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# Chafer grubs and leatherjackets on golf courses

## Integrated management in Scandinavia

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**SAMMENDRAG/SUMMARY:**

Larver av hageoldenborre og myrstankelbein kan forårsake alvorlige skader på skandinaviske golfbaner – hovedsakelig i de sørlige områdene. Skader fra hageoldenborre ses sporadisk, skader fra myrstankelbein er i økning. Restriksjoner på insektmidler har nødvendiggjort bruk av alternative bekjempelsesmetoder. Mange eksperimenter med mikrobiologiske midler som entomopatogene nematoder (EPN) og stammer av *Bacillus thuringiensis* har blitt utført, men overvåking og varsling, og metoder for applicering, sprøyteutstyr og teknikk, formulering av og effektive arter av mikrobiologiske midler må forbedres. God kommunikasjon med golfspillerne er avgjørende, da flere skader fra insekter vil oppstå nå og i fremtiden, og alternative metoder er ofte dyrere og mindre effektive enn de syntetiske insektmidlene. Baneansvarlige og greenkeepere må bli eksperter på bruk av mikrobiologisk kontroll.

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# Preface

The R&D project 'IPM-GOLF: Integrated management of important turfgrass diseases and insect pests on European golf courses' was initiated by Norwegian Institute for Bioeconomy Research (NIBIO) and Scandinavian Turfgrass and Environment Research Foundation (STERF) and received funding from STERF and R&A in December 2019. The project has several work packages investigating alternative methods to prevent turfgrass diseases which causes severe problems on Scandinavian golf courses every year.

This literature review summarises the last 15-20 years' work on integrated management to prevent damages from chafer grubs and leatherjackets on Scandinavian golf courses. The experiments with entomopathogenic nematodes in Finland in 2021 (described in Chapter 5.1.2) was financed by the company Aasatek Oy (www.aasatek.fi).

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# Summary

Chafer grubs and leatherjackets can cause severe damages to Scandinavian Golf Courses – mainly in the southern areas. Damages from chafer grubs are occasional, damages from leatherjackets tend to be increasing. Restrictions on insecticides have necessitated the use of alternative control methods. Many experiments with microbiological agents like entomopathogenic nematodes (EPN) and strains of *Bacillus thuringiensis* have been conducted, but monitoring and warning, and methods for application, spraying equipment and technique, formulation of and effective species of microbiological agents must be improved. Good communication with the golfers is essential, as more damages from insect pests will occur now and in the future, and alternative methods are often more expensive and less effective than the synthetic insecticides. Course managers and greenkeepers have to become experts in the use of microbiological control.

# 1 Introduction

The larvae of Garden chafer (*Phyllopertha horticola*) called chafer grubs and the larvae of Crane flies (*Tipula paludosa*) called leatherjackets are among the insect species that can cause severe damages to golf courses, soccer fields and lawns in the Scandinavian countries. Most damages are seen in Denmark and the southern parts of Sweden especially on light sandy soils. Some years damages are even observed at golf courses in the southern parts of Norway and Finland.

Other insect larvae can cause damages to turfgrass: The larvae of marsh flies (Bibionidae) and other species of grass grub larvae, but this report will focus on chafer grubs and leatherjackets.

As the use of insecticides to control insect pests on turfgrass areas in Scandinavia have been reduced to a few biological products, many experiments to improve their effect have been carried out. Entomopathogenic nematodes and other alternative products have been tested and greenkeepers have collected experiences with alternative methods such as irrigation and other cultural practices to decrease damages from chafer grubs and leatherjackets.

A big challenge in the work with control of insect pests is that populations and damages differ between years. Often experiments are planned after a year with high populations and then the next year very few larvae occur, with the result that little or no effect can be evaluated. Up to now we have no control methods that are comparable with the effect of the synthetic insecticides, but many useful experiences are collected to improve the methods we have.

This report presents an updated review on damage and control of chafer grubs and leatherjackets on Scandinavian golf courses, and it collates conclusions from experiments and experiences done through the last 15-20 years in Denmark, Sweden, Finland, and Norway. Most of the references are in Scandinavian language and some of the information has been given via personal communication.

Terms used in this report:

Garden chafer (*Phyllopertha horticola*) – larvae are chafer grubs.

Crane fly (*Tipula paludosa*) – larvae are leatherjackets.

Entomopathogenic nematodes are referred to as EPN.

For additional updated information on insects see Book of Abstracts from the 26th International Congress of Entomology in Finland (Hokkanen & Menzler-Hokkanen, 2022).

