Key Research Messages from MushTV

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MushTV is a network of 18 compost producers, grower associations, businesses and research organisations from across Ireland, United Kingdom, the Netherlands, Belgium and Poland, all working together to tackle real industry concerns. In 2011, the Consortium was successful in securing €2.5 million of EU FP7 research funding to find 'solutions for the mushroom industry to threats from *Trichoderma* and Virus'. This is where the MushTV name comes from - **Mush**room research on ***T****richoderma* and **V**irus – it is not a mushroom TV channel, as some have thought, however a video of the project is available to view on the MushTV website (www.mushtv.eu).

Figure 1 Consortium meeting in Poland June 2014

At the outset of the project, one of the key challenges facing the European mushroom industry was the regulatory obligation to adopt an 'Integrated Pest Management' (IPM) approach to pest and disease control. The EU legal requirements were outlined in the Sustainable Use of pesticides Directive 2009/128/EC (SUD) and individual countries had to then enforce what are known as the "Sustainable Use of pesticides Regulations". The underlying principles of the SUD regulations are to safeguard human health and the environment, but it does require a change in attitude by composters and growers towards pest and disease management. The objectives of MushTV were to provide information and solutions that were compatible with an IPM ethos.

IPM Solutions

Integrated Pest Management is described as *'a program of prevention, monitoring, and control which offers the opportunity to eliminate or reduce the use of pesticides, and to minimise the risk to human health and the environment'*. Managers and technical staff must have a greater understanding of the life cycle and biology of the pests and diseases they are trying to control. They must monitor levels of pests and diseases, know how they spread around the farm or facility, know the best hygiene measures to control them, ensure that hygiene measures are employed correctly, use biological and non-chemical control measures where possible, keep updated with advances in IPM control measures, and, only as a last resort, use the least toxic chemicals available when other avenues have been exhausted. The mushroom industry is already well placed to be IPM compatible, but it can still encounter serious pest and disease issues which may be challenging to control.

***Trichoderma* and Virus**

Two diseases were of primary concern to the MushTV network; 'compost green mould' caused by *Trichoderma aggressivum* (Figure 2) and 'Brown Cap Mushroom Disease' associated with the Mushroom Virus X (MVX) complex of viruses, which causes white mushrooms to turn brown and loose quality (Figure 3). Both diseases have caused serious economic losses to businesses across Europe since 2000. Disease prevention is preferable to disease control as the impact of early infections can have devastating consequences.

Figure 2 Compost Green Mould

Figure 3 'Brown Cap Mushroom Disease'

Three things are the key to a good IPM strategy. **Diagnostic tools** are an aid to identifying pathogens precisely and can provide an early warning of a problem if used routinely. Similarly, **new knowledge** is needed as technological developments can uncover new niches for pathogens to exploit. And thirdly, **disinfection** and hygiene are the cornerstone of all IPM programs. MushTV provides new information on all three.

Diagnostic Tools

MushTV has developed two new diagnostic tools – one for detecting *Trichoderma aggressivum* in Phase 3 compost (Figure 4) and one for detecting the viruses causing Brown Cap Mushroom Disease.

New research has shown that the pattern of volatiles produced by *Agaricus bisporus* during a normal spawn run in a Phase 3 tunnel is different to the volatile pattern produced when it is infected with *Trichoderma aggressivum.* The method requires expensive equipment at the moment which makes it less attractive for routine use but the cost of such equipment is decreasing all the time and the method may become more affordable in the future.

Figure 4 New volatile diagnostic techniques under development

We now know that Brown Cap Mushroom Disease is caused by the virus identified as '*Agaricus bisporus* Virus 16' or AbV16 and that two other viruses (AbV6-2 and MBV) may also have some involvement. Genome-sequencing of the many MVX viruses has enabled the development of new highly-sensitive diagnostic tests that can detect the viruses at low levels in compost, prior to mushroom production. This test offers the European mushroom industry innovative opportunities to monitor virus and disease levels and focus hygiene measures on a prevention strategy.

New Knowledge on *Trichoderma aggressivum* in bulk Phase 3

MushTV has generated new knowledge about how *Trichoderma aggressivum* develops and spreads within the Phase 3 system. We now know that a single *Trichoderma* infection only colonises a small (~1 m diameter) localised volume of compost inside a Phase 3 tunnel. Most of the compost in the tunnel will therefore be "*Trichoderma*-free" and, under normal conditions, will produce high yields. However, experiments have shown that when a small volume of *Trichoderma*-infected compost is mixed with uninfected Phase 3 compost during tunnel emptying, transportation and shelf filling, the effects are catastrophic, with large volumes of good quality "selective" compost suffering 80-100% crop loss. Furthermore, machinery, conveyors and vehicles in contact with the *Trichoderma*-infected compost were shown to spread the disease to compost from a newly opened tunnel, causing compost green mould to occur in the new crop, although the effects were not as severe. Meticulous attention to cleaning and disinfecting equipment and facilities successfully eradicated the infection sources so it is recommended to continuously monitor for the presence of *Trichoderma* during tunnel emptying. This can be achieved with simple air-drop plates and swabs or by having Phase 3 compost analysed for presence of *Trichoderma aggressivum* on a regular basis. Farms that do not use steam cook-out to kill off crops have a high risk of recirculating the disease on the farm. Thus it is the responsibility of ALL – composters, transportation contractors and growers - to prevent major outbreaks occurring.

