through good sanitation and hygienic work practices. ***Refer to the Farm Hygiene and Sanitation section in this guile for detailed information.*** Poor hygiene is the single greatest cause of this disease. The following sanitation and hygiene practices should be targeted for this disease:

Wash all tools going into production houses, from spawning to harvesting.

If necessary, pasteurizing the casing materials. ***Refer to Disease Chemical Control Recommendations in this guide for detailed information.*** Protect casing from any possible source of contamination. Prepare and store casing materials in a clean disinfected and protected area away from dust and water run off that may carry soil. Cover prepared casing material with a clean sheet of plastic until needed.

Prevent dust from being drawn into the growing areas. Adequate filters (HEPA) used on the intake should be monitored for efficacy and changed regularly especially in dryer weather where dust outside is more common. Out-take louvers should also be filtered and closed when fans are inactive.

Dust arising from wind outside or by sweeping dry concrete inside or outside is a possible source of disease spores and must be avoided. Apply a light water mist or use dust reducing agents over floors prior to sweeping and use a squeegee to clean up dirt from the floor.

Control movement of soil. Contaminated soil can get into the mushroom production system in many ways. The most commonly means are by wind blown dust; soil carried on wheels of vehicles or footwear and water run off.

Monitor for disease frequently with trained workers. Early recognition of the presence of the disease is important for effective control. Harvesters should be very familiar with the disease and not pick symptomatic mushrooms. Use markers or flagging to indicate where a disease outbreak has occurred and decide if the mushrooms in the surrounding areas can be picked. Provide clear instructions to workers to know what should be done.

Immediately cover diseased areas with salt to prevent further spread. This is important even if a tiny amount of a disease is seen early in the first flush.

Remove old stumps from the beds after harvesting. Mushrooms which fall on the floors and between or behind beds are good sources of contamination. The large masses may be picked off. However, never pick off diseased mushrooms with bare hands as this can result in efficient spreading of disease. Alternatively, pick off a diseased mushroom using a plastic bag with one's hand inside the bag and then carefully close the bag over the diseased mushroom. The area on the bed where the diseased mushroom was removed should then be treated with salt as mentioned above.

Control flies - ***Refer to Mushroom Flies section in this guide for detailed information.***

Keep doors to growing areas and around the farm closed.

Ensure harvesting clean rooms prior to diseased rooms.

Terminate crop early if disease incidence is severe. In a disease epidemic the disease can easily spread to other production areas.

As with *Verticillium* there are few registered chemicals for control of this disease. Chlorothalonil (Bravo) can be applied to casing for Verticillium disease and may be of some help. ***Refer to Disease Chemical Control Recommendations in this guide for detailed information.***

VIRUS DISEASE

Viral Diseases

Common Name: ***La France, Mushroom Virus X, other viral diseases***

Pathogen: ***Viruses***

Introduction

Viral diseases have been reported in most production areas where commercial mushrooms are grown. These diseases frequently occurred in the 1960s before much was known about their cause and origin. To date La France Disease continues to be a serious threat. A new virus complex known as Mushroom Virus X (MVX) was identified in UK in 1996 and has since been reported in the Netherlands and Ireland. In the UK, this virus has been a factor resulting in the closure of phase III compost facilities. Other viruses that can exist in mushrooms include; Mushroom Bacilliform Virus which is present most of the time in conjunction with La France Disease and Vesicle Virus which appears equally in healthy and La France Disease infected mushrooms, but does not produce symptoms or yield losses. Viral diseases can be extremely devastating. An infected mushroom farm may need to cease production temporarily in order to eradicate the problem.

Symptoms on Mushrooms

Symptoms of virus infected mushrooms can vary from a modest reduction in mushroom yield to rapid dying of mushrooms, progressive degradation of the mushroom mycelium and total suppression of mushroom fruiting. The type of symptoms manifested by the disease depends on the mushroom strain, the stage of development, environmental conditions and the pathogen's virulence and abundance.

La France Disease: During the spawn run there are no visible symptoms. However after the casing is applied the mycelium may have difficulty growing in the casing or dies back, leaving patches with no mushrooms. Mushrooms that do grow may appear normal, pin later than normal and frequently below the surface, be loosely attached to the casing, have small caps on normal size stems, have elongated stems that are slightly bent, die

rapidly followed by bacteria soft rot, open prematurely, be off-white, ashen or tan or turn brown rapidly after harvested.

Mushroom Virus X*:* Little is known about Mushroom Virus X as it is a relatively new disease. Generally there are two distinct types of symptoms: (a) bare areas, crop delay with poor quality mushrooms and (b) brown mushrooms in a white crop. Both types of symptoms can occur in the same crop. Symptoms associated with virus X in the Netherlands and Ireland has been cream to light-brown coloured mushrooms growing in between white mushrooms. The quality was not affected but the discolouration of the paper thin layer on the mushroom cap makes them unacceptable for the fresh market.

In The UK the symptoms linked to Virus X have had far more disastrous consequences including delayed harvest, bald patches, and a drop in production and deterioration in quality. Reports have noted that certain farms seem more vulnerable to Virus X than others, but the virus also appears more prevalent in certain batches of compost than others. This means that the same compost can show Virus X symptoms at one farm but not at another. It's even feasible that in the same growing room one batch of compost will have Virus X symptoms while another batch doesn't. It has been reported that Virus X shows no symptoms in 'low' concentrations but manifests itself under 'stressful' conditions during compost production or cultivation.

Disease Cycle and Spread

Transmission and spread of the virus is through living host tissue such as mushroom mycelium or spores. The virus cannot reproduce in water or compost, only on the living material found in the compost and casing. Viral diseases are transmitted through hyphal fusion (anastomosis) of diseased to healthy mycelium and later through the release of virus-infected spores. Mycelium fragments that remain on the woodwork, netting, or equipment can anastomose and transfer the virus particle.

Virus-infected mushroom spores are easily airborne and therefore can infect new spawn beds, compost (after peak heat), casing and untreated wood at any time. A single mushroom with an 8 cm cap can discharge 1.3 billion spores and only 10 to 100 virus-infected spores spread over 3 m^2 of compost surface are needed to induce a disease outbreak. Virus-infected spores kept in a dry state are capable of transferring the disease after six years and when kept at 4°C may be still viable after 10 years. Infected spores may be carried by water, insects, mites or nematodes but these pests do not transmit the virus themselves; only by distribution of the infected spores. Wild mushrooms are not known to be a host of viruses that attack *Agaricus bisporus*.

La France Disease: Infected mushroom spores are the most likely means of spreading the disease. The infected mycelium from previous crops can also survive in the mushroom beds and transmit the disease to new mycelium of the next crops. Dust from around the farm may introduce infected spores into the spawning or growing rooms. In general, infection of the crop at spawning can lead to a higher level of disease and greater crop losses than infection at later stages.

Mushroom Virus X: Experiments have shown that very little infected material is needed to produce an infected crop with as little as 1 gram of infected compost in a tonne of healthy compost (1 ppm) is capable of producing severe symptoms.

Disease Control and Management

Disease symptoms may be confused with other production problems. The only way to assess the presence of the virus is through proper lab testing. Contact your spawn supplier or the Plant Diagnostic Lab, B.C. Ministry of Agriculture and Lands, Abbotsford Agriculture Centre, Tel: 604 556-3001 if you suspect you have a virus problem.

Observations of the symptoms are important for early detection. The earlier the symptoms appear can suggest that there will be a greater crop loss. For example, infections that occur close to the spawning cycle will generally have greater disease severity. This also indicates infection occurred during the composting or spawning cycles. Look for small open mushrooms that may spread the virus through infected spores. Mark off and quarantine any dead areas or abnormally emerged pins. Map these areas and keep proper records.

Successful control of mushroom viral diseases can be accomplished by strict hygiene. Once the disease is established, it is impossible to control without completely sterilizing the production facilities, tools and materials. If the virus is diagnosed, heat the compost at 70°C for at least 12 hours. Research has shown that mushroom spores can survive 16 hours at 60°C but not at 65°C. ***(Refer to the Worker Hygiene and Farm Sanitation section in this guide for further information.)***

Mycelium can migrate into wood frames, netting and remain on equipment enabling transfer to a healthy crop. Diligent sanitation procedures must be established and strictly adhered to with an infected crop in production and after cleanout of the infected crop. Treatment of wooden shelves with propiconizole (approved in Canada) will not only preserve the wood but inhibit mushroom mycelia from penetrating the wood and possibly surviving during post-crop heating procedures. Thus, the mycelia from a new crop will not be able to anastomose (join) with the mycelia from a previously infected crop.

Since the spread of the disease can be transmitted by infected spores, the intake air of a production area must be filtered adequately. High-efficiency filters in the fresh air system must be secured in maintained in all growing rooms. Filters must be fine enough to capture 5 by 7 micro meters spores. Ventilation systems need to be tight and not create a negative pressure, thereby sucking spores beyond the filter. Out take (exhaust air) should also be filtered in infected houses to prevent further spread of spores. Infected mushroom must not be allowed to open and release their spores.

Cultural practices such as ruffling the casing (which consists of breaking up the mycelium and relocating it within the casing material) and adding fully colonized compost to the casing material (cacing) can increase the risk of disease spread. The risk is in moving the infected mycelium from an infected area e.g. “dieback area” to a non-infected area. Emphasis must be made on a preventative hygiene program such as disinfecting equipment between each use. Work in the infected areas last.

No solution has yet been found for Mushroom Virus X. To keep it under control, provide nutritious compost, stimulate evaporation, prevent unbalanced stress situations and make sure everyone adheres to strict hygiene.

All mushroom species are susceptible to the virus, there are no know mushroom strains resistant to virus. Although changing spawn strains can be helpful in restoring yield, selecting a strain that does not readily anastomose (join) with the infected strain can help reduce the inoculum on the farm. Contact your spawn supplier for more information.

Pick mushrooms before the veil opens to prevent liberation of spores that carry the virus.

Cover spawned compost with plastic so that diseased spores cannot land on the surface.

Store spawn in a separate cooler from harvested mushrooms.

Equipment, picking and shipping containers shared between farms should be disinfected immediately when returned to the farm.

Avoid hiring workers who visit or do part time work on a farm where virus is present. Discourage visits from other growers and visits to other mushroom farms where virus is present.

Weed and Indicator Moulds

There are many weeds and indicator moulds associated with *Agaricus* mushroom production. Only the most common ones are discussed below.

Weed Moulds

Weed moulds are fungi that grow in properly prepared compost that is selective to producing Agaricus mushroom. Some weed moulds may have little to no effect on the *Agaricus* crop while others can entirely inhibit *Agaricus* production. Weed moulds compete for nutrients and grow in competition or in association with the *Agaricus* mushrooms. Thus, they differ from infectious fungal diseases which attack the *Agaricus* mushroom. Proper use of cultural control practices can favour *Agaricus* production over weed moulds and allow for the *Agaricus* mushroom to overcome the weed mould growth.

Cinnamon Brown Mould (Chromelosporium sp.)

Cinnamon brown mould is one of the most common brown moulds found in *Agaricus* mushroom production. Dense growth of cinnamon brown mould can retard the growth of the first break *Agaricus* mushroom and cause a slight decrease in yield.

Cinnamon brown mould is most frequently seen growing during the first two weeks after the casing material has been applied and less frequently on the compost surface during spawn-run. It is often seen growing on the structural surfaces made of wood. It first appears as large circular patches of white aerial mycelium. Spores form within a few days and the mould colour changes to light yellow or light golden brown. The edges of the mould remain white. Overtime, the mould develops a granular appearance and turns to golden or cinnamon brown colour. The mould grows rapidly but usually disappears within 10 days or by the time the *Agaricus* mushroom is first harvested. It then reappears within 10 to 14 days as small dark brown, rubbery disk or cup-shaped apothecia which contains spores (the sexual phase of the fungus.)

Cinnamon brown mould is an opportunistic fungus that is commonly found in soil. It is most commonly known to colonize over-pasteurized casing material and spent compost. Growth in the compost is encouraged by overheated compost during spawn run or where the *Agaricus* mycelium has been killed by virus or green mould or where the *Agaricus* mycelium has been weakened by filling overly wet compost. Cinnamon brown mould is often found in compost containing green mould. The mould grows rapidly from infested compost into casing, especially in areas where spawn growth is weak or nonexistent. High humidity of 90 to 95% and warm temperatures following casing are ideal for its growth. Widespread infestations are due to poor sanitation or wet and improperly conditioned compost. Spores can be carried in the air and secondary infections can occur if hygiene is not adequate. Cinnamon brown mould has been observed growing on undistributed supplements added at spawning and develops well on damp wood.

Lipstick Mould (Sporendonema purpurascens)

Lipstick mould causes significant yield losses when there are heavy infestations in the compost prior to casing. Minimal yield losses occur when lipstick moulds appear during the third break of Agaricus mushroom production.

Lipstick mould can colonize in the compost and in the casing layer during production. It grows slowly and normally remains confined to the infected areas; however it can eventually grow into uninfected areas in the casing soil. Initially, the mould growth on straw or casing resembles frost on a windshield or small white cotton balls (which are not easily distinguished from developing *Agaricus* mushroom pins.) As the lipstick mould spores mature, a distinctive pink, cherry, red, and eventually orange or buff lipstick colour appears and the mould's vegetative mycelium turns brown with age. Lipstick mould in casing soil made of peat moss and limestone may remain white without development of the red colour.

Lipstick mould has been associated with wet poultry manure; wet, dense compost at filling time; excessive use of steam during Phase II and where virus infections have occurred. The spores

of lipstick mould may survive when the compost is not completely pasteurized which may be caused by phase I compost that is overly wet or when there are clumps of wet chicken manure in the compost. These same conditions also create excessive nitrogen at spawning time and may be related to increased lipstick mould infections.

Heavy infestations usually reflect a build-up of spores around a mushroom production area. Infections may continue for several crop cycles. Poor sanitation and inadequate post-crop steaming are potential causes for an increase in spore loads. Spores from contaminated casing or spent compost are spread by air currents, during watering the crop or by harvesters. Control is achieved through a complete post-crop steaming and adequate pasteurization during Phase II.

Indicator Moulds

Indicator moulds are fungi that grow in compost that is not selective for *Agaricus* mushroom production. Thus, the compost contains a food source for the indicator mould that *Agaricus* mushroom cannot use. Once this food source has been depleted, the indicator mould will stop growing and usually disappear. As the compost was not selective for *Agaricus* spawn growth, fewer nutrients available and the cop yield is usually reduced.

Black Whisker Mould (Doratomyces stemonitis)

Black whisker mould is rarely found in production facilities; however it can be a serious competitor of *Agaricus* mushroom. It first appears in spawned compost as erect, gray-black, whisker-like structures (bristles) about 2mm long on the surface of straw or casing material. The distinctive black whisker appearance develops as the spores mature. Heavily infested compost will appear darker than usual (gray to black in colour) due to the high amount of spores. When disturbed, the spores are released and thus resemble smoke.

Black whisker mould grows rapidly through the compost at the end of Phase II and at the beginning of the spawn run. The presence of this mould usually indicates that the straw has not been completely decomposed. The mould's development is favoured when the C:N ratio is too high. Excess carbohydrates may result from low Phase I temperatures, inadequate nitrogen supplementation or inadequate C:N proportions of compost formulas. The mould can also occur if the compost is over heated during the spawn run. Growth of *Asperigillus*, *Penicillium* and *Chaetomium* moulds species are also favoured by these conditions and may be present in the compost at the same time. Human allergic reactions to the spores of these moulds have been reported. Proper preparation of compost prevents the development of black whisker mould.

Brown Mould (Oedocephalum glomerulosum)

Brown mould does not inhibit the growth of *Agaricus* mushroom; however crop yield can be reduced as conditions that favour brown mould are not optimal for *Agaricus* production. Brown mould most often develops late in the spawn run but can occasionally appear during cool down before spawning. Its' growth varies from weak growth over the compost surface to a dense coating on the compost straw. It grows slowly through the casing and appears as pearly-white mycelium growing loosely over the casing surface near the time of pinning. As the brown mould spores form and mature, the mould's colour changes to silver gray and then within a few days to dark tan or light brown. The spores are visible through a hand lens and can be identified as an erect spore-bearing structure with globular cluster of large spores at the top. The spores feel gritty, when rubbed between two fingers which can distinguish *Oedocephalum* brown moulds from other white-brown moulds which have a smooth or flour-like feel to the spores.

Brown mould is commonly found in most mushroom composts. This fungus remains dormant unless induced to germinate and grow. The environmental and nutritional conditions that favours its' growth is not fully understood; however, its' growth usually indicates that ammonia and amines were not completely eliminated during Phase II and are serving as a food source. Growing conditions described for plaster moulds are also associated with the growth of brown mould.

Green Mould (Trichoderma viride)

Refer to green mould section under mushroom diseases in this guide for further information.

Ink Caps (Coprinus fimetarius, Coprinus radiatus, Coprinus spp.)

Ink caps may begin to grow as early as the end of Phase II but more often first appear during the spawn run, after casing, or just before the first break. The presence of a few ink cap fungi has no direct effect on mushroom yield. However, large numbers of ink caps indicate that the compost is not selective to growing *Agaricus* mushroom and thereby production can be significantly reduced. Once the ink caps form they disintegrate quickly into black ink liquid that can drip onto and discolour the *Agaricus* crop making it unmarketable.

Several species of *Coprinus* Ink caps can occur with the mushroom crop. The larger ink cap, *Coprinus fimetarius*, is characterized by a thick hollow stem and a greyish scaly cap and is associated with severe substrate preparation problems, either during Phase I or Phase II. The smaller species, *Coprinus radiatus*, has a shorter thinner stem and a very fragile pale brown to yellow brown cap and is associated with a breakdown in supplements added at spawning time or a minor composting problem that resulted in ammonia-type compounds being released by the supplement. Other *Coprinus* species have been isolated from mushroom compost and unnamed species have been reported.

Ink caps produce a white fine mycelium in or on the compost before or after spawning. Some ink caps develop a long fibrous rhizomorph (root-like structures) that extends into the compost. Round white pin initials the sizes of peppercorns (1/16-inch diameter) begin to develop on the compost as early as 3 to 4 days after spawning. Pins develop into ink caps with narrow white stems and scaly white to gray cone-shaped caps.

Ink caps fruiting bodies may reappear in flushes. More often ink caps appear only once during the growing process. Once ammonia compounds in the compost are gone, the compost pH decreases and there is a gradual disappearance of ink caps. Mushroom spawn then will gradually colonize the previously infested compost.

If a strong ink cap spore load is established, secondary infections may enter and cause problems in a cropping system that otherwise produced a good crop of *Agaricus* mushroom. Epidemic infestations are often associated with: difficult or poorly managed Phase II compost including: too much breakdown of raw materials, too high moisture content and excessive amounts of inorganic nitrogen.

Ink caps problems may develop as a result of Phase I materials, formulation and its preparation and Phase II handling of the material and its management. During Phase II ammonia type compounds left in the substrate provide food for ink cap development. Ensure the proper microbial and substrate interaction to make the compost selective for *Agaricus* mushroom. If the C:N ratio is incorrect an imbalance will occur which may create suitable conditions for ink cap.

Overly wet compost may make the compost difficult to condition, due to the reduced aeration within the substrate. Dry compost at filling, excessively high temperatures or high ventilation throughout Phase II will result in moisture being the limiting factor for microbial growth. Therefore, the microbes will die before they are able to completely condition or convert ammonia into microbial protein.

Improper temperature management during Phase II pasteurization and conditioning may create conditions for ink caps growth. For example, composts that reheat (recycles) as little as a few degrees near the end of Phase II. Low air temperature, cooler than 38°C, maintained to manage the internal compost temperature can create an ammonia-laden layer (~ 1 cm in depth) at the compost surface. In such instances, ink caps can flourish on the ammonia remaining in this surface layer.

Excessive use of steam, or steam used to maintain air temperatures during Phase II. When too much fresh air is brought into the room, condensation on the surface of the compost may occur. Excessive condensation will interfere with air and gas exchange from the compost into the air during Phase II.

Residual ammonia during phase II may be caused by: improper filling of Phase I Compost.

Fill compost uniformly, not packed too tight or too loose. Filling equipment and methods must be monitored to assure uniform compaction. The density across the mass of compost affects the compost's aeration and heating which in turn affects the biological conversion of the raw materials.

To control ink caps, adequate control of phase I and phase II composting is required. Locating the origin of ink caps can aid in deciding why the compost supports ink cap growth. The larger ink cap, Coprinus fimetarius, is associated with severe substrate preparation problems, either during Phase I or Phase II. The smaller species, Coprinus radiatus, is associated with a breakdown in supplements added at spawning time or a minor composting problem that resulted in ammonia-type compounds being released by the supplement. Variations in the frequency of ink caps from year-to-year may be a result of an abundance of ink caps in the straw or hay used in compost production.

Where ink caps are a prolific problem optimum sanitation techniques are required for control. Remove developing ink caps. Filter Phase II and spawn run air to reduce re-inoculating the crop with the ink cap spores. Apply extra post harvest cook-out. A normal steaming-off procedure is accomplished by maintaining a compost temperature of 60 ºC to70 ºC for 8 to 24 hours. Remove spent compost from the farm to reduce the chances of recontamination.

