Eco-innovation in golf: pest control or stress control? Institutional aspects of the control of Microdochium patch disease in Britain and Ireland

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Reviewing in progress – comments appreciated

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1. Introduction

Microdochium patch

Microdochium patch, also known as fusarium patch or pink snow mould is a cryptogamic disease caused by the fungus Microdochium nivale (Fr.) Soraurer. It is the most important disease of fine turf on putting or bowling greens in the UK, northern Europe and the Pacific North-West of America. Per year, a typical golf course can experience 7 to 8 outbreaks. The fungus has a wide range of grass hosts, including cereal crops [Gange and Case 2003: 58]. Typical for Microdochium nivale is that it is a low-temperature and high-humidity loving turf pathogen. Cool and wet conditions tend to promote outbreaks in spring and autumn (Ibid.). Typical too, and important for this work, is that this fungus lives predominantly as a saprophyte. It lives on the decaying organic matter at the base of the sward and in the root zone. In order to become a pathogen, the fungus needs to be given the opportunity to infect the turf rather than being able to forcibly enter a healthy plant [Entwistle 2006]. Following this reasoning, a stressed turf will

be more sensitive to Microdochium patch disease. This aspect reinforces the rationale behind comparing two stylised strategies to combat Microdochium patch [Morand 2006b]: S1, or pest control, tries to kill the pathogen while S2, or stress control, tries to reduce host stress so that the saprophyte cannot become a pathogen. In general terms, S1 works with fungicides and S2 with biostimulants, although the boundaries between those tools are not perfectly strict. Biostimulants is a loose term that includes microbial inoculums, energy sources for microbes, soil conditioners and other non-nutritional growth-promoting substances. Some of these are proven to improve resistance to stress. Especially arbuscular mycorrhizal fungi have been found to be effective [Morand 2006b: 14 ff].

Less leeway for pest control strategies (S1)

The evolution of sustainable development policy in Europe has gradually formalised the integration of environmental concerns in all European policies [Morand and Barzman 2005]. In the golf sector, sustainable development policy finds an expression mostly through the regulation of pesticides authorization, and namely the Plant Protection Products Directive (91/414/EEC). This Directive regulates 'the authorization, placing on the market, use and control within the Community of plant protection products in commercial form and the placing on the market and control within the Community of active substances intended for a use specified in Article 2 (1)' [Council of the European Communities 1991 (2004), Art. 1]. This Directive is in the process of being complemented with the proposed REACH Regulation and the Thematic Strategy on the Sustainable Use of Pesticides.

These regulations exert increasing constraints on the technology available to greenkeepers for controlling pests and diseases. A number of active molecules and products have been withdrawn, in particular the most persistent and the ones with the largest spectrum of activity. Innovation means that new molecules emerge but at great R&D costs. In addition, because this stays within the realm of S1, it is an incremental rather than a radical innovation. The history of authorisation followed by withdrawal gives good reasons to expect that a significant number of currently accepted pesticides are likely to face withdrawal pressure. This means that, despite

incremental innovations, fungicide use in the fight against M. patch as part of strategy S1 will become further constrained with time.

Objectives

Our main research objective is to compare the institutional status of two distinct strategies for controlling M. patch in golf putting greens, S1 and S2. With reference to the analytical framework exposed in Morand and Barzman [2005] and Morand [2006a], we equate institution and regularity in human behaviour, and we assume that the effectiveness of an institution depends on its integration both across sectors and across governance levels. Our hypothesis is that S1 is a well institutionalised strategy whereas S2 is not institutionalised yet despite its proven potential.

2. Method

Details leading to the questionnaire are given in Morand [2006b]. These details include an overview of the green turn in the golf sector (and the emergence of tentative environmental management plans), a literature review, the identification of strategies to be compared, the choice of a model disease, the choice of the analytical model, and the specification of hypotheses.

Implementation of questionnaire

Preliminary versions of the questionnaires were tried from 2004 to 2006 and circulated among resource persons (turfgrass and turf disease experts). A finalised and shorter version was created in April 2006. Approximately 250 greenkeepers in Ireland and 650 the UK were emailed an invitation to complete the questionnaire online. We extracted email addresses randomly from a register of the golf sector covering all or most counties in the UK and the Irish Republic. We completed the sample by telephone interviews targeting all UK and Irish counties. The implementation lasted approximately one week. A total of 48 questionnaires were completed (as of 31 May 2006) but for the present paper analysis has started as soon as 44 questionnaires were completed. This represented a low response rate but provided enough material for a pilot survey and a test of our approach.

