
RESEARCH & DEVELOPMENT
PROGRAMME WITHIN
INTEGRATED
PEST MANAGEMENT
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SUMMARY AND CONCLUSION

Integrated Pest Management (IPM) refers to the integration of all available pest control techniques that discourage the development of pest populations and keep the use of pesticides to levels that are economically justified and environmentally sustainable (FAO 2016). STERF's first program on IPM was developed in 2010 in direct response to the EU Directive 2009/128/EU on sustainable pesticide use, which is now being implemented in the five Nordic countries. Since then, STERF has funded or co-funded about 20 IPM research projects and developed 28 fact sheets on IPM for turf.

The objective of the revised program for the period 2016-2021 is to promote high-quality golf courses and managed turfgrass areas with optimal use of input factors and integrated solutions for the control of weeds, insects and diseases. STERF shall, in close collaboration with golf clubs, greenkeepers and other turfgrass managers, national authorities and industry partners, contribute to functioning ecosystems and a healthy environment and continue to take responsibility for research, development and knowledge transfer on IPM for golf and for other types of turf, thus making the Nordic golf sector a role model and exemplar regarding sustainable societal development. Important strategies to reach this objective are:

- encouraging researchers at universities and research institutes to work on issues related to IPM for turf;
- funding relevant research, preferably in collaboration with other national and international research foundations, national authorities, and the turfgrass industry;
- developing an industrial scientific partner program in collaboration with leading international companies to ensure that new products and methods for pest control are consistent with IPM principles;
- ensuring research results and new knowledge on IPM are made easily accessible to end-users and providing support to implement changes.

In compliance with 2009/128/EU and regulation 2009/1107/EU, the five Nordic countries have imposed strict regulations, but the national authorities do not foresee a general pesticide ban for turf within the program period. Except for Denmark, there is a lack of information about total pesticide consumption for turf in Nordic countries, but this is likely to change as new requirements for reporting are enforced. STERF may also contribute to the establishment of good practices in this regard. While Finland had a strong reduction, the total number of active pesticide ingredients approved for use in turf in Sweden, Denmark and Norway was approximately the same in 2016 as in 2010.

New research projects within STERF's IPM program will follow the eight IPM principles recognized by EU and the national authorities. In this program 14 relevant topics for research grouped in the three thematic areas are proposed:

- Breeding, evaluation and management of species, varieties and turfgrass mixtures to create more disease resistant, stress tolerant and weed-competitive turf;
- Identification, biology and proliferation of specific harmful organisms in various types of turf and under Nordic conditions, including possible effects of climate change, and;
- Safer and more efficient use of pesticides, including alternative plant protection products.

The 14 identified research topics are not exclusive and should be regarded as examples. New pests may be discovered and/or become more harmful during the program period, e.g. due to the combination of climate change and numerous golf players travelling worldwide. STERF will continue to have a focus on ready-to-use research projects and active dissemination of results to the golf and turfgrass industry and to the society through fact sheets, popular articles, videos and webinars presented at www.sterf.org and elsewhere.

BACKGROUND AND OBJECTIVE

Golf is a land-demanding sport that occupies more than 70 000 ha in the Nordic countries. The Nordic golf federations have around 1 000 000 members who play on more than 1 100 golf courses. An eighteen-hole golf course covers an average of 65-70 ha, of which approximately 20 ha are intensively managed and utilized playing surfaces and approximately 50 ha extensively managed nature areas.

Like other land-based industries, golf has to take responsibility for sustainable societal development, i.e. produce golf courses of a high standard while at the same time ensuring the sustainable use of natural resources and contributing to functioning ecosystems and a healthy environment. The Nordic golf federations have recognized this responsibility by establishing The Scandinavian Turfgrass and Environment Research Foundation (STERF). STERF's vision is to be the leading international center of expertise in management of golf courses and other turfgrass areas and to make the golf sector in the Nordic countries a role-model regarding responsibility for sustainable societal development. Important strategies to fulfil this vision are: (1) international collaboration and support to universities and research institutes within and outside the Nordic countries to become involved in turfgrass research; (2) the development of an industrial scientific partner program in collaborating with leading international companies to ensure that research and development is integrated from producer to end-user; (3) making research results and new knowledge easily accessible to end-users and providing practical support and guidance to implement changes.

STERF's first program on Integrated Pest Management (IPM) was developed in 2009/2010 in direct response to EU's directive on sustainable pesticide use. The objective of the present revised version remains the same as in 2009/2010, namely, to promote high-quality and environment-friendly golf courses with optimal use of inputs and integrated solutions for the control of weeds, insects and diseases.