Clean and disinfect floor, walls, and ceiling, growing net, air handlers, ductwork, picking platforms, ladders, hoses and tools. Remove and replace old brooms and other materials that may contain spores. Apply wood treatments between crops. No chemical fungicides are available for controlling ink caps. ***(For a listing of registered sanitizers and wood treatments refer to the Chemical Control Recommendations section in this guide.)***

Olive Green Mould (Chaetomium olivaceum)

Agaricus mushroom yield can be reduced proportionally to the amount of olive green mould infection. Delayed *Agaricus* spawn growth occurs when olive green mould occupies area in the compost during early spawn run. The *Agaricus* spawn growth is delayed but can usually grow through the infected areas. Widespread infestation of olive green mould can significantly reduce *Agaricus* spawn growth and crop yields. Once olive green mould has formed in the compost it persists throughout a crop. Different mushroom strains react distinctively to olive green mould.

The mycelium of olive green mould is not easily noticed, however early signs of the fungus may be visible after 10 days, if plastic is not used on the compost surface after spawning, as a fine greyish-white mycelium or fine fluffy-white aerial growth on the compost surface. Within 14 days of spawning, this mould's fruiting structures (perithecia) develop on straws in isolated spots and appear as very small gray-green cockleburs or peppercorns about 1⁄16 inch in diameter. The fluffy white-greyish growth or green furry burs are easily seen on compost colonized by mushroom spawn. The characteristic green furry burs distinguish olive green mould from the blue-green spore masses of *Penicillium* mould or the forest-green colour of *Trichoderma* moulds. This mould has a distinctive mouldy or musty odour. Compost infested with olive green mould often do not support mushroom spawn growth; therefore, it is common to see olive green mould growing in black compost that is not colonized by mushroom spawn.

Lack of oxygen, during the phase II promotes the growth of olive green mould. Anaerobic conditions allow for compost temperatures to reach higher than 61ºC and compounds can then form in the compost that are toxic to *Agaricus* spawn but favour olive green mould growth. Compost having good structure that is resilient when compressed or is not overly decomposed during Phase I allow for better aeration during Phase II. At filling time, excessive compaction or overly wet compost should be avoided.

Adequate air exchange throughout the entire Phase II process is necessary to prevent compost from becoming anaerobic. Even a few hours of too little air can be enough to create conditions where the compost becomes anaerobic and olive green mould may grow. Maintain proper air temperature and air volume by use of steam valves, fresh air dampers, and exhaust or intake fans to ensure the availability of enough air to the compost during Phase II. Maintain an air temperature differential

between the compost and the air (where the compost temperature remains higher than the air temperature during Phase II) to allow for good gas exchange and better aeration.

The spores of olive green mould are commonly found in straw, soil and spent compost. They are carried in air currents and on clothing and other materials. They are heat tolerant and can survive 60°C for 6 hours.

Plaster Moulds

Agaricus mushroom spawn can grow in conditions that support widespread growth of plaster moulds however maximum crop yield will not be achieved. Plaster moulds are indicators that nitrogen-type compounds have not been fully converted into microbial protein during the compost preparation. The nitrogen sources formed during Phase I remain after Phase II and become a source of food for the plaster moulds. Plaster moulds most often appear when the pH of the composts is 8.5 or above. Compost that is overly composting or overly wet during Phase I composting and/or improperly conditioned during Phase II composting create conditions suitable for plaster mould growth. Changes in composting practices (during phase I and phase II) to improve compost quality will reduce their occurrences.

Several other fungal species have been associated with white and brown plaster mould conditions including *Botryotrichum piluliferum*, *Papulaspora byssina*, *Scopulariopis brevicaulis*, *Scopulariopsis fimicola* and *Trichothecium roseum*. Please refer to other references to obtain details on these fungal species.

White Plaster Mould (Scopulariopis fimicola)

This mould is the most common plaster mould found in mushroom compost. It may appear on the compost surface near the end of phase II as irregular patches of white filamentous aerial growth. After spawning the aerial growth disappears and the white mould becomes appressed to the compost surface leaving a mould that resembles flour or plaster of Paris. The mould then may grow up through the casing. Other moulds that resemble white plaster mould include: *Botryotrichum piluliferum* and *Trichothecium roseum* however there are colour differences when these fungi mature. White plaster mould remains white, *B. piluliferum* has a tan-buff appearance and *T. roseum* develops a rose-pink tint.

Brown Plaster Mould (Papulaspora byssina)

This mould appears during the spawn run period. It appears as 15 to 40 cm patches of dense plaster-like white mould. At maturity the center will turn to brown or orange-brown colour. The fungus grows through the casing and develops the characteristic brown centre with a white fringe. It grows well with compost pH of 8 or more.

Mushroom Workers' Lung

A number of weed moulds that occur in *Agaricus* mushroom production produce clouds of spores that may produce allergic reactions in workers. This condition is known as mushroom workers' lung. Some moulds that have been implicated in this condition are *Asperigillus fumigatus, A. flavus, Mucor, Pussillus, Penicillum* spp. *Spicaria* sp. and *Stysanus stemonitis*.

Symptoms of mushroom workers' lung are asthma type respiratory congestion, headache and vomiting. Workers affected with the above symptoms should seek medical attention. Workers should be required to wear dust masks when working in houses heavily infested with moulds.

Abiotic Disorders

Abiotic disorders differ from normal pests such as insects, viruses, bacteria and fungi as they are caused by non-living organisms and cannot be transmitted. *Agaricus* mushroom affected by an abiotic disorder differ in appearance when compared to healthy mushrooms. Some abiotic disorders are easy to identify but others are difficult or even impossible. They are generally caused by external factors such as excess spawn growth, shallow casing material, watering practices or environmental conditions such as diesel and paint fumes. Most damage caused by abiotic disorders is not reversible once it has occurred. Keeping good production records can aid in identify an abiotic. These records may reveal that there has been a lack or excess of an element that supports or interferes with the normal *Agaricus* mushroom growth and a correction to the growing practice can be made.

Insects

Mushroom Flies

Flies are the most destructive insect to *Agaricus* mushroom production. High fly populations are often associated with high disease pressure and are usually an indicator of poor insect management either inside or outside the production area.

The sciarid flies (i.e. *Lycoriella mali*) are responsible for fly damage to *Agaricus* mushroom crops in British Columbia, The sciarid fly larvae (immature flies) reduce marketable yields of *Agaricus* mushrooms by feeding on mycelium and by burrowing into pins, stems and caps of the maturing mushrooms. The adult flies do not cause direct damage but reduce the crop's shelf life, yield and quality by vectoring (transporting) nematodes, mites, i.e. pyemotid (pigmy) mite, and diseases such as dry bubble, green mould and cobweb.

The phorid fly (i.e. *Megaselia halterata*) may be responsible for a small amount of fly damage to *Agaricus* mushroom crops in British Columbia, however these flies are not commonly seen in B.C. Phorid flies, if present, could be more numerous than sciarid flies but cause less damage. The greatest threat of this insect is with vectoring disease. The larvae of this species may reduce crop volume by feeding on the outside of the stem and gills of *Agaricus* mushroom but they do not tunnel into mushroom. Phorid flies also carry bacteria that induces blotch in *Agaricus* mushroom.

The cecid fly (identified as *Mycophilla speyeri* and *Heteropeza pygmaea* in the United States) have not been reported to cause damage to the *Agaricus* mushroom crop in British Columbia. However, cecid fly species do exist in B.C. Cecid flies are a serious pest in mushroom production in other parts of the world and are considered to be the most potentially damaging fly to the mushroom crops in the United States. The presences of the cecid larvae can make the product undesirable and unmarketable.

Identification

Sciarid and phorid flies have four developmental stages during their life cycle: the egg, larva, pupa and adult fly.

Sciarid Flies

The sciarid fly is commonly known as the dark-winged fungus gnat or the large mushroom fly. The adult sciarid fly is about 5 mm long. Female flies are larger and more numerous than the male flies. The sciarid fly's wings, antennae and legs are all long. The wings have a distinctive forked and cross venation pattern and fold over the insect's back when at rest. The sciarid larva has a white translucent body and a distinctive black head capsule and is about 7mm long when fully mature. The pupa is about 2 to 2.5 mm in length, initially having white capsule eventually turning brown as the pupa ages. Eggs are whitish and oval. The adult fly, larva and pupa can be seen without a lens but magnification is required to see the eggs.

Phorid Flies

The phorid fly is commonly known as the humpback or small mushroom fly. The adult phorid fly is small, about 2 to 3 mm long and has a distinctive humpbacked appearance. The wings lack the forked and crossed venation as found in the sciarid fly and the wings rest at an angle on the insect's back when at rest. Adult phorid flies move with quick jerky movements which can help distinguish it from the sciarid flies which move less erratically. Newly emerged larvae are nearly transparent and taper towards the head end. The larva turns grayish white as they mature, is about 4 mm long and do not have the black head capsule as sciarid larva do. Phorid eggs are whitish but oblong and concave. Dung flies are often misidentified as phorid flies. However, their presence also suggests poor fly management.

Cecid Flies

Cecid flies are commonly known as the gull midge. The cecid adult flies are very small, 1 to 1.5 mm long, and for this reason are seldom if ever seen. Cecids reproduce without going through a complete life cycle (i.e. egg, larva, pupa and adult). A mature larva may give birth to 12 to 20 daughter larva in about 7 days without becoming an adult and mating. Thus, the population of larvae can explode within a very short time period. The larvae of the cecid are about 2 mm long, either white or orange, are legless and bluntly pointed at both ends. The head and the tail are not easily distinguished, except by the direction of travel.

Life Cycle and Environmental Conditions

Sciarid flies

In British Columbia, the sciarid flies are commonly found in *Agaricus* mushroom production and outdoors in composting debris and on wild mushrooms. They are present throughout the year but are most numerous during the months of May through November. In the winter months the fly populations are at the lowest; however, flies that over-winter inside mushroom production facilities can be a problem.

The *Agaricus* mushroom is the preferred host for sciarid flies to breed. The flies migrate toward mushroom farms and can move between farms several kilometers apart. Flies move into mushroom buildings through small cracks that can be smaller than the fly itself, through open doors and from one production room to another through corridors and lofts. The adults flies are attracted to the fermentation odours produced during phase II compost cool-down and first invade mushroom crops as the air temperature drops below 43°C. Peak invasions are known to happen within 4 days of the spawn application. On average, a mated female can lay 150-170 eggs on unspawned compost.

Depending on the *Agaricus* mushroom crop length and temperatures used during production, there can be one or more complete generations of sciarid flies before the compost is removed. The average length of a complete sciarid fly generation can range from 35 to 38 days at 18°C and 25 to 28 days at 21°C.

Female sciarid flies lay their eggs, singly or in groups of up to15 eggs at the first available site almost immediately after entering a production room. If the growing room is tightly sealed, most sciarid flies will enter through open doors and will lay their eggs within the first few sections (1.2 to 2.4 m) of growing beds. The preferred areas for laying eggs are in compacted compost along the side, bottom and end boards which represents only about 5% of the exposed compost in the bed. If the aggressive green mould is present, the flies will prefer laying their eggs in the decomposing area rather than the compost. If the rooms are not sealed tightly, the eggs can be laid anywhere in the production room. Egg laying patterns are likely to be different from room to room on the same farm which reflects the tightness of the room. The incubation time required for sciarid eggs to hatch ranges from about 4-6 days; approximately 4 days at 24°C and 6 days at 18°C.

Sciarid flies have four larval stages that occur over 10-22 days; approximately 10 days at 24°C, 12 days at 21°C, 18 days at 16°C and 22 days at 13°C. As the larvae hatch they move away from the hatching site. They prefer darkened areas which may be why they are seldom seen on the casing surface. The larvae continuously feed using their large mouth parts consuming compost, *Agaricus* mushroom spawn, mycelium and developing mushrooms. They may consume the total contents of developing mushroom pin. Larvae prefer to feed in moist areas and move away from dry areas.

After the larva stop feeding they enter a pupal stage for about 6 days at 18°C. The time required for the pupa stage to be completed is less dependent on temperature and may only vary by a few days at temperatures between 13-24°C. The pupae then emerge as the adult fly.

After emergence, adult flies fly around and mate within an hour and most females can lay eggs within 4 hours. The adult male sciarid fly live about 5-9 days; approximately 5 days at 24°C, 7 days at 18°C and 9 days 13°C. The female fly can live longer, about 10 days at 18°C. Adult flies feed on water and other liquids.

Adult sciarid flies, both male and female prefer darkened areas compared to an illuminated area. Adult sciarid flies are not often seen due to their flight patterns in which the largest numbers of flies are in the air from approximately 6 PM to 9 PM. Male sciarid flies are not attracted to light and are normally found on the casing surfaces searching for females to mate with. Female sciarid flies are attracted to light and may be observed on windows, vents, around picking lights.

Phorid Flies

Phorid flies are most abundant during the late summer or early fall. During this time, swarms of phorid flies may be found outside a mushroom farm. Once mated, the females are attracted to odours of actively growing *Agaricus* mushroom mycelium (spawned compost). The

greatest numbers of phorid flies enter mushroom production rooms 4 to 5 days after spawning.

Phorid flies lay their eggs near *Agaricus* mycelial tips beneath the surface of the compost or in the casing. The average generation time, from egg to adult, is about 45 days at 16°C and 24 days at 24°C. The eggs hatch in 2-3 days. The developmental time required for the larva, pupa and adult fly stages to be completed is reduced by about half when the temperature increases from 16 to 24°C. The larva stage is about 14 days at 16°C and 7.5 days at 24°C, the pupa stage is about 20 days at 16°C and 10 days at 24°C and the adult fly stage is about 8 days at 16°C and 4 days at 24°C.

Adult phorid flies are commonly observed during the daylight hours due to their daytime flight pattern that occurs approximately between 6 AM to 6 PM. For this reason they may be more noticeable than sciarid flies. They may be seen swarming around windows, production doors and packing sheds and large amounts of dead flies may be found beneath windows and outside production room doors. Both female and males phorid flies are attracted to light.

Fly Management and Control

Non-chemical means of fly prevention provide the most effective and reliable means of fly control. Sanitation and fly exclusion i.e. use of physical barriers is the first line of defense against fly invasions. For a fly control program to be most effective, it is important to detect fly invasion early, determine the breakdown in sanitation and physical barriers and implement immediate action to correct these problems.

Physical Barriers

Initially, prevent flies from getting into the building by using physical barriers.

Tightly seal up production rooms by caulking cracks in the walls and around air conditioners and pipes which are usual routes for fly invasion. Do not overlook the obvious entry points. During the previous crop, new cracks may have formed as the building expanded or contracted as a result of temperature changes during production. When the growing room is empty inspect the room for cracks by turning off the lights inside the room and look for light penetration from outside.

Limit the access doorways into the mushroom facility. Only one or two doors should be used as entrances. All other doors should be kept closed and tightly sealed. The entrances doorways should be sealed around the edges with weather stripping or filter material. These sealed edges may be sprayed with oil or adhesive for additional barrier action against invading pests.

Use fine mesh netting (screens) to cover doors, fan intakes, vents, windows etc. There are different types of netting material that can be used. A 100 mesh or finer nylon screen is adequate to keep flies out of a room. Netting can be tested by placing a known number of flies into a container (i.e. glass jar) and tightly securing the opening of the container with the netting material and then determine if the flies are able to escape. The netting material used should be inspected prior to use and on a regular basis to ensure that there are no rips or obvious holes that flies can pass through.

Netting must be installed so that flies can not crawl under or around it. The edges must be sealed tightly. Loose or bunched edges of netting provide entranceways for flies. Fasten the netting over fan intakes, vents, windows with batten strips held tightly with short nails or staples. Seal the edges of doors by folding over the netting and staple the edges directly to the doorjamb. Replaceable boards attached to the doorjambs with extend the life of the jambs. Another method is to use Velcro. These sealed edges may be sprayed with an adhesive i.e. Tangle Trap for additional barrier action against invading flies and will prevent the flies from escaping and finding other cracks. Regardless of the method used a good seal is most important. Netting on the intake side of the fan can reduce the volume of air movement in the room and an adjustment of air volume may be necessary.

Control movement of people. Minimize movement into production rooms or tunnels during the peak fly invasion period occurring during phase II cooldown through spawn run. During spawning keep doors closed as much as possible. Make small openings next to the door for hydraulic hoses and tightly seal the hole after use. During the casing operation minimize the size of the open areas and the time the room is open. During production and towards the end of the crop the objective is to try to keep the flies in the room rather than out of the room. Prevent flies from escaping the production rooms by

keeping the doors closed as much as possible and by using a fine mesh netting to cover open doors as mentioned above.

Cover compost with plastic immediately after spawning to keep out flies and disease and maintain higher moisture level for better production.

Shorten Production Cycles

Shortening the production cycles will reduce the number of fly generations and thus overall fly population. A shorter cool-down period provides less time for sciarid fly invasion. A shorter spawn-run and casing periods reduces the number of days that fly larvae are kept at 24°C slowing their development. The use of casing inoculum shortens the time from casing to first pick. Limit production to three breaks or less. If necessary, terminate the crop early to reduce the spread of insect and disease problems.

Hygiene and Sanitation

Good hygiene and sanitation practices are important for both fly and disease control.

Control movement.

- Insects can be carried on equipment, tools and people. Equipment used in older rooms, i.e. hoses, spraying equipment, harvesting equipment should not be used in clean rooms. If necessary, clean and sanitize equipment thoroughly before using in clean area. Do not leave spawn or spawn equipment in areas where mushrooms are stored or in corridors where movement of insects are greatest. Keep spawning equipment separate from equipment used during other cropping periods.
- Segregate spawn workers from those who do other tasks on the farm. Limit movement between growing, casing and spawn-run rooms.
- Clean filters regularly.
- Promptly remove crop debris.
- Keep outside production areas clean. Remove trash, spent mushroom compost and prevent accumulation of water and debris and long grass from growing around the premises.

(Refer to the Farm hygiene and Sanitation section in this guile for detailed information.)

Crop Termination

Steam off the *Agaricus* mushroom crop when the harvest is completed and before emptying the production room by raising the compost temperature to at least 65°C for a minimum of 12 hours. Compost temperatures in excess of 54°C for a few hours will kill flies at all stages. The additional time and temperature is required for disease control. The use of insecticides for adult flies, i.e. premise or fogging applications, has a value when used at the end of the crop and before post-crop steam-off. This prevents fly movement out of the room when the air temperature is increased.

Monitoring for Flies

Monitor your fly population using light traps. It is best to check the traps every 24 hours at approximately the same time every day. Record the fly counts for your reference. The counts will tell you which fly species is present, when fly invasion first occurred and if fly populations are increasing or decreasing. It can also tell you if certain rooms are chronically prone to higher fly populations. Monitoring for flies can help a grower evaluate the effectiveness of the fly control program. If the same procedures and monitoring system is used, management strategies can be compared from room to room, grower to grower and year to year.

Fly light traps may be purchased from an agricultural supply company. Otherwise a simple low cost trap can be made by using a clip board with an attached sticky surface to capture flies (e.g. yellow sticky sheets or the use of an adhesive such as tangle trap sprayed onto strips of wax paper) and light source to be used as an attractant. Sciarid flies respond equally to blacklight and normal fluorescent light. If phorids are known to be present in the area, then a blacklight blue bulb is necessary.

If Phase II is completed in shelves, a fly trap should be placed inside the growing room during cooldown when the temperature drops to 40°C. The fly trap should remain in operation through the spawn run and preferably through the entire cropping period, or at least until harvest begins. If Phase II or spawn run compost "in bulk" is used, a fly light trap should be maintained in the working areas.

Additional fly traps can be placed outside the barn and in corridors which can provide information on the background fly populations and the effectiveness of the outdoor fly control. Changes in background populations may be caused by outside temperature, wind speed and direction. Be careful with the placement of traps outside production rooms so that the traps are not attracting flies into the vicinity of growing rooms.

Chemical and Biological Control

Economic Thresholds

The economic threshold is reached when the number of flies in a growing room justifies the expense of using an insecticide. Economic thresholds may be determined by monitoring fly counts and fly crop damage and considering other economic and environmental factors (e.g. what happens when there are multiple pests and disease present). These thresholds can change from one season to the next, from one grower to another and in different production systems. Insecticides need to be applied before the economic threshold is reached (the action threshold) in order to prevent the pest population from reaching economically damaging levels. By determining and using economic and action thresholds that are appropriate for your farm, unnecessary and expensive pesticide applications can be avoided and the ones used will also give better results. In general, the presence of the first fly on the monitor signals when to apply the first chemical application during pre-spawning and spawn-run period.

Timing of Application

Understanding the lifecycle of the insect is important for good control. This includes knowing when the eggs are laid, when the larvae emerge from the eggs and when the pupae occur. Temperature can greatly influence the rate of development of each insect stage. As temperature increases, each developmental stage require less time. ***(Refer to the "Life Cycle and Environmental Conditions" in the above section for further information.)***

The larvae and adult fly are the most vulnerable insect stages. For maximum effectiveness insecticides to control larvae must be applied when the larvae are most abundant and susceptible. Premise sprays outside the growing rooms are most effective when flies are resting or swarming on surfaces.