3. Results

General information

14 Irish and 30 UK golf courses are included in this analysis. The Irish subsample covers 11 counties with three maxima of two cases per county. The UK subsample covers 22 counties with one maximum of four cases per county. A majority of golf courses (28/44) is of the parkland type. The sample includes as well 11 links and 2 heathlands. Most courses (30/44) have 18 holes, just 3 courses have a minimum of 9 holes and 4 golf courses have the maximum of 36 holes. Even though as a rule the smaller courses charge less than the larger courses, fees vary greatly, as do the number of rounds played per year. The 18-holes golf courses charge weekend fees varying from 10 to 160 €. About half of the golf courses follow an environmental plan (21/44) but having this plan does not affect the fees.

The average age of the respondent greenkeepers is 43 and 24/44 respondents are younger than 44. Age bears no relation to having an environmental plan or not. The greenkeeper's education level is very variable. The easiest distinction is between 13/44 without any formal education in greenkeeping or related skills (horticulture, agriculture) and those who have at least attended some form of training.

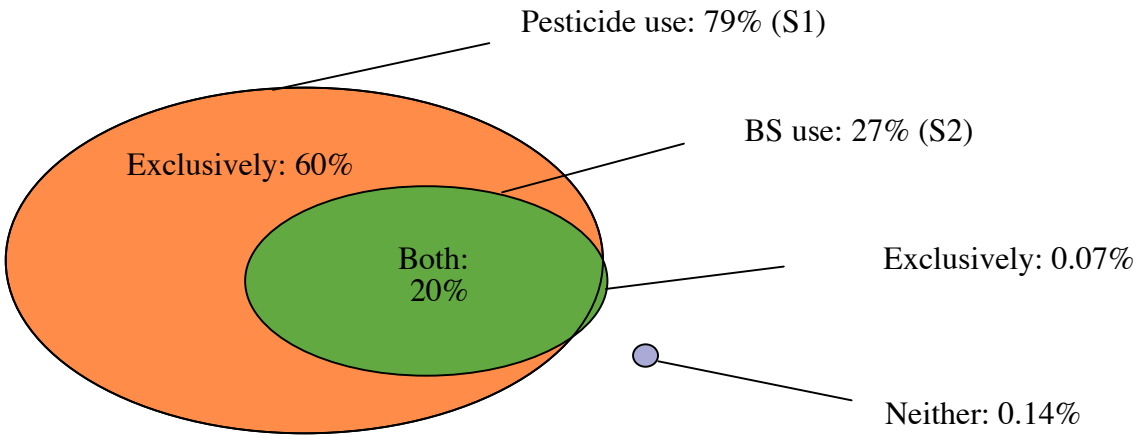

Figure 1. Venn diagram of observations grouped according to strategies (areas are approximations of percentages)

Incidence of Microdochium patch

With regard to the importance of Microdochium patch and its economic incidence, the golf courses split into two groups (Figure 2): 15 with a low percentage of greens affected and a low importance rating (0 or 1 on a scale 0-5) and 19 with a high percentage of greens affected and with a high importance rating (2 or higher). Parklands are clearly more affected than links and heathlands: 14/28 parklands courses versus just 1/11 links course state an incidence of 5. This makes sense as Microdochium patch is reportedly a moist-loving fungus while links courses are typically established on dry coastal sands.

