INTEGRATED DISEASE MANAGEMENT OF TURFGRASS - THE THEORY

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Integrated disease management (IDM) is a procedure of maintaining disease pressure below defined thresholds by using all of the available control options in a combined manner, while minimising the risk to humans, other organisms and the environment. IDM is not a new concept but the idea of implementing a complete IDM plan can be rather daunting with regard to the time and effort that can be involved in putting it together. The aim of this article is to outline the fundamental steps involved in any IDM plan and to show the benefits of each with regard to disease management. Your IDM plan can be started at any time and can include as much or as little information time and resources allow, but can be added to over time, as new problems develop or as new information on control options becomes available. It really is a process of continuous improvement.

WHY HAVE AN IDM PLAN?

One of the main reasons for having an IDM plan is to ensure that you and your staff are aware of all potential disease problems that can develop on your course, the reasons for their development and the control options available. If the IDM plan is maintained as a written document, all members of the greenkeeping staff can ensure that they are up to date on disease management procedures.

HOW DO YOU BUILD AN IDM PLAN?

1) MANAGE THE TURF TO MINIMISE DISEASE

The first step in any IDM strategy must be to plan and manage the turf in such a way that minimises the likely incidence of disease. Trying to limit the conditions that favour disease will mean that disease incidence and severity of outbreaks will be lower and control options become more effective. Whether you are involved in the design of a new course, construction of a new area or reconstruction of parts of your course, you can keep in mind the conditions that are likely to favour disease while planning the physical design and specification of materials to be used.

Water availability and relative humidity

Since most disease problems are caused by fungi and the majority of fungi need a period of free water to enable infection to take place, planning and management should include consideration of factors that will minimise the period of leaf wetness and improve surface drainage. The water requirement of fungi for infection may not necessarily be leaf wetness, but high relative humidity, encouraged by water availability around the base of the sward, air and rootzone temperature, shade and reduced air movement, can be all that is needed for infection to take place. Ensuring that all of these factors are managed to minimise the duration of humidity will lessen the opportunity for the fungal pathogen to develop in the sward.

Temperatures and rootzone

Temperature is also a key factor in fungal growth and infection. It is not necessarily the temperature that supports optimal fungal growth that provides the ideal temperature for disease to develop. Disease occurs when the balance of environmental conditions is more strongly in favour of the fungus than the plant and therefore we must try to

keep this balance in favour of the plant. The type of the rootzone is not strictly important when it comes to disease development but what is important is the ability of the rootzone to support healthy plant growth. If the rootzone is prone to compaction, reduced oxygen availability to the plant roots, restricted nutrient availability and limited water movement away from the base of the sward, the plant's strength is more likely to be compromised and fungal growth encouraged. Disease development under these conditions is therefore much more likely.

Maintenance of the sward

(e.g. height of cut, plant strength, plant nutrition)

The way in which the sward is maintained has an important part to play in both the occurrence and the severity of disease development. Right from the initial preparation of the seedbed, young plants need to be encouraged to establish quickly and mature into a strong sward. Any slow establishment or forced, weak growth is likely to succumb to infection. The height of cut can have a dramatic effect on disease development and the severity of several foliar diseases can be significantly reduced by slightly raising the height of cut.

It is worth being aware that the nutrient availability to the sward can have an important effect on the development of certain diseases. One example is the role of manganese in the development of take-all patch disease. Manganese is utilised by the plant in the production of compounds that are released in to the rootzone and that effectively reduce root infection by the take-all pathogen, Gaeumannomyces graminis. This fungus, however, is able to convert the manganese to a form that cannot be taken up by the plant roots, effectively reducing its availability in the rootzone and reducing the plants ability to produce the required compounds. An equilibrium develops between the fungus converting the manganese to an unavailable form and the beneficial organisms (antagonists) in the rootzone that convert the manganese back to a form that can be taken up by the plants. The greater the amount of manganese applied to the rootzone or the higher the antagonist population, the more likely the plant is to maintain its natural defence from this pathogen.