Types of Products

There are various types of products available for control of mushroom flies however the number of products is very limited. The most important factor when using any product is to adhere to the product label which includes: rates of application, personal protection to be worn and other precautions, days from last treatment to harvest, re-entry restrictions after treatment and storage of product. Overuse (too many applications of a chemical product) and using lower than recommended rates can cause resistance to the pesticide in fly populations. To prevent resistance from happening on your farm do not use the same chemical repeatedly or rely on them alone for your insect control. Only apply insecticides when fly trap counts are high enough to indicate potential crop damage. Insecticides should not be relied upon and should only be used as part of an overall fly management program which includes exclusion and sanitation.

(Refer to the Insect Chemical Control Recommendations in this guide for a list of Canadian registered and available products and timing in which they may be used during the mushroom production cycle.)

Chemical Control for Fly Larva

Citation 75WP (cyromazine), Apex (methoprene) and Malathion are the only registered chemical control products available for larval control. Cyromazine is an insect growth regulator (IGR) that works by interfering with the normal molting process of larval. It is somewhat persistent; heat stable and compatible with beneficial insects. One application per crop cycle is registered for use in the compost operation, spawn operation or casing material. To avoid potential resistance to cyromazine in the fly population do not use this product on every crop and limited applications to summer and fall when fly populations are at the highest and fly counts indicate potential damage to the crop.

Apex (methoprene) is registered for use in Canada but due to lack of sales this product is being taken off the market. Methoprene is an insect growth hormone mimic. It affects the development of the insect larva's change to the pupal stage. Apex can be used at spawning or in the casing. It has a short residual activity and is not heat stable. Timing of application to older larvae (approx 10 to 12 days after adults are recorded) is critical to maximize effectiveness.

Malathion is a nerve poison and kills the larvae on contact. It can be applied as a spray mist on bed surface immediately after picking and repeated as required but not within two days of harvest. Although registered for this purpose, it is rarely used.

Non-Chemical and Biological Control for Fly Larva

Due to the availability and affordability of chemical controls in the past, biological controls have not been widely used. Current trends toward organic production and fewer available chemical controls may make these products of more interest. The advantage of biological controls over chemicals controls include that they: have a specific host range, leave no toxic residues or crop re-entry periods, have little or no risk for exposure to workers and are less likely to develop resistance.

Biological controls are living organisms and must be handled with care in order to be most effectively. This includes how they are transported, stored on the farm and applied. Read and follow label directions carefully when using these products. It is also necessary to consider the compatibility of biological controls with insecticide treatments as their effectiveness may be reduced by some insecticides. They should also be applied when the larval stage is most predominant. By monitoring fly populations a timely application can be made.

Steinernema feltiae is a beneficial nematode that has been proven to effectively control sciarid fly larvae in *Agaricus* mushroom production. These nematodes target older larvae and young pupae. Once the nematode is inside the fly larvae, they release deadly bacteria that rapidly kills the fly host within 48 hours, the nematodes reproduce and are released after consuming the host. The nematodes are somewhat mobile and can seek out their host.

The recommended application rate for *Steinernema feltiae* is 1 million nematodes per m^2, with two applications, one application at casing and one application seven days later. Nematodes may be applied with a backpack sprayer or irrigation system. Screens on sprayers must be removed to allow nematodes to flow through. Agitation during application must be constant and gentle to keep the nematodes mixed into solution, but gentle enough not to damage them. Nematodes are active and mobile in water, and need a moist environment.

Other biological controls that could potentially be used to control sciarid fly larvae in *Agaricus* mushroom production include: *Hypoaspis mile*, a beneficial mite (however the effectiveness of this mite has not been proven) and *Bacillus thuringiensis var. israelensis (Bti)* a bacterium that is used widely in biocontrol (however registered in Canada the formulation for mushrooms is not currently available.) ***(Refer to Chapter 3.4 Choosing Control Methods – Biological Controls for more information on these biocontrol agents.)***

Diatomaceous earth is another potential product but again has not been proven to be effective. It is made up of geological deposits of fossilized skeletons of marine and fresh water organisms. When crushed, it breaks up into tiny pieces of glass-like particles which feel like talcum powder. This powder is easily picked up by insects which then scratches through the insect's protective wax layer (cuticle), the insect loses water rapidly, dries up and dies. Diatomaceous earth was used extensively in the US mushroom industry before insect growth regulator insecticides (e.g. cyromazine) became available.

Chemical Control for Adult Flies

All insecticides registered adult flies, kill flies almost immediately (immediate knock down) and are nerve poisons. Extreme caution needs to be used when applying these products as they are also moderately toxic to mammals including humans. Follow the label direction and ensure that well maintained personal protective equipment is used. Also ensure re-entry restrictions are adhered to in order to protect other employees on the farm.

Some insecticides for adult flies can only be used as surface residual sprays (i.e. spayed or painted on physical structures which do not come in contact

with the crop i.e. malathion). Other products may be applied to the air to control flying insects when the crop is present (i.e.. dichlorvos, permethrin and pyrethrins). Pyrethrin is one of the most popular insecticide used however it does not have a long residual activity (it break down rapidly) and has a history of developing resistance in fly populations. To prevent resistance from happening on your farm do not use the same chemical repeatedly.

Application with foggers or fine misting machines is an effective means of application and may be used for some chemical products to cover larger areas. This application method has minimal employee exposure risk, as long as staff do not re-enter the treated area after treatment and until the re-entry time interval is up.

Routine or Preventative Insecticide Applications

The number of adult sciarid fly daily counts can be used as the basis for when to apply routine or preventative insecticide applications in a growing room.

Red Pepper Mites

Common Name: ***Red pepper mites***

Scientific Name: ***Pygmephorus spp.***

Introduction

Mites are tiny 8-legged spider-like creatures that can be microscopic in size or seen without magnification. They are commonly found in straw and manure used in mushroom compost and therefore plentiful during phase I composting. Proper pasteurization of compost, good farm hygiene and shortened cropping periods reduce the presence of mites.

There are a number of mite species that have been associated with the *Agaricus* mushroom cultivation. These include: tyroglyphids, tarsonemids, pyemotids, and gamasids. Most mite species are beneficial to mushroom growing, however, some species can damage the mushroom crop directly by attacking the spawn and/or mushrooms or indirectly by vectoring (transporting) diseases. Mites may also contaminate harvested mushrooms making them unmarketable and be a nuisance to mushroom harvesters. The main concern to *Agaricus* mushroom production is the pyemotids or red pepper mites.

Identification

Red pepper mites, also known as the pigmy mite, belong to the family Pyemotidae. They are tiny, 0.25 mm in length and brown in colour. They tend to congregate in the tops of mushroom caps and can be seen by shining a light across the pre-harvested mushrooms. They quickly move when light is shined on them.

Life Cycle and Environmental Conditions

Mites have a sexual adult stage. Adult females can lay up to 160 eggs over a 5 day period. Eggs can hatch into adults in 24 hours. The life cycle is temperature dependant; at higher temperatures the generation time is decreased. The generation time is normally occurs over 4-5 days, at 10°C is about 7.6 days, at 20°C is about 4.8 days and at 25°C is about 3.9 days.

Red pepper mites do not feed on *Agaricus* mushrooms. They feed on various moulds, such as *Trichoderma*, *Monilia* and *Humicola* spp. These mites cause indirect damage to the *Agaricus* mushroom crop by vectoring (transporting) disease organisms from infected to clean areas (such as *Trichoderma* green mould and *Verticillium* dry bubble and thus their presence often contributes to losses in marketable yields. Red pepper mites can also be a nuisance to mushroom harvesters. The presence of red pepper mites indicates that *Trichoderma* green mould is emerging.

Mite Management and Control

Prevent conditions that promote weed mould growth. Proper preparation and pasteurization of compost will minimize weed moulds and reduce or eliminate red pepper mites by eliminating their food source. When an outbreak occurs, elimination of the moulds (i.e. *Trichoderma* spp.) is very important. ***(Refer to Green Mould sections in this guide for further information.)***

Red pepper mites are very small and can easily be transported from mushroom house to mushroom house by flies, air currents, dust, tools, equipment and on workers clothing. Any practices that

minimize these factors will contribute to mite control.

- Maintain a good sanitation and fly control program.
- Plan the activities on the farm to reduce cross-contamination. Prevent workers from moving from dirty to clean production areas and ensure workers wear clean clothing when starting work in clean areas.
- Proper sanitation of tools and equipment and eliminating dust can help reduce mites from spreading.
- During the interval between the old and new crop, pay attention to details in fly control, post crop steam-off and cleanup.
- Record the abundance and location of mites to determine the cause of infestation and control measures. Use the same methods used for monitoring green mould. The presence of mites is an indicator that *Trichoderma* (aggressive green mould disease) is developing. Mark off infected beds for treatment of aggressive green mould.
- Watch that workers adhere to hygiene guidelines and do not pick or handle mushrooms in affected areas.

(Refer to Green Mould, Mushroom Flies and Sanitation sections in this guide for further details.)

Chemical control: Approved chemical applications for adult fly control as surface residual sprays will help control mites ***(refer to Insect Chemical Control Recommendations Table 4.5 Adult Flies – Surface and Residual Sprays.***) If mites have been in other growing rooms, it would be appropriate to drench the casing at casing with the approved use of Senator 70WP. This will reduce the appearance of the casing *Trichoderma* (not the aggressive one) and thus this will then help reduce the mite population because the mites will have less 'food' to eat. Should mites appear on the casing, the approved use of malathion for controlling fly larva sprayed onto the bed surface immediately after picking and within 2 days of the next harvest, will also help reduce mites ***(refer to Table 4.4: Immature and Larval Stages of Flies - Application during Production.)*** Follow the chemical product label direction and ensure that well maintained personal equipment is used and re-entry restrictions are adhered to.

Nematodes

Introduction

Nematodes are very small primitive round-worms. They can be found world-wide in marine and freshwater water, soil, decaying organic matter, plants and animals. They are extremely abundant and there are about 12,000 species currently known to exist. Nematodes associated with *Agaricus* mushroom production can be grouped into two broad categories: harmful and beneficial.

The impact of harmful nematodes on *Agaricus* mushroom production is generally minimal; however, under heavy populations they can significantly reduce the mushroom crop. For this reason precautions should be taken against nematode proliferation. The two types of harmful nematodes include: parasitic and saprophytic nematodes.

Parasitic nematodes rarely now occur in *Agaricus* under modern mushroom farming techniques. They may be present in compost materials or soils used for casing materials. Under optimal conditions they can strip the entire *Agaricus* mycelium, reducing or eliminating the mushroom crop.

Saprophytic nematodes are commonly found in *Agaricus* mushroom production. They are not really a pest of *Agaricus* mushrooms but are indicators of problems associated with composting or casing preparation, cultural practices or sanitation. At low levels they have little impact, but as their population increases the *Agaricus* mycelium grows slower and weaker. The effects on mushrooms production can range from little damage to total elimination of the crop. They can also lower the quality and whiteness of harvested mushrooms.

Beneficial nematodes, on the other hand, naturally control insect populations. They occur naturally or may be applied to the *Agaricus* mushroom crop. *Steinernema feltiae* is a commercially produced beneficial nematode is proven to be effective as a biological control for sciarid flies. They do not feed in the compost or affect *Agaricus* mushroom production when used at the recommended rates. ***(Refer to Mushroom Fly – Non-Chemical and Biological Control for Fly Larvae section in this guide for further information.)***

Identification

Nematodes are tiny, microscopic, round-worms. They range in size from 0.2 to 6 mm in length. Identification of the types of nematodes by non-experts is very limited. Sometimes virus die-back disease symptoms are confused with nematode problems Compost or casing samples suspected to have nematode infestations can be tested in a laboratory. Samples are best taken from cool locations or areas where heating has been non-uniform in the past. Samples taken from the hottest portions of the materials usually give negative results as nematodes rarely survive these conditions. Nematode identification can be made at the Plant Diagnostic Lab, B.C. Ministry of Agriculture and Lands, Abbotsford Agriculture Centre, Tel: 604 556-3001.

Parasitic nematodes associated with *Agaricus* mushroom production are in the genera *Ditylenchus* spp. and *Aphelenchoides* spp. The distinguishing characteristic of the parasitic nematode is the mouth parts which are located at the anterior (front) end and appear as a blunt end with a needle-like stylet. Symptoms on infested compost appear soggy, sour smelling and sinks or are depressed. The *Agaricus* mushroom mycelium becomes stringy and weak resulting in bare areas on the bed that grow larger as the nematodes move outward into healthy compost.

Saprophytic nematodes that have been recovered from mushroom casing samples in Canada are in the genera *Acrobeloides* spp., *Rhabditis* spp., *Choriorhabditis* spp. and *Caenorhabditis* spp. The distinguishing characteristic of the saprophytic nematode is the mouth parts which lack the stylet and appear to have liplike bulbs stuck on the anterior (front) ends.

Typical symptoms of saprophytic nematodes are reduced mycelial growth into the casing, poor or spotty pinning or a drop in production or quality. Symptoms may be first noted on spawned compost prior to the casing application. The infected areas will either be colonized by the *Agaricus* mycelium but the mycelium will be fragmented and the compost will be wet or black, barren, watery, patches will appear that are not colonized or re-colonized by the *Agaricus* mycelium. When these dark, barren patches develop the production will be severely affected and the surrounding colonized compost will eventually degenerate. During this time, it may be possible to see the nematodes flicker on the compost straw when a bright light is shined on them.

Later symptoms of saprophytic nematodes occur after the casing material is applied. The casing may be slow to colonize or may be seen as well colonized, however, after scratching or ruffling the casing material the *Agaricus* mycelium will not re-knit well in the infected spots or over the whole bed. The mycelium will be fragmented and the casing will not hold together well. At this time, high infestations of this nematode can be seen on the casing surface as swarms that appear as moist cylindrical aggregates swaying to and fro when a bright light shined on the casing at a 45° angle.

Life Cycle and Environmental Conditions

The primary difference between parasitic and saprophytic nematodes is in their feeding habits. Parasitic nematodes have needlelike mouthpart that feeds directly on *Agaricus* mushroom mycelium by penetrating the cell wall and draining the contents. Saprophytic nematodes have a chewing mouth and do not attack the *Agaricus* mycelium but consume other food sources such as organic nutrients, microorganisms and especially bacteria that exist in compost and casing.

Optimal conditions for development of nematodes include wet and moderate temperature of about 20-25°C. Nematodes are only able to move on their own in a film of water. Under optimal conditions parasitic nematodes can multiply 30 to 100-fold in 2 weeks and saprophytic nematodes can multiply 10 to 100 fold in one week. Populations can grow incredible fast in compost substrates that are non-selective for *Agaricus* mushroom production. High populations of saprophytic nematodes are associated with wet compost or a slimy layer between the casing and compost. Nematodes have also been observed in areas infested with ink caps which suggest that there is a compacted, tight, or wet substrate which was unable to properly heat during Phase II pasteurization.

Nematodes are associated with raw materials entering the compost yard. Compost materials provide a rich habitat of food, water, oxygen ideal

for nematode development. Nematodes in phase I compost can exist in excessive numbers and survive until compost reaches lethal temperatures. If there are conditions such as inside clumps of compost materials, excessively wet compost or cooler parts of the compost (i.e. if cooler outer portions of the compost are not heated properly by turning into the interior) the nematodes may survive Phase I composting and be carried forward to Phase II composting.

Most nematodes found in phase II composting are destroyed during pasteurization temperatures of about 60°C. Species of saprophytic nematodes found in Canada do not form a resting stage so they can be eradicated by proper Phase II composting and sanitation practices. If the surface of the compost becomes dry, nematodes can form a heat-resistant dormant state that helps them survive the pasteurization temperature. The surviving nematodes can survive in wet or dry areas and in clumps. These nematodes then carry on to spawning period where there are more favourable environmental conditions for nematode development including: temperatures of about 24°C, moist conditions and near neutral Ph of 7.5. Watering compost at spawning tends to favour increased population of nematodes. Nematodes multiply faster in younger spawn-run than in the mature spawn-run. The mixing process at spawning can distribute nematodes throughout a bed and thereafter the spawning machine if not cleaned and sanitized properly can contaminate subsequent growing beds.

There is a significant relationship between the wetness of phase II compost, saprophytic nematodes, bacteria and mushroom mycelium. Wet compost conditions stimulated bacteria to grow faster than *Agaricus* mycelium and the bacterial provide ideal conditions (food) for saprophytic nematodes. High numbers of bacteria inhibit mycelium growth, the compost deteriorates, becomes wet and eventual anaerobic. In less wet conditions the mycelium spread, use water for its own growth and dry out compost to a point that limits bacteria development. Greater crop damage occurs when both the bacteria and nematodes are present in high numbers than when only bacteria are present. Additional crop injury may results from toxins which the nematodes make possible thorough bacterial colonization of the compost.

Casing material can also be a source of nematodes, however the multiplication of nematodes in un-spawned compost is great than in casing soil. Casing should be pasteurized at 60°C unless the grower is confident that each shipment is free of nematodes. Pre-packed peat is generally not a problem as it is dry, has a low pH and usually does not contain nematodes. However, if the peat bags are broken open and become wet nematodes may contaminate the peat and multiply. Once the peat is placed as a casing layer and it is moistened there is less interference of the *Agaricus* mycelium which is a favourable environment for nematodes to move into. Casing machines can provide nematodes with an efficient means of distribution from infected to non-infected areas and the machines should be routinely cleaned and sanitized to avoid this.

Ruffling the casing tends to stimulate nematode multiplication. Watering practices should be carried out to ensure that the casing material is moistened but not made to wet. Good watering practices can reduce or eliminate nematode problem; however, failure to manage moisture conditions will allow nematodes to move further in the growing process. Poor harvesting techniques, i.e. when mushroom stipes and remains are left on the bed, promote further development of nematodes.

Subsequent crops may be contaminated by previously infested growing rooms if post-cropping temperatures are not brought to sufficient temperatures to penetrate woodwork, ceiling insulation and in cracks and crevices. Moisture dripping from infested ceilings will contaminate new beds with nematodes.

When there are high numbers of nematodes and the nematode's food supplies in compost, become limited, the nematodes go into a collective swarming behaviour that brings them to the compost or casing surface. This behaviour provides them with greater chance of dispersal. The nematodes can then be vectored (transported) by workers, irrigation, flies and mites.

Nematodes, if dried slowly, will enter a heat-resistant dormant state. In this state they can persist for years until they contact enough moisture to break the dormancy. Dried dormant nematodes may be distributed by even slight air movements. Dust can carry dormant nematodes between rooms.

Nematodes can also survive without food for months and are not susceptible to cold or freezing temperatures. Once the temperature becomes more moderate they regain their vigour.

Nematodes may survive in spent compost which if stored on or near the farms may be a source of contamination.

Nematode Control and Management

The total prevention of invasion or total eradication or nematodes during infestations is unlikely as nematodes may be found almost everywhere. A grower's IPM plan should take into account the condition in which nematodes survive and their dispersal mechanisms.

Phase I Composting

Ensure uniform heating and maintain good phase I temperatures. Mix raw materials adequately and ensure that cool shoulders or the rick are moved to the interior positions to avoid cool spots. This is the first opportunity for nematode control.

Phase II Pasteurization

Avoid over-drying the compost surface prior to pasteurization. In order to subject nematodes to killing temperatures the compost needs to be pasteurized at 60°C for at least 2 hours. The heating system should be checked and compost temperatures monitored to verify that uniform peak heats are reached in all areas of the compost. The compost may require moisture adjustment to avoid becoming overly dry but care should be taken not to make the compost too wet (soggy) or bacterial development will be encouraged. Poorly prepared and pasteurized compost is not well suited for the development of mushroom mycelium, but is favourable for the nutrition and reproduction of nematodes.

Spawning

Any compost areas suspected of harbouring significant nematode populations should be processed last. Spawning mixing equipment should be cleaned and sanitized between batches to reduce risk of spreading nematodes to new production areas.

Casing

Materials should be pasteurized at 60°C unless the grower is confident that each shipment is free of nematodes. If using pre-packed peat this may not be necessary. Pre-packed should be handled with care to ensure the material remains clean and dry while being stored.

Unloaded casing material in a well sheltered location away from sources of contamination. Mix casing material under a covered roof and on a concrete slab or in a container. Store and mix casing material in a well cleaned and disinfected area. Prepared casing material should be covered with a clean sheet of plastic until it is required. Thoroughly clean and disinfect all casing equipment used. Do not allow outside traffic to cross over into the casing area

Cropping

During cropping, the grower can do little to control an infestation other that to prevent further spread. Mark off infected areas and only allow work in these areas to be done last. Prevent transporting nematodes to non-infected areas by using clean tools and equipment. Sanitize all tools after use in production and picking. Workers should wear clean clothing and wash hands or use fresh gloves between work areas or sections of beds that are suspect. Enforce rules restricting personnel movement between compost areas and growing rooms.

Cultural Practices

Maintain good cultural practices .Check beds do not become compacted or settle before spawn and casing processes. Maintain optimal moisture content of compost and casing material. Over watering promotes conditions for nematode development. When watering, ensure applications are done evenly, do not allow puddles to develop. Monitor watering personnel and train them in correct application techniques.

Sanitation

Maintain good sanitation practices throughout the growing process. Clean up any spilled compost at filling before it can be carried into non-infested areas. Ensure cleanup between crops is thorough. Pay special attention to cleaning wood surfaces and the ceiling. Focus on complete removal of

soil debris from wooden boards. Use low pressure washing to prevent contaminated material being blown back up to the ceiling and wall surfaces. Use sanitizers in rooms and on equipment. This is especially important on floors since they act as a heat sink during pasteurization and rarely achieve temperatures that are sufficient to kill nematodes. To achieve lethal temperature for controlling nematodes, cook-out old growing rooms by raising the compost temperature to 71°C.