# 2 Chafer grubs

**Photo 1: When sodding grass for maintenance or reparations at golf courses in late summer in Denmark chafer grubs are often found in the topsoil of light sandy soils. Photo: Karin J. Hesselsøe.**

## 2.1 Biology and damage

The larvae of the Garden chafer feed on grass roots. Primary damages occurs when the larvae eat the roots of the grass causing wilting due to desiccation. This is often observed as yellow patches in the lawn which sometimes easily can be rolled or torn off like a carpet (Hofsvang & Sundbye, 2020a). However severe damages in turfgrass areas are detected when the larvae are in the third stage of development, in August-September where secondary damages from birds digging for these larvae can cause serious disruption of the turf surface (Jensen & Ravn, 2016a). Especially crows can damage the turf in search for the larvae (Photo 2).

**Photo 2: Damages from birds digging for chafer grubs on a golf green in Northern Jutland, Denmark. September 2018. Photo: Susanne Olsen.**

Garden chafers thrive in dry, sandy soils. Well drained golf courses and sports fields provide therefore ideal conditions for the larvae. Garden chafer can be present on golf courses on heavier soil types, but rarely causes problems there except in the bunker edges. The density fluctuates irregularly from year to year (Milne, 1984).

Garden chafers are found throughout Europe and appear primarily on areas with mowed grass. Generation time is one year, and one adult beetle is about 8-12 mm long. Wings are brown with metallic green head and chest. From late May to mid-June, the adult beetles (June beetles) swarms just above the grass in sunshine in the middle of the day. They are observed on all types of lawns – on the golf courses most frequently on fairways but some greenkeepers report that they also swarm on greens. Right after mating the females dig 10-15 cm down in the soil where the eggs are laid. Whitin a week one female garden chafer lays around 50 eggs. After 6-7 weeks small larvae are developed, which goes through 3 larvae stages. In the first stage they are 1-2 mm feeding on organic debris in the soil. In the second stage they start to feed on the roots of the grass and in the third stage (typically in August) the larvae are about 20 mm, white with a brown head with a characteristic C-form (Photo 3). In this stage they do the most damage on turfgrass areas. Later in the autumn the larvae dig deeper down in the soil where they stay for the winter. In spring they pupate and in May/June new adults are developed.

**Photo 3: Closeup of fully developed chafer grubs (Photo: www.syngentaturf.co.uk).**

In Denmark and Sweden chafer grubs do serious harm to golf courses (Chapter 4). In Norway garden chafers appears only sporadically as a problem on turfgrass areas in the southern parts of the country (Hofsvang & Sundbye, 2020a).

In Finland chafer grubs mainly possess a direct problem on several golf courses on the southern coast. Based on a survey done by Heikki Hokkanen (Aasatek Oy, www.aasatek.fi) and Janne Lehto (Hirsala Golf Oy) in 2021 the extent of the problem is minor and usually covers about 1000 $m^2$, sometimes up to 1 ha. However, damage by birds is widespread, and the identity of the insect larvae, which the birds are hunting for, usually is not determined.

## 2.2 Control

For chafer grubs no pesticides are available for control at present in the Scandinavian countries. Imidacloprid, formulated as a granular (Merit Turf) was approved in Denmark in 2006 but banned in 2019. Several experiments with entomopathogenic nematodes and other alternative methods to control chafer grubs have been conducted through the years– especially in Denmark with the Danish Golf Association (DGU) as a driving force. See chapter 5.1.1 for more details.

In Norway entomopathogenic nematodes (*Heterorhabditis bacteriophora)* are recommended to control chafer grubs (Hofsvang & Sundbye, 2020a).

In Finland experimental treatments using entomopathogenic nematodes to control several problematic insect species were carried out at two golf courses by Aasatek Oy in 2021. See chapter 5.1.2 for further details.

At present (August 2022) in the UK, the insecticide Acelepryn can be used to control chafer grubs with an Emergency Authorisation (EA). An EA permits application in situations where there is an acknowledged instance of economic damage, or risk of bird strike on airfields, and where the product has been recommended by a BASIS qualified agronomist. The regulatory system only permits a 120-day use period. Acelepryn users will be required to submit online stewardship records of areas treated (Syngenta, 2022).