2) KNOW YOUR POTENTIAL DISEASES

Being aware of the potential disease problems that could develop on your turf is the second key step in any IDM strategy. Once you have identified what the potential problems are, it is important to be able to recognise the initial stages of disease development and appreciate all of the factors that can encourage pathogen activity so that they can be minimised before disease occurs. Accurate identification of the cause of any disease problem is fundamental to ensuring that an effective long-term control plan is implemented. You cannot effectively manage a disease outbreak if you misidentify its cause. All disease is caused by a pathogen and the majority of diseases in cool-season turf are caused by fungal pathogens. However, it is worth keeping in mind that plant parasitic nematodes are increasingly being associated with symptoms of disease and that other microorganisms can also adversely affect the sward. Many fungal diseases provide evidence of their infection, e.g. black mycelial growth along the stem and root tissues in take-all patch, blackened rotted crown tissues in anthracnose basal rot and red needles throughout areas affected by red thread. Nematode problems may be more difficult to see but reduced root depth and quality, deformed root growth and galling/swelling to the roots and stem bases may be indicators of nematode infection.

Once the potential diseases have been are confirmed it is important to monitor their populations and establish thresholds above which damage to the sward is unacceptable. Nematode populations can be monitored through analysis but fungal disease must be maintained below unacceptable levels by monitoring for the initial symptoms and preventing development to unacceptable levels.

3) PULL TOGETHER ALL TOOLS OF DISEASE CONTROL

Once you have identified the unacceptable disease thresholds, you can begin to pull together all aspects of disease control that will allow you to maintain conditions that are unfavourable for disease development. There are four main ways of controlling disease development and these are either through cultural, genetic, biological or chemical means.

Cultural Control

With regard to cultural control, the emphasis has to be on ensuring strong plant growth, not only strong leaf tissues but also strong, deep root development that is achieved through the maintenance of a healthy rootzone. The importance of a balanced nutrient input, correct mowing height for the grass type and use, water management and air movement through the rootzone and the sward have all been mentioned earlier but overall, cultural management of the sward and the rootzone to optimise turfgrass strength is the key to reducing disease outbreaks. All other control options increase your ability to maintain minimal disease outbreaks as long as the basic, cultural maintenance procedures are implemented.

Genetic Control

Genetic control relies on the inherent variation within different grass types and cultivars to minimise disease development through any sward. Monocultures, where one grass cultivar is used on a give area, may have advantages over a mixed sward with regard to the playing quality and sward uniformity. However, the perfection that can be achieved through this practice may be short-lived if disease takes hold in the sward because, with an identical genetic make-up, all plants will be equally susceptible to infection and disease can spread rapidly. In a sward containing different grass types or cultivars, the variation in the plants genetic make-up will present a barrier to the rapid progression of any disease. Although all grasses are susceptible to one or more diseases, they will vary in their sensitivity to infection and to the conditions that will allow disease to develop.

Biological Control

Biological control can be broken down in to two main areas, i.e. the application of microorganisms to the sward/rootzone to bolster the

natural population and reduce the likely incidence of infection, or the application of products or practices to increase the natural population of beneficial microorganisms in the rootzone.

Chemical Control

Chemical control or perhaps more correctly, the use of fungicides or plant protection products in an important component in an integrated approach to disease management. There have been a number of recent changes made in pesticide legislation and greater emphasis on users achieving accurate product application. The following is an attempt to bring you up to date with the current UK approval status for fungicides and to summarise the different types of product available, their mode of application, their activity against the pathogen and the likely chance of the target fungi developing reduced sensitivity or resistance.

Although more correctly called plant protection products, I will continue to refer to these products as fungicides as this term is now so familiar to us all. Fungicides can be broadly regarded as either contact or systemic in their movement once applied to the turf. Additionally they are also classified as to how they arrest the development of the fungus (also referred to as the mode of action). Understanding both of these attributes of a fungicide will help you chose the correct product for each particular application.

MOVEMENT OF FUNGICIDES

Contact fungicides

With contacts, the fungicide remains where it has been applied, forming a barrier to infection that protects the treated leaf but that will not prevent development of any infection that has already taken place. Since contact fungicides remain on the leaf surface, they are prone to breaking down or weathering over time and newly emerging tissues are not protected. They can be applied at any time of the year but if applied whilst the plant is actively growing, they will need to be reapplied quite frequently to maintain efficacy. They are ideally used when there is little growth in the plant and when the environmental conditions are more conducive to certain fungal disease as their barrier against infection is more long-lived. In the UK amenity market, we have only one active ingredient that can be classed as having contact activity and that is chlorothalonil.