Control dispersal mechanisms of nematodes from infected to clean areas maintain good fly, mite and dust control. Mites and flies are excellent vectors for carrying nematodes into the growing rooms and then moving them about the room.

Monitor

Monitor of nematodes by checking slow growing areas or dead wet areas in the production and determining if this condition is caused by nematode development. Mark off affected areas and take samples for analysis. Nematode identification can be made at the Plant Diagnostic Lab, B.C. Ministry of Agriculture and Lands, Abbotsford Agriculture Centre, Tel: 604 556-3001.

Chemical Controls

There are no chemical controls registered for use for nematodes. The best treatment is to remove conditions that promote development of bacteria that benefit nematode survival.

Brown or off white mushrooms have been considered more susceptible to nematode infestations.

References

2007/2008 Berry Production Guide. British Columbia Ministry of Agriculture and Lands.

2006/2007 BC Vegetable Production Guide. British Columbia Ministry of Agriculture and Lands.

An Integrated Pest Management System against Mushroom Sciarids.

http://www2.warwick.ac.uk/fac/sci/whri/research/mushroompests/ipmsciarids.pdf

Beyer, D. M. Cobewb/Mildew disease Fact sheet. The Pennsylvania State University.

http://mushgrowinfo.cas.psu.edu/cobweb_mildew_fact_sheet.htm

Beyer,D.M., P. J. Wuest, J.J. Kremser. Verticillium Dry Bubble Fact Sheet. The Pennsylvania State University.

http://mushgrowinfo.cas.psu.edu/Verticillium%20Dry%20Bubble.htm

Coles, P.S., W. Barber, D. M. Beyer, S. J. Fleischer, C. Keil, D. L. Rinker, C. P. Romaine, S. P. Whitney, P. Wuest. 2002. Pennsylvania Mushroom Integrated Pest Management Handbook. The Pennsylvania State University.

http://pubs.cas.psu.edu/PubDept.asp?varDept=14

EPPO Standards Guidelines on Good Plant Protection Practices Mushrooms. 2000. European and Mediterranean Plant Protection Organization.

http://archives.eppo.org/EPPOStandards/PP2_GPP/pp2-20-e.doc

Fletcher, J. T. Cobweb Disease, A New Challenge. Mushroom News, Vol. 50, No.4 April 2002. 20-23 pp.

Grogan, H., R. Gaze, J. L Burden and J. Fletcher (eds). 2006. Assured Produce (UK) Fact Sheet Control Document# 00035/06.

http://www.assuredproduce.co.uk/resources/000/163/355/Mushrooms_00035_06.pdf

Howard, R.J., A. Garland, W.L. Seaman (eds). 1994. Disease and Pests of Vegetable Crops in Canada. The Canadian Phytopathological Society. 363-381 pp.

Hermans, C. 2003 Thrichoderma. AdVisie 'the mushroom cultivation advisors'

http://www.mushroombusiness.com/data_2008/content/tips/detail/3/thrichoderma

Keil, Rinker, and Royse. 2004. Green Mold Harbored by Wood: Post-crop Steaming and Preservatives. Science and Cultivation of Edible and Medicinal Fungi. Penn State Publications: (4). 449-456 pp.

Keil, C. The Use of Pesticides for Control of Adult Mushroom Flies. Mushroom News, Volume 50, No. 4, April 2002. 11-19 pp.

Mushroom Production 3. Hygiene Procedures. Department of Primary Industries and Fisheries. Queensland Government, Australia.

http://www2.dpi.qld.gov.au/horticulture/5195.html

Nematodes.

www.ppath.cas.psu.edu/MushGrowInfo/nematodes.htm

Rinker, D.L. (ed). 2003. Ontario Mushroom Pesticide Recommendations – Publication 367. Ontario Ministry of Agriculture and Food.

Rinker, D. L. and P.J. West. 1993. Pest of Commercial Mushroom Production: Bacterial Diseases. Mushroom World, December 1993, 52-53 pp.

Rinker, D. L. and P.J. West. 1994. Pest of Commercial Mushroom Production: Fungal Diseases. Mushroom World, March 1994, 25-34 pp.

Rinker, D. L. and P.J. West. 1994. Pest of Commercial Mushroom Production: Indicator Moulds. Mushroom World, June 1994, 11-16 pp.

Rinker, D. L. and P.J. West. 1994. Pest of Commercial Mushroom Production: Insects. Mushroom World, December, 1994, 39-43 pp.

Rinker, D. L. and P.J. West. 1995 Pest of Commercial Mushroom Production: Mites and Nematodes. Mushroom World, March 1995, 45-51 pp.

Rinker, D. L. and P.J. West. 1994. Pest of Commercial Mushroom Production: Virus Disease. Mushroom World, September 1994, 26-27 pp.

Rinker, D.L. Nov 17, 2005. Principles of Controlling Green Mould Disease (Power-point presentation): University of Guelph, Vineland Station, Ontario.

Rinker, D.L. Weed Mould Management in Commercial Mushroom Production: An Integrated Approach. University of Guelph, Vineland Station, Ontario.

Sciarid Life Cycle. 2008. Agri-Food and Biosciences Institute

http://www.afbini.gov.uk/index/research/contracted/eccraft-introduction/eccraft-project-objectives/eccraft-insect-life-cycle/eccraft-objectives-lc-sciarid.htm

Staunton, L., R.M. Dunne, T. Cormican and M.Donovan. 1999. Chemical and Biological Control of Mushroom Pests and Disease. Teagasc, Kinsealy Research Centre.

http://www.bak.teagasc.ie/research/reports/horticulture/4095/eopr-4095.asp

Van Griensven, L.J.L.D. (ed). 1988. The Cultivation of Mushrooms. Darling Mushroom Laboratories Ltd. Rustingron, Sussex, England.

Wuest, P.J. and G.D. Bengston (eds). 1982. Penn State Handbook for Commercial Mushroom Growers. The Pennsylvania State University.

Chemical Control Recommendations

The information contained herein is offered only as a guide to the handling of specific product, and has been prepared in good faith by technically knowledgeable personnel. This information is not intended to be all-inclusive, and the manner and conditions of use may involve other and additional considerations. Please refer to the current product label for the full and most current requirements for use.

General Precaution

Do not eat, drink or smoke while mixing or during application. Remove contaminated clothing immediately after application. Change and wash clothing after use. Wash contaminated clothing in detergent and hot water before reuse. Store and wash all protective clothing separately from household laundry. Wash hands and face thoroughly with soap and water after handling products and before eating, drinking or smoking or using the toilet.

Products and Timing

The following tables include information on products available and registered as Sanitizers, Wood Treatments, Disease and Insects Chemical Control. These tables are sorted by phases and time intervals normally used in the cultivation of *Agaricus* mushrooms. Including:

Compost Preparation

This is the first phase of compost preparation that may take place in windrows or bunkers. Pesticides may be mixed into the growth medium prior to transfer to the second phase for pasteurization and conditioning.

Cool-down and Pre-Spawning

After the compost is pasteurized and conditioned in phase II compost preparation, it is cooled to a temperature that is not harmful to *Agaricus* mycelium when it is introduced. Pesticides products can be used on structural surfaces or in the air during this period of temperature decline and before mushroom spawn is added.

Spawning

The mushroom growing medium is inoculated with the *Agaricus* mushroom mycelium (the spawn) that is grown on a cereal grain. Pesticides may be added during the spawning operation.

Spawn-run and Pre-casing

The spawn-run is the time period when the mushroom mycelium grows through the compost. About two weeks later the substrate is covered with a casing layer which is made of peat moss or peat soil mix. Pesticide products can be applied to surfaces or to the air before covering with the casing material.

Production

Once the crop is in the harvesting stage, products may be applied to structural surfaces, the growing medium or air.

Between Crops

About three weeks after harvesting, the spent medium is discarded and replaced with fresh growing medium. This interval between old and new crops is very important in managing insects and disease.

Table 1: Sanitation of Non-porous and Non-food Contact Surfaces

Prior to use of any sanitizer, remove soil deposits using a squeegee. Avoid creating dust and dispersal of spores. Clean the area with water and apply the solution thoroughly wetting the surface. Refer to Farm Sanitation section in this guide for further information.

Chemical	Product	Rate	
didecyl dimethyl ammonium chloride (quaternary ammonium)	Verticide **PCP# 25276**	**Foot dip:** : 4 mL in L of water **Bactericidal:** 4mL in L of water **Fungicidal:** 4mL in L of water **For greater detergency:** 8 -16 mL per L of water.	**Comments:** A concentrated, multi-purpose germicidal and detergent effective in hard waters. Disinfects and cleans. Recommended for use in mushroom farm sanitation. For use on hard non-porous surfaces such as floors, walls, metal and plastic. Applied by thoroughly wetting surfaces with a mop, sponge, cloth, by spraying or soaking. Allow treated surfaces to remain wet for 10 minutes and air dry. Do not apply to mushroom crop, compost or casing. Foot dip - use according to recommended facility procedures. Bactericidal - effective against *Pseudomonas sp.*. Fungicidal - effective against *Verticillium fungicola, Mycogene perniciosa, Trichoderma viride*, *Dactyllum dendroides* **Precautions:** Protect eyes by wearing goggles or face shield. Protect skin by wearing rubber gloves. Wash thoroughly with soap and water after handling. Remove contaminated clothing, wash before reuse.
formaldehyde	Formalin Fungicide Solution **PCP# 6998**	**Mushroom House:** 2-4 L per 100 L of water **Mushroom Equipment:** 100 mL in 10 L of water **Composting Yards and Concrete Slabs:** 4 L in 100 L water apply to 10 m^2	**Comments:** Broad spectrum, non-corrosive used for controlling fungi. Do not let the formalin solution contact mushrooms. US export restriction - zero residue tolerance. **Uses:** **Mushroom house cleanout.** Treat empty houses only. Heat house to at least 18° C and wash down with formalin solution. Maintain temperature. Keep the house closed for 24 hours. **Mushroom Equipment:** (baskets, tools, boots, hoses, etc.): Apply as spray or dip. Rinse with potable water if equipment or tools are to be used immediately. **Composting Yards and Concrete Slabs**: Apply as a drench. **Precautions:** Avoid exposure to fumes and contact with skin, eyes, and clothes. Protect eyes by wearing chemical splash goggles; if splashing is likely wear a full face shield. Protect skin by wearing rubber gloves, apron and boots. To prevent inhaling of the gas fumes wear a suitable NIOSH/MSHA approved respirator with organic vapour cartridge or self-contained breathing apparatus. Leave the room as soon as possible after treatment. Use with adequate ventilation
sodium and calcium hypochlorite	Bleach or other trade names	1000 ppm (ratio of product to water depends on concentration of product)	**Comments:** General disinfectant, not tolerant to organic matter, corrosive, inexpensive; effective at pH 7.0 or slightly lower. Rinse with potable water if equipment or tools if to be used immediately. **Precautions:** Avoid direct contact with the product. Do not get in eyes, on skin or clothing. Do not breathe fumes. Wear goggles and rubber gloves when handling.
Do Not mix formaldehyde and sodium or calcium hypochlorite (chlorine). The mixture can form a potent carcinogen.			

Table 2: Between Crops – Wood Treatment

Chemical	Product	Rate	
Copper 8-quinolinolate	PQ –57 **PCP# 15314**	2 L in 10 L water (2 parts PQ-57 to 10 parts water)	**Comment:** For the control of decay and mould. May be applied to all wood surfaces. Applied by brush or spray application starting at lowest shelves. Use a low pressure sprayer to reduce foaming. Allow to dry before filling with compost. Caution: PQ-57 is corrosive. **Precautions:** Avoid direct contact with the product. Do not get in eyes, on skin or clothing. Do not breathe fumes. Wear goggles and rubber gloves when handling.
Propiconazole	SAFETRAY™ P **PCP# 24813** Plant Products SAFETRAY™ P **PCP# 24813.01**	6 ml per L water (to ensure complete wetting apply about 95 L of spray solution per 465 m^2 or 5,000 sq. ft.)	**Comments:** For the control of adhesion and penetration of mushroom mycelium in timber trays. Apply spray solution with a large droplet sprayer on the internal surfaces, ends and bottom boards. Make sure all corners are well treated. Let dry before adding compost. Dry in well ventilated place. The wood needs to dry before compost is added. **Precautions:** Avoid contact with skin or eyes. Avoid breathing spray mist. Wear coveralls or long pants and long sleeved shirt, respiratory protection and gloves when mixing and loading. For manual application, wear impermeable suit, gloves and respiratory protection during application. On tray farms, application should be through mechanical systems. Do not re-enter treated area until residues have dried. Wear gloves if treated trays are handled prior to drying. Wash thoroughly with soap and water after handling and before eating and smoking. Ventilate prior to re-entry.

Table 3.1: Time of Application – Spawning
Aggressive Green Mould (Trichoderma aggressivum f. aggressivum)

Chemical	Product	Rate	
thiophanate methyl	Senator 70WP Emergency Use registration until October 31, 2009. **PCP# 25343**	Mix 1.25 g Senator 70WP with 50-62 g gypsum, limestone, or chalk per 1Kg of spawn	**Comments:** One application of Senator 70WP may be applied as a coating to the spawn OR as a drench to the casing (see Table 3-2), not both. Spawn coating is used for controlling Aggressive green mould (*Trichoderma aggressivum* f. *aggressivum*). Spawn application is limited to mechanical means of applying spawn to beds. Hand spreading of treated spawn in any manner is not allowed. The maximum amount of treated spawn that any one worker can handle in one day is limited to 800 kg treated spawn (1 kg of Senator 70WP). To be used with meticulous sanitation and hygiene programs. Use only full label rate. To avoid resistance use only when required. **Precautions:** Every effort must be made to reduce exposure to workers. Avoid breathing dust. Avoid contact with eyes, skin or clothing. Wash thoroughly with soap and water after handling. Wash contaminated clothes before re-use. Applicators MUST wear chemical-resistant coveralls over long sleeved shirt and long pants, chemical resistant gloves, rubber boots, goggles or face shield and a NIOSH/MSHA approved N, R, P or HE respirator during mixing, loading and application of treated spawn. Exposure Mitigation Measures: Cover cement mixer with a plastic bag or other type of cover and secure with cord during mixing in order to minimize dust exposure. After coating the spawn grain, spawn should be mechanically transferred to minimize dust exposure.

Table 3.2: Time of Application – Casing and Pre-Production up to Pinning

Dry Bubble (Verticillium fungicola), Wet Bubble (Mycogone permiciosa), Cob Web (Cladobotryum dendroides) and Non- Aggressive Green Moulds (Trichoderma species, T. viride, T. koningii)

Chemical	Product	Rate	
formaldehyde	Formalin **PCP# 6998**	20-25 L Formalin in 100 L of water apply 3.6-4.2 L of solution per m^3	**Comments:** Sprinkle the solution over the casing soil while mixing. Mix thoroughly and keep the soil covered for at least 24 hours after treatment. Air and soil temperature must be at least 18° C. All odour of Formalin must be gone before treated soil is applied to the beds. **Precautions:** Always keep containers tightly closed. Wear chemical splash goggles to prevent eye contact. If splashing is likely, full face shield should be worn. Wear protective rubber gloves, apron and boots to prevent skin contact. Use with adequate ventilation. This product has a zero residue tolerance in the USA.
chlorothalonil	Bravo 500 **PCP# 15723**	1st application at casing: 254 mL in 100 -130 L of water applied to 100 m^2 2nd application at pinning: 128 mL in 100 -130 L of water applied to 100 m^2	**Comments:** For controlling dry bubble. No more than two applications may be applied. The 1st application immediately after casing or in the casing mix and the 2nd application at pinning. Do not apply within 7 days of harvest. **Precautions:** Wear a full face respirator during all activities. Wear coveralls over long pants, and a long-sleeved shirt, goggles or a face shield, apron, and chemical resistant gloves during mixing, loading, clean-up and repair activities. Wear pants, a long sleeved shirt and chemical resistant gloves during application. Do not re-enter treated areas within 48 hours. If required, individuals may re-enter treated areas within 48 hours for short-term tasks not involving hand labour only if at least 4 hours has passed since application, and long pants, long-sleeved shirt, hat and chemical-resistant gloves are worn.
thiophanate methyl	Senator 70WP **PCP# 25343** Emergency Use registration until October 31, 2009.	61 g in about 75 L water apply to 100 m^2 of casing surface	**Comments:** One application may be applied as a coating to the spawn or as a drench to the casing, not both. Apply Senator 70WP as a drench to the casing for control of the non-aggressive *Trichoderma* species. Apply to casing shortly after incorporating casing material. Do not apply within17 days of harvest. Research has demonstrated that Senator 70WP manages casing green moulds and was quite effective for the first 18 days after fungicide application but its effectiveness began to decrease as the crop aged. Bravo 500, permitted as a drench to the casing, was ineffective in managing the non-aggressive Trichoderma. **Precautions:** Every effort must be made to reduce exposure to workers. Avoid breathing dust. Avoid contact with eyes, skin or clothing. Wash thoroughly with soap and water after handling. Wash contaminated clothes before re-use. Applicators MUST wear chemical-resistant coveralls over long sleeved shirt and long pants, chemical resistant gloves, rubber boots, goggles or face shield and a NIOSH/MSHA approved N, R, P or HE respirator during mixing, loading and application.

Most products listed below are readily available to mushroom growers in BC. Other products may not be held in stock and may need to be special ordered. Check with your chemical supplier regarding availability.

Table 4.1: Immature or Larval Stage of Flies - Application during Compost Preparation

Chemical	Product	Rate	
cyromazine	Citation 75 WP PCP# 24465	5 ppm active ingredient (wet weight) See full label for specific rates.	**Comments:** Insect growth regulator to reduce the emergence of adult sciarid flies. Use no more than 1 application per cycle. May be applied during compost preparation, spawn operation or to casing material. Apply during compost preparation using a coarse drenching spray with low pressure to minimize the formation of mists. Apply in enough water for uniform distribution. The volume of product will vary depending on weight and moisture of the compost being turned. See label for specific rates **Precautions:** Avoid contact with eyes or prolonged contact with skin or clothing. Avoid inhalation of dust. Causes moderate eye irritation. When mixing, loading or applying the product wear water-tolerant coveralls (TYVEC) over long-sleeve shirt and long pants, boots and rubber gloves.

Table 4.2: Immature or Larval Stage of Flies - Application during Spawn Run and Pre-Casing

Chemical	Product	Rate	
cyromazine	Citation 75 WP **PCP# 24465**	5 ppm active ingredient (wet weight) See full label for specific rates.	**Comments:** Insect growth regulator to reduce the emergence of adult sciarid flies. Use no more than 1 application per cycle. Apply to compost at spawning using a coarse drenching spray with low pressure to minimize the formation of mists. Apply in enough water for uniform distribution. The volume of product will vary depending on weight and moisture of the compost being spawned. See label for specific rates. **Precautions:** Avoid contact with eyes or prolonged contact with skin or clothing. Avoid inhalation of dust. Causes moderate eye irritation. When mixing, loading or applying the product wear water-tolerant coveralls (TYVEC) over long-sleeve shirt and long pants, boots and rubber gloves.

Table 4.3: Immature or Larva Stages of Flies - Application during Casing and Pre-Production

Chemical	Product	Rate	
cyromazine	Citation **PCP# 24465**	5 ppm active ingredient in wet casing or 18.7 g in enough casing material to cover 100 m^2 (5-8 cm deep)	**Comments:** Insect growth regulator to reduce the emergence of adult sciarid flies. Use no more than 1 application per cycle. Apply as a single low volume drench to the casing material. See label for specific rates. Do not apply within 14 days of harvest. **Precautions:** Avoid contact with eyes or prolonged contact with skin or clothing. Avoid inhalation of dust. Causes moderate eye irritation. When mixing, loading or applying the product wear water-tolerant coveralls (TYVEC) over long-sleeve shirt and long pants, boots and rubber gloves.
Steinernema feltiae	Nematodes		Applied at casing. Apply in the irrigation water. Effectiveness of nematodes will vary with species and biotype. Check with your supplier with recommended rates, species and use patterns.

