Development of methods for non-pesticide weeds control on fairways.

Project period:

From February 2008 to December 2012

Principle investigator / contact person:

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Collaborators:

Financing

- STERF (Scandinavian Turfgrass and Environment Research Foundation)
- The Danish Golf Union
- Faculty of Life Sciences, University of Copenhagen
- Forest & Landscape, University of Copenhagen
- Asserbo Golf Club
- Furesø Golf Club

Supervisor team

- Supervisor; Palle Kristoffersen, Forest & Landscape, University of Copenhagen
- Supervisor; Christian Andreasen, Faculty of Life Sciences, University of Copenhagen
- Co-supervisor; Anne Mette Dahl Jensen, Forest & Landscape, University of Copenhagen

Objective according to project proposal:

Aim

The aim of the project was to develop new and improved strategies for pesticide free mechanical management of weed, with focus on timing and frequency in order to reduce herbicide use on golf course fairways.

The project aims to test how different maintenance principles individually and in combinations and at different frequencies affect the occurrence of weeds, while taking into account the lawn quality. Moreover the timing issues should be involved in the evaluation of the mechanical maintenance principles. It is assumed that the time of a specific mechanical treatment, is a strong contributing factor for treatment effect.

This project could potentially generate targeted effective maintenance strategies, either problem specific or general recommendations for controlling weeds on the fairways.

Output

The project is expected to generate knowledge that can provide a basis for practical recommendations on pesticide free management of weed.

Hypotheses

The basic assumption in pesticide free lawn maintenance is that the amount of weeds in particular can be limited indirectly through good lawn maintenance, giving the grass the best competitiveness against weeds. This is believed to be promoted by optimizing / ensure nutrient supply (fertilization).

Weeds are also presumed to be inhibited by direct action of mechanical maintenance such as vertical cutting, harrowing and topdressing. Additionally it is assumed that the time and frequency of specific mechanical treatments are a strong contributing factor for treatment effect.

Picture 1. Topdressing at Asserbo golf course. Photo; Ken S. Krogholm.

Key outcomes of the project:

Results

- Vertical cutting, tine harrowing and topdressing in different combinations, with different frequency and at different times have no effect on the weed occurrence after 2 years.

- Knowledge of weed species development and demographic under frequent moving has been increased.
    - The flowering period of weed species (dandelion) is extended under a frequent mowing regime
    - Many small dandelions are observed in late summer and fall

- Weed control using a weed burner might be a method to control some weed species. Further experiments needs to be performed.

- Turf stripping followed by a re-sowing can be a method to reduce the amount of superficial weed species and change the grass composition to more competitive species/varieties. Weed species with deep tap roots will reappear.

- Problems caused by earthworm casts might be reduced on fairways with topdressing and an acid fertilizer. Further experiments needs to be performed.

- Evaluation of the economic costs of performing mechanical weed control is difficult when it is based on only two golf courses. Procedures and equipment are very different.

Conclusion

- More knowledge of the weed species morphology, physiology and demography is needed in order to find mechanical methods that can be used to control/reduce the weed population in turf.

Project summary:

We present results of weed control strategies conducted on fairways from two golf courses placed on two different soil types over a 2-years period. The two soil types were clay and sand. The management strategies in focus were various combinations of vertical cutting, tine harrowing, topdressing and fertilizer levels. The aim was to improve the competitiveness of the turf and reduce the presence and further invasion of weeds. Our focus was especially on the combined effects of various combinations of the chosen management methods on the distribution of weeds. The experiments were conducted on actual golf fairways and placed as randomized block experiments with 4 repetitive blocks on each soil

type/golf course. Data were collected by digital photographing using a fixed camera on a movable stand with a build inn 100 squares frame. This method of data sampling allows for much more reliable and undisturbed analysis of data as compared to on location data analysis. Data were collected during the growing season from early April till late October. The weeds investigated are *Bellis perennis*, *Taraxacum sp*. and *Trifolium repens*.

The fact that the Ph.D. student quit due to illness in early summer 2010 resulted in a change of focus and a number of small experiments were planned. Additionally knowledge collection from a number of golf courses was carried out from 2010 to 2012. These small experiments indicated some interesting trends and ideas for further experiments on methods for weed control without pesticides have been generated.

Background

Environmental concerns about the use of land for golf courses have grown over the past fifty years (Aramburu and Escribano, 1993, Markwick, 2000, Neo and Savage, 2002, Briassoulis, 2007). Specific issues include the amount of water, chemical pesticides and fertilizers used for golf course management, as well as the perceived destruction of wetlands and other environmentally important areas during construction. These issues, along with health and cost concerns, have led to research into more environmentally sound practices of turf grass management and a significant reduction in the amount of chemicals and water used on golf courses in Denmark.
In Denmark, the risk of pesticide contamination of groundwater/drinking water reservoirs has resulted in several restrictions on the use of pesticides in urban areas including the golf courses. A voluntary agreement between the Minister of Environment and the Danish Golf Federation (DGU) was signed in 2005. The goal in the agreement was to reduce pesticide use on Danish golf courses with 75% over a 3 year period. In order to fulfil this agreement, the need for alternative control methods has increased substantially however the quality and function of the land (golf course) must be maintained (Kristoffersen et al. 2004).

Weed can impair one golf course quality and therefore it is often necessary to combat this, especially on the fairways. A fairway is the playing field between the tee site and putting green. There are significant requirements for the playing quality on the fairway - though less demanding compared to the putting green. It is primarily desirable that the fairway grass has a high shoot density, which can carry the ball up, in order to achieve a better contact between the ball and the golf iron which gives a higher precision (Jensen and Jensen, 2012). In addition, the fairway should be smooth, uniform and relatively firm, so the ball can roll smoothly after impact. Finally, the fairway should appear with an attractive appearance, which is equal to a smooth and lush vegetation cover and no flowering weeds that might interfere with the game.

Weeds can be controlled by chemical means, but the demands for more sustainable solutions (a reduction in pesticide use) means that alternative methods is a priority. However, it can be a challenge to get the grass to survive when using mechanical treatment methods whose purpose is to reduce or eliminate unwanted weeds. At present there is a lack of effective solutions without pesticides.

The fairway makes up the largest area of the golf course and is generally cut short and evenly which favours weeds like *B. perennis*, *Plantago major*, *Poa annua*, *Taraxacum sp*. and *T. repens*. Various management strategies have been developed during the years with focus on obtaining and maintaining a homogeneous and uniform turf. In many years pesticides have been the major method of restricting weed growth (Turgeon et al., 1994). Various mechanical weed control methods are also common practice though there is a lack of scientific documentation for their effect.

Danish legislations are reducing the pesticide use on golf courses, which in near future will enhance the need for alternative methods of weed control dramatically. The most common management practices on golf fairways in Demark are mowing, vertical cutting, spring tine harrowing, aeration methods, fertilizing, top-dressing and up until resent the use of pesticides (Jensen et al., 2012). These management practices have mostly been thought of as turf improving methods, with focus on the

growth stimulating benefits on the grass species as well as maintaining a uniform and high quality playable turf at all times. Our intentions of this study have been to challenge these management methods in relation to weed control.

A common feature of non-chemical weed control methods is that in order to achieve an effective control repeated treatments are requires. Using chemical for weed management only requires one or two treatment each year (Popay et al., 1992; Elmore, 1993; Augustin et al., 2001; Reichel, 2003; Kristoffersen et al., 2004; Rask & Kristoffersen, 2007). Non-chemical treatments mainly affect the above-ground plant parts, whereas systemic herbicides kill the entire plant (e.g. Augustin, 1990; Popay et al., 1992).

A plant is a weed, when it occurs in a place where it is unwanted. It may for example be a dicotyledonous plant that grows on a golf fairway, which theoretically should be a monoculture of grass. In many cases, there will be a need for control because weeds can have a big impact on the playing quality. Whether or not the weed must be controlled depends on the golf club/course and what they can accept.

There are two main approaches in weed control; 1) Use of chemical agents that are relatively effective for removing most types of weeds. 2) Fighting without chemistry, either on the basis of ideology or because of restrictions due to an environment and health concern.

Pesticide free weed control in a lawn comprise of different strategies. 1) Grass plant density can be promoted which makes the lawn becomes more competitive. It can be done by increasing the level of fertilization (Jackman & Mouat, 1972). Cultural practices aimed at giving the weeds poor growing conditions. 2) Mechanical, thermal and cultural practices that stress, harm and kill weeds can be initiated (Andersen, 2000). Today, we have no effective methods due to the lack of specific knowledge about the weed species under lawn condition. Knowing the stage of development where the weed species are most vulnerable to mechanical damage is particularly important. (Nkurunziza et al., 2011). Mechanical methods such as grooming and vertical cutting may damage the plant. 3) Prevent seed dispersal, in order to minimize the pressure of weeds. 4) Use of bio-stimulants or biological control agents such as bacterial and fungal preparations, gluten-containing preparations and special types of compost (Abu-Dieyeh & Watson, 2007). At present there are no effective pesticide-free maintenance methods that can eliminate weeds. Manual hand weeding is the only option but it requires a lot of personnel which is not available in Danish golf clubs.

At University of Copenhagen, Denmark, experiments with mechanical weed control were carried out in 1999 – 2011. The effect of vertical cutting, various types of harrowing, fertilizer, topdressing, etc. have been evaluated in various combinations. These trials demonstrated that some of the treatments had an effect on the weed occurrence. But it was a small effect and it was not possible to effectively reduce the incidence of weed on football pitches and golf course fairways. The experiment did not focused on the individual weed species, but has been on weeds in general (Fisher and Larsen, 2002).

A new experiment must go into details with some of the above mentioned principles of pesticide free maintenance. This includes the supply of nutrients (fertilizer), mechanical treatments (e.g. vertical

cutting, harrowing, aeration), transfers of new plant material (overseeding with new and improved grass varieties) and in some cases the addition of new growth material (e.g.. by topdressing). Future studies should be based on some of these maintenance principles.