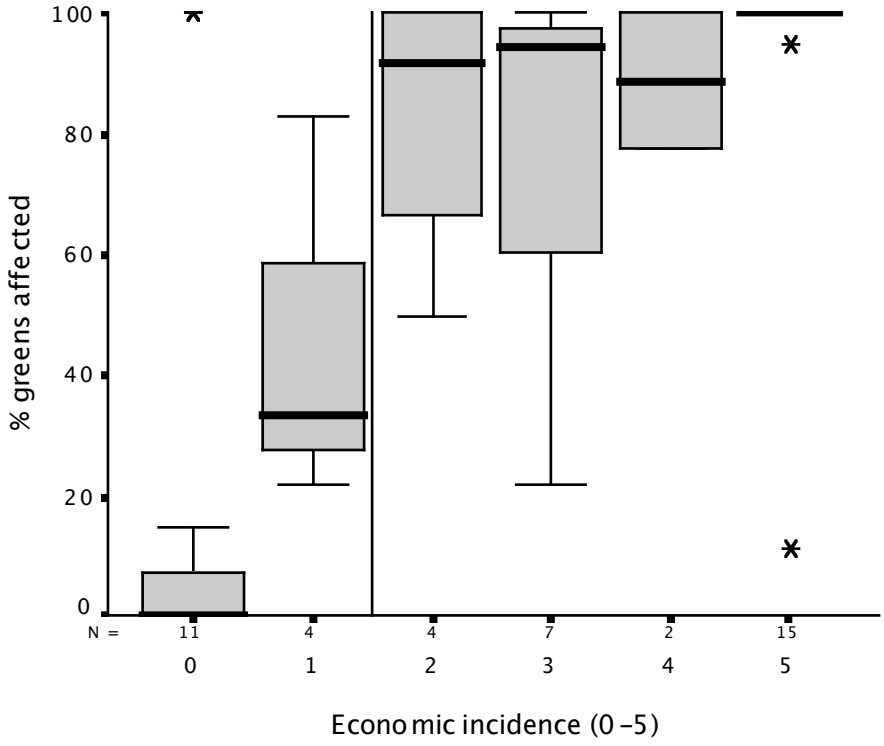

Figure 2. Box-plots of the average percentage of greens affected by Microdochium Patch (M. patch) per category of its stated economic incidence (scale 0-5). Outliers exist for both extremes: 0 incidence but 100% greens affected and 0% greens affected by 5 incidence. Note the high number of cases in the extreme categories (0 and 5).

However, other presumed relationships with M. patch do not show up. The playing intensity (quantified by number of rounds per year) is a stress factor to the greens that tends to favour the establishment of annual grass *Poa annua* which gradually outcompetes sown perennial grasses (mainly *Agrostis* spp. and *Festuca rubra*) [Gange and Case 2003]. *Poa annua* is very sensitive to the disease [Gange et al. 1999], but in our survey a high economic incidence and/or a high percentage of greens affected could occur at any % cover by *Poa annua.* Likewise the annual number of rounds did not affect the dominance of *Poa annua* nor the economic incidence of M. patch (Figure 3).

No other relationship could be established with the importance of the disease. For example, having an environmental plan and fungicide and/or biostimulant use were found to be unrelated to incidence of the M. patch. As to which possible factors determine the risk of a M. patch outbreak, the average ranking of the greenkeepers is climate > grass species mix > nitrogen fertilisation > mowing height > phosphorus fertilisation > pesticide use. So the main factor, climate, is considered beyond the greenkeeper's control even though its importance is believed to be reduced by "good greenkeeper's practice".

(refer to discussion) (refer more to figure)