Table 4.4: Immature or Larval Stages of Flies - Application during Production

Chemical	Product	Rate	
malathion	Malathion 50 Insecticide **PCP# 13883**	2.5 - 3.5 L in 1000 L water apply 100 L solution per 1000 m^2 bed surface	**Comments:** For controlling mites and Phorid and Sciarid flies. Apply spray mist to bed surface immediately after picking. May be repeated twice a week or as required. Do not apply within 2 days of harvest. **Precautions**: Avoid contact with skin and eyes. Wash exposed skin with soap and water after spraying. Remove contaminated clothing and clean before re-use. Use a proper respirator when spraying in an enclosed area.
	Wilson Malathion 50 EC **PCP# 16099**	25 - 40 mL in 11 L water apply to 100 m^2 bed surface	
	Cheminova Fyfanon 50% EC **PCP# 4590**	25 - 40 mL in 11 L apply to 100 m^2 bed surface	
	Malathion 85E **PCP# 8372**	12-20 mL in 11 L water apply to 100 m^2 bed surface	
	Malathion 500E **PCP# 4709**	25-40 ml in 11 L water apply to 100 m^2 bed surface	

Table 4.5: Adult Flies - Surface Residual Sprays
Applications during Cool Down and Pre-Spawning, Spawn Run and Pre-Casing, Casing and Pre-production and Production

Chemical	Product	Rate in water	
malathion	Malathion 50 Insecticide **PCP# 13883**	2-3 L in 1000 L water	**Comments:** For controlling sciarid and phorids flies. Apply as a spray or by paint brush. Treat all wooden surfaces to the point of run-off. Do not spray on compost. **Precautions:** Avoid contact with skin and eyes. Wash exposed skin with soap and water after spraying. Avoid inhalation of spray mist. Use a proper respirator when spraying in an enclosed area. **Precautions:** Avoid contact with skin and eyes. Wash exposed skin with soap and water after spraying. Avoid inhalation of spray mist. Use a proper respirator when spraying in an enclosed area.
	Cheminova Fyfanon 50% EC Insecticide **PCP# 4590**	25-40 mL in 11 L water	
	Malathion 85E **PCP#. 8372**	12-20 ml in 11 L water	
	Malathion 500E **PCP# 4709**	25-40 ml in 11 L water	

Table 4.6: Adult Flies - Fogging or Aerosol Treatment - Application during Cool Down and Pre-Spawning

Chemical	Product	Rate	
permethrin	Ambush® 500EC **PCP# 14882**	50 to 65 mL per L water for 1,000 m^3	**Comments:** For controlling phorids and sciarid flies. Applied as fogging or aerosol treatment. May be use prior to filling, during cool down, during spawning, up to pinning and between breaks. Do not use when air temperature is less than 12^o C or greater than 30^o C. Depending on fly populations and crop stage, treat once daily or as needed. Do not make more than 20 applications prior to pinning of first break. Do not apply more than 2 applications between each break with maximum of 10 applications during cropping. Do not apply within one day of picking. Monitor adult fly populations to reduce the number of applications. Exposure time should be limited to one hour. Ventilate the mushroom house after exposure. Use fans to ventilate in houses that do not have forced air circulation. **Precautions:** Avoid splashing concentrate in eyes or on hands. When applying this product in enclosed areas use an adequate respirator. Close all doors, windows and ventilators prior to application. Lock or barricade all entrances, turn off pilot lights, post warning signs and take precautions to prevent persons from entering the area. Re-entry to treated areas is allowed as soon as the spray deposit has dried.
	Pounce® 384 EC Insecticide **PCP# 16688**	65 to 85 ml per L of water per 1000 m^3	

Table 4.7: Adult Flies - Fogging or Aerosol Treatment - Application during Spawn Run and Pre-Casing, Casing and Pre-production

Chemical	Product	Rate	
dichlorvos	Wilson DDVP-5 Fogging Insecticide **PCP# 10150**	20 ml per 100 m^3	**Comments:** For controlling phorids and sciarid flies. May be used twice weekly during spawn run to prevent fly build-up. Then used as required. Do not use within 24 hours of harvest. Treat at house temperature of about 21^{0}C. Close windows, doors and ventilators. Apply as a dry fog using mechanical fogging equipment. Direct fog downward and away from compost while walking backwards through the building. Keep fogger nozzle at least 3 metres away from beds. Expose for one hour then ventilate area with fans before resuming work. **Precautions:** Avoid contact with skin, eyes and clothing. Do not breathe dust or spray mist. Wear protective clothing, natural rubber gloves and suitable mask or respirator when handling concentrate. Wear full face respirator while applying sprays.
	Wilson DDVP-10 Fogging Insecticide **PCP# 10585**	10 ml per 100 m3	
	Gardex Vapona Fogging Solution **PCP# 11819**	200 ml Per 1000 m^3	
permethrin	Ambush® 500EC **PCP# 14882**	50 to 65 mL per L water for 1,000 m^3	**Comments:** For controlling phorids and sciarid flies. Applied as fogging or aerosol treatment. May be use prior to filling, during cool down, during spawning, up to pinning and between breaks. Do not use when air temperature is less than 12^o C or greater than 30^o C. Depending on fly populations and crop stage, treat once daily or as needed. Do not make more than 20 applications prior to pinning of first break. Do not apply more than 2 applications between each break with maximum of 10 applications during cropping. Do not apply within one day of picking. Monitor adult fly populations to reduce the number of applications. Exposure time should be limited to one hour. Ventilate the mushroom house after exposure. Use fans to ventilate in houses that do not have forced air circulation. **Precautions:** Avoid splashing concentrate in eyes or on hands. When applying this product in enclosed areas use an adequate respirator. Close all doors, windows and ventilators prior to application. Lock or barricade all entrances, turn off pilot lights, post warning signs and take precautions to prevent persons from entering the area. Re-entry to treated areas is allowed as soon as the spray deposit has dried.
	Pounce® 384 EC Insecticide **PCP# 16688**	65 to 85 ml per L of water per 1000 m^3	
pyrethrins	P-100™ Mushroom House Insecticide **PCP# 10923**	50 mL to 100 m^3	**Comments:** Applied undiluted using a thermal fogger or mechanical (electric) fog generator, which will produce small dry particles. Large, wet droplets may cause brown spotting and deformity of mushroom caps. Follow the fogger manufacturer's instructions to achieve the desired "dry" fog. During fog application, keep the fogger nozzle at least 3 m away from the mushroom beds. May be used twice weekly during spawn run to prevent fly build up, then use as required to maintain control. Do not apply within 1 day of harvest. DDVP (Dichlorvos) insecticides are recommended as an alternative. **Precautions:** Avoid contact with skin and avoid inhalation of fog or spray. Prior to fogging shut off all possible sources of ignition. Close doors, windows and ventilators and turn off watering systems. Post warning signs and take precautions to prevent humans from entering the area to be treated. Close the treated area for at least one hour and ventilate thoroughly for one hour before re-entering.

Pesticide Regulations and Safety

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This information on safe pesticide use is summarized from the "B.C. Pesticide Applicator Course for Agricultural Producers". The course is available from (Office Products Centre at 1-800-282-7955).

Legislation

Laws protect applicators, bystanders, consumers and the environment. You can be fined for breaking the laws.

Canadian Laws

Pest Control Products Act and Regulations

Every pesticide used or sold in B.C. must be registered by Health Canada. Each label must have a PCP Act number on it. Using pesticides without a PCP Act number against the law.

Each label must also list the crops and pests the pesticide can be used on - eg. mushroom and sciarid fly. Using pesticides for uses not on the label is against the law. However, there are a few minor pesticide uses that may be approved but not be on the label.

Pesticides are labeled as Domestic, Commercial or Restricted. Restricted products are more hazardous and have special restrictions on the label.

The Food and Drugs Act

All foods must be free of harmful amounts of substances. Health Canada sets levels of allowable pesticide residues on crops at harvest. These levels are called maximum residue limits or MRLs. The Canadian Food Inspection Agency (CFIA) takes random samples of crops to test for pesticide residues at the time of sale. If residues are more than the MRL the crop may be seized. If you follow the recommendations on the labels and wait the required days before harvest, you should not be over the limit.

The Fisheries Act and Migratory Birds Regulations

You can be charged if you kill or harm fish or migratory birds with pesticides. This applies to creeks, rivers, and lakes on your own property as well as on public land. It is illegal to introduce pesticides into waters either directly or indirectly through spray drift or run-off.

Transportation of Dangerous Goods Act

Certain dangerous goods cannot be transported unless you use shipping documents, special labels, and vehicle signs. Ask the pesticide dealer if the product that is bought needs special transport procedures. Growers are usually exempt from this when they are transporting less than 500 kg of pesticide.

British Columbia Laws

Integrated Pest Management Act and Regulations

B.C. Ministry of Environment also has rules about the sale and use of pesticides in B.C.

Rules that apply to farmers include:

1. Pesticides labeled "Restricted" or "Commercial" must be kept in locked storage that is vented to the outside and has a warning sign on the door.
2. Anyone buying or using pesticides labeled "Restricted" must have an applicator certificate.
3. WorkSafeBC regulationsrequire that a grower spray record is kept and that re-entry requirement ae listed. See spray record sheets in this guide.
4. An authorization such as a pesticide use licence, pest management plan or permit is required to apply pesticides to public land. Contact the regional Ministry of Environment office for details.
5. Businesses selling pesticides must be licenced and their sales people must be certified.
6. Anyone applying pesticides in exchange for a fee must have an applicator certificate and a Pesticide Use Licence. But, if you spray your neighbour's crops you do not need a licence if the work is done as a favor and no money is exchanged.
7. Everyone must dispose of containers and left-over pesticides safely.

WorkSafeBC (formerly: Workers' Compensation Board)

WorkerSafeBC Regulations for Occupational Health and Safety apply to farmers who must be registered by WorkSafeBC. If you are unsure whether they apply to you, call WorkSafeBC at 1-888-621-7233. FARSHA (Farm and Ranch Safety and Health Association) at 1-877-533-1789 can also provide information on WorkSafeBC regulations.

The WorkSafeBC regulations cover conditions of workplaces such as general safety procedures, hazardous substances, pesticides, confined spaces such as silos and storage bins, protective clothing and equipment, tools, machinery and equipment, and animal handling.

The regulations on pesticides outline requirements for pesticide applicator certification, emergency medical care, washing facilities, personal protective clothing and equipment, application equipment, pesticide application, posting warning signs, re-entry into treated areas, and record-keeping. Copies of the regulations are available from any WorkSafeBC office.

Their pesticide regulations state that workers must be over 16 years old and must have a valid pesticide applicator certificate from the BC Ministry of Environment if they mix, load or apply moderately toxic or very toxic pesticides; or if they clean or maintain application equipment for these pesticides. It also identifies which pesticides can only be used by certified applicators. Anyone under the age of 25 years is considered a young employee and must complete a "new or young employee" orientation. FARSHA (1-877-533.1789) can help develop or present a program for your farm.

[Refer to the regulations for the rest of WorkSafeBC's requirements.]

[The Farm and Ranch Saftey and Health Association (FARSHA) can provide information on WorkSafeBC regulations.]

Toxicity

Some pesticides are more poisonous or toxic than others. The ratings are: very toxic, moderately toxic and slightly toxic. They indicate short term toxicity and are based on the LD_{50} of the active ingredient. The LD_{50}s which correspond to the categories are:

Toxicity	Oral LD_{50} (mg/kg)	Dermal LD_{50} (mg/kg)
Very toxic	0 to 50	0 to 200
Moderately toxic	51 to 500	201 to 1,000
Slightly toxic	over 500	over 1,000

The values are only a guide to the toxicity to humans.

Pesticide warning shapes and symbols

Pesticide warning symbols and shape on chemical labels show the hazards of the product. The symbols on the labels are:

most poisonous → *less poisonous*

DANGER POISON

- very poisonous
- (oral LD_{50} less than 500)
- always wear a respirator
- always wear eye protection

WARNING POISON

- moderately poisonous
- (oral LD_{50} 500 to 1000)
- wear a respirator in confined spaces
- always wear eye protection

CAUTION POISON

- slightly poisonous
- (oral LD_{50} over 1000)
- wear a respirator in confined spaces
- could be an eye irritant, eye protection advisable

most flammable → *less flammable*

DANGER EXTREMELY FLAMMABLE

WARNING FLAMMABLE

CAUTION FLAMMABLE

most corrosive → *less corrosive*

DANGER EXTREMELY CORROSIVE

WARNING CORROSIVE

CAUTION CORROSIVE

Hazard Shapes and Symbols

Shapes and symbols on pesticide labels tell how harmful a pesticide can be. The shapes indicate how hazardous the product is. The symbols inside the shapes show the type of hazard. If symbols are not on labels, the pesticide has very low hazard.

Exposure

Pesticides can enter the body through the skin (dermally), the mouth (orally), the nose (inhalation), or the eyes. The skin is the most common route of poisoning for pesticide applicators. Skin contact may occur from a splash, spill or drift. The skin is most likely to get contaminated when mixing and loading pesticides.

Hazard

The hazard of using a pesticide depends on both its toxicity and the amount of exposure. Reduce hazards by choosing pesticides with low toxicity and by reducing exposure. Wear protective gear and follow safety guidelines.

Poisoning and First Aid

Symptoms of Pesticide Poisoning

Know the poisoning symptoms of the pesticides you use. Read pesticide labels for symptoms. Effects from pesticide poisoning vary from person to person and are often hard to recognize. Some poisoning symptoms are headache, tiredness, nausea, dizziness, irritation of the skin or nose or throat, blurred vision, tiny pupils, trembling, perspiration, difficulty breathing, vomiting, and unconsciousness. Call the Poison Control Centre or a doctor immediately if you suspect poisoning. Follow their instructions.

Poison Control Centres

Poison Control Centres are open 24 hours a day. They give first aid information and treatments for poisoning.

The phone number of Poison Control Centre is in the front of the phone book under Emergencies.

First Aid

Make sure you and other people working on the farm know what to do in case of an emergency. Consider taking a first aid course and CPR course.

If someone has been poisoned:

1. Protect yourself.
2. Move the victim from the area of contamination.
3. Check if the victim is breathing. If breathing has stopped or is very weak, clear the airway and begin artificial respiration. Continue until the victim is breathing normally or until medical help arrives. **When doing mouth-to-mouth resuscitation, use a plastic mask to protect yourself from poison.**
4. Call the Poison Control Centre (1-800-567-8911) or ambulance. Be ready to tell them the pesticide name, active ingredient and PCP Act registration number.
5. Unless the Poison Control Centre or doctor tells you otherwise, follow the procedures listed below, then;
6. Transport the patient to the nearest hospital.

If a pesticide contacts the eyes, put on waterproof gloves and hold the eyelids open and rinse with clean water for 15 minutes or more. Do not use an eye cup. Do not use chemicals or drugs in wash water.

If pesticide contacts the skin, put on waterproof gloves, remove the contaminated clothing, and wash the affected area of the skin with lots of soap and water. Cover burned area with a loosely applied, clean cloth. Do not apply any drugs or medications to the burned area. Do not use ointments, greases, creams, lotions or other drugs. If the victim is in shock, keep the person lying down and warm until medical help arrives.

If pesticide was breathed in, take the victim to fresh air as quickly as possible; loosen tight clothing and watch for signs of unconsciousness or convulsions. Keep the airway open and begin resuscitation if breathing has stopped or is difficult. Use a plastic face mask to protect yourself. To prevent chilling, wrap the patient in blankets but do not overheat. Keep patient as quiet as possible.

If a pesticide is swallowed:

- If a person is conscious and able to swallow, give them 1/2 to 1 glass of milk or water. Larger quantities may cause vomiting.
- Do not induce vomiting.
- Call the Poison Control Centre at 1-800-567-8911 for further advice.
- If the patient is retching or vomiting, place the patient face down with their head lower than their body in the recovery position. This prevents vomit from entering the lungs and causing more damage. Do not let the patient lie on their back. Clean the vomit from the patient and collect some in case the doctor needs it for chemical tests.
- When medical advice cannot be obtained, check and follow the pesticide label for directions.
- The doctor may recommend activated charcoal be administered to adsorb any remaining pesticide in the stomach. Follow the doctor's instructions. Activated charcoal should be administered only with the advice of a medical attendant or doctor.

Protective Clothing and Equipment

Wear protective clothing and equipment to minimize exposure to pesticides. **Remember to wear safety equipment during mixing and loading, application, and clean-up.** Always wear coveralls, waterproof boots, waterproof gloves, and a proper hat. You may also need to wear eye or face protection, respirator, waterproof apron, waterproof pants and jacket. The equipment you wear depends on the pesticide and type of application. Therefore, follow the safety recommendations on the pesticide label.

Coveralls

Wear long sleeved coveralls over full length pants and long-sleeved shirts. Make sure the **coveralls are closed at the neckline and wrists**. Remove your coveralls as soon as you have finished your pesticide activities. Remove them immediately if they become wet through with pesticide. Wear waterproof clothing if you might get wet during pesticide application.

Some disposable coveralls are suitable for pesticide use. Check with your supplier to see which ones can be used for pesticide application. **When removing disposable coveralls, take care not to contaminate the inside** if you will wear them again. Between wearing, **hang them in a well ventilated area away from other clothing.** Do not launder disposable coveralls but do wash clothing worn under disposable coveralls as you would other clothing worn during pesticide use. Replace with a new coverall when severe pilling (balls on the surface), rips or holes appear. **To discard, place in a plastic garbage bag and take to a landfill site.** Do not burn.

Gloves

Always wear gloves when handling pesticides. Many glove materials are available. Use **unlined water-proof gloves** unless the pesticide label recommends a specific material. Do not use gloves made of leather, cloth, or natural rubber or gloves with cloth linings. Make sure the gloves do not have holes or leaks. **Keep your coverall sleeves over the gloves and fold down the tops of the gloves to make cuffs. Wash your gloves before removing them and after each use.**

Boots

Wear waterproof, unlined knee-high boots of rubber or neoprene when you load, mix or apply pesticides. **Wear your pant legs outside of your boots.** Do not wear boots made of leather or fabric. **Wash the outside of your boots after each use.**

Goggles and Face Shields

Wear goggles if there is a chance of getting pesticide spray or dust in your eyes. Do not use goggles with cloth or foam headbands. Do not wear contact lenses when handling pesticides. Face shields provide extra protection when mixing and loading toxic pesticides. Wash goggles and face shields after use.

Hats

Wear a waterproof hat when pesticides may be splashed or when you could be exposed to drift. Wear a wide brimmed waterproof hat when you will get wet with spray. Do not wear baseball caps, fabric hats, or hats with leather or cloth inner bands.

Aprons

Wear a waterproof apron when you pour and mix concentrated pesticides.

Respirators

Wear a respirator when the label says to wear one; or when the label says to avoid inhalation of dust, vapour, or spray mist; or if there is a danger poison symbol on the label; or if you are applying pesticides in an enclosed space. Make sure your respirator fits. Men should shave before using a respirator as facial hair prevents a proper fit.

Full face respirators give more protection and may be more comfortable than a half face mask and goggles.

Do not use dust masks when applying pesticides. They do not protect you from the fumes.

Special respirators must be worn when using a highly toxic fumigant such as formaldehyde. Check the label for details.

Respirators must be approved by NIOSH or an agency sanctioned by the WorkSafe BC (previously Workers' Compensation Board). The cartridges remove toxic fumes from the air. Cartridges labeled for organic vapours or pesticides are needed for most pesticides. Filters remove dust and mist. Both filters and cartridges must be replaced regularly for the respirator to work.

When using respirators:

- Check the intake and exhaust valves.
- Make sure there are no air leaks around the face mask. Do an inhalation or exhalation test.
- Change the dust filter after 4 hours of use or more often if breathing becomes difficult.
- Change the cartridges after 8 hours of use or sooner if you can smell the pesticide. Replace cartridges at least once a year, and more often if you use them frequently.

Cleaning Protective Clothing and Equipment

After application wash your gloves, boots, goggles, faceshield and apron. Wash your respirator face piece with soap and warm water. Then rinse it with clean water and dry it with a clean cloth. Keep the cleaned respirator in a plastic bag in a clean, dry place. Store the respirator and protective clothing away from pesticides and spray equipment.

Discard any clothing that has become soaked with a pesticide.

Launder all your clothing after each day of applying pesticides. Wash protective clothing separately from the rest of the laundry. Do not touch contaminated clothing with bare hands. Use rubber gloves. Pre-rinse clothing using the presoak cycle. Use a high water level and the hottest water setting on your machine. Use a heavy-duty detergent.

If clothes are heavily contaminated, run two complete cycles. Hang clothes outside to dry in the sunlight if possible. Clean the washing machine by running it through a full cycle with detergent and no clothes to remove any pesticide residue.

Personal and Environmental Safety Guidelines

Buying Pesticides

- Make sure the pesticide is registered for your specific use (crop and pest).
- Buy only what you can use up in a year.

Transporting Pesticides

- Never transport pesticides with food, feed, fertilizer, clothing, or household goods.
- Lock up the pesticides if you leave your vehicle.
- Never transport pesticides in the passenger section of any vehicle.
- Ask the supplier if you need shipping papers and vehicle warning signs.

Storing Pesticides and Shelf Life

Pesticides vary in their stability and response to storage conditions. Try to only purchase quantities of pesticides that can be used up in one growing season. However, under proper storage conditions most pesticides can be used after at least one year of storage. Follow these guidelines for storage:

- The law says "Commercial" and "Restricted" pesticides must be kept in locked storage that is vented to the outside and that has a warning sign on the door.
- Store pesticides in their original container with the original label. If a label is illegible or missing, label it with the trade name, active ingredient, quantity in the container and PCP number. Then obtain a replacement label from your dealer or the PMRA website http://pr-rp.pmra-arla.gc.ca/portal/page?_pageid=34,17551&_dad=portal&_schema=PORTAL .
- Never keep pesticides near livestock, food, feed, seed, wells, water supplies, or in your home.
- Pesticide storage should be 30.5 metres from any well.
- Keep herbicides separate from other pesticides.

- Return pesticides to storage when not in use.
- Keep a list of the pesticides in storage.
- Protect the pesticides from extreme temperatures. Some liquid pesticides are destroyed by freezing.
- Close containers when not in use.
- Dispose of unwanted, unmarked and damaged containers.
- Keep containers above floor level to protect from dampness and flooding.
- Post emergency numbers nearby.
- Keep a fire extinguisher, broom and shovel, absorptive material, and protective clothing nearby in case of emergencies.