Systemic fungicides

All of the other active ingredients tend to be called systemics but should more correctly be regarded as local or acropetal penetrants (see Table 1). There is only one fully systemic compound with approval for use and that is fosetyl-al which has off-label approval for use against Pythium on greens and tees. Following application of all other systemic products, their movement within and around the plant can vary and it is therefore important that you select the correct active ingredient and it is imperative that you apply the formulated product correctly to ensure efficacy.

Table 1. Active ingredients identified within their different chemistry group and movement following application

a Approval revoked on certain products (as of 31 August 2008) and others have the approval amended to include only worm control
b Approval revoked on certain products (as of 31 August 2008)
c Approval revoked (as of 30 June 2008)
d Products must be re-evaluated under PPPR
e Approval unsupported on certain products (as of 31 August 2007)

Local penetrants

For the local penetrants, the applied active ingredient moves in to the plant cells around the area of application but does not move through the vascular system of the plant. Some of these local penetrants have high mobility in a vapour phase that means that they are continually being redistributed around the leaf surface.

Acropetal penetrants

As for the acropetal penetrants, these products move upward through the plant, from the point of application, in the xylem (water moving vessels). The degree of control achieved against a given disease will depend upon correct product placement, as there will be no downward movement in the plant by any of these products. Using the correct water volume, (which varies with each product label) is very important to ensure that the turfgrass is adequately covered. As an example, azoxystrobin has approval for use against take-all patch, a disease of the root and stem base tissues. If the product is not applied in sufficient water to allow it to be taken up through the roots, the product will not reach its target site.

Mode of action

(how a fungicide stops the development of the fungus)

It is important to understand how these products work to ensure that you apply them in the most effective way to achieve the desired control. In addition to their differential movement around the plant, active ingredients vary in the way in which they target the fungus.

Multi-Site Inhibitors

In the case of chlorothalonil, it is a so-called multi-site inhibitor that means that it targets many processes within the fungus, stopping fungal growth in several different ways. Due to this multi-site activity, it is quite unlikely that any fungal population will develop reduced sensitivity to this active ingredient.

Single Site Inhibitors

The same cannot be said for the other active ingredients. Regardless of the chemical group to which they belong, the local or acropetal penetrants all target a single site in the fungus (the target site varies on the group of chemistry to which the product belongs). Being active on a single site there is more of a chance that the fungal strain with reduced sensitivity will be selected from the general fungal population, if it is repeatedly exposed to the same chemistry. What this means is that is if you continually select, for example, a fungicide from the strobilurin group for application to the turf, there is a strong risk that a strain of the fungal pathogen will be selected that shows reduced sensitivity to

Contact activity	Systemic activity (local penetrant, acropetal penetrant)			
Phthalonitriles	Dicarboximides	Methyl Benzimidazole Carbamates (MBC)	DeMethylation Inhibitors (DMI)	Strobilurins
chlorothalonil **de**	iprodione **d**	carbendazim **a**	epoxiconazole	azoxystrobin
		thiophanate-methyl **b**	fenarimol **c**	pyraclostrobin
			myclobutanil	trifloxystrobin
			prochloraz	
			propiconazole	
			tebuconazole	

that class of fungicides and once that happens, future applications of fungicides containing that chemistry will be ineffective. The same is also true for the MBC group of fungicides but for the DMI (also known as the SBIs) and Dicarboximide groups of fungicides, any strain that shows reduced sensitivity compared to the natural fungal population will not be as fit for survival as the natural strain. Reduced sensitivity to DMI fungicides is generally seen as limited longevity of the applied product and a need to reapply more frequently to achieve the same level of control. As for the Dicarboximides, if application of the formulated product is suspended, the selected fungal strain showing reduced sensitivity will be lost from the fungal population and the products will eventually be able to be reintroduced in to the IDM plan. It is also worth knowing that some groups of fungicides are more susceptible to resistance than others.