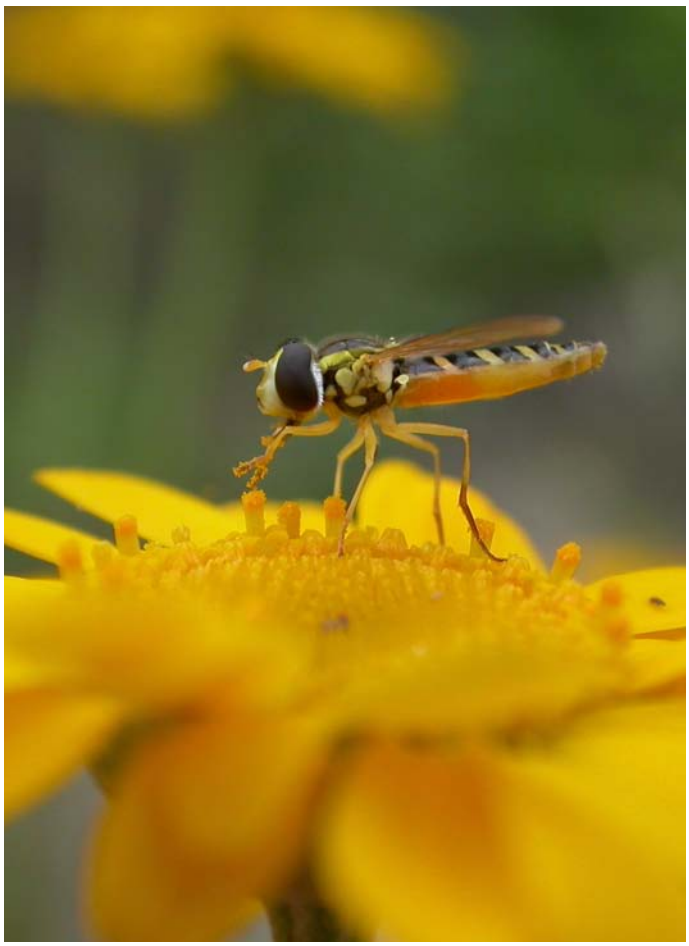
FAO (Food and Agriculture Organization of United Nations) IPM definition:

Integrated Pest Management (IPM) means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/ipm

SOCIETY'S BENEFITS AND RESPONSIBILITIES

Regardless of EU-membership, the five countries Iceland, Norway, Denmark, Sweden and Finland have decided to implement EU-Directive 2009/128 EU in 'establishing a framework for community action on achieving sustainable use of pesticides' and EU-Regulation 1107/2009 'concerning placing of plant protection product on the market'. This is in line with the long-term national quality targets of ensuring a toxin-free environment (e.g. Norwegian Government 2006, Swedish Parliament 2009). Soil types, climate and topography vary markedly between individual countries, but the importance of protecting both humans, terrestrial and aquatic organisms from pesticide exposure are well recognized. Examples of negative implications of pesticide use are risks for contamination of ground and surface water used for human consumption, and the long-term antagonistic effects on pollinators.



Agriculture is responsible for most pesticide consumption in the Nordic countries, but pesticide use in the golf and park sector is of special concern because many of these areas are open to the public. As an example, Norway has introduced a total ban on pesticide use in children's playing areas (Norwegian Government 2015). Actions plans for less and the safer use of pesticides are currently under implementation in all Nordic countries, and it is important that these plans not only focus on agriculture, but also on the specific challenges facing the turfgrass sector.

THE GOLF SECTOR'S GAINS AND RESPONSIBILITIES

The implementation of IPM has created, and will continue to create, a better knowledge base among greenkeepers through the documentation on influence of different turfgrass management practices on pest occurrence. It will enable greenkeepers to analyze the effects of different cultural, biological and chemical measures to prevent and control pests, and to create a foundation for more efficient golf course management. Managing turf within the park and golf sector becomes more challenging, but also more rewarding. Implementation of IPM will also help the golf industry counter the still far too common misconception that golf course management is not sustainable and implies abundant pesticide use.

The golf sector includes commercial companies producing and marketing commodities such as seeds, growing substrates, fertilizers, surfactants, biostimulants, pesticides, machinery and equipment. Most of these companies also provide consultancy services related to their products. By signing an industrial partnership agreement with STERF, these companies have a unique opportunity to have the quality and applicability of their products tested by independent universities and research institutes. In the context of IPM, it is especially important that commercial companies take a proactive role in developing low-risk alternatives to old pesticide chemistries. The involvement of leading suppliers furthermore strengthens the important strategy that research and development should be integrated all the way from producer to end-user.

It is STERF´s ambition not only to promote applied and ready-to-use research projects, but also to ensure that the new insights from research are easy accessible to end-users. This places great demands on effective communication strategies. Since there is considerable overlap between golf and other turfgrass sectors that do not have their own research foundations, STERF will take responsibility for communicating IPM management not only for golf, but also for other types of turf in the private and public sector. This implies research and communication with matched funding for various sectors and can only be achieved through a continuous and close dialogue between STERF, national authorities, turfgrass managers, as well as golf players and other users of the green amenity areas.

CURRENT SITUATION

Status for implementation of IPM for turf

As of June 2016, the implementation of the aforementioned EU directives and regulations is well underway in all Nordic countries. Three major measures taken in all countries are:
(1) regular inspection and testing of spraying equipment;
(2) compulsory courses /exams for everybody who is going to apply pesticides, and
(3) mandatory documentation / reporting of all pesticide use in special records on each golf course.

In collaboration with and with financial contributions from the national authorities in Sweden, Denmark and Norway, STERF has contributed to the implementation of IPM by developing a digital IPM library for turf. The library consists of 28 fact sheets and covers a wide range of topics such as optimal choice of competitive and resistant grass species for different types of turf, pesticide application technology, turfgrass maintenance practices such as mowing, irrigation, fertilization, topdressing and mechanical treatments; and biology and control strategies for the most important weeds, diseases and insect pests on turf in the Nordic countries.