Fertilization: Fertilizer generally promotes grass growth, and several studies have found that an increased amount of fertilizer can reduce the amount of weeds in the lawn, mainly by promoting grass growth Kopp and Guillardb 2002). A fertilization strategy includes; choice of fertilizer, fertilizer amount and timing of application. When the intention is to fight weeds fertilization is supposed to be very significant but it is important to find an optimal balance between, on the one hand, the strengthening of the established grass and on the other hand, an increased risk of nutrient leaching. Experiments should be based on the average amount of fertilizer used in Danish golf clubs and then chose level on both sides of this. In 2007, 53.2 kg N / ha was used in average on fairways in Denmark.

Mechanical methods: The mechanical methods which are believed to have the greatest impact on weed control are those that are affecting the lawn surface. Vertical cutting is designed to promote the growth conditions of the grass by removing dead plant material (thatch), stressing the weeds by removing a part of the leaves and to limit the propagation of weed by removing a part of the inflorescences. The same effect can to some extent be achieved by using a harrow, but thatch and the inflorescence are not removed. Although harrowing is less expensive vertical cutting is believed to be more effective. If the vertical cutting is intensive it can also damage the grass. When choosing the treatment intensity it is important to find the optimal balance where weed is inhibited but the grass growth is not disturbed too much. It is therefore relevant to find the optimal treatment frequency for vertical cutting and harrowing of grass on fairways and to elucidate the optimal timing of execution of these treatments.

Introduction of new plant material: Overseeding with grasses aims to add new plants to the lawn and thus to ensure a close turf with high shoot density and with minimal space for the establishment and growth of weeds (Morris, 2004; McCarthy, 2009). When overseeding, it is possible to change the lawn composition of species and varieties and thus optimize it to the current use. Overseeding is particularly relevant in lawn areas with a worn and thin grass cover. Removal of weeds at a given site is only part of the solution. Equally important is it to establish a grass cover of desired species and varieties.

Introduction of new growth material: New growth material can be supplied by the application of topdressing. The material can be incorporated easily into the lawn surface using drag mats. The function is to make the lawn more even, increasing the turnover of the thatch layer, to provide better growth conditions in the lawn surface and to improve conditions for germination after sowing grass seed. The method accounts for a substantial maintenance expense, which has limited the method's use on fairways. Growth material can also be incorporated into the growing layer by spreading after verti drainage or pricking, and the function is then to improve the root zone properties by changing the soil texture and structure. It is estimated that topdressing followed by sowing grass has a potential controlling effect on the weeds.

The following project involves fertilizing, vertical cutting and harrowing as typical maintenance methods.

Experimental design - Original experiment

The trial was carried out during the growing season from May 2008 to October 2009. It was a block design including two trial sites (Asserbo golf course and Furesø golf course). These sites were situated in northern Zealand, Denmark. The trials were located on fairways. The fertilizer levels on these fairways were 28 kg nitrogen per hectare on Furesø golf course and 32 kg nitrogen per hectare on Asserbo golf course. In the growing season fairways were mowed 2 times per week.

The project includes two experiments

Experiment 1.	Investigation of the effect of combining fertilizer quantities, frequencies of vertical cutting, frequency of tine harrowing and timing of the treatments.
Experiment 2.	Investigation of the effect of topdressing in combination with vertical cutting and tine harrowing.

Three important weed species in turf grass in Denmark were evaluated; dandelion (*Taraxacum officinale*), daisies (*Bellis perennis*) and white clover (*Trifolium repens*) (Raikes et al., 1994; Jensen et al. 2012). These three species have different growth habit (Korsmo et al., 1981).

Picture 2 and 3. Vertical cutting at Asserbo and the plot after the treatment. Photo; Ken S. Krogholm.

Experiment 1.1

Vertical cutting - frequency	0, 1, 2 and 3 times
Vertical cutting – time	May, June and September
Fertilization level	30, 60 and 90 kg nitrogen per hectare per year

Experiment 1.2

Vertical cutting – frequency	0, 1, 2 and 3 times
Vertical cutting – time	May, June and September
Tine harrowing – frequency	0 and 3
Tine harrowing – time	May, June and September
Fertilization level	30, 60 and 90 kg nitrogen per hectare per year

Fertilizer is given in April, June and September. A mineral fertilizer (NPK 14-3-18) was used.
Time and frequency of vertical cutting was performed in the following 4 combinations; 1) none 2) May 3) May and June 4) May, June and September. Vertical cutting and tine harrowing was always performed 2 times on the same date – one time in each direction – along the direction of play. It was always followed by mowing (standard fairway mowing) also in the control.

Experiment 2.1

Vertical cutting – frequency	0, 1 and 2
Vertical cutting – time	May and September
Topdressing	Yes and no
Fertilizer level	60 kg nitrogen per hectare per year

Experiment 2.2

Tine harrowing – frequency	1 and 2
Tine harrowing – time	May and July
Topdressing	Yes and no
Topdressing – time	May and September
Fertilizer level	60 kg nitrogen per hectare per year

Fertilizer was given in April, June and September. A mineral fertilizer (NPK 14-3-18) was used.
Time and frequency of vertical cutting was performed in the following 4 combinations; 1) none 2) May 3) May, June and September. Time and frequency of tine harrowing was in the following combinations; 1) May 2) May and July. Vertical cutting and tine harrowing was always performed 2 times on the same date – one time in each direction – along the direction of play. It was always followed by mowing (standard fairway mowing) also in the control. Overseeding was performed together with the September topdressing (6 kg per 100 m^2).

Registrations of weed

Registrations were made using a digital camera mounted on a mobile tripod. The stand was fitted with a measuring frame (70cm x70cm) with 100 fields there. In each plot 6 photos were taken 4 times pr. Year (May, July, September, October).
The percentage weed cover was measured within a frame, which was divided into 10 x 10 squares. Within each square the weed cover was estimated and the result was the sum of weed cover of 100 squares for the entire frame. The frame was attached to the mobile tripod – se picture below.



Picture 4 and 5. Photo registration box with the 10 x10 frame, Photo; Ken S. Krogholm.



Picture 6 and 7. Weed registration in 10 X 10 frames, Photo; Ken S. Krogholm.

Data analysis
A statistician was consulted but due to the fact that data is only available for 2 years, the variation within each treatment and the high variation in initial weed occurrence reliable statistic cannot be performed on the data. Figures and tables are constructed in order to visualise some of the data.

Results and discussion – original experiment

Variation in weed occurrence on the experimental fairway in May 2008
The amount of weed on the experimental fairways (Furesø and Asserbo) varied significantly between the different plots when the experiment was initiated in May 2008. This was the case for both fairways (Furesø and Asserbo) and for all three weed species.
Clover was the weed with the highest occurrence frequency but the variation between plots was way too high to use the data for analysis. Dandelions were found in most plots but at a low frequency and again the variation between plots were high. Bellis was the weed with the lowest occurring frequency

and it was missing from many plots. Table 1 and table 2 are selected examples where this can be observed.

Table 1. Furesø data from May 2008. Clover frequency (%). Experiment 1-2, (Verti. = Vertical cutting, Harrow = Tine harrowing).

	0 Verti.		1 Verti.		2 Verti.		3 Verti.	
	No harrow	Harrow	No harrow	Harrow	No harrow	Harrow	No harrow	Harrow
Block 1	1,92	0	11,5	12,28	15,83	35,5	4,42	6,67
Block 2	7,25	10,83	25,67	9,17	22,67	12,67	22,92	24
Block 3	2,75	21,25	15,83	30	9,33	0	34	20,5
Block 4	7,68	23,92	11,5	21,58	34,83	38	4,17	6,33
Mean	**4,90**	**14,00**	**16,13**	**18,26**	**20,67**	**21,54**	**16,38**	**14,38**
STDV	2,99	10,91	6,68	9,44	10,90	18,33	14,67	9,21

Table 2. Asserbo data from May 2008. Dandelion frequency (%). Experiment 2-1.

	Verti cutting/Topdress					
	O Verti cutting		1 Verti cutting		2 Verti cutting	
	- Topdress	+ Topdress	- Topdress	+ Topdress	- Topdress	+ Topdress
Block 1	2,46	0,83	0,63	1,21	0,58	0,67
Block 2	2,38	1,33	2,38	0,96	0,54	2,21
Block 3	0,21	0,21	1,25	0,58	1,33	0,92
Block 4	0,33	0,83	0,63	0,58	0,88	0,58
Mean	**1,35**	**0,80**	**1,22**	**0,83**	**0,83**	**1,10**
STDV	1,24	0,46	0,83	0,31	0,36	0,76

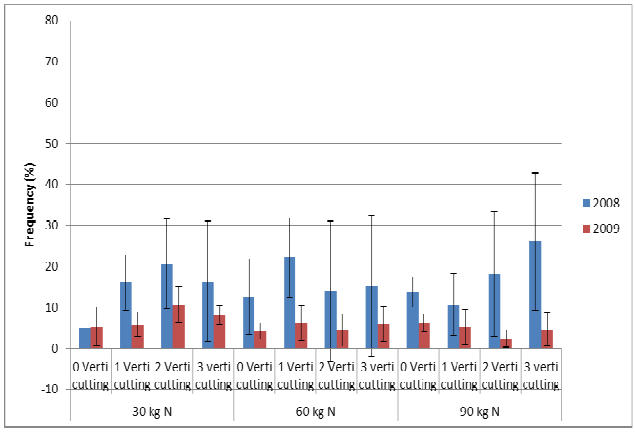
These experiments have demonstrated that investigation on mechanical management methods effect on weed occurrence must be planed very carefully, especially when the weed occurrence varies within the experimental field. The experimental fairways were selected in winter 2007/2008 before there was any weed growth. Those responsible for the project should have search for other experimental areas with more weeds. If this type of experiment has to be performed in the future the solution would be to choose a place where weed species can be planted in/sown in a turf to secure a high and even percentage of weed species in the different plots.