**Photo 4: Damages from chafer grubs and birds digging on fairway, September 2019. Photo: Karin J. Hesselsøe.**

# 3 Leatherjackets

**Photo 5: Leather jacket. Photo: E. Fløistad, NIBIO.**

## 3.1 Biology and damage

Leatherjackets overwinter as small larvae near the soil surface and down to 5 cm depth. As small larvae in the autumn they feed on humus and decomposed plants in the soil surface. At the third larvae stage (weight approx. 50 mg) they overwinter. In spring (May-June) they dig underground systems where they make ventilation holes enabling them to seek food on the surface - mainly at night (Laughlin, 1967). At this stage they start to damage the grass while eating grass roots and crowns mainly in the night. Fully grown leatherjackets are 3-4 cm with a weight of approx. 500 mg (Photo 5). They pupate in July in the upper 5 cm of the soil, and after two weeks the adult crane flies emerge from the pupae. Often this is observed on greens and tees (Photo 6) where the empty pupa is left visible in the short grass. Crane flies are swarming early in the morning and evening in July-August to mate and lay eggs. The female crane fly, which is characteristic with its tapered abdomen, has an ovipositor that is specialized to lay eggs in moist soil and rotting leaves. The female can lay 300 to 800 eggs per season. After two weeks the eggs will hatch to small larvae.

**Photo 6: Crane fly emerging from the pupa. Green 13 at Lyngbygaard Golf Club 5. august 2021. Photo: Frederik Fallesen.**

Leatherjackets can cause a problem on golf courses as the quality of the grass is reduced (Simard et al., 2006). It is especially on greens and on moist areas that the turf can be destroyed (Jensen & Ravn, 2016b). Damages are observed as large areas with dead, wilted grass, and secondary damages can be caused by birds in search of the leatherjackets. As they live close to the soil surface, they are pursued by birds with short beaks - such as starlings which make less harm to the turfgrass than crows seeking for chafer grubs.

In Scandinavia crane flies are most abundant in Denmark, at the southern areas of Sweden (up to the great lakes Vättern and Vänern) and at the south coast of Norway. They are favoured by mild winters and yearly precipitation above 600 mm. A wet autumn in combination with a mild winter can increase the number of leatherjackets the following summer, but damages differ a lot from year to year (Hofsvang & Sundbye, 2020b). Damages from leatherjackets to golf courses in Denmark and Sweden are estimated in chapter 4.

In Norway only very few golf courses at the south coast have observed leatherjackets. At Kragerø Golf Club they have observed increasing numbers of crane flies/leatherjackets the last 10 years, resulting in patches in the grass turning yellow in May/June. But they do not consider it as a problem for the play, because the patches are limited, and they have also noticed increasing numbers of starlings feeding on the larvae. “Before we had adult emergence in the end of September, concentrated to within a week and it was heavy. But now, I think due to the milder autumn months, I am seeing some emergence throughout the summer and especially around the end of August which means they have several months to feed before winter” (Pers. Comm. Dan Jürgens, course manager at Kragerø).

In Finland leatherjackets are cited by greenkeepers as the most common insect problem on golf courses. In a survey among Finnish greenkeepers in 2021 they were indicated as the problem taxon by 45% of those reporting problems (Pers. comm. Heikki Hokkanen). As knowledge about insect species is scarce, several other species are likely to be involved. The larvae of marsh flies (Bibionidae) commonly occur together with the leatherjackets (Photo 7), or on their own. Bibionids cause similar problems as leatherjackets.

