NEW DEVELOPMENTS IN INTEGRATED PEST MANAGEMENT FOR MUSHROOM CULTURE, CHALLENGES AND OPPORTUNITIES IN QUALITY MUSHROOM PRODUCTION

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ABSTRACT

The continuous and increasing consumer demand for reduced pesticide use in the production of food products highlighted the need to develop novel pest and disease control programs in mushroom cultivation. Strict pesticide regulations in the E.U. and U.S. give farmers less opportunity to use highly effective pesticides against pathogens. The combined technologies in integrated mushroom production might be effective in a high quality, well-maintained shelf system house. The air-circulation systems, over-pressure cultivation tunnels and steam cook-out ability, are helping growers to reduce their use of pesticides. This gives the grower the chance to produce “pesticide-free” *Agaricus* mushrooms. The above-mentioned technological elements are available only on mushroom farms that were built recently. In the very new mushroom units it is possible to produce *Agaricus* mushrooms without using any synthetic pesticides or fungicides. The well-controlled environment provides the potential to integrate pest control with other practical elements (high quality compost and casing, good hygiene) to provide more effective and sustainable pest and disease control. Mushroom houses with less technological instrumentation face a higher risk of pathogens. At the moment, the bulk of mushroom production in the world comes from less effective farms and this highlights the need for new approaches to solving the many problems that they face.

DIFFERENT SYSTEMS - SIMILAR SOLUTIONS

There are no mushroom farms in the world that are exactly the same therefore pest and disease management technologies can vary between growers. Integrated pest and disease technology should be adapted to the local circumstances as the types and ages of mushroom units can vary from farm to farm and problems may arise due to those variable structures. Additionally the growing systems (tray, shelf, bag, block etc.) may have an influence on the pathogen status of a farm. Farms built on the Dutch design usually have highly efficient air circulation and filtration system and the dominant fly species (Sciarids, Phorids and Cecids) must face over-pressured growing rooms, therefore reducing their numbers. The reduced number of mushroom flies reduces the risk of cross-contamination with fungal diseases. The cleaning process of such buildings often includes washing with high-pressure cleaners but this cannot be used on older farms where the floor condition is poor and high-pressure washing with water could spread pathogens hidden in crevices in the floor.

Despite the variability in types of mushroom farms, the main components of an integrated pest and disease management program are similar. The components are summarized in Table 1 followed by Fletcher & Gaze [1].

Table 1. The main components of an integrated pest and disease control programme [1]

Principles of pest and pathogen management	Practices and operations
Entry	Identification and records Filtration, ventilation, air movement Disease removal
Containment	Harvesting hygiene Disinfectant pads Crop termination Farm design
Elimination	Chemical control Environmental control Genetic control

Pathogen pressure can vary depending on continent and climatic conditions but the main mushroom pest and disease species are found wherever mushroom or compost production is significant.

ENTRY

It is essential to understand the importance of some very simple practices to avoid the spread of diseases. A fault in a daily routine, like hand washing, at the mushroom farm may have a high risk of spreading fungal spores. Use of a glowing gel that shows how well the pickers have washed their hands - by illustrating bacteria they missed while washing - may significantly improve hand hygiene. A study that was conducted on children, but which is also relevant for mushroom farms, – showed that it is necessary to improve hand washing techniques. To demonstrate proper hand washing, simply rub a specific lotion on the picker's hands (eg. Glo Germ), and the lotion simulates the spread of tiny plastic fluorescent 'germs' on their hands. Under a black light, the gel creates a yellow glow in areas where dirt and 'germs' are present. Then ask pickers to wash their hands as they normally would, following the prescribed farm process. Finally, a cheap UV lamp can be used to highlight any remaining 'germs'. Under the lamp the 'germs' fluoresce or glow brightly (Figure 1) so they can be easily seen by the pickers [2].

Figure 1. 'Dirty' hands after hand washing to simulate effectiveness of hand washing (from: http://www.teachersource.com)

CONTAINMENT

An effective way to isolate cobweb on the casing is still to cover with paper towel and salt [1]. It is often difficult to find the origin, where the infection comes from. A good preventative standard would be to identify and isolate the origin of the fungal diseases at the farm. Regular sample collection and analysis by molecular and classical methods from mushroom farms helps to find for example the sources of *Verticillium (Lecanicillium) fungicola* [18]. The major principles are to get as many samples as possible from different areas of the farm (entry, room, storage, social rooms, etc) and collect samples at different stages of the crop; before filling, after casing, after emptying, etc. A simple draw or graphical map about the farm, where the sources of pathogen are marked may help the grower to treat the infected areas with disinfectants.

ELIMINATION

The introduction of a new synthetic pesticide-fungicide for use in mushroom cultivation is not to be expected due to high costs of developing a new substance and the relatively low value of the mushroom sector, compared to other areas of agriculture. There are several ways to deal with pathogens but, if possible, they should be cheap and effective methods and techniques are necessary for growers, especially who have only less well-equipped unit.