The IPM fact sheets are available in Swedish, Danish and Norwegian language at www.sterf.org, and they are widely used in in the education of turfgrass managers in the Nordic countries. There have also been initiatives to translate the fact sheets into English and other languages for use outside Scandinavia.

Status for pesticide use on Nordic golf courses

Denmark is the only Nordic country with long-term records for pesticide use on golf courses. Until 2011, the Danish 'Golf Green Accounts' (Golfens Grønne Regnskab) were reported as amount of active pesticide ingredient. On average for all reported golf courses, this indicator showed a continuous reduction from 0.35 kg a.i./ha in 2003 to 0.24 a.i./ha in 2007 and 0.16 kg a.i./ha in 2011 (Danish Golf Union 2012). The report also showed that 84 % of the pesticide consumption was herbicides used on fairways, tees and parking lots, while fungicides used on greens accounted for 12 %. Since 2012, the format of the 'Golf Green Accounts' has been changed to a report on the 'total pesticide impact', in which each pesticide is given a specific load depending on

how harmful it is to humans and the environment. All Danish golf courses have to submit data for this annual report, and to document that the total pesticide impact is less than the threshold set for that particular golf course.

From 2014, Swedish golf clubs have to apply to the municipality for permission to use specific pesticides, and the actual application date, rate and area shall be reported after spraying. This gives the local authorities a unique opportunity to monitor changes in pesticide use over time, but no accounts have been published by the local authorities so far. A report based on 108 Swedish golf courses and published by the national Swedish Environmental Agency in 2009 indicated that only 53 % of the golf courses had been using pesticides (Österås 2009), but this figure was later questioned by the Swedish Golf Federation's agronomists who thought that the percentage was underestimated. Still, it is fair to assume that that pesticide consumption per area unit is lower on golf courses than in agriculture, and this is in agreement with a Norwegian investigation from 2000 showing pesticide consumption per area unit to be only 13 % of the average consumption in Norwegian agriculture (Arne Tronsmo, Norwegian University of Life Science, pers. comm.).

Whilst it may be risky to generalize, as of 2016, the situation seems to be that the majority of Nordic golf courses apply herbicides on fairways and roughs once every 1-3 years in order to control broadleaved weeds. Rather than overall blanket applications, this weed control is often made as spot treatments which considerably reduces the total herbicide consumption. Most golf courses also apply fungicides 1-3 times per year, usually in the autumn and winter to control winter active diseases, and almost exclusively on the greens and tees which – on average – covers less than 5 % of the total area of a golf course. Insecticides with a very high environmental load are used occasionally in Denmark and Southern Sweden to control the larvae of garden chafers and crane flies, but for the turf sector as a whole, insecticides contribute less than 5% of total pesticide consumption.

Chemical plant growth regulators are a pesticide category that has contributed to increased pesticide use on Swedish, Finnish and Icelandic golf courses during the past five years. The growth regulator Primo Maxx was approved for golf courses and athletic fields in Sweden in 2011. A survey conducted by the Swedish Golf Federation in 2012 indicated that approximately one third of the golf courses had been using the product, mostly on greens and tees, but a few golf courses applied Primo Maxx also on fairways, along bunker edges and in steep roughs that are difficult to mow (Aamlid and Edman 2014). Similar estimates are probably valid also for Finland and to a lesser extent Iceland. STERF research shows that Primo Maxx has to be applied at least once a month to have a consistent effect on turfgrass growth, and this contributes to a fairly high consumption of active ingredient compared with other pesticide categories. From a holistic point of view, it may still be argued that Primo Maxx and other plant growth regulators are environmentally friendly as they reduce the CO_2-emissions associated with mowing. However, as of June 2016, chemical plant growth regulators have not been approved for use on turf in Denmark and Norway.

EU's pesticide regulations still open for so-called 'minor-use' (formerly 'off-label') registration of agricultural products in turf. Table 1 shows that this option has been widely exploited by the golf federations, particularly in Denmark, but also in Norway and Sweden. Minor use registrations are likely to lower the pesticide budget on many golf courses because agricultural formulations are cheaper than turfgrass formulations of the same active ingredient, but there have also been questions about the efficacy and safety of agricultural formulations on short-cut turf.

Table 1 (page 8) shows the situation as of 1 June 2016 regarding pesticide registration in the Nordic countries. Compared with the situation six years ago (previous IPM program), the current total number of products with an ordinary or 'minor use' registration for turf is two more pesticides in Sweden and one more pesticide in both Norway and Denmark, but five less pesticides in Finland. Old herbicides such as 2.4 D, dichorprop and dicamba have lost their registration, and the most widely used herbicide for turf is now fluoxypyr. However, the approval of this product was not renewed in Sweden in 2015, and weed control on fairways is therefore likely to become a challenge on Swedish golf courses in the near future.

Table 1. Chemical pesticides approved for use on golf courses in the Nordic countries as of 1 June 2016 (Iceland is not included as this country has no special registration of products for turf. Data as of 1 June 2010 was included as a historical reference).