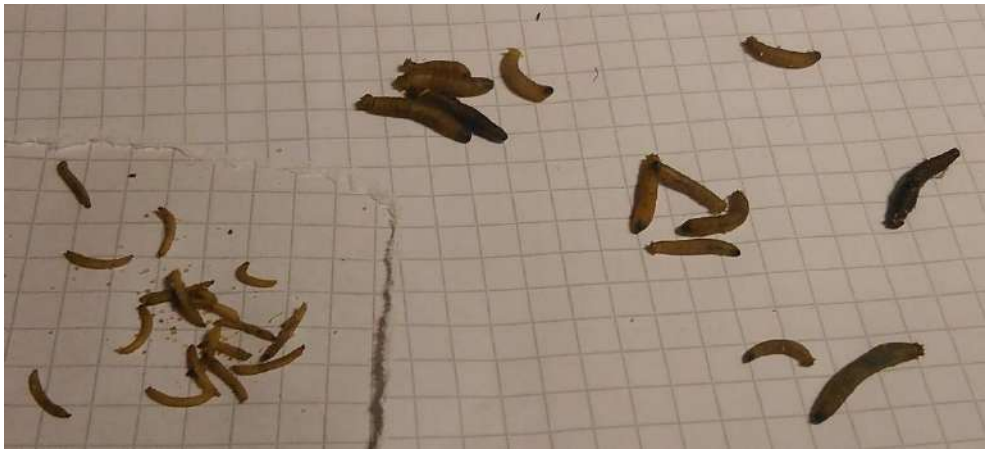

**Photo 7: Bibionid larvae on the left, leatherjacket larvae on the right. Photo: Heikki Hokkanen.**

The problems caused by leatherjacket and marsh-fly larvae on golf-courses in Finland usually cover large areas. Most problematic is their presence in or around the greens, and especially the bird damage associated with them. Sometimes control measures would be needed on several hectares, even up to 10 ha (From survey by Heikki Hokkanen, Aasatek Oy and Janne Lehto, Hirsala Golf Oy).

Damages from leatherjackets to golf courses have increased in the UK especially at the south-eastern coast (BIGGA, 2021).

## 3.2 Control

For leatherjackets no pesticides are available for control in Norway, Sweden and Finland.

In Denmark the insecticide Avaunt (active ingredient: indoxacarb) will be banned in September 2022 (Petersen, 2022). The product (Gnatrol SC) based on *Bacillus thuringiensis* has a “minor use”-approval to be used against leatherjackets with 3-6 l/ha in one to three treatments in the autumn on small larvae. In the spring it can also be used if the treatment in the autumn has not been sufficient (Dansk Golf Union, 2022).

The only guideline for non-chemical control relates to drainage and the promotion of natural enemies. Many greenkeepers install nest boxes in trees and on buildings to attract birds especially starlings which are known to feed on leatherjackets in spring (See chapter 5.2.1). In Finland at least one greenkeeper is using this method and is very satisfied with the result.

At present (August 2022) in the UK, the insecticide Acelepryn can be used to control leatherjackets with an Emergency Authorisation (EA) (Syngenta, 2022).

# 4 Survey in 2020

In autumn 2020 a brief survey was done among golf course consultants in Denmark and Sweden to get an overview on the current problems with chafer grubs and leatherjackets. In the survey the consultants were asked to estimate the problems they had experienced in 2020 and the recent 2-3 years back.

In Sweden, both occurrence and damages from chafer grubs and leatherjackets were estimated. 'Damages' were defined as the number of golf courses that had recorded problems related to the insects. 'Occurrence' was defined as the number of golf courses that had observed the insects but did not experience any problems related to them. In the survey in Denmark only 'damages' were estimated. The estimates are shown in % among the 450 golf courses in Sweden and 189 golf courses in Denmark.

**Table 1: Percentage of golf courses in Denmark and Sweden that had experienced damages and occurrence of chafer grubs and leatherjackets in 2018-20. 'Damages' are defined as courses that have recorded problems related to the pests, 'occurrence' are defined as courses that have observed the insects but had not recorded any problems related to them.**

| | **Denmark** | **Sweden** | |
|---|---|---|---|
| | Damages | Damages % | Occurence |
| Chafer grubs | 3.7 | 1.1 | 6.7 |
| Leatherjackets | 20.0 | 5.1 | 18.9 |

The results showed that problems were larger in Denmark than in Sweden with 20% of the golf courses experiencing problems with leatherjackets compared to 5.1 % in Sweden. For chafer grubs 3.7 % of the Danish golf courses experienced problems compared to only 1.1 % of the Swedish courses.

Problems with chafer grubs were located to sandy soils primarily in the south-eastern parts of Sweden, and in Denmark they were located to the northern parts of Jutland. The problems were mostly on fairways and semi roughs but also on greens and tees.

The problems in both Sweden and Denmark had been relatively alike in the years from 2018-2020. Compared to the situation in 2005-10 in Denmark with high damages from chafer grubs it was decreased in 2018-20. In contrast damages from leatherjackets have caused increasing problems especially on golf courses in Western Denmark on sandy soils (Pers. Comm. Allan Brandt). In Sweden they see the same pattern with increasing damages from leatherjackets especially in Southern and South-western Sweden (Pers. Comm. Peter Edman).

In the survey the golf course consultants were also asked about the use of alternative control methods. In Sweden there had been a few experiences with the use of EPN to control chafer grubs and leatherjackets with limited results on greens, but no experiments on fairways. The conclusions were that the use of EPN was an expensive and unreliable method according to the greenkeepers involved in the experiments (Pers. Comm. Peter Edman).