Managing Resistance

In the UK, there is currently no evidence of resistance having developed to any class of fungicide in amenity situations although in agriculture and horticulture, resistance to fungicides is a real issue. However, laboratory tests have identified reduced sensitivity of Microdochium nivale to the MBC fungicides. Elsewhere around the world, and most notably in the USA, certain turf diseases (or more correctly, the fungi that cause the disease) have shown resistance to a range of fungicide chemistries and in some cases, an individual disease has developed resistance to two or more different types of chemistry.

In the past, fungicides were approved in the UK under the Control of Pesticide Regulations (COPR) however, with the on-going EC review of all active ingredients and a change towards harmonisation of plant protection products across Europe, fungicides are now approved under the Plant Protection Products Regulations (PPPR). The initial phase of this harmonisation of approvals across the EC meant that all active ingredients had to be assessed and, if accepted, placed on to the so-called Annex 1 list of approved active ingredients. Once on the Annex 1 list, it becomes the responsibility of individual EC Member States to register approvals of formulated products. The active ingredients listed in Table 1 were those with approval for use in the UK in June 2007. Some of the products containing these active ingredients have since been withdrawn from the market or the approvals for the active ingredients themselves may have changed. An outline summary of these changes is also shown in Table 1 but the Pesticides Safety Directorate web site *www.pesticides.gov.uk* will provide complete and up to date information on all approvals. The Turf Disease Centre can be contacted at: *www.theturfdiseasecentre.co.uk.*

In many cases, the marketing companies will need to re-register products that contain active ingredients that were initially approved for use under COPR (e.g. chlorothalonil, iprodione). Under the new regulations (PPPR), there is much greater emphasis placed on companies to provide information relating to the possible risk of resistance developing and to justify the recommended application rate to ensure that it is the minimum effective dose (the least amount of product that needs to be applied in order to achieve the required control). The provision of information on the risk of resistance developing to any active ingredient and on resistance management strategies, including this information being detailed on the product label, is now necessary before any approval is granted. In addition a range of other data may be requested by the Regulatory Agency. This increases the registration cost to the development company and with amenity being such a small market, certain products will be lost due to the company taking the decision to withdraw support of the approval as it considered not being economically viable. All new active ingredients that come to market will automatically be registered under PPPR.

In order to maintain approvals for the fungicides we need to use the products carefully and correctly, to maximise their efficacy and minimise the potential for selecting resistance from within the fungal population. The new systemics are used at very low application rates and therefore, the onus is on the user to ensure that the area to be treated is accurately measured, that the correct amount of formulated product is used in a given application and that the water volume chosen will allow the product to be deposited where it is needed. In addition to that, it is imperative that the sprayer is correctly maintained and calibrated; the correct nozzles have been selected and checked to ensure that they are not damaged and that the speed and pressure of the application is set for the correct delivery the fungicide to the turf.

If a fungicide application fails to control the disease, it is usually the case that the product itself is blamed. However, failure of any fungicide application could be due to incorrect product selection or incorrect application by for example, inaccurate calculation of the spray area to be treated, wrong selection or faulty nozzles, incorrect application rate of product or water volume. It could also be due to application to a wet sward or to turf that receives rainfall soon after application. Incorrect disease identification can also lead to control failure. Whether you have misidentified the causal fungus or whether the problem is caused by something other than a fungus, incorrect target identity will at best result in limited control. It is always advisable to seek confirmation of the disease identity if you are uncertain.

4) RECORD AND REVIEW PAST CONTROL OPTIONS

The final steps in any IDM plan must be to evaluate the control options that you have implemented with regard to the management of each disease problem and keep records of what you have done, whether successful or not, so that in future, successful options can be improved upon and those that fail can either be re-evaluated to try and increase their contribution to disease management or disregarded as part of your IDM plan.

The increased legislation that is governing our industry and that is placing ever-tighter controls on product applications, is in place to reduce our impact on the environment and to ensure our safety and that of other organisms. As long as we all play our part in using these control options wisely, there is a greater chance that they will remain available for use for future turf grass managers for diseases we have today and ones that may develop. Turf disease management without fungicides is possible but some compromise on quality may have to be accepted. With an IDM plan in place, you can work to maximise the efficiency of a reduced number of fungicide applications whilst utilising other control options to maintain the diseases below their damage thresholds.