Active ingredient	Commercial products	Registered in			
		Sweden	Norway	Denmark	Finland
Herbicides					
Amidosulfuron	Gratil		X		
MCPA	MCPA 750, Ariane S/FG S		X		
Clopyralid	Ariane S/FG S, Cloflufix, LFS		X	X	X
Florasulam	Starane XL		X		
Fluoxypyr	Ariane FGS, Starane, Spitfire, LFS, Lodin, Tomahawk	X[1]	X	X	X
Glyphosate	Roundup, Touchdown etc.	X	X	X	X
Iodsulfuron	Hussar OD			Minor use	
Tribenuronmethyl	Express ST, Express SX, Nuance WG			Minor use	
Fungicides					
Azoxystrobin	Amistar	Minor use[2]			
	Headway	X			
Cyprodinil	Switch, Acanto Prima		Minor use	Minor use	
Fludioxinil	Medallion, Switch	X	X	Minor use	
Picoxystrobin	Acanto Prima		Minor use		
Prochloraz	Sportak EW, Basso	Minor use[1]			X
Propiconazole	Tilt, Banner Maxx, Basso, Bumper, Headway, Stratego	X	X		X
Prothioconazole	Proline, Stratego, Delaro		X	Minor use	
Tebuconazole	Folicur			Minor use	
Trifloxystrobin	Stratego, Delaro		X		
Insecticides					
Alpha-cypermetrin	Fastac 50		X		
Cypermethrin	Cyperb 100			X	
Deltametrin	Decis Mega		X		
Esfenvalerat	Sumi-Alpha	X	X		X
Lambda-cyhalotrin	Karate, Agros lambda-C			X	
Imidacloprid	Merit Turf	X		X	
Indoxacarb	Avaunt			Minor use	
Growth regulators					
Trinexapac-ethyl	Primo Maxx	X			X
Total, all chemical pesticides, 2016		**8 + 2 minor use**	**13 + 3 minor use**	**6 + 7 minor use**	**7**
Total, all chemical pesticides, 2010		**6 + 2 minor use**	**13 + 3 minor use**	**11 + 1 minor use**	**12**

1) Will disappear from the Swedish market. Last day of use: 30 June 2017.
2) Formerly 'off-label'; expansion of application of agricultural products for minor use in turf which is given to (a) certain (group of) user(s) by the national Food Safety Authorities.

THE IPM PRINCIPLES

The directive 2009/128/EU defines all actions that contribute to healthy and robust plants as 'plant protection measures'. Through the eight principles of Integrated Pest Management (IPM) (Table 2), the directive encompasses a wide range of aspects related to 'Best turfgrass management' and thus a large part of STERF's total research activities. Chemical control is not prohibited, but considered the last solution if other measures are not sufficient (Fig. 1.)

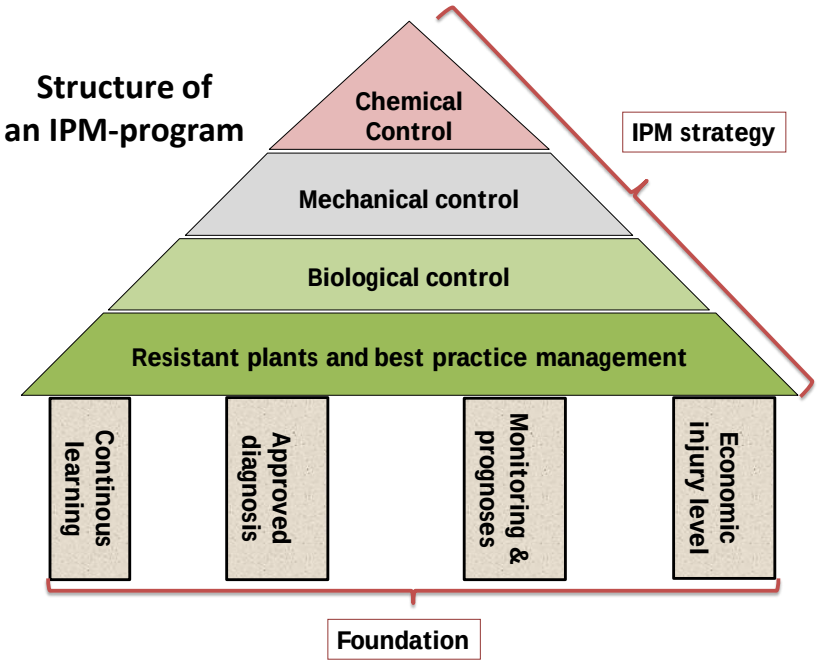


Figure 1. Framework for Integrated Pest Management (after T. Espevig).

Table 2. IPM principles relevant for turf (After FAO 2016).