The effect of mechanical treatments on weed occurrence

Experiment 1.1

Experiment 1.1 examines the effect of fertilizer, frequency of vertical cutting and time for vertical cutting. Figure 1, 2, 3 and 4 are examples of data. It is clear that no tendency of a treatment effect is seen. Again the variation is much too high. The same is seen in the data from Asserbo golf course. From the data analysis it is clear that the occurrence of weed change over the growing season, but the growing seasons are very different. In 2008 the amount of clover is highest in spring where as in 2009

the amount of clover is highest in fall. For the dandelions it is more unclear how the seasonal variation is. The observed frequencies are very low and the standard deviation is much too high.



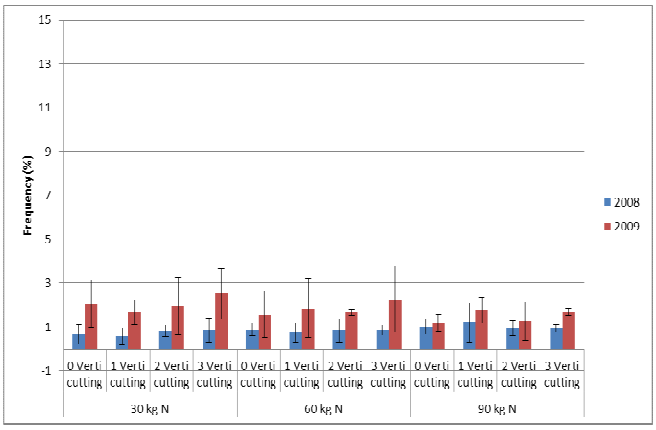
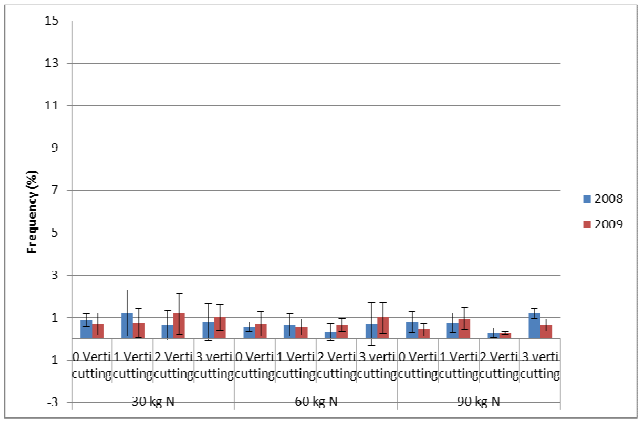


Figure 1 and 2. Furesø, Clover, May and October.



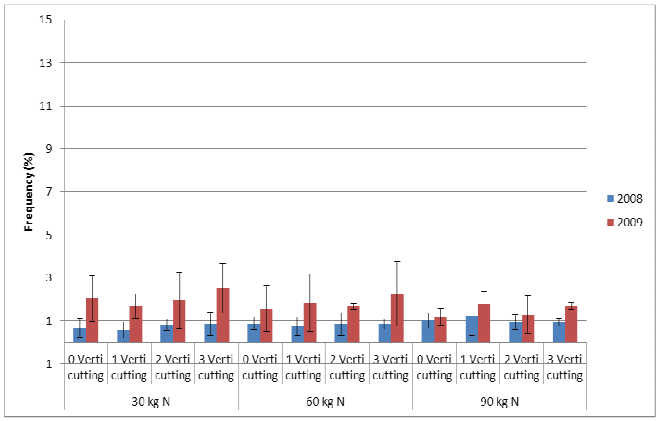


Figure 5 and 6, Furesø, Dandelion, May and October.

Experiment 1.2

Experiment 1.2 examines the effect of vertical cutting, tine harrowing and fertilizer amount. Figure 7, 8 and 9 are all examples of data from this experiment. Again there are no sign of an effect of the different treatments. And statistic analysis of data is not possible due to a high standarddeviation and only 2 years results.The experiment performed by Fisher and Larsen (2002) demonstrated a significant effect of combining several methods but they did not registre on individual weed species. It was a significan decrease in overall weed occurrence they registred and the weed frequences were very low.

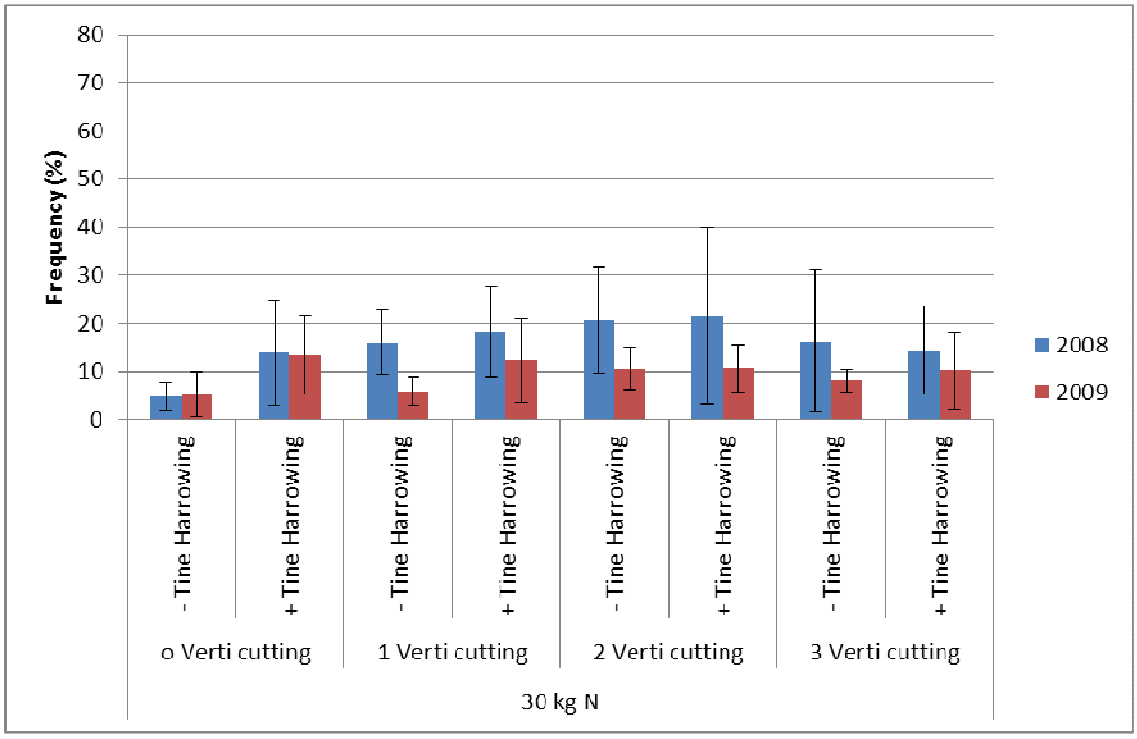


Figure 7. Furesø, Clover, May 30 kg N.

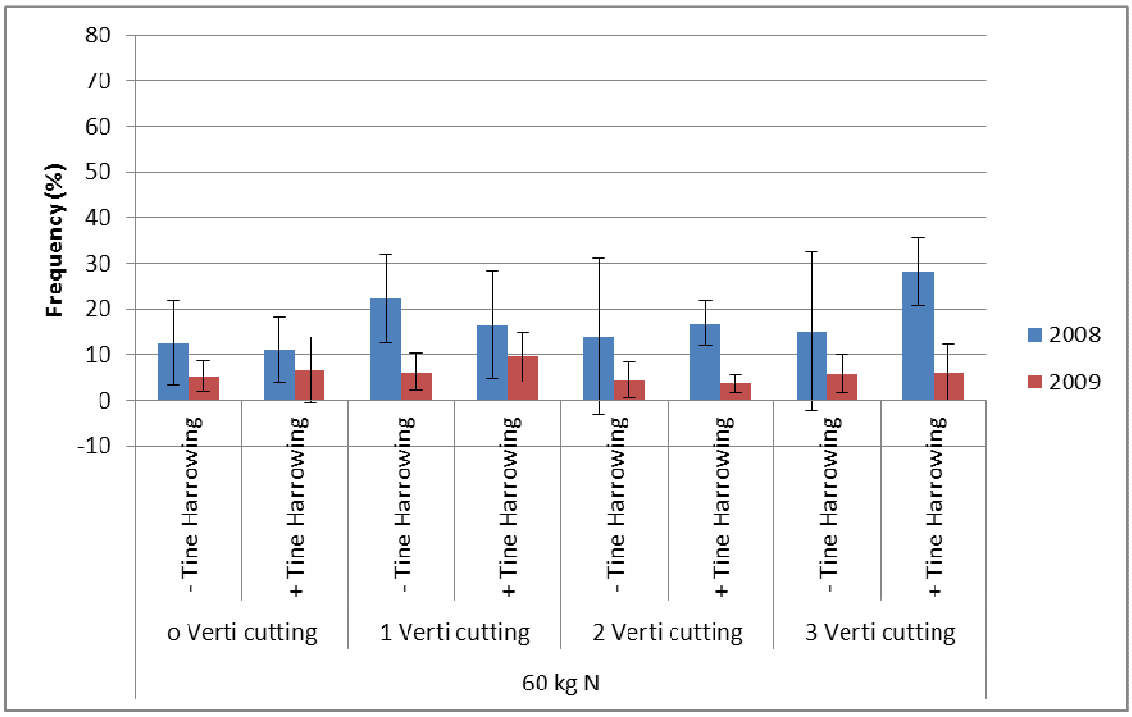


Figure 8. Furesø, Clover, May 60 kg N.