# 5 Alternative control methods

## 5.1 Experiments with microbial control agents

Microbial control agents include in this text entomopathogenic nematodes (EPN), entomopathogenic fungi and strains of *Bacillus thuringiensis*. The use of microbial control agents in turfgrass is very limited due to high turf quality standards and competition from synthetic insecticides (Koppenhöfer & Wu, 2017).

EPN are commonly used to control insect pests in many different crops and against a wide variety of insect species. They thrive in a sandy, humid soil. Application can be performed by a gentle spraying technique with plenty of water, usually 800 l/ha or more. Soil penetrants and/or nematode protectant additives significantly improve their efficacy (target dependent). Applications are best carried out in humid weather, in the evening or early morning even just before rain. At golf courses overcast irrigation immediately after treatment helps. EPN die from direct sunlight (UV damage). When spraying, all filters in the sprayer must be removed (because the nematodes will be stuck in them) and nozzles must be at least 0.8 mm and max. pressure of 1 bar. Infected larvae will stop to eat within 3 days after infection and die after 10-14 days. Optimum soil temperature is around 20-25 $^{o}$C (range 10-30 $^{o}$C). (Pers. Comm. Heikki Hokkanen).

Experiences with the use of EPN to control chafer grubs at golf courses in the UK (Hansell, 2018) are inconclusive. One of the secrets are to get the nematodes to where they need to be as quickly as possible which could include a machine that injects nematodes directly into the soil. If EPN are used in collaboration with monitoring traps with special attractants, success rates can be increased.

### 5.1.1 Experiments in Denmark 2001-2021

From 1998-2003 damages from chafer grubs became an increasing problem on golf courses, football pitches and amenity lawns especially in Denmark, so several experiments were carried out and the use of EPN showed the most promising results (Petersen, 2019). Some of the first experiments (Ravn & Phillipsen, 2001) showed that applications of nematodes in July gave the best effect to control the chafer grubs, but totally the effect of these experiments was low. In 2002 laboratory experiments with the entomopathogenic fungi *Metarhizium anisopliae* to control chafer grubs showed promising results (Vestergaard, 2003). The year after field trials with *Metarhizium anisopliae* (dispersed in two ways – in water and on a Sorghum-media), EPN (*Heterorhabditis bacteriophora*) and the systemic insecticide imidacloprid (formulated as a granular) were tested on two fairways at Give Golf Course where there had been severe damages from chafer grubs in 2002 (Larsen et al., 2004).

The results showed a very high effect of imidacloprid (reductions of chafer grubs of 76-94%) compared to *Metarhizium anisopliae* (6-61% on Sorghum-media). *Metarhizium anisopliae* in water and EPN had almost no effect. The EPN was injected into the soil to enhance contact between nematodes and larvae. The treatment with EPN was done on August 19$^{th}$ to get a high population of 3. stage larvae, but maybe the timing was too late for the nematodes while they need a minimum of min. 10-12 $^{o}$C to reproduce (Larsen et al., 2004). Two years later the product Merit Turf (imidacloprid formulated as a granular) was registered for use against chafer grubs on turfgrass in Denmark and the approval continued until 2018. In 2019 the use of neonicotinoids was banned in the EU.

The latest experiments conducted in Denmark in 2021 (Kemezys et al., 2022) focused on control of leatherjackets as there were only very few attacks from chafer grubs. Seven different products were tested: Two EPN-products ('Nemasys' and 'Leatherjacket Killer'), a product based on *Bacillus thuringiensis* ('Gnatrol SC'), a product based on an entomopathogenic fungi ('BotaniGard WP') and a

product based on a fatty acid ('Flipper'). As reference three synthetic insecticides were used: Merit Turf (imidacloprid), Coragen (acelepryn) and Steward 30 WG (Avaunt) (Table 2).

**Table 2: Products tested in field experiments (Kemezys et al., 2022).**

| Product name | Content | Dosage | Time | Application |
|---|---|---|---|---|
| Control | - | - | - | - |
| Merit Turf (imidacloprid) | Insecticide | 30kg/ha | A | Granular mixed with sand |
| Nemasys Leatherjacket Killer | Nematodes | $5x10^7$ units/100 $m^2$ | A and AB | In water (0.67 l/$m^2$) |
| Coragen (acelepryn) | Insecticide | 0.55 l/ha | A and AB | In water (600 l/ha) |
| Gnatrol SC | Bacteria | 6 l/ha | AB | In water (600 l/ha) |
| BotaniGard WP | Fungi | 0.0625% w/w | AB | In water (600 l/ha) |
| Flipper | Fatty acid | 9 l/ha | AB | In water (600 l/ha) |
| Steward 30 WG (Avaunt) | Insecticide | 0.225 kg/ha | A | In water (600 l/ha) |