Principle 1 Prevention and suppression	The prevention and/or suppression of harmful organisms should be achieved or supported among other options especially by:
	• Use of adequate cultivation techniques (e.g. stale seedbed technique, sowing dates and densities, conservation tillage)
	• Use, where appropriate, of resistant/tolerant cultivars and standard/certified seed and planting material
	• Use of balanced fertilization, liming and irrigation/drainage practices
	• Preventing the spreading of harmful organisms by hygiene measures (e.g. by regular cleansing of machinery and equipment)
	• Protection and enhancement of important beneficial organisms, e.g. by adequate plant protection measures or the utilization of ecological infrastructures inside and outside production sites
Principle 2 Monitoring	Harmful organisms must be monitored by adequate methods and tools, where available. Such adequate tools should include observations in the field as well as scientifically sound warning, forecasting and early diagnosis systems, where feasible, as well as the use of advice from professionally qualified advisers.
Principle 3 Decision-making	Based on the results of the monitoring the professional user has to decide whether and when to apply plant protection measures. Robust and scientifically sound threshold values are essential components for decision-making. For harmful organisms, economic threshold levels defined for the region, specific areas, and particular climatic conditions must be taken into account before treatments, where feasible.
Principle 4 Non-chemical methods	Sustainable biological, physical and other non-chemical methods must be preferred to chemical methods if they provide satisfactory pest control.
Principle 5 Pesticide selection	The pesticides applied shall be as specific as possible for the target and shall have as ow side effects on human health, non-target organisms and the environment as possible
Principle 6 Reduced pesticide use	The professional user should keep the use of pesticides and other forms of intervention to levels that are necessary, e.g. by reduced doses, reduced application frequency or partial applications.
Principle 7 Anti-resistance strategies	Where the risk of resistance against a plant protection measure is known and where the level of harmful organisms requires repeated application of pesticides to the crops, available anti-resistance strategies should be applied to maintain the effectiveness of the products. This may include the use of multiple pesticides with different modes of action.
Principle 8 Evaluation	Based on the records on pesticides use and on the monitoring of harmful organisms the professional user must evaluate the success of the applied plant protection measures

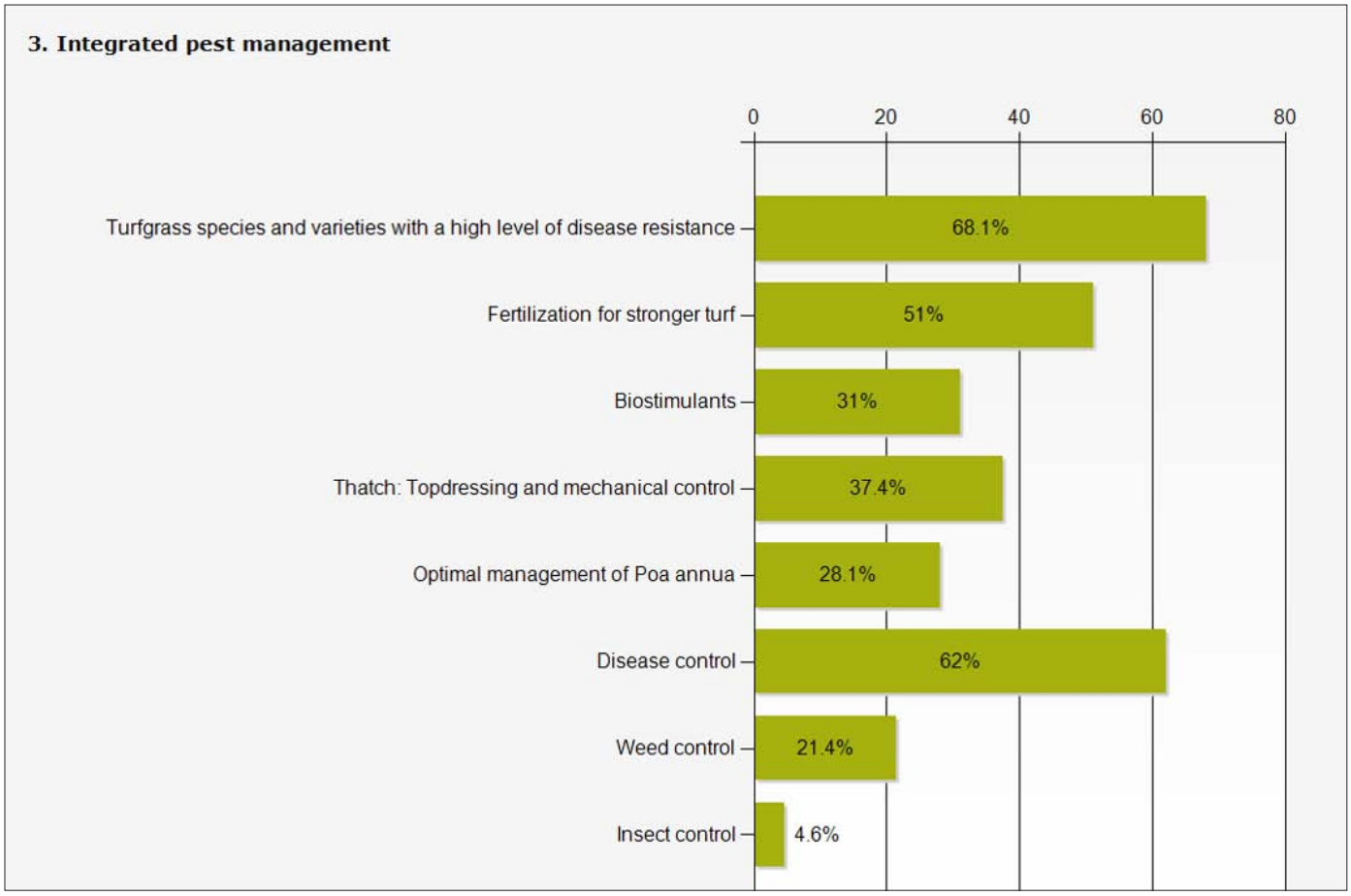


Figure 2. Research priorities within the program area Integrated Pest Management prioritized by 497 Nordic golf clubs in 2013.