Mixing and Loading Pesticides

- Wear protective clothing and equipment.
- Read and follow label directions.
- Choose a mixing and loading site away from people, livestock, pets, wells, and water bodies.
- Measure accurately.
- Do not rip open paper pesticide bags. Slit them open with a sharp knife.
- Mix pesticides in still or low wind conditions. Stand upwind of the pesticide.
- Hold the container below eye level when measuring or adding pesticide into the spray equipment.
- Only use mixing equipment for pesticides and return it to locked storage when not in use.
- Triple rinse pesticide containers as soon as they are empty. Rinse measuring and mixing equipment. Put rinse water into the sprayer.
- Use clean water. The pH of the water should be from 5.0 to 7.0.
- Prevent overflow. Don't leave the tank unattended.
- Prevent contaminating the water supply by leaving at least a 15 cm air gap between the end of the filler hose and the water in the spray tank. You can also use a backflow preventer valve.

Applying Pesticides

- Read and follow label directions.
- Use calibrated application equipment.
- Use the label or production guide rate.
- Wash before eating, drinking, smoking, or using the toilet.
- Have fresh water and emergency supplies on hand.
- Make sure the area to be treated is clear of people and animals.
- Don't work alone when handling very toxic pesticides.
- Post warning signs if necessary to keep people out of treated areas.
- Use separate equipment for applying herbicides.
- Cover or remove animal food and water containers near the treatment area.
- Wear gloves to replace or clean plugged nozzles. Do not blow out a plugged nozzle or screen with your mouth. Use a soft brush or toothpick.
- Shut off the spray nozzles when you turn and stop the flow of granulars at the end of rows.
- Pesticides must be registered for chemigation before they can be applied through irrigation systems. Therefore only apply pesticides through the irrigation system when the label has instructions for chemigation. If chemigation is used, follow "Chemigation Guidelines for B.C." This publication is available from BCMAL.
- Use and maintain speed chosen during calibration.
- When applying pesticides outside, prevent pesticides from contaminating non-target areas. Leave an untreated area around lakes, streams, ditches, and wells. Spray downwind from sensitive areas.

After Applying Pesticides

- Clean equipment away from water supplies.
- Remove and clean protective clothing and equipment.
- Shower.
- Keep records of every application.

Disposal of Unwanted Pesticides

- Calculate the amount needed so none is left over.
- Do not re-spray an area to get rid of leftover spray.
- Apply left over material according to label directions on another site. Do not put unwanted pesticides into sewers, down drains, or on the land.
- Contact the regional office of the B.C. Ministry of Environment or BCMAL for information on the disposal of unwanted pesticides.

Disposal of Containers

- Drain the container into the spray tank for at least 30 seconds or shake out the bag.
- Triple or pressure rinse drums, glass bottles, plastic and metal containers. Single rinse plastic and paper bags.
- Put the rinse water into the spray tank.
- Crush, puncture or damage empty containers so they cannot be re-used.
- Return the containers to your pesticide storage until you can take them to a public dump, back to the supplier, or to a collection site. Containers can be buried on your land 0.5 metres below the surface. The burial site must be flat, not a bog, gravel or sandy soil and at least 200 metres from wells, lakes, rivers, streams or ponds.
- Do not burn pesticide containers.

Re-entry Restrictions

Poisoning may occur when people work in treated areas too soon after pesticides have been used. Such poisoning may be from breathing pesticide fumes or handling treated mushrooms. Warn farm workers of areas recently sprayed.

Some pesticide labels tell when treated areas can be re-entered. Follow these directions.

When there are no re-entry times on a pesticide label, follow the Workers' Compensation Board regulations. They state people may not enter a treated field until they have waited the following re-entry or restricted entry intervals:

- 24 hours for a slightly toxic pesticides;
- 48 hours for moderately or very toxic pesticides.

If a person needs to enter a treated area before the re-entry period is over, wear protective gear. Farmers must post a sign to tell workers when they can enter the area. The sign must state the application date and the re-entry time. FARSHA gives out signs to use.

Grazing Restrictions

If animals are to graze a treated area, check the pesticide label for grazing restrictions. Wait the required time before grazing.

Harvesting Restrictions

Wait the pre-harvest interval (days to harvest) before harvesting to avoid illegal pesticide residues on crops. Pre-harvest intervals are on labels.

Special Environmental Precautions

Buffer Zones

Many pesticide labels now have buffer zone information. Buffer Zones are strips of land next to sensitive areas that cannot be treated with a pesticide (see figure below). The purpose of the buffer zone is to protect sensitive areas from pesticide drift. Applicators are required to leave a buffer zone when the label says to. Labels will tell you what sensitive areas must be protected and the size of the buffer zone. Labels may require protection of water bodies (aquatic) or planted areas (terrestrial).

Protecting Fish and Other Wildlife

All insecticides, as well as some fungicides and herbicides, are very toxic to fish. Insecticides are also toxic to birds and wildlife. Exposure to trace amounts of these pesticides may kill fish or birds. Destroying the vegetation along fish-bearing water harms fish by removing food and shelter.

Protect fish and wildlife from pesticide poisoning by following label precautions.

Protecting Bees and Beneficial Insects

Bees and other pollinating insects are essential for the production of many crops. Some other insects help control pests. Many pesticides, particularly insecticides, are very toxic to honeybees, wild bees, and beneficial insects.

Protecting Groundwater

Groundwater is the source of water for wells and springs. It is very difficult to clean contaminated groundwater. The best solution to groundwater contamination is prevention.

Groundwater contamination is most likely to occur where soils are gravelly or sandy, the water table is close to the soil surface, there is high rainfall or extensive irrigation, or the pesticide is injected or incorporated into the soil. Pesticides that are persistent in the soil, are weakly absorbed and leach quickly, or are highly soluble may contaminate groundwater.

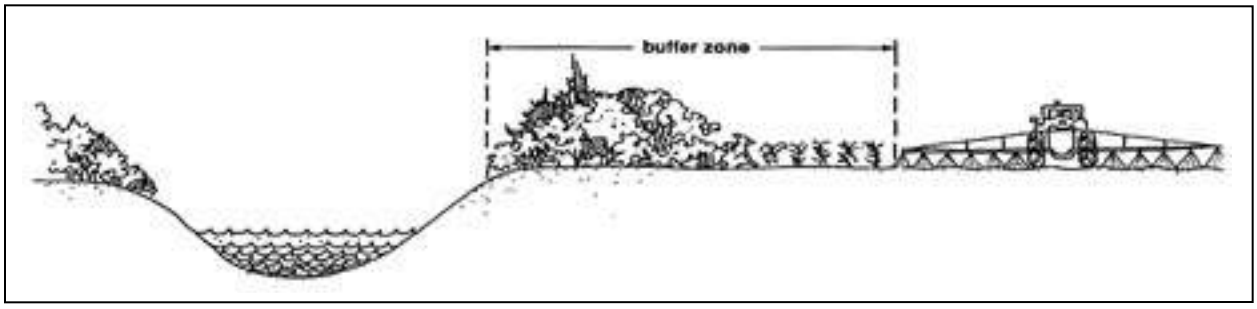
Remember to avoid spills, drift, and irrigation run off and to properly dispose of unwanted pesticides and empty containers. Never store pesticides near wells or pumphouses and guard against leaking containers.

Well construction, maintenance and location can be factors in contamination. Maintain proper seals between pump and pump base, as well as seals between well casings.

Streamside Protection

Growers are encouraged to examine their farm activities and modify any practices that could put fish habitats at risk. Some areas where risk may occur include the use of pesticides, fertilizer, manure and woodwaste.

Buffer Zones



Emergency Response

- Keep the phone numbers for Poison Control Centre, doctor, ambulance, and Provincial Emergency number for dangerous goods spills nearby (1-800-663-3456). The Poison Control Centre phone number is in the front section of the telephone book.
- Have protective gear and equipment easily available.
- Keep absorptive material, a container for contaminated waste, tools to pick up contaminated material, bleach, and hydrated lime available.

Spills

- Protect yourself.
- Keep bystanders away.
- Don't eat, smoke or drink during clean-up.
- Work upwind of the spill.
- Contain the spill. Surround and cover with absorbent material.
- Clean up the spill.
- Decontaminate the area using bleach or detergent. Absorb excess liquid with absorbent material.
- Put absorbent material in the special waste container and seal it.
- Remove and wash protective gear. Shower.
- If you need help, call the Provincial Emergency number (1-800-663-3456).
- All spills greater than 5 kg or 5 L must be reported to the Provincial Emergency Program (1-800-663-3456).

Fires

Fires involving pesticides can be very dangerous. Burning pesticides may release toxic fumes that are poisonous to firefighters, bystanders, and animals or contaminate the environment. Pressurized containers can explode. Pesticides can spill out of containers damaged by the fire. Runoff from fighting a fire can contaminate a larger area.

Ahead of time, give your fire department a list of all pesticides in storage (brand names, active ingredient, PCP #'s and quantity remaining). Update the list each year.

In case of a fire, call the fire department and tell them there is a fire involving pesticides. Keep people and animals away from the fire.

For more information on practices to reduce the potential of fires and dealing with fires involving pesticides see the BCMAL Pesticide Wise website:

www.al.gov.bc.ca/pesticides/g_5.htm

Sprayer Equipment

5

Application methods specific to mushroom operations can be divided into the following types:

- High volume applicationss
- Low volume applications
- Dust applications
- Compost or casing drench applications

Pesticide application equipment is important to the pest management program. Proper selection of equipment, calculation, use and maintenance determine effectiveness, efficiency and safety of pest control program.

The following information was taken from the Field Vegetable Production Guide. Although this information is not specific to mushroom equipment, the guiding principals can be used.

For further information refer to Pesticide Wise Application Equipment at

http://www.agf.gov.bc.ca/pesticides

and Pesticide Applications Course for Agriculture Producers.

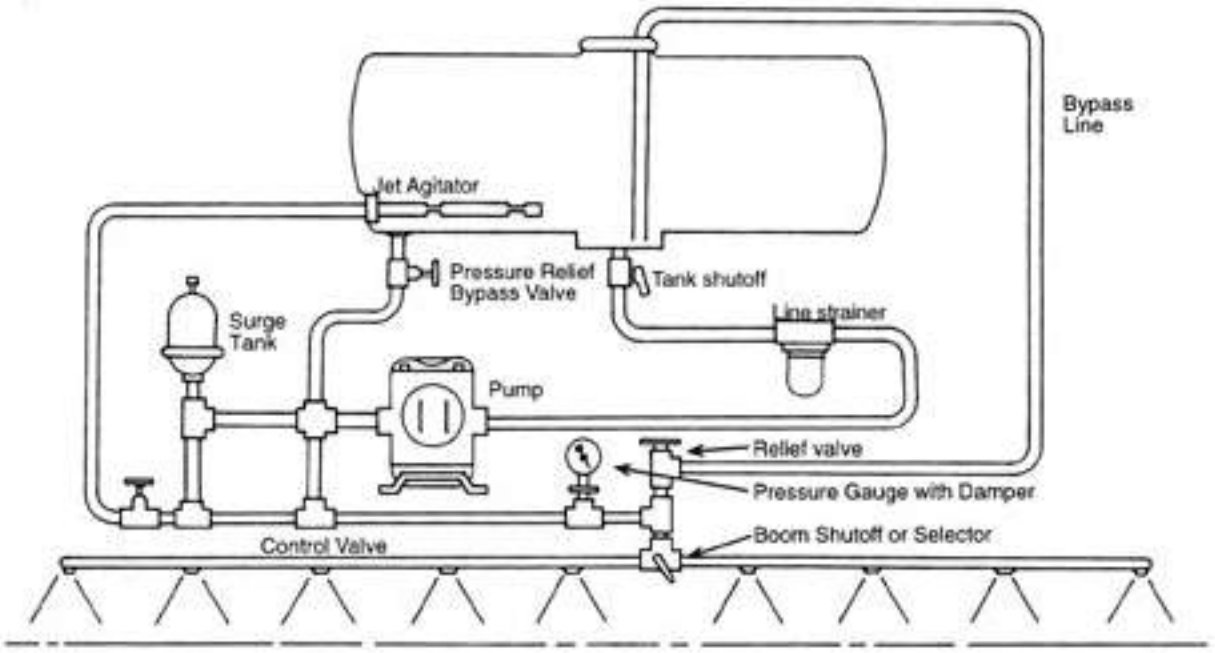
Hand Operated Sprayer

One of the most common spraying equipment is the hand-operated sprayer. Basic, low cost backpack sprayers will generate only low pressures and lack features such as diaphragm pumps, agitators, pressure adjustment controls (regulator), and pressure gauges found on commercial grade units. These low pressure sprayers without pressure regulators and gauges should not be used for applying insecticides and fungicides where uniform coverage is important. These sprayers with their limited control options are better suited for the home gardener.

Diaphragm pumps and agitators will allow sprayers to be used with wettable powder sprays more effectively. Pressures should be above 80 psi to achieve the finer sprays suitable for applying insecticides and fungicides. Pressure gauges and pressure regulators enable the sprayer to operate at higher pressures (80 to 200 psi), and the operator to achieve a more uniform output from the sprayer. Note that a smooth uniform walking speed and spray wand motion is also required to achieve uniform coverage. Nozzles must be selected for the operating pressure of the sprayer and spraying conditions.

Backpack sprayers should have a positive shut-off spray control valve to eliminate pesticide drips from the wand and nozzle. Drip-proof nozzle assemblies are also available as an alternative. Ball check valves in the nozzle body require 5 to 10 psi of liquid pressure to start spraying and close when the pressure drops below this level to prevent drips. Full protective equipment should be worn to reduce the operator's exposure to pesticides especially when spraying at high pressures and with small droplets.

Components of Spraying Equipment



Operation of Sprayers

Essential components of any chemical spraying equipment are the power source, pump, tank and nozzles. Others which must be considered are agitators, screens, filters, valves, pressure regulators, booms, hoses, and gauges.

Power Source

The power-sprayer is normally driven by an auxiliary engine. The power rating of these should be double the theoretical power required by the pump.

Pumps

A pump creates the pressure required for atomization and penetration of the spray on almost all types of sprayers.

Choose a pump that has the characteristics required for the job. Common pumps include:

- roller pump—excessive wear can occur with wettable powders
- piston pump
- diaphragm pump

For spraying insecticides or fungicides, sprayers require either diaphragm or piston pumps to develop the higher pressures needed (700 kPa or 100 psi) to get thorough plant coverage. Determine the capacity of the pump by the highest rate of application the sprayer is expected to deliver, an adequate volume for agitation and an additional 25% volume to account for the pump's wear. During operation there should always be flow in the bypass line indicating the pump has sufficient capacity to send some excess to the tank. Note the maximum rpm allowed for the pump.

Tanks

The size of the spray tank depends on the intended application rate and the mounting space available. The tank should be equipped with a large screened opening for easy filling and cleaning. Tanks may be constructed of steel, stainless steel, epoxy-coated steel, fiberglass, polyethylene or aluminum. Fibreglass, stainless steel and polyethylene tanks are preferred because of their rust and corrosion resistance.

The rusting of steel tanks can be reduced by proper draining, cleaning and airing of the tank after use and by the use of rustproofing compounds. Either hydraulic bypass or mechanical agitation must be provided. If hydraulic agitation is used in the spray tank, additional pump capacity is required. Mechanical agitation is preferred if wettable powders are to be used.

Mechanical agitation with paddles gives the best mixing for wettable powder formulations. If hydraulic agitation is used, 1/10 to 1/20 of the tank capacity should be recirculated per minute. This flow should be supplied from a separate pressure line, not from the relief valve bypass.

Tanks should be equipped with drains in the lowest part of the tank to allow complete emptying of the tank. Drains should be easy to operate to encourage operators to drain the tank at the end of each day.

For proper mixing of pesticide dilutions it is important to know the volume capacity of the spray tank.

Hoses

Suction hoses (from the tank) should be reinforced so they will not collapse, be resistant to chemicals and oils, and be of the same diameter as the pump inlet hole. The same type of hose can be used for the bypass line.

Hoses on the pressure side of the pump must be able to handle pressures higher than the intended use and preferably as high as the maximum pressure the pump can develop. To avoid excessive pressures on the hose, the relief or unloading valve should be released before flow to the boom is shut off.

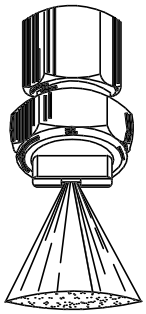
Nozzles

The size of droplet produced by various nozzles depends upon operating pressures and nozzle design. The droplet size decreases with a higher pressure and with a smaller nozzle tip opening. Droplets that are too big give poor coverage and droplets that are too small drift easily.

Types of nozzles

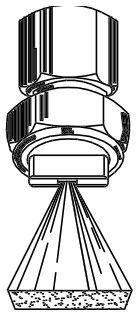
The main nozzle types used for chemical application are:

- **Flat spray nozzles.** (Also called fan type or TeeJets.) These are used for low-pressure spraying such as the application of herbicides and insecticide drenches. They produce a fan-type pattern with less material applied along the edges of the spray pattern (see figure below). By properly overlapping the spray, a uniform application is produced across the spray boom. Offset flat spray nozzles at an angle of 10 degrees to the boom to prevent interference of the overlapping spray patterns. Nozzle spacing on the boom and the height of the boom above the target are critical to obtain a uniform application. Sprayer equipment suppliers and nozzle manufacturers' catalogues can advise growers as to the correct height of the boom at different nozzle spacings and for different nozzle spray angles. Do not operate these nozzles above 400 kPa (60 psi) to prevent excessive wear and fine spray droplets. Refer to manufacturer's specifications for recommended nozzle pressures.



Flat spray nozzle

- **Even spray nozzle tips.** These produce an even spray pattern across the entire fan width (see figure to right). These nozzles are used in band spraying where there is no overlap from other nozzles. Align even spray nozzles with the spray boom. These nozzles are designed to operate at low pressures (less than 400 kPa or 60 psi). Refer to manufacturer's specifications for recommended nozzle pressures.

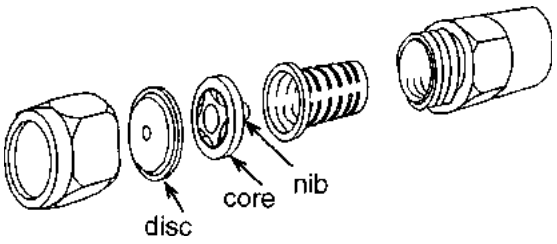


Even spray

- **Cone nozzle tips.** These are used for medium to high-pressure spraying (mostly fungicides and insecticides). These nozzles produce a good swirling mist so the spray material can reach the undersides. Nozzle spacing should allow the adjacent spray patterns to cover the entire target otherwise skips may occur. Cone nozzles are available as either hollow cone or solid cone types – both produce the same swirling mist but the solid cone nozzles are used when larger volumes are required (see figure below).

Hollow cone

Solid cone



Assembly of disc-core cone

Nozzle sizes

Various sizes of flat, even and cone nozzle tips may be used to obtain the volume of water desired. Consult with your sprayer equipment supplier for information on nozzle outputs for the various nozzle sizes. Ask for a catalogue with nozzle outputs in litres per minute. (For your convenience, nozzle outputs for Spraying Systems flat spray tips and disc-core type hollow cone spray tips are shown in Table 5.1 and Table 5.2 respectively.)

Nozzle tip materials

Nozzle tips are made from a variety of materials. Choice of material depends upon the abrasiveness of the spray mixture. Wettable powders are more abrasive than emulsions. Brass tips are cheap but the metal is softer and the tips wear faster. In increasing order of durability the following materials are used: plastic, brass, stainless steel, hardened stainless steel, ceramic and tungsten carbide. By making flat and even spray tips out of colored plastic with a small amount of stainless steel or ceramic in the center with the spray orifice, the more durable tips can be made at a very reasonable cost. These nozzles are more cost-effective than nozzles made entirely of brass.

As nozzle tips wear out, the rate of application increases. Tests have shown that some wettable powders wear nozzle tips sufficiently to increase the rate as much as 12% after spraying only 20 ha. For this reason, frequent calibration of equipment is necessary. Also, very worn nozzles should be replaced because their spray pattern is distorted and uneven application will result.

Screens

Screens prevent foreign material from entering the system, clogging the nozzles and wearing out the sprayer.

Suction strainers, line strainers and nozzles should all be equipped with 50 mesh or coarser screens when wettable powders are to be used. Some pesticides may require coarser suction strainers. It may be necessary to have more than one suction strainer for the sprayer.

Screens finer than 50 mesh (100 mesh, for example) may plug with some wettable powders.