A: First treatment (Sep 24th in Fredericia, Oct 5th in Horsens)
B: Second treatment (Oct 13th in Fredericia, Oct 21st in Horsens)

The experiments were conducted on two golf courses in Jutland (Two experiments in Horsens and one in Fredericia). Both are golf courses with well-known yearly populations of crane fly's/leatherjackets. Timing of the treatments was done in close dialogue with the course managers/greenkeepers as they observed the crane fly's swarming to optimize the right time for applications. Treatments were done at two dates A and B: In Horsens (A: Oct 5$^{th}$, B: Oct 21$^{st}$), in Fredericia (A: Sep 24$^{th}$, B: Oct 13$^{th}$).

Results were evaluated by collecting soil samples at three dates in November where numbers of leatherjackets were counted. The experiments were conducted according to GEP (Good Experimental Practice). The results showed that Coragen had the highest effect (both as single A and combined AB treatment) followed by Merit Turf and Steward 30 WG. The alternative products (EPN, bacteria, fungi, and fatty acid) resulted in a lower effect, but significantly higher than the control when analysed collected in the whole dataset. By analysing the individual experiments, the alternative products were mostly not significantly different from the control. Two treatments (AB) 2-3 weeks after first treatment A increased the effect of Coragen in one of the experiments. Two treatments with EPN did not improve the effect though this was expected, but this could be due to the low temperatures (Air: 8.8-9.9 $^{o}$C, soil: 8.0-9.0 $^{o}$C) at the second treatment dates (B).

In autumn 2022 practical field experiments with Gnatrol SC and EPN-products will be repeated at the two golf courses to get more knowledge on the most effective methods of using these biological control agents.

Table 3: Results from field experiments to control leatherjackets (Kemezys et al., 2022).

| Product name | Effect | Mean of larvae/m² | % effect |
|---|---|---|---|
| Coragen AB | Good | 0.9 | 85.3 |
| Coragen A | Good | 2.5 | 72.4 |
| Merit Turf | Moderate | 23 | 67.9 |
| Steward 30 WG | Moderate | 51 | 52.2 |
| Nemasys Leatherjacket Killer A | Low | 58 | 47.5 |
| Nemasys Leatherjacket Killer AB | Low | 58 | 42.4 |
| Gnatrol SC | Low | 63 | 41.1 |
| Flipper | Low | 53 | 40.1 |
| BotaniGard WP | Low | 63 | 39.1 |
| Untreated | | 106 | 0 |
| lsd P=0.05 | | 3.12 | 19.49 |

### 5.1.2 Experiments with EPN in Finland

Photo 8: Early spring application of EPN on a golf course in Finland, March 2021. Photo: Heikki Hokkanen.

The efficacy of EPN (entomopathogenic nematodes) in controlling insect pests under outdoor conditions can be substantially improved. The main factors to improve the performance of EPN are formulation, application technology and EPN species. Particularly the rearing of certain species of EPN that best would fit to the Nordic climate, is a challenge. The performance of currently available EPN species utilizing formulations that enhance efficacy and survival has not been tested against chafer grubs and leatherjackets in the field in Finland. This work should be carried out during the coming years.

EPN from the company Aasatek Oy were tested in 2021 on two golf courses in Finland.

At the first golf course, treatments were carried out at three times during the season:

**First treatment** was conducted over an area of 1000 m² on 29.3.2021, to control larvae of leatherjackets and marsh-flies, which had surfaced in masses on some greens and adjacent areas (Photo 9).

Photo 9: Larvae of leatherjackets and marsh-flies on a golf-course in Finland in early spring. Photo: Heikki Hokkanen, Aasatek Oy, 29.3.2021

The EPN product "PeltoSukkula" (Aasatek Oy) was employed at a double dose, combined with a protectant, and sprayed with conventional spraying equipment in the evening of an overcast day. The greenkeeper inspected the site after one week, and repeatedly after that. The larvae had disappeared and did not re-appear.

**Second treatment** was carried out at the same golf course with a double dose over an area of 1 ha on 27.5.2021. The same procedure was followed as in the first treatment, except that this time instead of the protectant, a soil penetrant was used as an additive. The target was dipteran larvae (Tipulidae, Bibionidae) in the soil. According to the greenkeeper, the treatment worked well, and the problem eased.