Figure 5 *Trichoderma aggressivum* compost and cropping trials at AFBI, Loughgall

New Knowledge on Brown Cap Mushroom Disease in bulk Phase 3.

New knowledge has also been generated about how Brown Cap Mushroom Disease develops and spreads. Experiments have shown that when Phase 3 compost is infected with the Brown Cap Mushroom Virus (AbV16) it does not always lead to symptoms developing in the crop (Figure 6), and consequently the infection is likely to go unnoticed. Severe symptoms tend to occur when infected compost from a crop with symptoms, re-infects Phase 3 compost at filling. Thus the problem tends to be more severe on particular farms where post-crop hygiene is compromised. A good steam-cook out is essential to ensure all virus-infected compost is killed off before the spent compost is emptied. Just as with *Trichoderma aggressivum*, virus-infected compost fragments can contaminate equipment, transportation vehicles and filling equipment therefore meticulous attention to cleaning and disinfection is needed to eradicate the problem. We still do not understand why

some virus-infected mushrooms remain white and others go brown, but virus levels in the brown mushrooms are very much higher. The fact that many virus-infected mushrooms appear normal means that the extent of the problem is probably underestimated. Regular monitoring of compost and mushrooms for presence of virus is key to ensuring the disease does not get out of control.


Figure 6 Brown Cap Mushroom Viruses (BCMV) trials at Teagasc

Disinfection.
MushTV reviewed the efficacy of 12 disinfectants, representing all the major groups of products available across Europe. Apart from Formalin (currently available in the Netherlands but under review), no disinfectant was able to kill *Trichoderma aggressivum* in compost fragments, while few totally killed *Agaricus* (which transmits virus) in compost. This makes control of *Trichoderma* and Virus more difficult. It is therefore essential that all equipment and surfaces are thoroughly cleaned of compost fragments in order to protect Phase 3 compost from contamination.

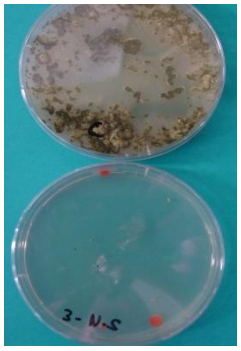

Figure 7 Disinfectant efficacy and residue trials at PRI, Wageningen and Inagro, Belgium

Collaboration into the Future.
Probably, the most outstanding achievement of MushTV has been the collaboration and networking that has flourished among a group of passionate mushroom composters, growers and scientists (Figure 8), all working together to resolve common problems. MushTV partners look forward to working together in the future on other challenges of mutual concern. There is still new knowledge required and innovations to be discovered that can benefit the mushroom industry.

So stay tuned to the MushTV channel!

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Figure 8 MushTV Consortium

	MushTV Consortium	Country	Logo
Grower Association	Commercial Mushroom Producers Cooperative Society Ltd.	Ireland	
	Agriculture and Horticulture Development Board (AHDB)	United Kingdom	
	Coöperatie Funghi UA (Fungi)	Netherlands	
	Stowarzyszenie Brany Grzybów Uprawnych (SBGU)	Poland	
	Vereniging van Onafhankelijke Champignonkwekers (VOC)	Belgium	
	CNC Grondstoffen B.V. (CNC)	Netherlands	
Industry Partners	Custom Compost	Ireland	
	Monaghan Mushrooms Ltd	Ireland	
	Hooymans Compost BV	Netherlands	
	NV Karel Sterckx	Belgium	
	International Mushrooms Ltd. Trading as Sylvan Ireland	Ireland	
	The CIRCA Group Europe Ltd.	Ireland	
Research Partners	Teagasc – Agriculture & Food Development Authority (Co-ordinator)	Ireland	
	Stichting Dienst Landbouwkundig Onderzoek (PRI)	Netherlands	
	East Malling Research (EMR)	United Kingdom	
	Agri-Food & Biosciences Institute (AFBI)	United Kingdom	
	PROVINCIAAL EXTERN VERZELFSTANDIGD AGENTSCHAP IN PRIVAATRECHTELIJKE VORM VZW (Inagro)	Belgium	