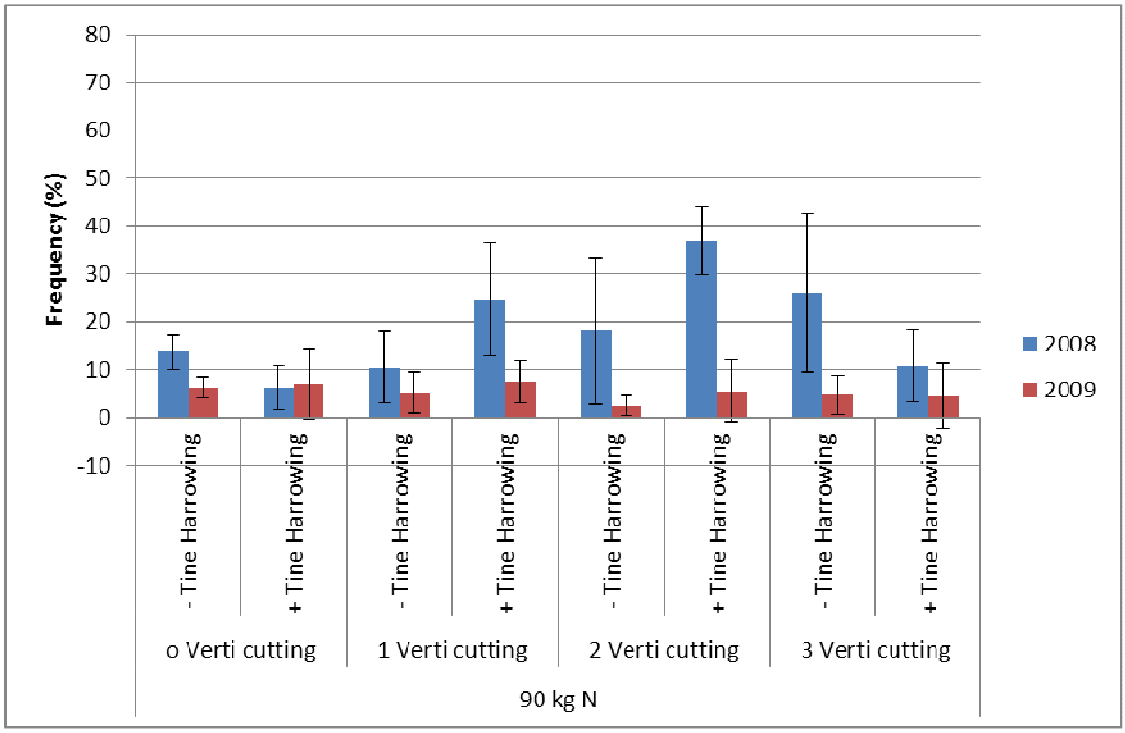
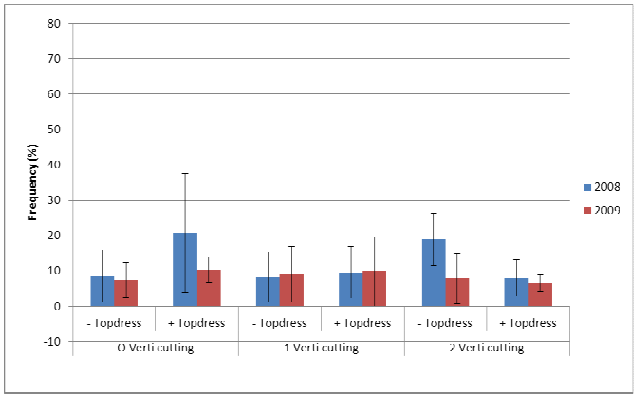


Figure 9. Furesø, Clover, May 90 kg N.

Experiment 2.1

Experiment 2.1 examines the effect of combining vertical cutting and topdressing. Examples of these results are given in figure 10, 11, 12 and 13. There are no clear indications of an effect of the different treatments. In spring the amount of weed is lower in most treatments in 2009 compared to 2008 where as in fall 2009 the weed occurrence is higher in all treatment combinations compared to 2008.



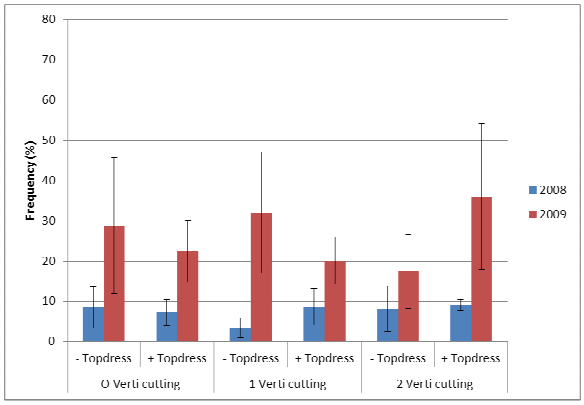
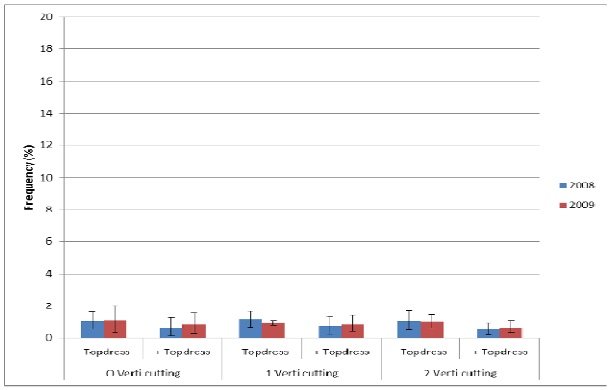


Figure 10 and 11. Furesø, Clover, May and October.



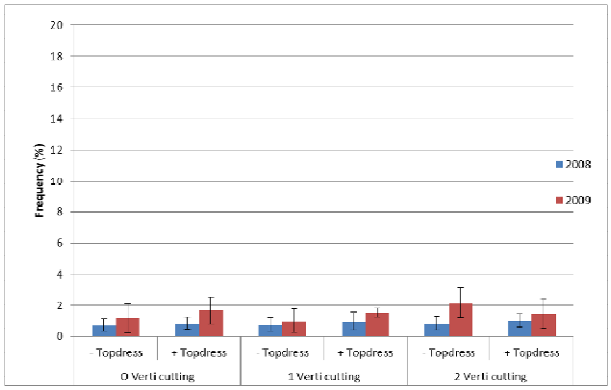
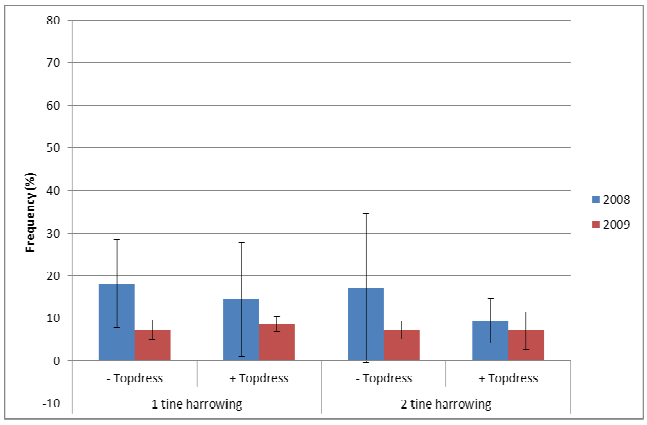


Figure 12 and 13. Furesø, Dandelion, May and October.

Experiment 2.2

Experiment 2.2 examines the effect of tine harrowing and topdressing. Figure 14, 15, 16 and 17 are examples of data from this experiment. These data also visualise that no tendencies of a treatment effect can be found. Again the variation in weed occurrence over the growing season is displayed.



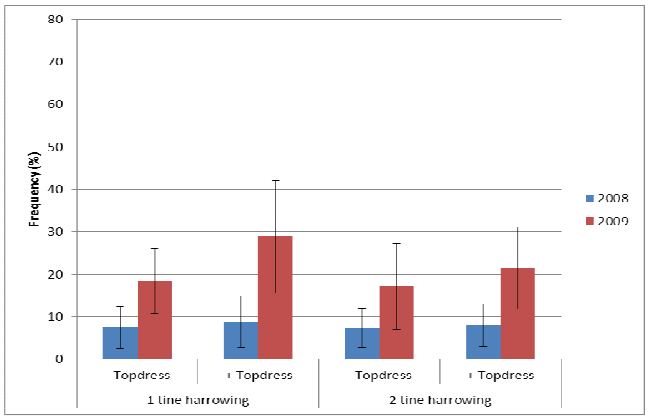
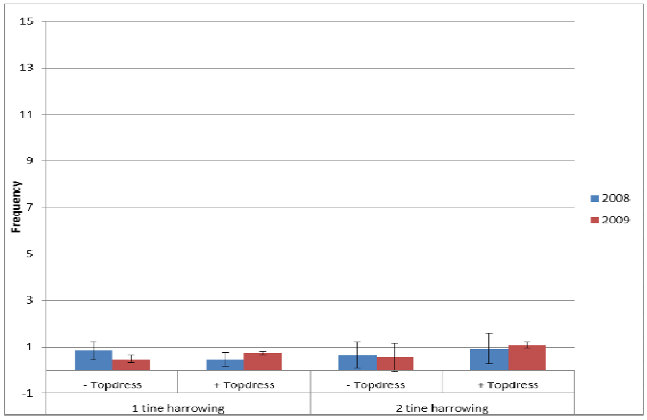


Figure 14 and 15, Furesø, clover, May and October.



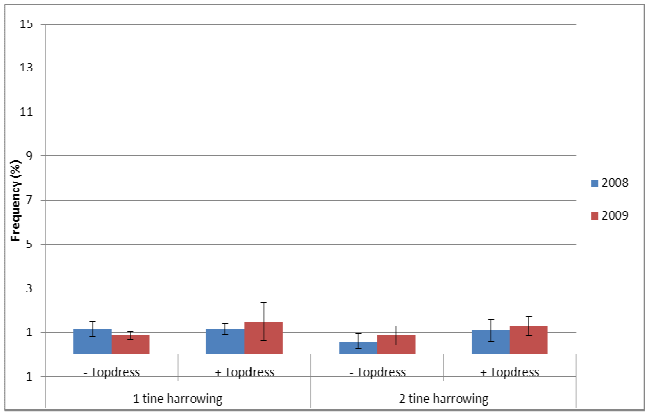


Figure 16 and 17. Furesø, Dandelion, May and October.