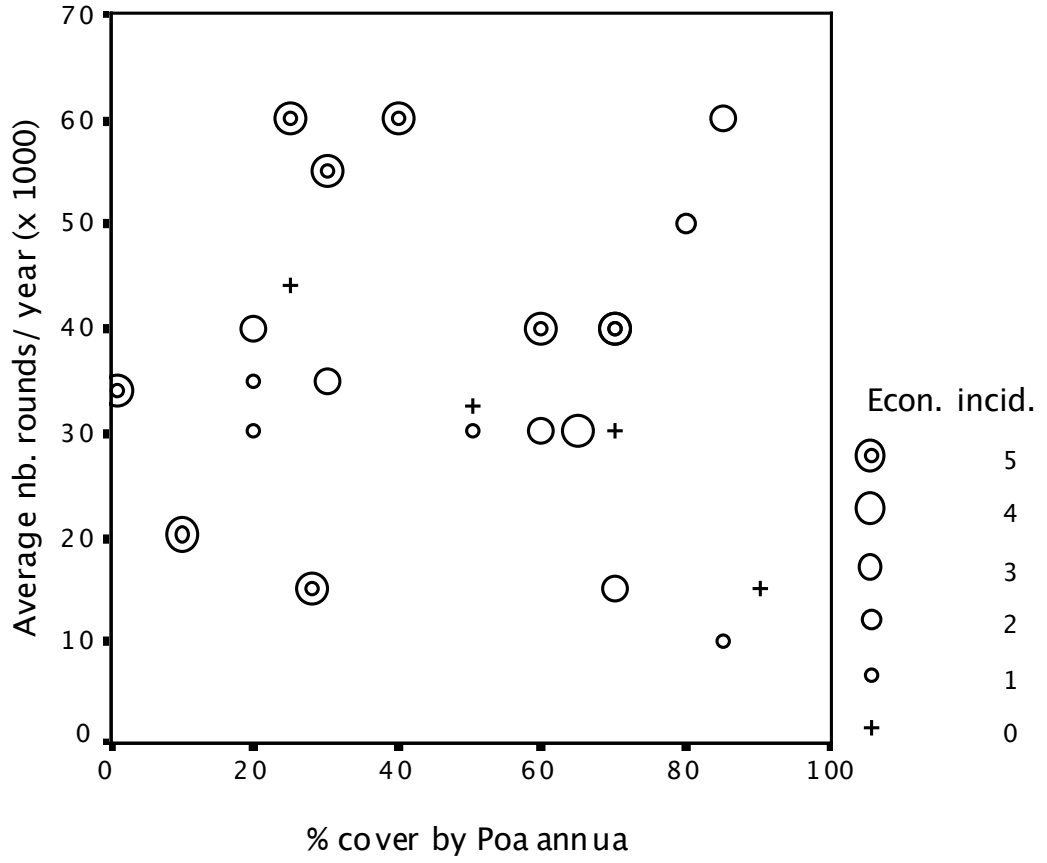

Figure 3. Scatter plot of the percentage cover by *Poa annua* of the greens and the average number of rounds played per year. Markers are according to the stated economic incidence of Microdochium Patch (scale 0-5).

Product use against M. patch

The questionnaire concentrated on the stated use of fungicides to fight M. patch and biostimulant use as an alternative to fungicide use. The majority (35) uses at least one fungicide to fight M. patch. 9 greenkeepers out of 44 state using no fungicide at all and 12 greenkeepers use biostimulants. When crosstabulating biostimulants and fungicide use against M. patch, 26 greenkeepers uniquely use fungicides and 3 uniquely use biostimulants. 6 greenkeepers use none of either type of product and 9 greenkeepers complement both types of product. It should be added though that most biostimulants users say they do not use biostimulants specifically against M. patch.

Among the 9 non-users of fungicides, 4 manage links and 4 manage parklands courses. The economic incidence of M. patch among those non-users is significantly lower than among the users. Only 1 non-user states an economic incidence of 5 of M. patch, the 7 others state incidence 0 (5 non-users) or 1 (2 non-users). It remains to be tested whether the non-users do not use fungicides because the disease is simply not there or because their greenkeeper's practice prevents outbreaks.

Fungicide non-use is again not linked with having an environmental plan or not. Biostimulant use is not linked to an environmental plan either, as a minority of 4 biostimulant users out of 12 adhere to one.

(concluding line)

Knowledge on pesticide regulations and soil ecology

A number of questions were devised, and aimed at testing the working knowledge of greenkeepers on pesticide regulations on one hand and soil ecology on the other. A minority of greenkeepers (16/44) states to "perform soil microbial testing" of their greens. However, the answers on the next question (Which test?) suggested that this test was frequently misunderstood as a soil fertility or pH test.

(how often?)

On the next question whether their greens contain beneficial fungi such as arbuscular mycorrhizal fungi, 36/44 answer "No" or "I don't know" (9 of them stating to "perform soil microbioal testing"). Again, neither of these two variables is related to adhering to an environmental plan.

The remainder of the knowledge questions aimed at typing greenkeepers according to their working knowledge. Greenkeepers were asked to score from -3 to +3 (degree of agreement) or from 0 to 5 (degree of familiarity) 9 statements relating to, on one hand, three important pesticide regulations (coded Q6), and to soil ecology on the other hand (coded Q12).

(too detailed?)

These scores are semi-quantitative variables and were subjected to a Principal Components Analysis, with the greenkeepers as variables and their scores of the statements as cases. Only the two first principal

components (PC1 and PC2 with eigenvalues 14 and 6 respectively) were suitable for intepretation. PC1 accounted for 32% of the total variation and PC2 for 14% of the variation, leading to a total of 46 % extracted. The loadings of the original 44 variables on the two Principal Axes shows a typology of three groups of greenkeepers (Figure 4):

(1) a dense cluster at the positive side of PC1

(2) a group of 6 greenkeepers close to the origin whose variation was not extracted by the two first PC's

(3) a group of 12 outliers whose beliefs differ strongly among each other (wide spread around the origin).

Overlays of categorical variables on this loading plot (such as adhering to an environmental plan, formal education, fungicide and/or biostimulant use) did not yield any interpretable pattern.