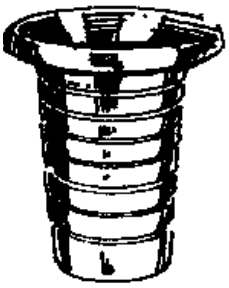
Table 5.1 Flat spray nozzle outputs (Litres per minute)

Nozzle	PSI	LPM	Nozzle	PSI	LPM	Nozzle	PSI	LPM
8002	15	0.45	8005	15	1.17	8010	15	2.31
	20	0.53		20	1.32		20	2.69
	25	0.59		25	1.48		25	2.99
	30	0.64		30	1.63		30	3.29
	35	0.70		35	1.76		35	3.54
	40	0.76		40	1.89		40	3.79
	45	0.79		45	2.01		45	3.97
	50	0.83		50	2.12		50	4.16
	55	0.87		55	2.21		55	4.35
	60	0.91		60	2.31		60	4.54
8003	15	0.68	8006	15	1.40	8015	15	3.48
	20	0.79		20	1.59		20	4.01
	25	0.89		25	1.78		25	4.47
	30	0.98		30	1.97		30	4.92
	35	1.06		35	2.12		35	5.30
	40	1.14		40	2.27		40	5.68
	45	1.21		45	2.40		45	6.06
	50	1.29		50	2.54		50	6.43
	55	1.34		55	2.65		55	6.62
	60	1.40		60	2.76		60	6.81
8004	15	0.91	8008	15	1.85	8020	30	6.43
	20	1.06		20	2.16		35	7.00
	25	1.19		25	2.38		40	7.57
	30	1.32		30	2.61		45	7.95
	35	1.42		35	2.82		50	8.33
	40	1.51		40	3.03		55	8.89
	45	1.61		45	3.20		60	9.46
	50	1.70		50	3.37			
	55	1.78		55	3.54			
	60	1.85		60	3.71			

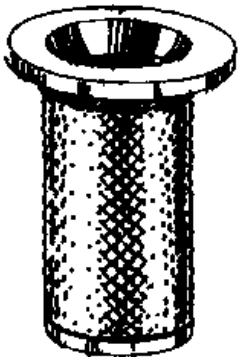
Table 5.2 Hollow cone nozzle outputs (Litres per minute)

		Pressure (psi)							
Disc	Core	80	100	125	150	175	200	250	300
2	25	0.83	0.95	1.02	1.10	1.19	1.29	1.42	1.55
3	25	0.98	1.10	1.21	1.32	1.42	1.51	1.67	1.82
2	45	1.06	1.21	1.32	1.44	1.55	1.67	1.84	2.01
3	45	1.25	1.36	1.51	1.67	1.80	1.93	2.14	2.35
4	25	1.51	1.70	1.87	2.04	2.20	2.35	2.59	2.84
5	25	1.82	2.04	2.25	2.46	2.65	2.84	3.12	3.41
4	45	1.89	2.12	2.35	2.57	2.76	2.95	3.27	3.60
5	45	2.42	2.69	2.97	3.26	3.50	3.75	4.18	4.62
6	45	3.14	3.52	3.94	4.35	4.69	5.03	5.62	6.21
7	45	3.67	4.20	4.66	5.11	5.53	5.94	6.64	7.34
8	45	4.58	5.11	5.73	6.36	6.85	7.34	8.21	9.08
10	45	5.94	6.70	7.48	8.25	8.86	9.46	10.60	11.73

Screens are generally used in fine nozzles, but slotted strainers can be used in those that have a larger opening. Consult the nozzle manufacturer's catalogue for recommendations on specific screen mesh sizes for specific nozzles. Generally for flat spray nozzles with small holes (TeeJet 80015 or smaller) a 100 mesh nozzle is recommended. Generally larger nozzles (TeeJet 8002 to 8008) should use a 50 mesh screen. Disc-core cone nozzles should normally be used with a slotted strainer equivalent to a 16 mesh screen (any Spraying Systems D3 or larger disc and No. 25 and larger core). A slotted strainer equivalent to a 25 mesh screen should be used with D2 discs.



Slotted Strainer



Screen Strainer

Clean screens and strainers are essential to the efficient operation of the spray system. They should be cleaned often and checked for breaks in the screen. If the nozzle screens are plugging too often, check to make certain the chemicals are properly mixed, the spray tank and plumbing system are properly rinsed and cleaned between sprays, and that the suction and tank screens are in place when filling and using the sprayer. If the plugging problem persists, consider changing to an alternative pesticide formulation. Also check to see if a larger nozzle that has a larger recommended screen size can be used. **Do not operate the sprayer without the recommended nozzle screens**.

Mixing Chemicals

When mixing the chemical in the sprayer tank, NEVER put the chemical in first and then top with water. Always fill the tank 1/3 to 1/2 with clean water, start the agitator and then add the required quantity of chemical. Continue agitating while filling the tank.

For tank-mixes of two or more chemicals, first check the product label for compatibility information. Add the first chemical at the 1/3 to 1/2 full stage and the second chemical at the 2/3 to 3/4 full stage. Mixing by this method will ensure that the chemical is completely mixed in the water. To keep the chemical completely mixed keep the agitator on until you are finished spraying. Never turn off the hydraulic agitation to get enough pump pressure to spray – the chemical will not stay mixed in the water.

For best results, wettable powders should be premixed before being added to the spray tank. Make a slurry of wettable powder and water and then pour it into the spray tank.

Always follow manufacturers' directions when mixing. Always keep the agitator running once the spray materials have been added to the tank.

Excess Pesticide Spray Tank Mixtures

Avoid mixing surplus spray by carefully calculating rates, calibrating the sprayer and carefully measuring the area. If too much is mixed, use that material according to label directions on another site. If no such area can be found, spray the mixture over an area on the property where it will cause no damage. Never re-spray the treated area with extra tank mix. Spraying an area twice will double the rate and may cause high residues in the crop.

Sprayer Cleaning

Immediately after use, drain and collect any excess spray mixture. This excess material can be very difficult to dispose of properly, therefore sprayers should be properly calibrated to avoid any excess. Then flush the sprayer out with soapy water and rinse with clean water. Talk to the equipment dealer to have a new drain installed if the current drain is hard to use. Select a cleaning area where water will not contaminate wells, streams or crops.

Even stainless steel nozzles will rust if left in the sprayer. Nozzles and nozzle screens should be removed and cleaned. For periods when not in use, nozzles can be stored in a can of light oil or diesel fuel. After a spray application the nozzles should be cleaned and coated with a light coat of oil to prevent corrosion. Ceramic nozzles are not subject to corrosion.

Sprayer Calibration

6

Calibration helps ensure good pest control. It also helps prevent crop damage from pesticides, high pesticide residues, and environmental contamination. Calibrate all application equipment to ensure a pesticide will be applied accurately and uniformly at the recommended rate. Calibration involves preparing the equipment so it is working properly, measuring the delivery rate, adjusting the equipment to change the delivery rate, and calculating how much pesticide to add to the sprayer tank. Calibrate equipment regularly (at least once per year) to make sure the output is not changing. Also calibrate equipment when it is new and when making changes that affect the delivery rate. Proper calibration will minimize, if not eliminate, left-over mixed pesticides in the sprayer tank which can be very difficult to properly dispose of.

There are four basic procedures to be carried out when calibrating sprayers. Details on these procedures are given below. (Also refer to the "Pesticide Applicator Course for Agricultural Producers".)

Use the "Calibration Worksheets - Mushrooms" in this section to follow these four procedures when applying pesticides to your crop.

1. Set-up
2. Measuring delivery rate
3. Adjusting delivery rate (if different from recommended rate)
4. Calculating how much pesticide to add to the spray tank

Set-Up

During sprayer set-up check that the sprayer nozzles and spray pressure are correct for the applied pesticide and the crop conditions. Check the equipment to ensure all parts are in good condition and working properly (see the sprayer's operating manual). The sprayer must apply the pesticide uniformly across the width of the watering boom and over the whole bed area.

You must choose which nozzles to use and nozzle pressure before you can move on to the second step in calibration, "Measuring Delivery Rate".

The last page of the "Calibration Worksheet" gives formulas for checking the speed of your tractor gears.

Selecting Spray Volume

Drench Appliation

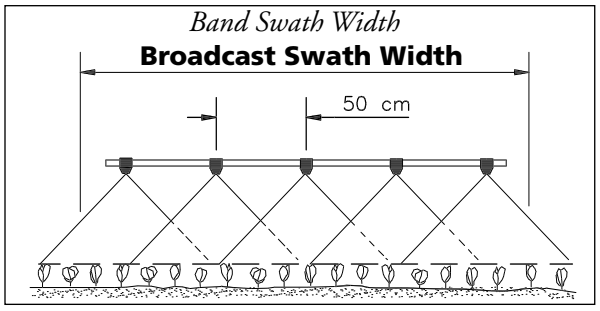
Before calibrating your sprayer, you should determine how much spray mixture should be sprayed in the given area. The recommended amount of spray mixture (spray volume) is usually found on the pesticide label.

Selecting Nozzle Pressure

Many nozzle manufacturers have chosen to report nozzle outputs with pressures in "bars" not kilopascals (kPa). The bar unit is equal to 100 kPa. Pesticide labels report pressures in kPa. Use a pressure gauge on the sprayer marked in both psi and kPa (or bar) so both units can be read directly from the gauge. The maximum pressure on the pressure gauge should be twice the maximum spray pressure used to protect the gauge from damage and allow it to be read accurately.

Determine Sprayer Swath Width

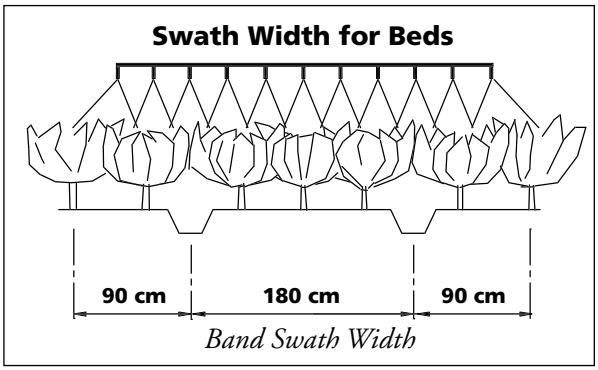
Swath width is the width of treated area over which spray droplets are distributed in one pass of the applicator (see figures below). In a broadcast spray, it is the nozzle spacing multiplied by the number of nozzles, and for band treatments it is the sum of the treated band widths. For crops grown in beds, sprayer swath width is the bed spacing (from center to center of wheel tracks) multiplied by the number of beds.



Broadcast swath width

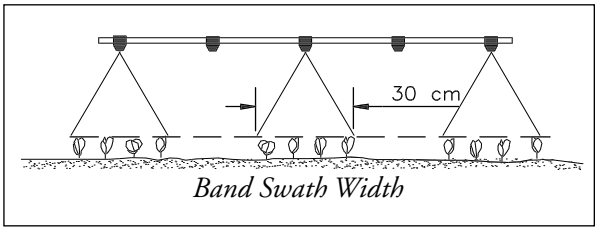
= # of nozzles x spacing
= 5 nozzles x 50 cm
= 250 cm
= 2.5 m

Swath width is usually measured in meters or feet. The swath width is used in sprayer calibration to calculate the sprayer's delivery rate. As the sprayer swath width is based on the treated area, the delivery rate will also be based on the treated area when band spraying herbicides.



Broadcast swath width
= # of beds x bed width
*= 2 * x 180 cm*
= 360 cm
= 3.6 m

**Note: no. of beds = 1/2 bed + 1 bed + 1/2 bed*
= 2 beds



Band swath width
= # of bands x band width
= 3 bands x 30 cm
= 90 cm
= 0.9 m

Measuring Delivery Rate

There are two basic methods used to measure sprayer delivery rates — the test area method and the timed output method.

a) The test area method uses fewer calculations, however, it can take longer to carry out. If an entire production room (growing area) is used as the test area, the measured discharge of water is the delivery rate per production room and no calculations are required. The most common problem with the test area method is measuring the amount of spray water discharged.

b) The timed output method requires more calculations. By using both the test area and timed output method, the accuracy of your sprayer calibration can be checked.

Adjusting Delivery Rate

If the measured delivery rate of the sprayer is different than the spray volume listed on the pesticide label or recommended in the production guide, it can be adjusted in three ways:

1. Nozzle size should be changed if large changes in delivery rate are needed. Check with the nozzle supplier or agricultural advisor. Obtain a catalogue listing nozzles and nozzle outputs in litres per minute (L/min). Some of these are given in Tables 9.1 and 9.2.
2. Forward speed changes will adjust the delivery rate. Slower speeds increase the amount sprayed and faster speeds reduce the amount.
3. Spray pressure should be set for the correct droplet size. Changing pressure is recommended only for very small changes in delivery rates. Otherwise the droplet size will change and cause drift or runoff problems. Since pressure must be increased four times to double the delivery rate, this is not a good way to adjust delivery rate.

After making the adjustments, measure the delivery rate again.

Calculating How Much Pesticide to Add to the Spray Tank

When the sprayer delivery rate is known, then calculate how many square feet can be sprayed by a full tank and how much pesticide to add to the spray tank. Be very careful to accurately measure the area to be covered by the last tank to minimize left over spray mixture in the tank when you are finished spraying.

Calibrating Hand Operated Sprayers

Sprayer Set-up

Hand-operated sprayers should be checked to make sure there are no leaks, especially where the hose enters the tank and around the trigger valve. The nozzle should deliver a uniform spray pattern. Many nozzles can be adjusted to produce the desired droplet size. Adjust the nozzle to produce a coarse spray (larger droplets) for herbicides and medium to fine spray (smaller droplets) for insecticide and fungicide applications.

For uniform spray application it is important to maintain constant spray pressure and coordinate the walking speed with uniform back and forth movements of the nozzle. The back and forth movements determine the swath width.

Most pesticide labels give instructions as a specific amount of pesticide per unit area (e.g., apply 2.4 L/ha). Some pesticides like **Roundup** give directions to dilute an amount of pesticide in water and apply with thorough and complete coverage (e.g., **Roundup** –1 L of product in 100 L of water).

Application Rate Given as a Dilution with Water

When the application rate is given as a dilution rate, then the amount of pesticide to mix in a full tank can be calculated directly.

Example:

A label recommends mixing 1 L of pesticide in 100 L of water and applying to foliage with thorough coverage. A 12-litre backpack will be used.

Answer:

The amount of pesticide to add to the tank can be calculated with the following formula:

Amount of pesticide = label rate (product amount÷water volume) × sprayer volume

Amount of pesticide = 1 L product ÷ 100 L water × 12 L tank = 0.12 L product/tank

If only a partial tank full (e.g. 8 L) of pesticide mix is required, use that figure as the "sprayer volume" input in the formula.

Also estimate how much spray mixture is needed so tank mix is not left over. Do this by applying water to a measured test area and determine the total mix needed. Use the same procedures that follow for pesticide application rates given as an amount of pesticide per unit area.

Boom Irrigation Sprayer

Application Rate Given as Amount of Pesticide per Square Foot

Measuring delivery rate of the hand-operated sprayer follows the same basic steps as with the tractor mounted boom sprayer but on a smaller scale. Remember during set-up of the sprayer that a steady walking speed and swath width must be used.

1. Mark out a measured length of test strip at least 60 feet long.
2. Fill the tank about half full with water and record the volume or level of water. Pump the tank to the pressure level that will be used.
3. Carefully spray the measured test strip while maintaining a steady forward speed and pumping action. Repeat enough runs over the test area until at least 10% of a full tank has been sprayed.
4. Measure the volume of water sprayed in the test strip by refilling the tank to the starting level.

Follow these steps to determine the application rate:

(a) Calculate the test area:

Test area (ft^2) = strip length (ft) × swath width (ft) × # runs

(b) Calculate the delivery rate:

Delivery rate (gal/ft^2) = water sprayed (gal) ÷ test area (ft^2)

Adjust the delivery rate as necessary by changing the walking or application speed.

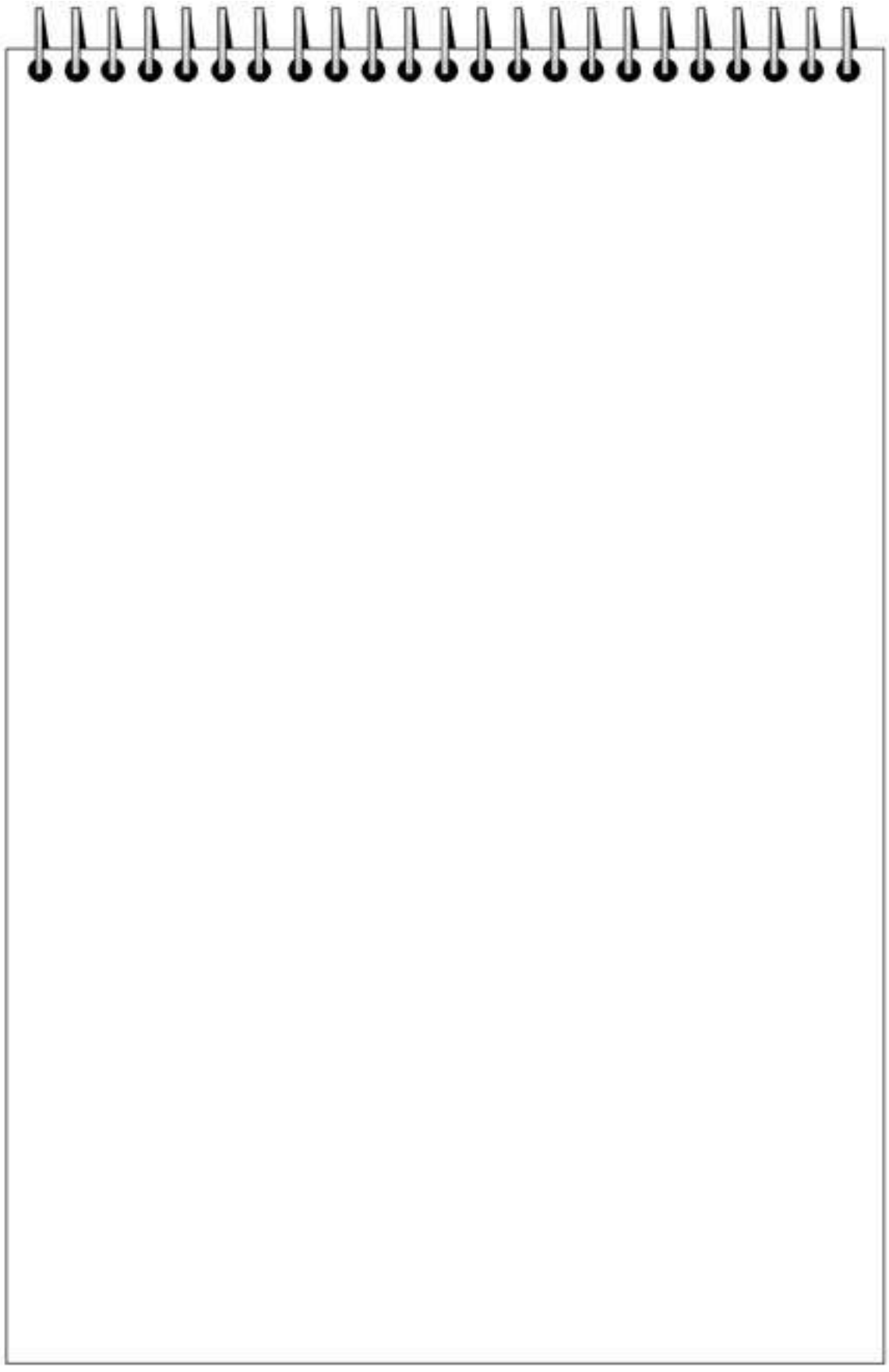
(c) Calculate the amount of area sprayed by a full tank:

Area sprayed (by full tank) = tank volume (gal) ÷ delivery rate (gal/ft^2)

(d) Calculate how much pesticide to add to the spray tank:

Amount of pesticide to add to tank = application rate × area sprayed by one tank

Scratch pad for math calculations



Appendix A

Definitions and Abbreviations

Active ingredient
That portion of a pesticide formulation that is toxic to pests (a.i.).

Acute toxicity
Ability of a substance to cause ill effects that develop soon after exposure.

Actual
The active ingredient of a fertilizer; for example 13-16-10 contains 13 kg nitrogen, 16 kg phosphate and 10 kg potash in each 100 kg of fertilizer mix.

Adjuvant
A chemical or agent added to a pesticide mixture that helps the active ingredient do a better job of wetting, sticking to or penetrating the target pest or weed.

Aeration
The process by which air in soil is replaced by air in the atmosphere; often refers to the time required for a toxic fumigant to leave treated soil before it is safe to seed or transplant into the soil.

a.i.
Active ingredient.

Carrier
A material mixed with active ingredients to make a fertilizer or pesticide safer to handle and easier to apply (e.g. finely divided clay or talc).

Chelate
A type of chemical compound in which a metallic ion (e.g. Fe) is firmly combined with an organic (contains carbon) chemical to improve uptake into the plant.

Chronic toxicity
Ability of a substance to cause ill effects that last a long time. They may not appear for some time after exposure.

Compatibility
Materials are compatible if one does not reduce the effectiveness of the other, and if crop injury does not result from use of the combination.

Contact pesticide

A pesticide that kills the insect or weed by direct contact. The spray must actually touch the insect or the insect must walk onto a droplet in order to be effective. A contact herbicide must cover as much of the foliage as possible to be effective. Good coverage is essential for control with contact pesticides.

Detergent

A cleaning agent. Because of their surface active properties, detergents have a variety of other uses. (See "Surfactant.")

D In pesticide terms, a **dust** formulation.

DF

A **dry flowable** formulation of a pesticide in which water dispersible granules are used instead of wettable powders which are dusty and more hazardous for the person filling the spray tank; sometimes referred to as WDG.