Overall results and discussion

A variety of factors can affect the occurrence of weeds in turf - both fundamental factors such as soil and climate and issues relating to the ongoing maintenance. Weed control on the fairways - and in turfgrass in general - has in recent decades been almost exclusively based on the use of selective herbicides. Herbicides which are characterized by combating certain types of plants typically only broadleaf dicotyledonous plant species. There has been little focus on the development of culture technical methods, such as a good lawn maintenance that can promote grass growth conditions as well as the grass competitiveness against weeds. Vertical cutting, tine harrowing and topdressing are maintenance methods that can improve the grass growth but the effect on weed occurrence have only been tested on a small scale and not in relation to individual weed species (Fischer and Larsen 2002, Larsen et al. 2004)

This experiment tried to focus on methods use in a previous experiment performed by Fisher and Larsen in 2002 but with focus on different weed species as well as the timing and frequency of the different maintenance methods. Unfortunately data was not generated for a three year period, the occurrence of weed was to low and the standard deviation to high and therefore no clear tendencies of the different mechanical treatments could be observed on the occurrence of clover, bellis and dandelion. There are no indications that the tested methods have the ability to effectively reduce the weed occurrence.

Mechanical treatments must be performed over a longer period in order to generate an effect on the weed occurrence. Results from a prior Danish experiment in 1990-2001 (Fisher and Larsen 2002, Larsen et al., 2004) only demonstrate small effects of mechanical treatment on the weed population.

A major problem in these types of experiments performed on real lawns (football pitches or golf course fairways) is the low frequency of some of the weed species. The total amount of dandelions was very low in this experiment, only 1-2 dandelions per image. Although the data were collected over a longer period, plant number was too small to say anything about effects. Using frequency (coverage ratio) as a measure of so few individuals is probably not correct since there are indications that the individual growth stages does not occur at specific times of the year.

Because of the requirements for a high playing quality on fairways and because of the large area they constitutes, fairways receive a significant part of the golf course's overall management efforts, including the use of pesticides. In the Danish Golf Federations yearly green accounts for the Danish golf courses, pesticides use on fairways has for many years been approximately 75% of the total consumption. Consumption is primarily due to herbicides. Now that pesticide legislation has come into force in relation to pesticide use on golf courses in Denmark, there is an increased need to develop and improve methods for pesticide control weeds on fairways. However, new ways must be found in order to develop effective methods.

In this experiment we have not been able to generate enough results in order to be able to conclude about timing and frequency. But the question is? Would we have been able to do that if we had three years results? Probably not because the selection of treatment time was not made on the basis of specific knowledge of weed species physiology and vulnerability. This type of knowledge is not available yet.

Economical calculations/comments from the greenkeeper

Economical calculations

The prediction is that mechanical weed control produces more CO^2 and is far more time consuming than the use of pesticide.

In order to get a preliminary evaluation of the economic and environmental cost of changing from pesticide use to mechanical weed control, the greenkeepers on Furesø and Asserbo golf course have been asked to comment on the following questions.

- How many hectares of fairways do you maintain on your golf course?
- If you have to vertical cutting all your fairways how long do you estimate it will take?
- If you had to groom all your fairways how long do you estimate it will take?
- If you had to top dress all your fairways how long do you estimate it will take?
- How much topdressing will you apply to your fairways?
- If you had to fertilize all your fairways how long do you estimate it will take?
- What is the salary (price pr. hour) for the person running the equipment?
- How long will it take you to wide spray all your fairways?
- Is it possible for you to estimate how long it will take you to spot spraying your fairways if the weed occurrence was 5% weeds?
- Is it possible for you to give an estimate of fuel consumption for the individual operations mentioned above (vertical cutting, grooming, top dressing, fertilizer application, pesticide application)?

Table 3. Answers from the two golf courses.

	Asserbo		**Furesø**	
	18 hole golf course 15 hectare fairway		27 hole golf course 12,6 hectare fairway	
Time used for vertical cutting of all fairways	1 week (37 hours)		22 hours - no players on the course 44 hours - players on the course Cleaning and grass collection not included.	
Time used for harrowing all fairways	1 day (7,5 hours)		15 hours - no players on the course Material collection not included	
Time used to top dress all fairways	2 weeks (74 hours)		30 hours with a medium dose 40 m^3 ha	
Topdress amount	150 m^3		40 m^3 ha x 12,6 ha = 504 m^3	
Salary per hour	165 D.Kr.		165 D.Kr.	
Full spray on fairways	3 hours		12 hours to spray fertilize fairways with a 10 m boom, 5 km per hour	
Spot spraying with 5 % weed occurrence	1 day		days	
Fuel price	?		?	

The conclusion from this inquiry demonstrates that pesticide free management is much more time consuming than spraying with pesticides. Also the consumption of fuel is much higher when practising pesticide free management using different mechanical control methods.
In a time with a financial crisis and the golf courses are cutting down on labour personnel there is a need for clear results that mechanical techniques can help to reduce the weed occurrence.
This experiment has not demonstrated results that will justify the use of extensive man hours on mechanical weed management on fairways.

Observations from other small projects on weed management on fairways

According to the fact that the Ph.D. student on this fairway project quit before it was completed and the fact that only 2 year of data was available, a number of small projects was initiated or evaluated in order to learn more about pesticide free weed management on fairways.

Flaming experiment at Furesø golf course.

Background
Different mechanical methods for pesticide free weed control on pavements have been performed over the last 10 year (Augustin B. 1990, Elmore C. L. 1993, Hansson D. 2002, Hansson D. and Ascard J. 2002 Hein R. 1990, Storeheier K. J. 1994). One of these methods is burning. It is a thermal control method. Sensitive weed species respond to a dose between 10 and 150 kg gas per hectare. 95% control of sensitive species such as *Chenopodium album* was obtained. Plants with a protected growth meristem such as grass plants do need a higher dose in order to be controlled (Ascard, 1995, 1998).

Hypothesis
Flaming might be effective in removing some weed species from a lawn without eliminating the grass plants

Experimental design
In fall 2010 an experimental field at Furesø golf course was established. Seven levels of burning intensity were used. The flame treatment was carried out using a HOAF (HOAF Infrared Technology; NL-7575 ED Oldenzaal, the Netherlands) hand-pushed gas-burner. The energy dose applied by the thermal weed control equipment was regulated by the driving speed. Burning was performed two times during fall 2010 and 2 times in spring 2011.
Due to limited amount of space each treatment was only performed once. Each plot was 28 x 1 meter. Registrations were made using a digital camera mounted on a mobile tripod. The stand was fitted with a measuring frame (70cm x70cm) with 100 fields there. For each treatment26 pictures were taken. On the photo the weed cover was estimated within each square. The total weed cover was the sum of weed cover of 100 squares for the entire frame.
The first measurement was made before the first treatment in September. Then the weed cover was measured just before the next treatments and 3 weeks after the last treatment.
To check for any response of flaming only pictures from the control and the highest dose was evaluated. Evaluation was on pictures taken before any treatments were performed and on pictures taken after the last treatment in spring.
It was not possible to analyze the weed content on all pictures due to the economy of the project.

No statistic was performed on the results due to the lack of a random design and lack of repeats. Results are used to look for tendencies in order to evaluate whether it would be interesting to go into a more detailed study of these heat treatments of turf weeds.

Treatments	Dose	Speed (seconds per 14 metre)
1	80	56
2	60	42
3	50	35
4	40	28
5	30	21
6	20	14
7	0 – control	No burning


Picture 8 and 9. Burning treatment. Photo; Thomas Pihl.


Picture10 and 11. The effect on weed leaves. Photo; Anne Mette Dahl Jensen

Results and discussion

Weed control using flaming is complicated because of the grass. The grass needs to survive. But the experience from experiments on pavements indicates that grass may be more resistant to flame treatment than broadleaved weeds.

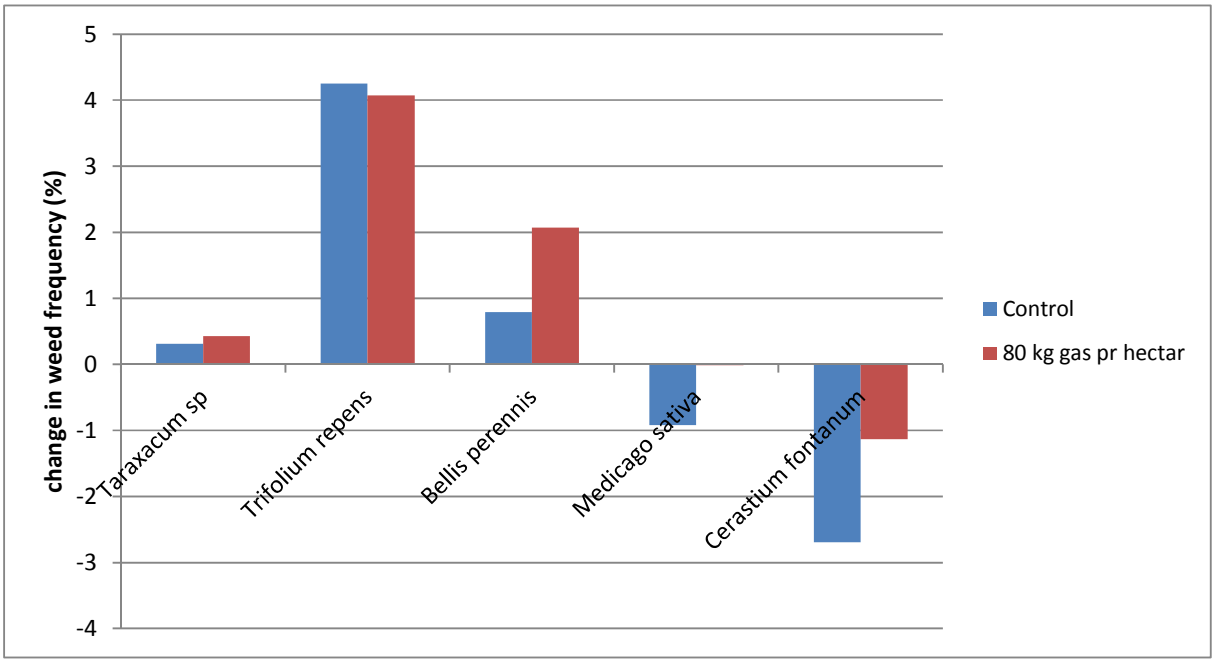


Figure 18. A positive % indicates a reduction in weed occurrence from fall 2010 to 2011.