The presence of *Trichoderma* species, and their negative effects on the yield and quality of mushrooms, is one of the high risks of mushroom production. Many species of *Trichoderma* have been described, producing a range of different symptoms. Many publications have helped to understand the biology of green mould [3, 4]. Farmers who buy Phase III compost usually have fewer problems with green mould, compared to Phase II composts. As Rinker & Castle found in 2005, '*Trichoderma* is a disease that must be managed preventatively' [5]. Recent research showed strains of *T. aggressivum* var. *aggressivum* were resistant to the fungicides thiophanate-methly and benomyl [6]. This underlines the importance of the prevention of green mould. The grains in spawn can serve as food source for *Trichoderma*, non-grain based and reduced grain spawn formulations have been developed and marketed [7]. As in nature *Trichoderma* species have antagonists; a biofungicide containing *Bacillus subtilis* was introduced to button mushroom cultivation in 2008 and its efficacy against green mould in oyster production was good [8]. The complex structure and high-range types of bacterial colonies in the compost may have some, as-yet unknown beneficial effects on the crop.

Other major fungal diseases like *Cladobotryum dendroides, Mycogone perniciosa* or *Lecanicillium fungicola* var. *fungicola* (formerly known as *Verticillium* [9]) are almost always present in the old farm structures. The well-maintained and disinfected Dutch-type houses are less susceptible to high losses due to of these pathogens but if they are present, then hygiene protocols must be reviewed. Fungal diseases cause more serious problems in older structures. The limited number of permitted pesticides in mushroom culture against fungal pathogens can make disease control more difficult. However, more tolerant and resistant pathogens can also be 'selected' for because of automatic and routine usage the fungicides. Recent researches also indicate that more aggressive strains of dry bubble disease can occur [10] and may cause serious losses to growers in the future. On the other hand, an earlier article suggested that the lack of variation in the recent isolates as compared to the older isolates (more than 45 year) indicates that the *L. fungicola* population may be becoming more homogeneous [11]. To prepare for the appearance of more aggressive pathogens it is essential to understand their biology. The host-pathogen interaction and its model is widely described; it is always under revision, particularly from with regard to humans [12]. More focused research is needed in relation to the edible mushrooms group. Mushroom breeders and geneticists are interested in what happens at gene level when a pathogen appears in cultivation. Improving the genetic resistance in mushroom cultivars is very costly and it is usually done by large spawn manufacturers, who could charge premium prices for new resistant cultivars.

The biological control of *Sciarids* has been used for years with good experiences; no tolerance has neen detected so far. *Steinernema feltiae,* an entomopathogenic nematode is effective against immature dipterous insects, including fungus gnats. Its life cycle is very short, completed in a few weeks and hundreds of thousands of new infective juveniles emerge in search of fresh hosts [13]. Casing can be treated by *Bacillus thuringiensis* var. *israeliensis* as well. It produces a toxin, which is poisonous to sciarid larvae [1]. The usage of these biopesticides is not so frequent with Hungarian growers because of the high costs of the products and limitations in storage conditions and spraying techniques.

Since antiquity, essential oils have been widely used for bactericidal, virucidal, fungicidal and insecticidal applications [14]. Most of them are extracted by distillation from aromatic plants and they contain a variety of volatile and non-volatile molecules. *In vitro* physicochemical assays characterized most of them as antioxidants [14]. In eukaryotic cells – such as fungi or animals - essential oils can act as pro-oxidants affecting inner cell membranes and organelles. Depending on type and concentration, they exhibit cytotoxic effects on living cells but are usually non-genotoxic [14]. Many essential oils were tested against many pathogens especially in plant production *in vitro* with variable results. The oils from mint and thyme were shown to have antifungal activity against *Mycogone in vitro* [15]. From the results it is a reasonable assumption that many essential oils may have a negative effect on the growth of fungal pathogens. The main objective is to find those oils (and concentration), that do not harm the mushroom mycelium and yet are still effective against the pathogen. Essential oils are natural products and are more easily approved for use, in addition they can be used for organic production. The importance of essential oils may increase in the future, but many questions remain to be addressed concerning when and how to use them in a crop.

The sterilizing ability of UV radiation is well known in laboratory practice and the food industry. Nowadays it is used in mushroom culture to increase Vitamin-D level [16] and might be effective in disease-prevention. A recent study showed the effect of UV light *in vitro* on *Verticillium fungicola* and *Mycogone perniciosa* tissue culture. The aim of the study was to determine what UV light range and irradiation time was most effective against the two pathogens. The results suggested that with proper application, UV irradiation could function as an additional technique in mushroom protection [17]. Certainly more tests are needed to evaluate the results in mushroom production conditions.

The toxic disinfectant formalin is very effective and relatively cheap but is no longer permitted for use in mushroom production in many countries. Therefore, other substitutes will need to be found which are less toxic to human health.

As a conclusion, new simple techniques in mushroom cultivation are needed in the future to reduce costs and increase efficiency of integrated pest management.

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