KNOWLEDGE GAPS AND SUGGESTED RESEARCH AREAS FOR THE PERIOD 2016-2021

In 2013, STERF sent out a questionnaire to all Nordic golf clubs asking for their research priorities within each of the foundation's four research programs. The questionnaire was answered by 497 respondents, representing almost 60 % of all golf clubs in the Nordic countries. The outcome of the investigation for the area 'Integrated Pest Management' is shown in Figure 2.

The results indicate that the golf clubs have developed an understanding that 'Integrated pest Management' is a diversified and holistic program not limited to the biology and curative control of disease, weeds and insects. The three research areas most highly prioritized by the industry were:

(1) Evaluation of turfgrass species and varieties suitable for IPM;
(2) Control of turfgrass diseases, and
(3) Fertilization practices.

Besides the questionnaire, a meeting on 27 May 2015 between STERF and the national authorities responsible of implementation of IPM, as well as the work with STERF's fact sheets on IPM during the winter 2015-2016, identified several knowledge gaps ought to be addressed during the program period 2016-2021. Below, suggestions for new research projects have been grouped into three program areas that together cover the IPM principles 1-7:

Breeding, evaluation and management of turfgrass species, varieties and mixtures to create more disease resistant, stress tolerant and weed-competitive turf

(IPM principle 1)

a) Evaluation and development of turfgrass species, varieties and seed blends/mixtures

Large differences exist in the ability of turfgrass species and varieties to compete with weeds and resist attacks from pathogens and insects. After 'official' turfgrass variety testing which had been discontinued by the national authorities around 2000, STERF initiated the SCANGREEN program for evaluation of species and varieties on greens, and from 2015 this program also evaluates seed mixtures and blends. The appreciation of species and variety testing as part of the IPM program was reflected in its high score in STERFs survey in 2013 (Fig. 2). SCANGREEN should therefore continue during the next program period, and it should also be considered to what extent STERF – in collaboration with breeding companies - can contribute to the evaluation of germplasm for other parts of the golf course, such as tees and fairways. Increased focus on the role of golf courses roughs for biological diversity also requires further studies into native grasses and the compatibility of various grasses with endangered species. The latter could be a joint project between STERF's programs for IPM and multifunctional golf facilities.

Over the past decade, there has been an unfortunate decrease in the number of new varieties entered by international companies into SCANGREEN. This reflects the overall reduction and the number of breeding companies working with turf, but also the limited marked potential for varieties especially adapted to Nordic climate conditions. A possible way for STERF to face this challenge is to line up with breeding companies in projects aiming for specific targets such as disease resistance or winter survival.

b) Management practices on Poa greens

Even though it is never seeded, *Poa annua* is the most common species on golf greens in Scandinavia. STERF projects up to now have not emphasized this species or they have focused on how to defeat it. Control of *Poa annua* is, however, a difficult task, and many greenkeepers therefore ask for optimal management procedures to make the best out of and their Poa with less use of pesticides. Recent results from the US suggest that is possible to minimize anthracnose (Murphy et al. 2014) and microdochium patch (Mattox et al. 2014) by specific combinations of cultural practices, and is should be investigated how these findings can be adapted to Scandinavian putting greens.

c) Fertilizer types, fertilization practices and biostimulants for stronger and more resistant turfgrass plants

As a result of earlier STERF projects, 'demand-driven fertilization' (Ericsson et al. 2012) has been implemented on many Scandinavian golf courses during the last decade. However, this concept is primarily based on growth responses to light and temperature and does not pay much attention to turfgrass diseases. During the past couple of years, preliminary results suggest that specific organic fertilizers, particular elements such as silicon (Si), and /or specific biostimulants, are likely to make the turfgrass more resistant to microdochium patch and other diseases. This is an area that warrants further research in collaboration with STERF's industrial partners.

d) Replacement of peat with compost

Research in North-America (Boulter et al. 2002) and Scandinavian (Aamlid et al. 2009) suggest that certain types of compost in the rootzone or sand used for topdressing will greatly reduce the incidence of turfgrass diseases on golf courses. The use of compost is interesting also because substitution of peat with compost will indirectly reduce the CO_2-emissions from the golf industry. On the other hand, increased use of compost may well result in more leaching of phosphorus from turfgrass areas. Benefits, trade-offs and mitigating measures to optimize the use of compost and other by-product from society is a relevant topic for a new research projects.

Research into identification, biology and proliferation of harmful organisms

(IPM principles 2 and 3)

a) Tools for early identification / improved diagnostics of turfgrass diseases

Qualified and fast diagnostics of disease symptoms can save the high doses of fungicides that are often needed for curative control at advanced stages of disease development. Research into diagnostics includes a better understanding of the primary and secondary causes for symptoms that are often not only related to pests, but also to dry spots, too low mowing, or nutritional disorders. It should also be explored to what extent molecular techniques can replace traditional diagnostic methods.

b) Dollar spot and other new diseases

Future development of IPM for turf must be considered in relation to global warming which increases chances that new organisms will be identified and that organisms that are already present will become more harmful. A preliminary STERF project recently documented that dollar spot caused by *Schlerotinia homeocarpa* has gained foothold in Scandinavia (Espevig et al. 2015). This is the pathogen requiring most fungicide use on American golf courses, and research is needed to avoid that we get into a similar situation in Scandinavia.

c) Prediction models and forecasting of insect damage and outbreak of diseases

IPM is a decision-making process. During the growing season and in the fall greenkeepers and other turfgrass managers have to make many decisions on correct pest control measures including pesticide choice, timing and rate. Based on correct pest diagnostic and pest monitoring, an IPM program has always to take in consideration the interaction between host plant, pest and environmental conditions which is commonly referred to as the 'disease triangle'.