Examination of the effect of 4 burning treatments (2 in fall and 2 in spring) is illustrated in figure 18 indicate that two weed types (*Taracacum sp*. and *Trifolium repens*) do not respond to a gas dose of 80 kg per ha. The occurrence frequency is almost the same in the control and when 80 kg gas per ha have been used. *Medicago sativa* was only found in the control block. Therefore it is not possible to conclude on this species.
The species *Bellis perennis* seems to respond to a flame treatment. There is a higher reduction of this species when using the highest dose of flaming compared to the control.
In all treatments the grass became a little brown after each treatment but quickly it recovered.

The variation in weed occurrence between growth seasons and between times of year differs. For some plant species the occurrence frequency decreases from September to May where as other increase. For *Cerastium fontanun* there is an increase from fall to the next spring but it seems as the use of burning reduced the increase in weed occurrence significantly compared to the control.

This small experiment was performed in order to get an indication of whether it would be of interest to go into detail with burning as a weed control method in turf. There are some indications that some weed species might be sensible to a flame treatment. It would be interesting to perform an experiment for a longer period an in a much larger scale to see whether these indications could be verified.

Värpinge experiment.

Värpinge golf course is a 9 hole pay and play course outside Lund, Sweden. It is owned by Håkan Rasmusson. The course is managed without pesticides and sheep's are grassing all over the course and help to manage the weed. Weed is a problem when pesticides are not used and the course owner has an interest in finding new mechanical methods for weed management. From 2010 - 2013 a special vertical cutting equipment has been tested (vertical cutting aggregate for a Toro 5610 – the aggregate has been modified. Blades are mounted at a distance of 2.5 cm). The main problem at Värpinge is dandelions on fairways. The hope was that this special designed equipment could control or reduce the incidence of dandelions. It was not at traditional vertical cutting procedure in the soil/upper turf layer. Vertical cutting was performed approximately 1 cm above ground. The intension was only to manage the dandelion and disrupt the leaves. By doing this several times a year the hypothesis was the weed could be managed and kept in a stage that is acceptable and gives a reasonable playing quality.
An experiment was set up in order to evaluate the effect of the verticutting.

Picture 12. Vertical cutting equipment. Photo; Håkan Rasmusson.

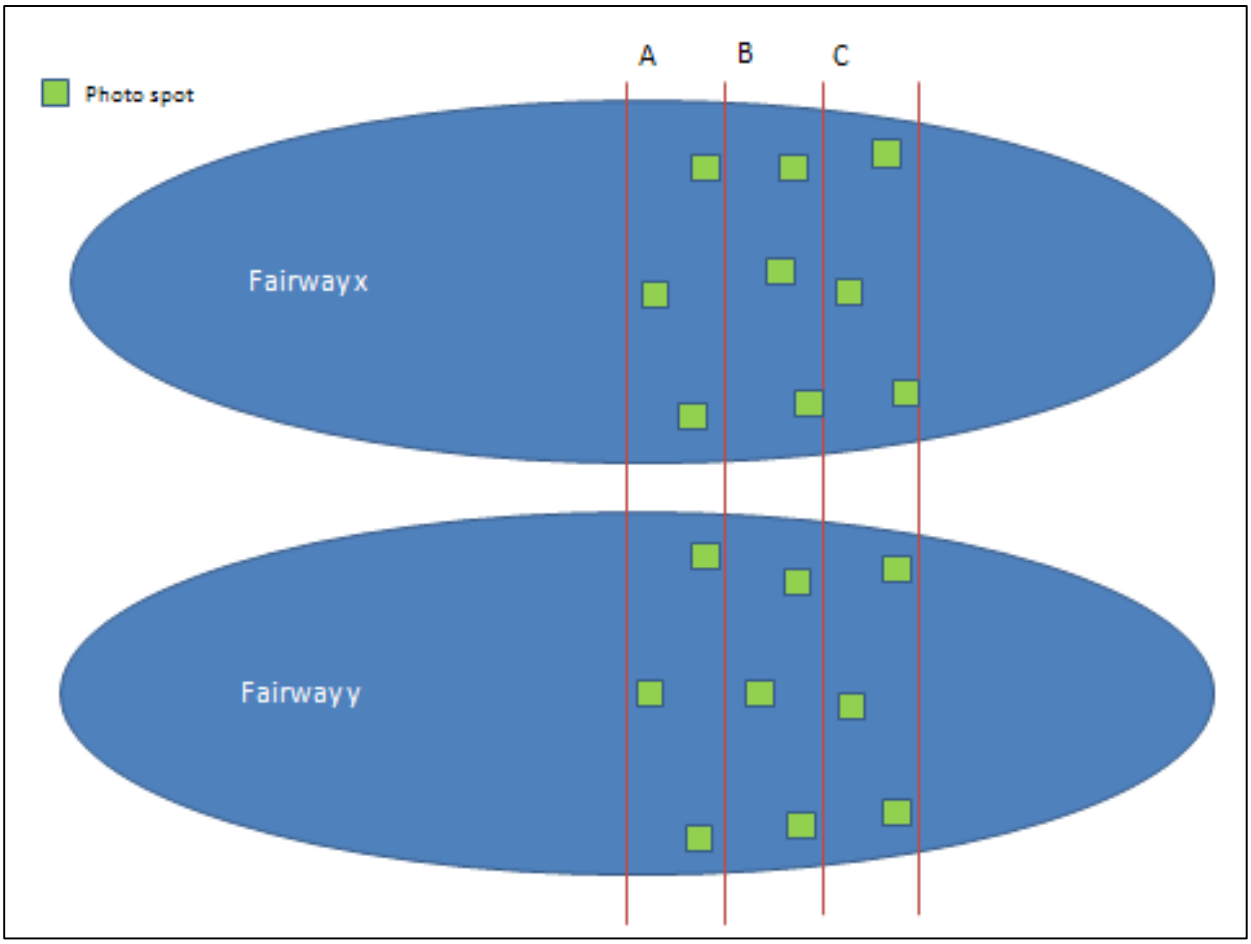


Figure 19. Experimental design at Värpinge.

Experimental design

A – Each treatment time = 2 verticut
B – Each treatment time = no verticutting = control
C – Each treatment time = 1 verticut

The verticutting was performed several times per year. The treatment time was set by the greenkeeper and was based on evaluation of the weed appearance.

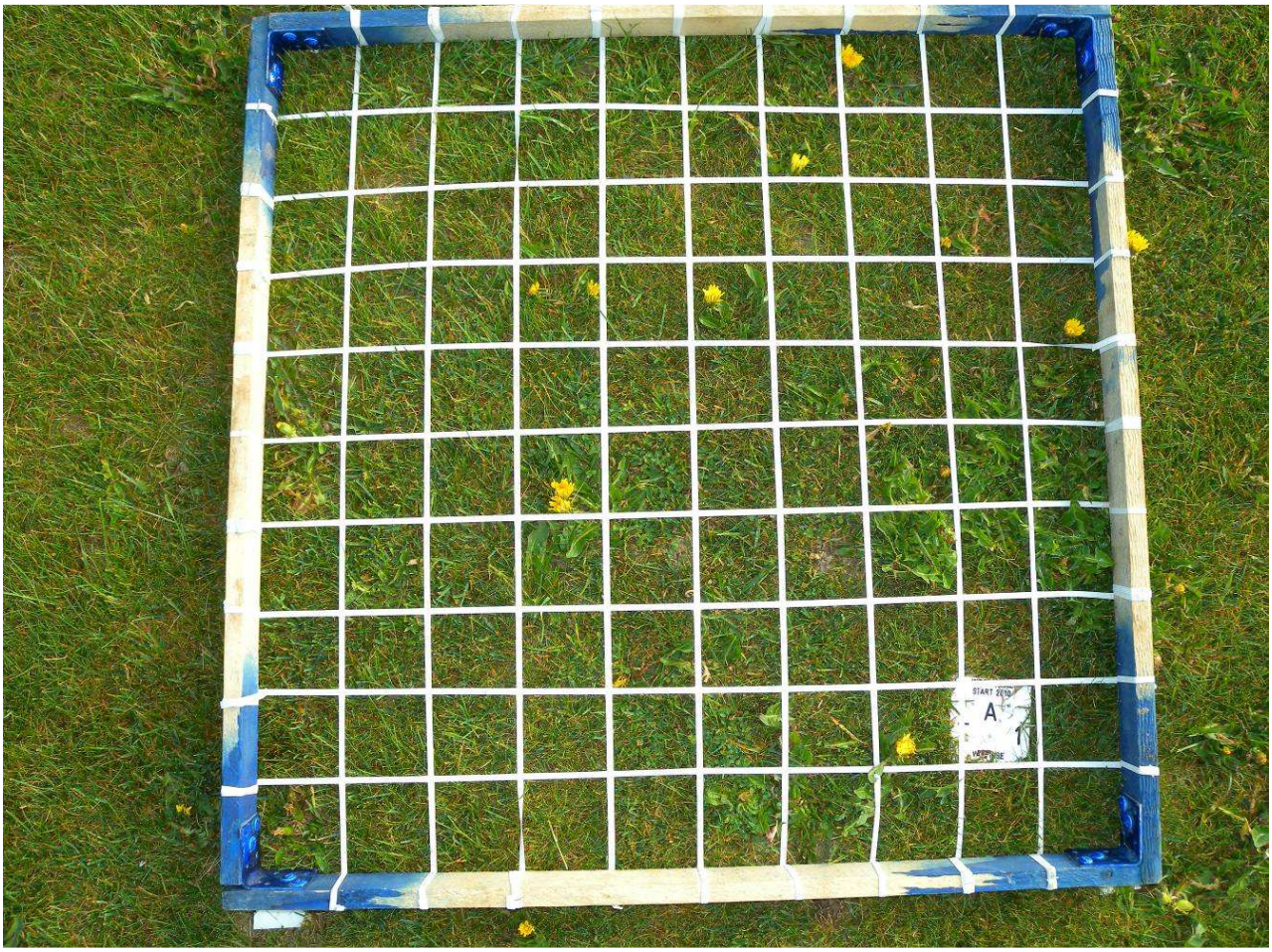
Actual verticutting time

Year 2010 – 4 times: 6 May, 24 May, 26 August, 21 September
Year 2011 – 7 times: 27 April, 13 May, 7 June, 6 July, 1 August, 21 August, 3 October
Year 2012 – 5 times: 1 May, 14 May, 25 June, 18 July, 1 October
Year 2013 – 3 times: 3 May, 17 May, 28 June