**Third treatment** took place on 27.8.2021 over an area of 1 ha. This time, a single dose was used, following otherwise the same procedure as in May. The targets were dipteran larvae, as well as grass grub larvae, with the aim of reducing their numbers for the following year. Follow-up studies were not possible for this treatment (Pers. Comm. Heikki Hokkanen).

At the second golf course, a single treatment over 1 ha area was carried out on 7. June 2021. A double dose of "PeltoSukkula" (Aasatek Oy) was applied following the same procedure as on the first golf course in May. The target pests were larvae of leatherjackets, marsh-flies ad grass grubs. The greenkeeper was satisfied with the efficacy of this treatment. At this golf course, also an earthworm repellent (Aasatek Oy) was tested on some greens for efficacy. According to the greenkeeper, the product worked well, and the earthworms disappeared.

One of the great challenges for the use of EPN and other biological products is that several factors must be right for optimum efficacy such as: Soil water content, method of application, age of larvae, depth of larvae, time of day to minimise UV damage to nematodes, etc. If the operators are aware of these conditions for a successful pest control and follow the instructions, the biocontrol options likely are providing a satisfactory control. The challenges for successful chemical control are similar, but operators are used to follow the instructions and requirements regarding the handling and use of chemical pesticides. Greenkeeper feedback from the survey in Finland indicated that spraying chemical pesticides provided varying results, sometimes good but often no noticeable reduction in pest damage. In this respect the experiences from applying EPN are at least equally good if not better (Pers. Comm. Heikki Hokkanen).

## 5.2 Bird boxes, irrigation, and other methods

### 5.2.1 Nest boxes for starlings

Two studies were done in 2018-19 at a golf course in Southern Denmark to investigate the breeding success for starlings on a golf course, and how much the starling contribute to the control of insect pests mainly leatherjackets (Heldbjerg et al., 2019). The first study: "Invite the starling to help the greenkeeper" was a study of starlings breeding in nest boxes. The second: "What do the starlings eat at the golf course?" studied the invertebrates in the turf layer.

**Photo 10: A nest box at Sydsjællands Golfclub is examined with an endoscope camera. Photo: Bo Kayser.**

100 nest boxes for starlings were placed all over the golf course in 2018. All were numbered and georeferenced via a Turfgrass app. All breeding birds were recorded, and juvenile starlings were ringed. 45 successful clutches were found in 2019 which produced on average 5.0 nestlings per clutch which is similar to (or slightly higher than) the production in natural breeding areas in cultivated land in Denmark. This proves that the golf course provides conditions that are sufficient for the starling to produce successful clutches, with an estimate of more than 100 kg prey removed from the grass.

The project also studied where the starlings foraged and simple counts at six counting points showed that there were markedly differences between the number of foraging starlings at different parts of the golf course and where they forage during the season. The starlings foraged mainly on the fairway and often also in the semi-rough, but rarely on the greens. Very few starlings were foraging in parts of the golf course with sandy soil probably with less prey for the starlings.

To see what the starlings preyed upon; samples of the turf were extracted in transects from the green to the semi-rough. Many different invertebrates were found but only earthworms and leatherjackets were in biomass of importance for the starlings. The number of earthworms per square meter of the fairway was more than twice as big as in the semi-rough and there were none in the greens.

The number of leatherjackets was lower than expected in 2019, and unfortunately, there was no results from before the setup of nest boxes for comparison, but the study concluded that the problems with the leatherjackets were reduced significantly due to the help from the starlings.

### 5.2.2 Irrigation

**Photo 11: Irrigation in the middle of the day at Viborg Golf Club to prevent garden chafers from laying eggs at greens. Photo: Torben K. Petersen, June 2018.**

At Viborg Golf Course in Jutland, Denmark they have collected experiences through many years by using irrigation to scare off swarming garden chafers from the greens (Hesselsøe, 2018). In 2015 course manager Per Knudsen at Viborg got the idea to start up the irrigation system daily a few minutes in the middle of the day in the 14 days of swarming period of the garden chafers in late May/beginning of June. The irrigation system was turned on from approx. 10am to 2pm and irrigated every green for 3-4 minutes. The short irrigation promotes cooling and increases soil moisture on the greens making them less attractive for the beetles to breed and lay eggs in. The idea is only to scare off the beetles from laying eggs on greens and the nearest surroundings which are covered by the irrigation system.

Good communication is essential to make this method work well, and therefore the golfers are informed on tee 1 (with a warning sign) in the period where the irrigation system starts up in the middle of the day.