Huge resources have been used on developing disease or insect forecasting models for major agricultural crops based on meteorological data, but the precision of such models for turf growing on the relatively scattered Nordic golf courses is likely to be limited by the variation in climate and topography regionally as well as locally. In many cases, prediction models will also have to be parameterized differently because the different susceptibility of various turfgrass species. Regional prediction models and forecasting services may perhaps be justified for microdochium patch and other ubiquitous diseases, but in most cases it seems more cost-effective to help local greenkeepers build up their own local knowledge on when outbreaks can be expected on various greens or other parts of their golf course.

d) Phytosanitary requirements and invasive species

Phytosanitary restrictions to avoid dissemination of new harmful insects and pathogens on plants and animals are common in agriculture and have lately also been supplemented with regulations to avoid biological pollution from invasive (black-listed) organisms. Golfers often travel internationally to play on new courses, and this inevitably incurs a risk for dissemination of pests. This is an area of great interest for agricultural and environmental authorities and there is a need for more knowledge about practical, yet efficient, measures to avoid dissemination of pests and unwanted plants to new areas.

e) Weed biology

Perennial grassland weeds in have mostly been studied in forage production system with one to three cuts per year. We therefore have limited knowledge in the biology and weak points of dandelions, daisies, plantains and other typical lawn weeds in short and frequently mowed turf. There are also indications that some species, e.g. daisy, have becoming more of a problem in norther areas due to climate change. Improved understanding of weed biology is a prerequisite for future control of these and other weeds with less herbicides.

Research related to more efficient and safer use of pesticides

(IPM principles 4-7)

a) Routines for compilation of reliable statistics on pesticide use for golf

As outlined in earlier sections of this research program, updated documentation on pesticide use on golf courses is lacking in all Nordic countries except Denmark. In collaboration with the local and national authorities it may therefore to be a task for a STERF project to develop simple but efficient routines for compilation and transparent flow of data of this type of data.

b) Continued testing of new active ingredients and formulations for various types of turf and under different climatic conditions.

The low number and slow turnover of active pesticide ingredients on the market increases the risk for turfgrass weeds, fungi and insects to develop pesticide resistance. Evaluation of safety, efficacy and optimal use of old and new chemistries is primarily the responsibility of the chemical companies, but STERF will mediate this type ore research and contribute to the provision of agronomic data for potential registration of new pesticides with a more benign ecotoxicological profile. The practice of some of the Nordic golf federations to apply for minor use registration of agricultural products for turf as a cheap alterative to special turfgrass formulations is debatable, especially if the agricultural and turf products contain the same active ingredients. To elucidate this practice, STERF welcomes research comparing the efficacy and safety of agricultural vs. turf formulation under Nordic climate conditions.

c) Risks for surface runoff

During the past decade, STERF has funded three projects on the risk for leaching and contamination of ground water environmental fate of fungicides used on golf courses. This research showed large differences in the leaching potential of various fungicides, but also that the models required by the authorities for fungicide registration are often inadequate to describe the situation on sand-based golf greens (Larsbo et al. 2008) There has, however, been less attention on the risk for pesticides in surface runoff, and this is a relevant problem both because most golf courses have open water close to the playing surfaces and because future climate scenarios project higher rainfall intensities in the future.

d) Risks for human exposure

Pesticides on golf courses are commonly applied using back-pack sprayers, small and open tractors/carriers or walk-behind spraying booms. When using such equipment, the greenkeepers are likely to be exposed to higher pesticide concentrations than farmers who operate large sprayers from their protected tractor cabins. Golfers playing on treated turf may also be exposed to pesticides through shoes, towels, and direct contact with golf balls, and non-golfers using golf courses for recreational purposes may be exposed by pesticides by crossing treated areas. National rules often prescribe that that treated greens and fairway should be labeled and closed to play for a certain number of hours/days after spraying, but this is difficult in practice, especially in the case of growth regulators which are often applied at weekly to two-week intervals. Human exposure after pesticide application on golf courses is an area that has not been explored by STERF previously and warrant more attention in the future.

e) Alternative products

According to current EU definition, pesticides include not only chemicals, but all products that are applied with the purpose of preventing or controlling harmful organisms. During the last program period, STERF was involved in the testing of biostimulants and microbiological products for control of Microdochoum nivale, but unfortunately, none of these products showed the necessary efficacy against the targeted insects and diseases. There is, nonetheless, a great interest within the turf sector to create beneficial interactions between the turfgrass plants and microbiota in the rhizosphere, especially on sand-based substrates. This is a complex area and largely unexplored area, but new techniques such as the identification of specific microorganisms after DNA extraction (PCR) may open new possibilities. Another novel group of pesticide is 'resistance elicitors', products that are applied to induce ('turn on') resistance to specific diseases or insects. STERF has an ongoing project on the induction of resistance by application of the Canadian mineral oil product Civitas, but there are many potential resistance inhibitors that may have similar properties and ought to be tested in collaboration with industry partners.