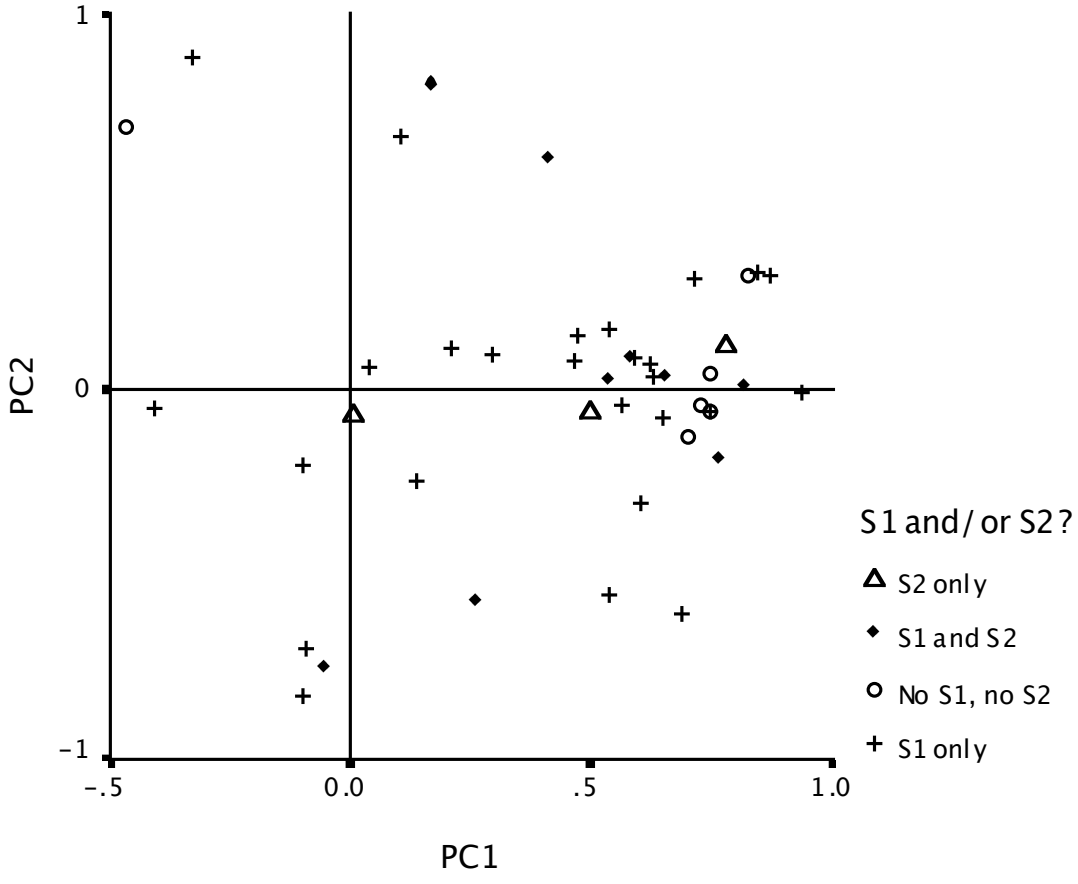

Figure 4. Loading plot of the PCA: scores of the original variables (greenkeepers) on PC1 and PC2. Stated fungicide use (S1) and biostimulant use (S2) to fight Microdochium Patch is overlaid.

(explain more the classification and interpretation of the 3 groups)

The scores of the statements on PC1 and PC2 (Figure 5) give insight into the nature of the statements and greenkeeper groups distinguished on the loading plot. All statements about pesticide regulations (coded Q6) and the statements Q12E (true) and Q12F (false) on soil ecology (Table 1) together at slightly negative values of PC1. They have in common that the majority of greenkeepers scored the majority of these statements 0 ("I am non familiar with this" or "I don't know"). It is interesting to observe that two opposed statements on the same subject (one false and one true) acquire very similar positions in the score plot. The remainder of the statements have slightly positive (Q12C, Q12D and Q12G) and highly positive (Q12A, Q12B, Q12H and Q12I) PC1-scores.

The group with slightly positive PC1-scores is again characterised by a high proportion of 0 scores ("I don't know"). Worth detailing is the pattern of scores of Q12C, which was a false statement like Q12F (Table 1). Apart from the 18 0-scores, there is but one negative score (-1) and 25/44 greenkeepers agree with the statement by scoring it +1 to +3.