From 2015-18 they have had a section of the course with no irrigation to be used as control and all years except for 2018 they have seen an effect in reducing chafer grubs by irrigation. Since the extremely dry summer in 2018 the problems with chafer grubs have declined at Viborg Golf Course, and they have not used the method the last 3-4 years (Pers. Comm. Per Knudsen).

### 5.2.3 Mechanical methods

Rotary knives can be used to crush the larvae of chafer grubs during the months when they are closest to the soil surface, but experiences from UK have shown that the damages increased while crows used the slits made from the rotary machine to get better access to the larvae (Hansell, 2018).

Sheeting is a method used in the UK where plastic tarps are placed on the surface to monitor populations of leatherjackets in the soil, but also to get control. The sheets/tarps are placed on the green surface at springtime and left overnight. Leatherjackets seek to the surface where they are brushed or mowed away. Sheeting is an effective but also laborious method to control leatherjackets and it is destructive to golf (BIGGA, 2021).

### 5.2.4 Compost and other organic products

The use of topdressing with compost to decrease chafer grubs was tested in 2003 at a compost producing facility in Denmark (KomTek) (Schmidt, 2003). They used topdressing mixed with 25, 50 or 80 w/w-% of compost and applications of Cyperb (cypermethrin) in the middle of June approx. one week before the garden chafers swarmed. The results showed that the amendment of 80% of compost to the topdressing and spraying with Cyperb had a reducing effect on the larvae population.

TourTurf Sports Turf Acidifyer (STA):

In 2018 practical experiments were done at Sindal Golf Club (Denmark) with liquid fertilizers TourTurf Sports Turf Acidifyer (STA) to control huge attacks from chafer grubs. Three treatments with the product were done on greens. According to the course manager at Sindal they have experienced no problems with chafer grubs since 2018, but that is on both treated and untreated areas, so an effect of the product cannot be confirmed in this case (Susanne Olsen, Pers. Comm., August 2022).

### 5.2.5 Scaring off crows

Different methods to scare off crows to decrease damages from the birds digging after the larvae are used on both Danish and Swedish golf courses. Methods like dragons and BirdAlert have been used, but the results have been differing. The main challenges have been to switch 'scaring off method' often, because crows are intelligent birds, that quickly learns. Most effective was to shoot some of the crows if this is a legal option (Pers. Comm. Peter Edman).

# 6 Perspectives and future research

At present it is not realistic to get Emergency Authorisations to use acelepryn (as in the UK) or other synthetic insecticides to control chafer grubs and leatherjackets in Scandinavia (Pers. Comm. Torben K. Petersen). The consequence of that is that we have to rely on biological and other alternative methods. Good communication with the golfers is therefore essential when a golf course is damaged by chafer grubs or/and leatherjackets, and though the biological methods have been (and is still) tested in several experiments (as described in this report) the golfers must get used to more damages from insect pests now and in the future. They also have to accept that the biological methods are more expensive and less effective than the synthetic insecticides.

**Table 4: A brief summary of the problems with chafer grubs and leatherlackets and available control methods in Scandinavia today.**

| | Chafer grubs | Leatherjackets |
|---|---|---|
| **Problem** | In the last 10-15 years damages are limited to a few golf courses (1.1-3.7 %) with sporadic attacks from year to year. Most abundant on sandy soils. | More widespread damages on golf courses (5.1-20.0 %), and it seems as they are increasing. Most abundant on moist areas |
| | No synthetic insecticides are available, and no prospect of Emergency Authorisations of new insecticides | |
| **Control** | Microbial agents like entomopathogenic nematodes (EPN) and strains of *Bacillus thuringiensis*. Better monitoring and warning to improve determination on how to use them correct. Greenkeepers have to become experts in using microbiological control | |
| | Irrigation on greens and surroundings at daytime when beetles are swarming to prevent them laying eggs | Nest boxes for starlings Sheeting greens in spring |
| | Scare off crows destroying the turf | |
| | Communicate to the golfers that they have to accept more damages from insect pests on the golf courses | |

For control of the leatherjackets, grubs, and other pest insects in turf, more research should be put into improving the efficacy and reliability of EPN. Overall, a more comprehensive pest management strategy needs to be developed, based on the principles of ecostacking (stacking of ecosystem services for improved biocontrol in this case) (Hokkanen, 2017; Hokkanen & Menzler-Hokkanen, 2020). Meanwhile course managers and greenkeepers must improve their skills to become experts in using alternative and biological methods.

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