DG

A **dry granular** formulation of a pesticide; usually applied in the planting furrow (in the case of insecticides) or broadcast on the soil surface (in the case of herbicides).

Drench

A drench is a spray applied in a high volume of water in order to penetrate dense foliage or soak the soil with pesticide in an attempt to control soil-inhabiting insects or pathogens.

Dust

A pesticide formulation in which a low concentration of active ingredient is attached to finely ground dry particles which are applied without further dilution.

E A liquid pesticide formulation in which the active ingredient will form an **emulsion** when mixed with water; also referred to as EC.

EC

In pesticide terms, an **emulsifiable concentrate**; in soil/water terms, **electrical conductivity** of the solution.

Electrical conductivity (EC)

The ability of a salt solution to conduct an electrical current. In crop production, a term for expressing the salt concentration which approximates the total of all nutrients in the soil solution. Not all nutrients are detected (e.g. urea). It is also used to describe the suitability of water for irrigation purposes.

Emulsifiable concentrate

A liquid pesticide formulation consisting of active ingredient, solvent and an emulsifier that can mix with water to form an emulsion (e.g. **Diazinon 500 EC**).

F Abbreviation for a **flowable** formulation of pesticide.

Flowable

Finely ground particles suspended in a liquid carrier.

Formulation

A mixture of active ingredient, carrier and adjuvants.

Fumigation

The use of pesticides in gaseous form to destroy pests or disease organisms.

G **Granular** formulation of a pesticide.

Granular pesticide

Relatively coarse particles with a low concentration of active ingredient. They are applied dry with a spreader, seeder or special applicator.

Instar

Any of the various stages in the life cycle of an insect between moults.

IPM

Integrated pest management; management of pests using a combination of cultural, biological and chemical methods with due consideration for the environment.

L or LC

A **liquid** formulation of a pesticide; similar to E and EC.

LD_{50}

Method of expressing the acute toxicity of a pesticide. Expressed as milligrams of chemical per kilogram of body weight of the test animals required to kill 50% of the test population. The lower the LD50, the more acutely toxic the pesticide. This does not, however, indicate the long term (chronic) health effects of the pesticide.

Nematicide

A pesticide used to control nematodes.

Pesticide

Any kind of material that is used to kill, control or manage pests. Pesticides include insecticides, fungicides, herbicides, nematicides, rodenticides, etc.

Pesticide residue

A deposit that remains in, or on, a product following application of a pesticide.

pH

A measure of acidity or alkalinity. It measures the activity of H+ ions in solution. (Expressed as a negative logarithmic scale, e.g. pH = 6 has ten times more H+ ions than pH = 7.)

Phytotoxicity

Damage to a crop plant following the application of pesticides. Chances of phytotocity can be reduced by reading the warnings on the label and carefully measuring the correct quantities and observing conditions prior to application.

PPM

A measure of concentration expressed as parts per million; often used to describe the concentration of nutrient sprays, disinfectant solutions, solubility of soil-applied herbicides and pesticide residues. 1ppm = 1 gram in 1000 kilograms or 1 mL in 1000 litres.

Residue tolerance The maximum amount of a pesticidal residue that may lawfully be present in, or on, a food product offered for sale. It is expressed in parts per million.

SC A **sprayable concentrate** pesticide formulation.

SG A **soluble granule** pesticide formulation.

SL A **soluble liquid** pesticide formulation.

SP A **soluble powder** pesticide formulation.

Spray

A pesticide formulation or nutrient dissolved or suspended in a liquid (usually water or oil), so it can be applied in fine droplets.

Spreader sticker

An adjuvant that assists in the even distribution of the spray solution over the target and also helps it to adhere to the treated surface.

Surfactant

Compounds which reduce the surface tension of a liquid (e.g. emulsifiers, soaps, wetting agents, detergents and spreader stickers).

Systemic pesticide

A pesticide which is absorbed into and flows through the vascular system of a plant or animal so that the plant becomes toxic to the pest to be controlled.

Toxicity

The degree to which a substance is harmful or poisonous to a plant or animal.

W or WP

A **wettable powder** formulation of a pesticide.

Wettable powder

Dry formulation which is normally mixed with water to form a sprayable suspension. Due to the danger of inhalation and spilling the powder while filling the spray tank, most toxic wettable powders are now sold in small soluble bags which can be dropped in the spray tank without being opened.

Wetting agent

An adjuvant that helps solutions or suspensions make better contact with surfaces to be treated.

Appendix B

Metric Conversion Factors

Imperial Units	Conversion Factor	Metric Units
LENGTH		
inches	2.5	centimetres (cm)
feet	30	centimetres (cm)
feet	0.3	metres (m)
yards	0.9	metres (m)
miles	1.6	kilometres (km)
AREA		
square inches	6.5	square centimetres (cm^2)
square feet	0.09	square metres (m^2)
acres	0.40	hectares (ha)
VOLUME		
cubic inches	16	cubic centimetres (cm^3)
cubic feet	0.03	cubic metres (m^3)
cubic yards	0.8	cubic metres (m^3)
fluid ounces	28	millilitres (mL)
pints	0.57	litres (L)
quarts	1.1	litres (L)
gallons (Imperial)	4.5	litres (L)
gallons (US)	3.75	litres (L)
bushels	0.36	hectolitres (hL)
WEIGHT		
ounces	28	grams (g)
pounds	0.45	kilograms (kg)
short tons	0.9	tonnes (t)
TEMPERATURE		
degrees		degrees
Fahrenheit (F - 32)	0.56	Celsius (^oC)
POWER		
horsepower	750	watts (w)
	0.75	kilowatts (kw)

Imperial Units	Conversion Factor	MetricUnits
oz./acre	70	g/ha
lb./acre	1.12	kg/ha
bu./acre	0.9	hL/ha
tons/acre	2.24	t/ha
fl. oz./acre	70	mL/ha
pt./acre	1.4	L/ha
qt./acre	2.8	L/ha
gal./acre	11.2	L/ha
gal./acre (US)	9.35	L/ha
plants/acre	2.47	plants/ha
oz./gal.	6.2	mL/L
lb./gal.	0.1	kg/L
oz./sq.ft.	305	g/m^2
lb./sq.ft	4.9	kg/m^2
oz./ft.row	93	g/m row
lb./ft.row	1.5	kg/m row
ft./sec.	0.3	m/s
m.p.h.	1.6	km/h
p.s.i.	6.9	kPa

To convert from imperial to metric, multiply by the conversion factor.
For example: 10 inches x 2.5 = 25 centimetres

To convert from metric to imperial, divide by the conversion factor.
For example: 25 centimetres ÷ 2.5 = 10 inches

Imperial Conversions:

lb/acre x 0.0033 = oz/yd^2
gal/acre x 0.033 = oz/yd^2

Useful Measurements

1	Imperial gallon	= 4 quarts	1	mile	= 5,280 feet
		= 8 pints			= 1,760 yards
		= 160 fluid ounces	1	yard	= 3 feet
		= 10 pounds of water			= 36 inches
		= approx. 1.2 US gallons	1	foot	= 12 inches
1	U.S. gallon	= 0.8345 or approx. 5/6 Imperial gallon	1	acre	= approx. 209 by 209 feet or 43,560 square feet.
		= 8.3 pounds			
1	Imperial pint	= 20 fluid ounces = 570 mL	1	square yard	= 9 square feet
1	U.S. pint	= 16 fluid ounces = 475 mL	1	square foot	= 144 square inches
1	pound	= 16 ounces	1	mile an hour	= 88 feet a minute
1	tablespoon	= 3 teaspoons = 14 mL	1	cubic yd	= 27 cubic feet
2	tablespoons	= 1 fluid ounce = 28 mL			
1	pound in 100,000 gallons of water	= 1 ppm (part per million)			

Litres per hectare x 0.4 = litres per acre
Kilograms per hectare x 0.4 = kilograms per acre

Calculating Parts Per Million

Parts Per Million

1 per cent	=	10,000 parts per million
Imperial:		
1 fl. oz./gallon	=	6250 ppm
1 gallon in 1,000,000 gallons of water	=	1ppm
1 litre in 1,000,000 litres of water	=	1ppm = 1 mL/1,000 L
Metric:		
1 mg/litre (water)	=	1 ppm
1 g/litre (water)	=	1000 ppm
1 mL/litre	=	1000 ppm

Metric Units for Farm Sprayers

Tank Capacities				*Pressures*	
Imp. gal	**litres (L)**	**US gal.**	**litres (L)**	**pounds per square inch (psi)**	**kilopascals (kPa)**
100	455	100	379	10	70
200	910	200	758	15	100
250	1138	250	948	20	140
300	1365	300	1137	25	175
400	1820	400	1516	30	200
500	2275	500	1895	35	240
600	2730	600	2274	40	275
800	3640	800	3032	45	310
1000	4550	1000	3790	50	345

The Metric System

LINEAR MEASURES

10 millimetres (mm)	= 1 centimetre
100 centimetres	= 1 metre (m)
1000 metres	= 1 kilometre

SQUARE MEASURES (AREA)

100 m X 100 m	= 10,000 m^2
	= hectare (ha)
100 ha	= 1 square kilometre (km^2)

CUBIC MEASURES (VOLUME)

Dry Measure

1000 cubic millitres (mm^3)	= 1 cubic metre (m^3)
1,000,000 cm^3	= 1 cubic metre (m^3)

Liquid Measure

1000 millilitres (mL)	= 1 litre (L)
100 L	= 1 hectolitre (hL)

WEIGHT-VOLUME EQUIVALENTS (FOR WATER)

(1.00 kg) 1000 grams	= 1 litre (1.00 L)
(0.50 kg) 500 g	= 500 mL (0.50 L)
(0.10 kg) 100 g	= 100 mL (0.10 L)
(0.01 kg) 10 g	= 10 mL (0.01 L)
(0.001 kg) 1 g	= 1 mL (0.001 L)

WEIGHT MEASURES

1000 milligrams (mg)	= 1 gram (g)
1000 g	= 1 kilogram (kg)
1000 kg	= 1 tonne (t)
1 mg/kg	= 1 part per million (ppm)

DRY – LIQUID EQUIVALENTS

1 cm^3	= mL
1 m^3	= 1000 L

Appendix C

Plant Diagnostic Lab Submission Form

Ministry of Agriculture, and Lands
Plant Diagnostic Laboratory
Abbotsford Agriculture Centre
1767 Angus Campbell Road
Abbotsford, British Columbia V3G 2M3
Fax: (604) 556-3154
Telephone: (604) 556-3126 Toll-Free 1-888-221-7141

PLANT DIAGNOSTIC LAB SUBMISSION FORM

LAB USE ONLY					
DATE RECEIVED	MAIL ☐	COURIER ☐	WALK-IN ☐	PAYMENT RECEIVED YES ☐ NO ☐	SPECIMEN NO.

PLEASE SUPPLY AS MUCH INFORMATION AS POSSIBLE, SEE REVERSE FOR DETAILS ON HOW TO MAKE SUBMISSIONS*
* All results are kept confidential. Copy of results is sent to submitter only unless stated otherwise.

GROWER	PHONE NO.	SUBMITTED BY	PHONE NO.
FARM NAME	FAX NO.	COMPANY NAME	FAX NO.
ADDRESS		ADDRESS	
POSTAL CODE		POSTAL CODE	
EMAIL		EMAIL	
SITE OF SAMPLE COLLECTION ☐Lawn ☐Garden ☐Greenhouse ☐Indoor ☐Field ☐Nursery ☐Orchard ☐Golf course ☐Landscape ☐Other		COPIES OF REPORT TO BE SENT TO	

COLLECTION DATE	CROP	VARIETY	CROP AGE
DESCRIPTION OF SYMPTOMS (PROBLEM DESCRIPTION, POSSIBLE CAUSES, SPECIFIC QUESTIONS, ETC.) ATTACH SEPARATE SHEET IF NECESSARY.			**PRIORITY** ☐Urgent ☐Routine ☐Casual ☐Research ☐Specific test(s) ☐Invasive Alien Species

CROP SIZE (ha, m^2)	% AFFECTED SIZE	DISTRIBUTION OF SYMPTOMS: ☐General ☐Random ☐Localized	SEVERITY OF SYMPTOMS: ☐slight ☐moderate ☐severe	DATE SYMPTOMS FIRST APPEARED
PREVIOUS CROP	**FUTURE CROP**	**OTHER CROPS OR WEEDS SHOWING SYMPTOMS**		

IRRIGATION TYPE & FREQUENCY	DRAINAGE	DESCRIBE SOIL/POTTING MIX:	pH	SALTS
☐ Overhead ☐ Trickle ☐ Other	☐ Good ☐ Fair ☐ Poor	☐ Light ☐ Medium ☐ Heavy		

PESTICIDES USED (Herbicides, Fungicides, Insecticides, Fumigants, Nematicides, Disinfectants, etc.). Give rates and dates. ☐**Organic**

Before symptoms noticed _____

After symptoms noticed _____

FERTILIZER PROGRAM:
☐ Liquid ☐ Organic
☐ Granular ☐ Other
☐ Slow Release

FEE SCHEDULE

COMPLETE DIAGNOSTIC PROCEDURE
Includes all tests that can be performed by the Plant Diagnostic Lab and are necessary to diagnose the problem. Cost per submission:*

Urgent – 3 days** =	$32.10
Routine – 7 days** =	$21.40
Casual – 14 days** =	$16.05

Complete Diagnostic Procedure Fee includes the Handling Fee ($10.00) and GST (7%)

OR

SPECIFIC TESTS – 3-5 days**
For samples requiring only one test, or a combination of the tests listed below:

- Insect identification
- Virus testing*** (TSWV, INSV, PMMoV, PepMV or BBScV)
- EC and pH (each soil sample)
- Xcp – (*Xanthomonas*-Bacterial Blight of Geranium)

$2 per specific test x number of samples/varieties + Handling Fee ($10.00) + GST (7%) = TOTAL

* Each crop (genus, species or variety) or sample taken from different locations is considered a separate submission. If the same problem is wide-spread on a number of plants of different genera, species or varieties, a combined sample (plants chosen from different species or varieties) will be considered as one submission. A diagnostic report will be provided on the submission, not on individual plants.

** Diagnosis response time (working days) may vary depending upon the total number of submissions in the Plant Lab at a given time. Suggested time frame is not guaranteed.

*** Tomato Spotted Wilt Virus (TSWV), Impatiens Necrotic Spot Virus (INSV), Pepper Mild Mottle Virus (PMMoV), Pepino, Mosaic Virus (PepMV), Blueberry Scorch Virus (BBScV)

(Working Hours: 8:30 A.M. to 4:30 P.M. Monday to Friday)

PAYMENT METHOD:
Cash/Cheque/Credit/Debit. Enclose payment with the sample.
Cheques payable to: **Minister of Finance and Corporate Relations**

(Updated July 13, 2005)

LAB USE ONLY		
CONDITION OF SAMPLE AT RECEIPT:	Cat.	Reg.

Sample Packaging and Submission Information

"Send us lots, tell us lots, and keep it fresh"

1. Specimens must be fresh. Wrap in plastic bags.
2. For woody specimens – wrap in damp newspaper or paper towel to prevent drying out, or wrap in plastic bag.
3. Try to send several plants or plant parts showing the various symptoms. Do not send badly decayed tissue. Include a healthy plant for comparison.
4. **Dig up plants rather than pulling them** from the ground to preserve the roots. If plants are potted, send the whole pot. Enclose base of the plant, roots and pots in a plastic bag that is secured at the plant crown to prevent drying of roots and contamination of leaves with soil.
5. Enclose the top of the plant in a plastic bag secured at the plant crown or wrap carefully in newspaper.
6. Include roots with samples showing symptoms of dieback.
7. Turf disease samples should be at least 10 cm by 10 cm and as deep as the roots. Include the margin of the affected areas in each sample.
8. **Fill out the form with as much detail as possible, attach another sheet if necessary. Package securely, enclose appropriate payment and send to the address below.**
   Diagnostic forms should never be packaged where they will be in contact with any soil or tissue.

Plant Diagnostic Laboratory
BC Ministry of Agriculture and Lands
Abbotsford Agriculture Centre
1767 Angus Campbell Rd
Abbotsford BC V3G 2M3
Tel: (604) 556-3126
Fax: (604) 556-3154

Greyhound bus —

Urgent samples can be sent prepaid via Greyhound, to the Abbotsford Bus Depot. Ministry personnel will collect packages from the bus depot. Send parcels early in the week (Monday - Wednesday) to ensure adequate delivery time.

Courier —

Urgent or perishable samples should be sent by courier.

BCMAL Plant Diagnostic Laboratory —

The BCMAL Plant Diagnostic Lab provides identification of pathogenic and non-pathogenic disorders affecting commercial crops in B.C. and promotes reduced pesticide use by making control recommendations which emphasize IPM (Integrated Pest Management). The Plant Diagnostic Lab is part of the Plant Health Unit in the Food Safety and Quality Branch. Its services help growers protect the production capability and marketability of their crops. The lab does not do soil or tissue, nutrient and/or chemical residue analysis.

Grower's Record

Grower Name: _____ **Farm #:** _____ **Room Size:** _____

Year: _____ **Room #:** _____ **Crop:** _____

Water Source: _____

Application Date	Application Time	Target Pest(s)	Pesticide & Formulation	Pesticide Used Rate/ft² or m²	Water Used (Rate/feet or metres)	Re-Entry Date	Days to Harvest	Notes

Grower's Record

Grower Name: _____ **Farm #:** _____ **Room Size:** _____

Year: _____ **Room #:** _____ **Crop:** _____

Water Source: _____

Application Date	Application Time	Target Pest(s)	Pesticide & Formulation	Pesticide Used Rate/ft² or m²	Water Used (Rate/feet or metres)	Re-Entry Date	Days to Harvest	Notes

Grower's Record

Grower Name: _____ **Farm #:** _____ **Room Size:** _____

Year: _____ **Room #:** _____ **Crop:** _____

Water Source: _____

Application Date	Application Time	Target Pest(s)	Pesticide & Formulation	Pesticide Used Rate/ft² or m²	Water Used (Rate/feet or metres)	Re-Entry Date	Days to Harvest	Notes

Grower's Record

Grower Name: _____ **Farm #:** _____ **Room Size:** _____

Year: _____ **Room #:** _____ **Crop:** _____

Water Source: _____

Application Date	Application Time	Target Pest(s)	Pesticide & Formulation	Pesticide Used Rate/ft² or m²	Water Used (Rate/feet or metres)	Re-Entry Date	Days to Harvest	Notes

British Columbia
Ministry of Agriculture and Lands

OFFICE	ADDRESS	PHONE	FAX
Abbotsford	1767 Angus Campbell Road V3G 2M3		
	Agriculture/Horticulture/Dairy/Food Safety	604 556-3001	604 556-3030
	Plant Diagnostic Lab	604 556-3127	604 556-3154
	Resource Management Branch	604 556-3001	604 556-3099
	Animal Health Branch	604 556-3003	604 556-3010
Burnaby	**Agricultural Land Commission** #133 - 4940 Canada Way V5G 4K6	604 660-7000	604 660-7033
Courtenay	2500 Cliffe Avenue V9N 5M6	250 897-7540	250 334-1410
Cranbrook	1902 Theatre Road V1C 7G1	250 426-1535	250 426-1767
Creston	1243 Northwest Boulevard V0B 1G6	250 402-6429	250 402-6497
Dawson Creek	1201-103rd Avenue V1G 4J2	250 784-2601	250 784-2299
Duncan	Access Centre 5785 Duncan Street V9L 5G2	250 746-1210	250 746-1292
Fort St. John	10043 - Voo Street V1J 3Y5	250 787-3240	250 787-3299
Kamloops	162 Oriole Road V2C 4N7	250 371-6050	250 828-4631
Kelowna	1690 Powick Road V1X 7G5	250 861-7211	250 861-7490
Oliver	Mailing Address: Box 5000, Oliver V0H 1T0 (Actual Address: 201 - 9971 350th Avenue)	250 498-5250	250 498-4952
Prince George	Suite 707 - 299 Victoria Street V2L 5B8	250 565-7200	250 565-7213
Smithers	Mailing Address: PO Box 5000, Smithers V0J 2N0 (Actual Address: 3rd Floor - 3726 Alfred Avenue)	250 847-7247	250 847-7556
Vernon	4607-23rd Street V1T 4K7	250 260-3000	250 549-5488
Victoria	Minister, Parliament Bldgs V8V 1X4 PO Box 9120, Stn Prov Govt V8W 9B4	250 387-1023 250 387-5121	250 356-1522
Williams Lake	300 - 640 Borland Street V2G 4T1	250 398-4500	250 398-4688

General

Crown Publications
For copies of legislation and other government publications 1 250-386-4636

Enquiry BC
Information on programs & services of the provincial government

Vancouver: 604 660-2421
Victoria: 250 387-6121
Other areas: 1-800-633-7867

Provincial Emergency Program (PEP)
To report hazardous spills 1-800-663-3456

Recycling Hot Line
Vancouver: 604 732-9253
Other areas: 1-800-667-4321

Canadian Food Inspection Agency
604 666-6513

Pest Management Regulatory Agency
Health Canada
2720 Riverside Drive
Ottawa, ON K1A 0K9
Website: www.hc-sc.gc.ca/pmra-arla