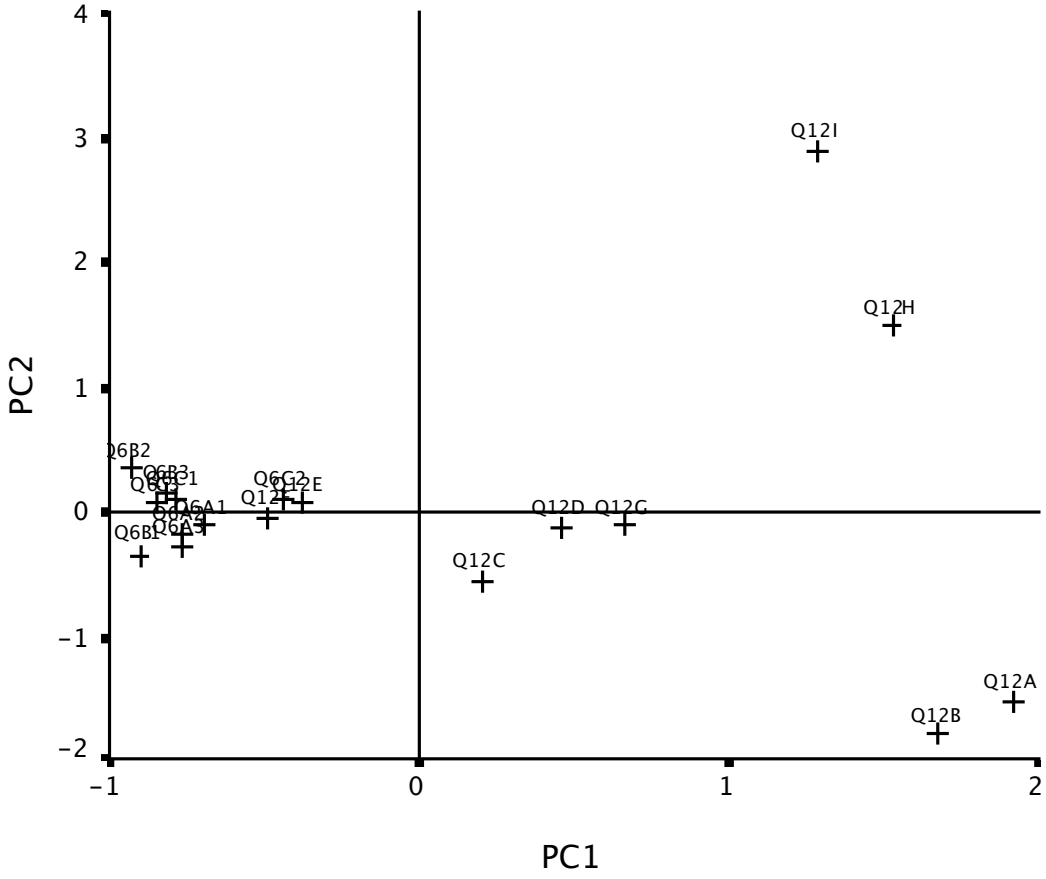

Figure 5. Score plot of the PCA: scores of the cases (statements) on PC1 and PC2. Labels refer to the question codes. Codes starting with Q6 belong to 9 statements on European pesticide regulations (clustered toward negative side of PC1) and codes starting with Q12 belong to 9 statements on soil ecology.

Table 1. Statements on soil ecology

Code	Statement	True/False *
Q12A	A number of fungi are associated with disease, but others can be significantly beneficial to turfgrass	True
Q12B	Some fungi directly enhance plant resistance to stress	True
Q12C	Compost is a BS primarily because it is rich in plant hormones	False
Q12D	Some BS directly enhance plant resistance to stress	True
Q12E	Most BS are rich in free radicals	False
Q12F	Most BS are rich in anti-oxidants	True
Q12G	Less mineral fertilizer is required when some BS are used	True
Q12H	Techniques for controlling turf stress offer a potential to complement fungicide use	True
Q12I	Environmental stress of turfgrass is negatively correlated with playing quality	True

*See Morand [2006b]

(move up the table?)

(explain more)

The group with highly positive scores consists of the only statements scored +3 by a majority of greenkeepers. It is striking that these all relate to controlling turf stress and turf disease. It is also striking to see that if the word "fungi" in Q12B is replaced by "biostimulants" (to become Q12D, Table 1), the statement primarily gets 0 scores. Q12I is the only statement with an extreme PC2-score which in part caused the wide spread within group (3), the outliers. The statement indeed opposes strong believers in the correlation between stress and playing quality and strong disbelievers.