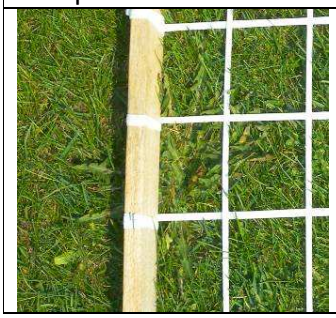
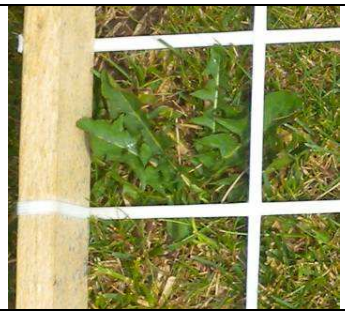
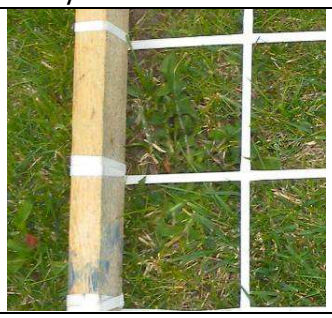
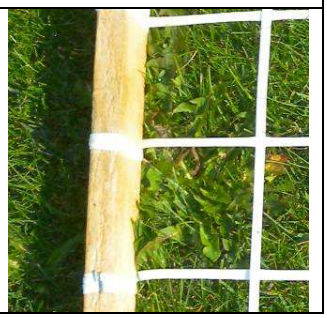
Pictures have been taken at 3 sites in each block at exactly the same spot before each treatment and some days after a treatment. A large number of pictures have been generated and it was not possible to analyse them with in this project. It will be too time consuming.

The course have been visited a number of times during the project period. A visit in 2013 at Värpinge indicates that there might be an effect of the vertical cutting on the dandelion population. The plants seem smaller. The mechanical treatment do not remove the dandelion but the growth seems to be altered and the plants do not appear as big as the dandelions that wasn´t verticut. An alteration in size with smaller individuals might have a positive effect on the playing quality.
These observations are visual observations on site. It will be interesting to have the possibility to look at all the generated pictures in order to try to confirm this.

All the pictures from Värpinge can also be used to learn more about the effect of mowing on dandelion appearance. A screening of a few pictures confirms that weed growing under a regular mowing regime change morphology and physiology. Flowering is from May to October. This indicates that it might be difficult to find a perfect time for weed control which was one of the aims in the original Ph.D. project.



Picture 13. Flowering dandelions. Photo; Håkan Rasmusson.

27 April 2011	7 June 2011	6 July	3 October
			

Picture 14. The same dandelion individual seen over the grooving season. Photo; Håkan Rasmusson.

The study of a few pictures taken at the same spot over the entire growing season indicates that dandelions are very vital in early spring with a lot of leaves. In late spring and early summer there is only a limited amount of leaves even then it does not produce a flower. In August and the rest of the growing season many leaves appears again on the plant that did not have many leaves in summer. They might stay in this stage during the winter. Knowledge of plant size over the growing season might be useful in the search for a time to perform optimal mechanical disturbance of this weed species. It would be interesting to investigate all the pictures from Värpinge because it is possible to follow specific individuals over the entire season due to the fact that pictures are taken at the same spot each time.

Turf-stripping experiment at Furesø golf course.

Furesø golf course have for a number of years had some restrictions on pesticide use set by the municipality. At some fairways there are problems with weed. Additionally the course wants to change the grass species composition to red fescue. For a number of years focus has been on fairways and how to renovate them. In order to find pesticide free solutions the head greenkeeper performed a number of small pilot experiments. One of these experiments examined the effect of stripping off the old lawn's surface on weed occurrence in the new turf. Stripping of the turf has been used earlier at Furesø golf course when renovating greens (Mortensen et al., 2005).

Table 4. Experimental design

Parcel nr	Grass cut down and blown away	Stripping depth 3 cm	Grass removed with pesticides	Area size	Sand applied 1 cm.	Sand applied 3 cm	Sown with pure red fescue	Sown with red fescue / bent grass mix	Sown with red fescue / ray grass mix
1	X	30-08-2011		4 m2		30-08-2011	30-08-2011		
2	X	30-08-2011		4 m2		30-08-2011		30-08-2011	
3	x	30-08-2011		4 m2		30-08-2011			30-08-2011
4			08-09-2011	4 m2	14-09-2011		06-09-2011		
5			08-09-2011	4 m2	14-09-2011			06-09-2011	
6			08-09-2011	4 m2	14-09-2011				06-09-2011

The greenkeepers experience from the experiment was that stripping could remove the superficial weed with a week and superficial root system. They seemed to disappear. However weed species with tap roots was not removed. They reappear in the new turf.
Stripping is a very expensive management procedure especially if it should be used on an entire fairway. The estimate is that it will take 4-5 hours to de turf 800 m^2. Fairways at Furesø are for the most part dominated by weed species with tap roots (*Taraxacum sp*. and *Plantago sp*.) and stripping is not a solution in these areas. However it might be a solution for weed management in small areas depending on the type of weed.
Another positive effect of stripping is that all the old grass species can be replaced by new and improved species and varieties. In the experiment at Furesø golf course only a small amount of the old raygrass plants reappear after the treatment.



Picture 14, 15 and 16. De-turfing experiment at Furesø golf course. Photo; Thomas Pihl

Sheep grazing – knowledge collection.

For many years grazing has been used for landscape management (Hadjigeorgiou et al., 2005). Some animal species are very effective in grazing/eating all kind of different plants. They can be used as a weed control agent (Popay and Roger, 1996).
On Danish golf courses weed problems can become a major issue due to a pesticide ban or the demand for reducing the amount of pesticides used (Danish legislation). As a consequence a number of golf courses are now using animals for weed control.

In 2010-2012 resources have been used to collect experiences from Danish and Swedish greenkeepers that are using grazing animals for weed control. Hørsholm, Smørum, Värpinge and Hornbæk golf course were visited. Information collected on these golf courses have been used in an IPM fact sheet (STERF) and articles for the Nordic greenkeeper Journals (Jensen and Edman 2011, Jensen and Petersen 2011, Jensen and Sintorn, 2010).


Picture 17 and 18. 17) Hørsholm golf course. Sheep's are grazing rough areas. Photo; Antoine Challe. 18) Smørum golf course. Sheep's are effectively grazing the giant hogweed. Photo; Per Rasmussen.


Picture 19 and 20. 19) Värpinge golf course. Sheep's are an integrated part of the whole golf course. Photo; Håkan Rasmusson. 20) Hornbæk golf course. Sheep's have effectively removed the shoots from willows. Photo; Anne Mette Dahl Jensen.

Experiences

Hørsholm: On Hørsholm golf course grazing was originally established on a part of the course where the sheep's had access to all the golf course elements (greens, tees, fairway and rough). Before the grazing was initiated clover, giant hogweed (*Heracleum mantegazzianum*) and poplar (*Populus sp*.) shot established from fallen seeds was a major problem. The introduction of sheep on the golf course has helped to alleviate these problems. The sheep's were effective in terms of preventing the poplar tree seeds from established itself as small trees. The greenkeepers also observed that giant hogweed in rough areas was eaten by the sheep's. In the rough, semi rough and on fairways the introduction of grazing resulted in clover being less dominant.
Another interesting observation was that the character of the rough seemed to change. Before grazing was introduced the rough was dense but the sheep's seems to eat many of the large, dense grass species and thereby creating an open rough with fine grasses and a better playing quality because the players are now able to find the golf ball.

However there was one main problem with this grazing regime. The sheep's were lying at the greens at night and their urine and feces caused scorched spots on the green. That was not acceptable in the long run and today the golf course and greenkeepers have the sheep´s in mobile enclosures mainly in the rough areas.

Smørum: At Smørum golf course a number of extensive rough areas were dominated by the giant hogweed. Instead of using pesticides for the control the course introduced grazing using sheep's. They have been at the course in enclosures on these extensive rough areas and they have been very effective in controlling the giant hogweed.

Værpinge: Værpinge golf course is a 9 hole pay and play course and for 4 years sheep's have been grazing all over the golf course. The course is not using any pesticides at all and the introduction of sheep´s was among others seen as a way of reducing the weed occurrence.
The experience from the course is that grazing reduces the occurrence of weed but also the appearance and keeps the plants at a stage that does not influence the playing quality. To prevent damages on greens due to urine the sheep's are removed at night to an enclosure outside the golf course.

Hornbæk: At Hornbæk golf course, sheep's are used to prevent an area from reverting to forest. Three years of grazing have demonstrated that sheep's has been very effective when it comes to preventing willows (*Salix sp*.) and birches (*Betula sp*.) in getting establishment. The area where the sheep's are grazing appears today as a fresh meadow.

Conclusion
The use of grazing animals for weed control on golf courses is effective. They can reduce the spread of weed seed from rough areas and they are really effective in controlling giant hogweed without the use of pesticides. For the last couple of years more and more golf courses have established sheep grazing. Many of these courses are using mobile fences.
More knowledge about grazing effects must be collected from golf courses. In 2014 a knowledge collection seminar will be held in Denmark or Sweden.

Earthworm at Furesø golf course.

Earthworms are known inhabitants of the soil especially moist soil with an organic content. The beneficial role of the earthworms is to recycle nutrient from organic material back into the soil. Additionally they can reduce the amount of fungi, loosen the soil and give it a better drainage capacity (Collins et al., 1995). Despite the fact that earthworms are a benefit to the soil they also create problems on golf courses. They produce "faecal matter castings" in the closely mowed turf (Williamson R. C. 2004). Especially in autumn, there may be many worm casts (picture 21, 22 and 23). These casts are squashed flat by the machines used for maintenance. These squashed casts have a negative influence on playing quality and they are also seen as perfect niches for weed establishment. However

more knowledge needs to be generated regarding the establishment of weed in worm casts. The assumption is that *Poa annua* is established in the casts due to the ability to germinate almost all year around.