COMMUNICATION

Every Nordic golf federation is – together with the Nordic greenkeeper associations, national authorities and municipalities - responsible for the implementation of new knowledge through training, advisory services, field days, seminars etc., but STERF plays an important role in facilitating and streamlining the information from research projects, especially through its website **www.sterf.org.**

STERF's goal is always to produce ready-to-use research. Within IPM as other program areas, this means that greenkeepers and other turfgrass managers, golf course architects, environmental authorities and other decisions makers shall have rapid access to the latest knowledge emanating from STERF-funded projects. Results shall not only be published scientifically in peer-reviewed journals or at international conferences, but as fact-sheets, handbooks and articles in the Nordic and English languages. Apart from STERFs own website, national and international newsletters and turfgrass greenkeeper magazines are important channels for this written information.

The educational institutions for greenkeepers in the Nordic countries also play an important role in using the 'ready-to-use'-research from STERF. Handbooks and fact-sheets must be a part of the curriculum in the education of new greenkeepers and in courses for further training of professionals, e.g. certification courses for pesticide use.

Field trials related to IPM usually have a strong visual component and many often serve as sites for demonstrations and field days. Large scale demonstration trials on golf courses can also be the last stage to disseminate new knowledge from one project or a group of projects to end-users, and this information can be spread to a wider audience using videos, webinars etc.

Although the primary target groups for STERF's research on IPM are the greenkeepers and other turfgrass managers, it is also essential that information hygienic measures and possible implications of pesticide restrictions on playing quality are spread to the ordinary golfer, e.g. though articles in golf magazines. It is further important for the golf and turfgrass industry's image that the industry's continuous search for alternative solutions is conveyed to the general public though press releases, newspaper articles etc.

TIME SCHEDULE

This program was written for the period 2016-2021. During this period, it may be refined and adjusted according to the industry's and authorities' needs for new knowledge about IPM for turf.

REFERENCES

Aamlid, T.S, T. Espevig, B. Molteberg, A. Tronsmo, O.M. Eklo, I.S. Hofgaard, G.H. Ludvigsen & M. Almvik 2009. Disease control and leaching potential of fungicides on golf greens with and without organic amendment to the sand-based root zone. International Turfgrass Research Journal 11: 903-917.

Aamlid, T.S. & Edman, P. 2014. Growth regulation with Primo MAXX on Nordic golf courses. STERF handbook, 18 pp. www.sterf.org (Accessed 10 June 2016).

Boulter, J.I., G.J. Boland and J.T. Trevors 2002. Assessment of compost for suppression of Fusarium Patch (Microdochium nivale) and Typhula Blight (Typhula ishikariensis) snow molds of turfgrass. Biological Control: Theory and Application in Pest Management 25: 162-172.

Espevig, T., M.B. Brurberg & A. Kvalbein 2015. First report of dollar Spot, caused by Sclerotinia homoeocarpa, of creeping Bentgrass in Norway. Plant Disease 99 (2): 287

FAO 2016. FAO's definition of IPM. Food and Agriculture Organization of the United Nations. http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/ipm (Accessed 10 July 2016)

Norwegian Government 2006. Sammen for et giftfritt miljø – forutsetninger for en tryggere fremtid. St.meld. nr. 14 (2006-2007)

Norwegian Government 2015. Forskrift om plantevernmidler. https://lovdata.no/dokument/SF/forskrift/2015-05-06-455 (Accesssed 10 July 2016).

Dansk Golf Union 2012. Golfsportens Grønne Regnskab 2011. www.dansk.golfunion.dk (Accessed 10 June 2016).

Ericsson, T., K. Blombäck, and A. Neumann. 2012. Demand-driven fertilization. Part I: Nitrogen productivity in four high-maintenance turf grass species. Acta Agric. Scandinavica Section B – Soil and Plant Sci. 62: 113-121.

Larsbo, M., T.S. Aamlid, L. Persson & N. Jarvis, 2008. Fungicide leaching from golf greens: Effects of root zone composition and surfactant use. Journal of Environmental Quality 37:1527-1535.

Mattox, C. M., A. Kowalewski, A. & B.W. McDonald, B. W. 2014. PDMR: Evaluation of fungicide alternatives for the control of Microdochium patch on annual bluegrass in western Oregon, 2013-2014 Plant Disease Management Reports. 8: p. T042

Murphy, J., B. Clarke, C. Schmid; J. Hempfling, & R. Wang 2014. Best management practices for anthracnose disease on annual bluegrass putting greens. USGA Turfgrass and Environmental Research Online. March/April. 13(2): p. 12-13.

Swedish Parliament 2009. Environmental objectives. Swedish Environmental Protection Agency. www.miljomal.se (Accessed 3 Aug. 2016).

Österås, A.H., K. Josefsson & J. Sternbeck 2009. Användning och spridning of växtskyddsmedel vid golfbanor. Naturvårdsverket 106 48 Stockholm. 22 pp.

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STERF (Scandinavian Turfgrass and Environment Research Foundation) is the Nordic golf federations' joint research body. STERF supplies new knowledge that is essential for modern golf course management, knowledge that is of practical benefit and ready for use, for example directly on golf courses or in dialogue with the authorities and the public and in a credible environmental protection work. STERF is currently regarded as one of Europe's most important centres for research on the construction and upkeep of golf courses. STERF has decided to prioritise R&D within the following thematic platforms; Integrated pest management, Multifunctional golf facilities, Sustainable water management and Winter stress management. More information about STERF can be found at www.sterf.org

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