4. Discussion

The main aim of this questionnaire survey was to test our hypothesis that strategy S1 to fight M. patch is highly institutionalised whereas S2 is poorly institutionalised. The quantifiable results as described in the previous section demonstrate that

- M. patch is an important disease that keeps worrying greenkeepers, whether they manage links or parklands and have problems with Poa annua or not;
- Fungicide use for pest control is indeed much more institutionalised than biostimulant use for stress control;
- Awareness of soil ecology is poor and hence acts as a barrier to appreciating the potential of certain biostimulants;
- Knowledge on emergent pesticide regulations is even poorer even though this knowledge is necessary to anticipate future withdrawals of today's fungicides.
- Knowledge on S2 appears poorly disseminated, whereas knowledge on S1 is widely disseminated, by virtue of the regulation itself [see Morand 2006b, Table 1].

Issues related to these general findings are (1) the misunderstanding of certain questions, (2) the lack of meaning of an environmental management plan and (3) the lack of codification of certain practices and concepts and the problems this entailed. These issues are especially apparent when inspecting the comments of greenkeepers, which therefore help illustrate the quantitative findings of the survey.

Significant misunderstanding of questions

Several questions triggered impertinent replies. The most significant example is the question "Do you perform soil microbial testing?" The nature of the answers strongly suggests a poor understanding of the vocabulary used in the question, even though its wording is unambiguous. Some "yes" answers actually covered soil pH tests or chemical soil fertility tests. Others answered "Yes" but could not reply what it involved and why is was done.

Environmental management plan

Adhering to an environmental plan or not, as stated by the greenkeeper did not prove of any significance in determining fees, strategies, knowledge levels or disease incidence. The reasons given for (not) having one show that the concept can cover very different realities, and that several greenkeepers have one or not for practical reasons as Table 2 shows.

Table 2. Selected comments on the question of adhering to an environmental management plan (EVM).

EVM?	Why / Why not?
No	Too much time consumed. Pays attention to environment nonetheless. Uses alternative techniques where feasible. Lots of wildlife on site.
No	Too time consuming. General environmental measures in place. No plan as such.
No	No specific plan but environment taken into consideration
No	Environment people tend to take over. Operates his own environmental plan that, however, is not affiliated to any particular government policy. Would not specify, except for the fact that his agronomist uses biostimulants.
No	The course is being re-developed so its not feasible but it is in planning.
No	Cost prohibition
No	I work to my own plans. I have looked at some of the systems but find them full of jargon and too restrictive.
No	We are running the course environmentally but are not affiliated to any system. I am using very little fertiliser and the small amount I use is organic. No fungicides.
No	Not had time yet
No	No reason, just have not put a plan into operation.
Yes	SSSI site
Yes	To keep up with current trends.
Yes	To document, promote and encourage the ecology thus improving the ambience around the course
Yes	Part of national park (Nature reserve)
Yes	Conserve local wildlife; improve diversification of wildlife post farming practices.
Yes	To achieve recognition for our commitment to ecologically sound environmental stewardship.
Yes	Very environmentally conscious. BIGA Award winners 2003
Yes	For reasons of public safety.
Yes	We are conscious of conservation.
Yes	Course is part of an agricultural estate and we have a conservation service.
Yes	I care , and wish to have continuity if i am not here.
Yes	We comply with iso 14001
Yes	Because its common land with sheep and horses.

Codification matters

In general, the responses made it clear that S1 is a highly codified practice, whereas S2 is a poorly codified practice. The strong codification of S1 results from the massive R&D being imposed by the regulation of plant protection products. The poor codification of S2 results partly from the fragmented institutionalisation of manipulating turf soil ecology in biological ways, but also partly from the fact that biostimulation can also happen through a host of cultural techniques such as aeration, surface drainage, fertiliser regimes, pH adjustment etc. In that sense, it is worth asking the question if S2 can be codified at all.

In general, lack of codification becomes a difficulty even for researching the ill-codified strategy itself. Several greenkeepers mention that they use products with biostimulation properties (compost, seaweed, etc.) and respond in the same that they are not using biostimulants. Lack of codification and poor working knowledge on soil ecology worked together to produce a host of interesting comments on biostimulants, as shown in Table 3.

Table 3. Answers on questions of advice on fungicides and corresponding answers on questions of advice on biostimulants.

Easy advice on fungicides?	Comments	Easy advice on BS?	Comments
N/A	I use soluble iron and you don't like to use chemicals and this means M.patch doesn't occur.	Yes	Why are they so expensive?
No	Support from reps that visit. Up to date information.	No	Not quite sure about biostimulants.
No	Don't use fungicides because the greens build up a resistance over time. We have improved seed cultivars as an alternative.	Yes	Is it effective?
Yes	Very good advice and backup from representatives, who provide very objective information on pros and cons of each individual chemical product.	Yes	Representatives provide all the information that greenkeepers may require.
Yes	From the reps and my own information and reading.	No	I'm not skeptical about BS but its a road I haven't gone down.
Yes	Sales reps and conferences and other greenkeepers.	No	I wouldn't be a big fan because how can you prove their effective. If I don't see a very noticeable difference I don't use them. I don't see them as important.
Yes	Try really hard to resist member/committee pressure to utilise chemical control of M.patch on greens. Sward is now able to cope more or less without chemical input for much of the disease period	No	DO THEY REALLY WORK!!!!!!!! I could probably answer yes to that one, but not 100% of the time and not for everyone or every site
Yes		No	Are they not another wonder product?
Yes	Alot of it is about educating yourself. Other products we use are fertilizers to harden up the plant.	No	It needs more research so we can get more information. Alot of products exist with very little research behind them. I would be quite skeptical about them apart from seaweed.
Yes		No	Are they effective?

Yes	No	No	I've read about them but I've never used them. No question. They take a long time to work. You have to keep applying them whereas a chemical is instant.
Yes	I have a specialist who helps me.	Yes	What are the after effects?
Yes		Yes	Why add biostimulants rather than produce them naturally by good practice?
Yes	Infornation provided is excellent. Nothing left to conjecture.	Yes	Do they work? Makes it look good rather than good management. Marketing ploy.
Yes	Close working relationship with suppliers. All questions answered.	Yes	Is it compatible with pesticides if there is an outbreak (particularly bioactive preparations such beneficial funghi)?
Yes	The company I deal with is very good at giving advice.	Yes	No questions as unfamiliar with the area. Soil treatment contracted out to agronomus.
Yes	I have been practicing sustainable golf for a few years and it is working well	Yes	Why are biostimolants needed for controlling M patch??
Yes	You'd know yourself anyway.	Yes	It's a drop in the ocean. You cannot get on the amount of biostimulants to deal with it effectively. It's not realistic because you can't get enough of it on. ...The amount of pesticide used in Ireland is minimal in damaging beneficial fungicide.
Yes	Manufacturer's advertisements often do not correspond with actual effects of application	Yes	Manufacturers are very cooperative
Yes	But I would try and do without it. It would have to be very serious.	Yes	I would have to hear what they had to say first.
Yes	Very good information. We deal with a reputable company.	Yes	I would want to speak to STRI or an agronomist.

5. Conclusion

Balance with WP5

Recap of main empirical results

Recap on the two strategies analysed:

- S1: highly codified, no significant inconsistencies observed among the various governance levels. S1 appears institutionally integrated. Its formal rules appear effective. Issue of incompleteness of the strategy: effects are measurable and normally rapidly observable, but they target a pest that lives on weakened plants. They don't address the cause of the weakness. This strategy polarises most of the attention of greenkeepers and fails to mobilise other resources that could complement or to a certain extent replace the use of synthetic chemicals with the stimulation of biological relations.
- S2: a major inconsistency appears between a corpus of scientific evidence that strongly suggests a evident technological potential, and the quasi-total ignorance of practices implementing this knowledge. Implementation failure seems to rest on the governance level of strategic plans because of the lack of advisory, extension and technical support available with regard to S2. This strategy suffers from a lack of codification which is also rooted in the formal governance level: no policy could be identified that injects a positive stimulus in favour of S2. Plant protection policy consists mainly in technological restriction.

Stress control strategy appears to have some degree of relevance:

- Experimental research, even if patchy, suggests the potential for mycorrhizal and rhizospheric technologies remains largely ignored, and untapped by, the sport turf industry.
- Turf maintenance techniques relying more on soil microbiology and ecology could help translate the integration of environmental concerns in this sector. This could materialise in conventions that could replace 'negative conventions.

Preliminary policy recommendations

Positive conventions appear lacking: environmental policy in golf is limited to constraining available plant protection technologies. Few or no new technologies are actually put forward. This raises the question of the integration of the environmental policy and of the innovation policy, an integration put forward in the Lisbon strategy [Morand and Barzman 2005].

Possible implications for the on-going greening of the sport turf industry are real. They concern in particular the attempts by Golf Environment Europe to establish environmental standards, with potential consequences for the environmental differentiation in the sector.

Limits and perspectives of this pilot application of the institutional integration analytical framework are further discussed in Morand and Stumpf [2006].

Acknowledgments

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