No pesticides are allowed for earthworm control and many greenkeepers are searching for nonchemical methods to reduce earthworm casts.
At Furesø golf course (Zealand, Denmark) worm cast is a serious problem and the head greenkeeper have performed a number of small experiments in order to find a method for reducing earthworm casts. Up and down movements of earthworms in the soil is influenced by soil moisture and soil temperature. Additionally earthworms are sensitive to acidic soil conditions (Guild 2008). The philosophy behind the small experiment at Furesø golf course was that application of sand mixed with an acid fertilizer could reduce the pH and moisture in the top soil.



Picture 21, 22 and 23. Squashed earthworm casts at a fairway in fall. Photo; Anne Mette Dahl Jensen.

Table 5. The head greenkeepers pilot experiment at Furesø golf course.

Parcel	**Iron sulphate 5g/m2 mixed with sand 100-140 g**	**Iron sulphate 10g/m2 mixed with sand 100-140 g**	**Iron sulphate 15g/m2 mixed with sand 100-140 g**	**Application of sulphur 5g/m^2**	**Application of sulphur 5g/m^2**	**Vitax ***	**Prodana**
7, H8	X (4 m^2)						
8, Range		X (2 m^2)					
9, Range			X (2 m^2)				
10, Range				X (2 m^2) x 2			
11, range					X (2 m^2) x 2		
12, H8				X (2x2 m^2)		Applied	Applied
13, H8					X (2x2 m^2)	Applied	Applied

* the products include turf fertilisers and turf bio stimulants together with water management, pest control, disease control and weed control products

The indication from this small scale experiment at Furesø golf course was that a sand application seems to reduce damages caused by earthworm casts. The amount of earthworm casts was probably about the same but the structure of the many earthworm casts was looser.
As a result of these experiments the head greenkeeper is now topdressing his fairways every year with sand. His experience is that the amount of worm casts has been reduced on fairways and the structure of the casts has changed. The casts are now more loos in texture and not comprised of a lot of mud. Using topdressing as a means of reducing the worm cast problem is however an expensive procedure and most Danish golf courses would not have the resources for this kind of management.

Overall conclusion from this report

The future calls for pesticide free management methods of weed in turf due to legislation and volunteer agreements regarding pesticide use.
Despite this failed Ph.D. experiment on mechanical weed control on fairways a number of interesting observations have been made in the supplementary pilot experiments.

In the future we need to focus on the development of specific control methods for each single weed species or weed type. Experiments so far have indicated that it is not possible to find a single method that can reduce or eliminate all the different weed species. Grazing animal might be an exception but we cannot use them on football pitches and many golf courses do not want them on fairways. As a consequence we need to perform differentiated weed management on some of our turf grass areas where weed disturbs the quality.

The indication that burning might have an impact on some weed species without harming the grass plant should encourage a more profound investigation of different turf weeds response to burning. This control method might be reasonable to use in small areas with severe weed problems.
The pilot experiment on turf stripping additionally indicates that some of the weed species without tap roots can be eliminate. This method might also be reasonable in small areas.

Working with methods suited for management in small areas provides a need to be able to evaluate where the weed is present in quantities that do pose a problem. We must, to a larger extent, work with thresholds in the future in order to decide when to begin a treatment in a given area.

Pesticide free weed control has focused on finding methods that can reduce the occurrence of weed. However the experiment on Värping golf course might indicate that it would be interesting to look more into weed maintenance and investigate whether we can reduce the effect of weed on playing quality by trimming the weed plant. Investigations on mechanical methods effect on weed morphology and playing quality would be interesting.

The results has visualised the importance and difficulties in selecting appropriate experimental fields at a golf course. It is always a dilemma when performing experiments on sites because weed populations differs from year to year.
Additionally choosing photo for documentation was the wrong choice. It is too time consuming. It is much quicker to evaluate on site if registration is performed when players are absent (in the early morning or in the evening)

Overall the project has visualised the need for more basic knowledge regarding physiology and population dynamic of the different weed species in order to develop suitable mechanical methods for pesticide free weed control.

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Researchers' assessment of objective fulfilment in relation to project proposal:

The original objectives of the Ph.D. project have not been fulfilled. Due to a depression the Ph.D. student was not working 100 % on the project in 2009 and in spring/summer 2010 he quit. It was then realised that he had not done any registrations in spring 2010.
When the Ph.D. student quit the turfgrass scientist at Forest and Landscape (Anne Mette Dahl Jensen) had to take over the project and finish the data analysis and perform some additional projects.
It was very difficult to analyse data when you have not been involved in the detailed planning process and the Ph.D. student did not respond on questions after he quit.
The objective of STERF grants has to a large extend been fulfilled. STERF funded the dissemination part of the project and pesticide free management have been presented and discussed at several meetings, seminars, conferences and in a number of articles. However these presentations have not been based on data from the original Ph.D. experiment but from indications found in the different supplementary pilot experiment and from knowledge collections among greenkeepers.

Dissemination, acceptance and implementation of results by the golf sector and by the society:

No information regarding mechanical methods for controlling weed without pesticides could be generated in the original experiment and disseminated to the greenkeepers. However the project has visualised the need for basic knowledge regarding physiology and population dynamic of the different weed species in order to develop suitable mechanical methods for pesticide free weed control.
The focus on dissemination in this project (supplementary grant from STERF) gave the project researcher time and money to participate in different seminars, meetings and activities that have produced information on pesticide free management and IPM.
Indications from the small supplementary projects hopefully will encourage researchers to use more time for knowledge collection. Greenkeepers are performing small experiments and the results just need to be evaluated and disseminated. Results from the small pilot experiments and the knowledge collection among greenkeepers will be used in a review article for the 2014 ETS conference.

Photo 24 and 25. The Danish Ministry of Environment visited the experimental site. Photo; Anne Mette Dahl Jensen.

Project economy and evaluation of resources spent on project in relation to scientific achievements:

The original objective was to recruit a Ph.D. student in 2006 or primo 2007. No one applied and one potential student found by one of the supervisors did not match the requirements in the final interview. The Ph.D. position was then announced again in summer 2007 and Ken S. Krogholm was hired. He started in 2008. Unfortunately Ken became sick in December 2008 and could not work for several months and during the growing season 2009 he was only working half time. In 2010 Ken S. Krogholm stopped the Ph.D. project in the middle of the growing season and it became clear that he has not been doing the monitoring according to plan in 2010. This changed the timeframe and the budget plan for the Ph.D. project. The rest of the budget was used in the following years.

	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**Total**
STERF	65.000	125.000	250.000					**440,000**
DGU		204.000	204.000	102.000	102.000			**612,000**
KU		204.000	204.000	204.000				**612,000**
S&L		204.000	204.000		80.000	80.000	44.000	**612,000**
SUM	**65,000**	**737,000**	**862,000**	**306,000**	**182,000**	**80,000**	**44,000**	**2,276,000**

DGU = Danish Golf Federation. KU = University of Copenhagen, S&L = Forest and Landscape (now IGN)

Project organization / partnership:

The project was not optimal organised. The Ph.D. student started out with one supervisor and then had to change supervisor after approx.one year due to discrepancies. None of the supervisors were involved in turfgrass research. The project was planned by a turfgrass scientist at Forest and Landscape but he quit before the Ph.D. student was hired. The new turfgrass scientist was on maternity leave when the project started and was planned in details.
Due to stress and depression the Ph.D. student was not 100 % on the project and in spring/summer 2010 he quit. It was then realised that he had not done any registrations in spring 2010.
When the Ph.D. student quit the turfgrass scientist at Forest and Landscape (Anne Mette Dahl Jensen) had to take over the project and finish the data analysis and perform some additional projects.
It was very difficult to analyse data when you have not been involved in the detailed planning process and when the Ph.D. student suit so sudden and was out of reach afterwards.

This project cannot be characterised as a team work project. The Ph.D. student did most of the work himself but needed some help from greenkeepers at the two participating golf courses when the different treatments had to be performed. The collaboration with the greenkeepers was satisfactory although there were some frustrations regarding the fact that the Ph.D. student did not plan the work to take place on the time of the day when players were almost absent from the course.

The Ph.D. student did not manage to get any international contacts or partnerships before he quit the project. Afterwards Anne Mette Dahl Jensen has been invited to several meetings /seminars /conferences in the Nordic countries to talk about pesticide free management of weed.

The relationship to the STERF administration has been fine.

Suggestions for follow-up research projects:

Experimental questions / hypotheses emanating from the project

- What is the effect of mowing on weed morphology? How do the different turf grass weed species respond on a frequent mowing regime? To what extend does the mowing influence the time for flowering, the production of horizontal growth etc.
- How is the weed population dynamic and weed demographic in a lawn that is frequently mown? When do the different weed types get established (time of year), do they survive over winter, when do they disappear?
- What is the effect of mowing on the different weed species physiology – especially carbohydrate metabolism? The assumption is that a frequent mowing where the plant have to regenerate green tissue all over the growing season will have an influence on the amount of carbohydrate stored but also on the regrowth after a stress full period.

This knowledge is important in order to be able to develop and optimise pesticide free management methods of weed in the future. A research application on this subject will be sent to the Danish Environment Protection Agency in 2014.

Experimental questions / hypotheses emanating from the small knowledge collection cases

- How do we handle earthworm casts? Which maintenance procedures do effectively reduce the negative aspects of earthworm casts? What kind of weed are established in worm casts – is it primarily Poa annua due to the ability to establish almost all year around.
- Can burning be used to control specific weed species in a turf community?
- Can the weed appearance be changed by some mechanical maintenance procedures and does this change the playing quality of the weed infected turf?

Acknowledgement

Thanks to head greenkeeper Thomas Pihl on Furesø golf course and head greenkeeper Michael Steen on Asserbo golf course for providing an area for the original experiment. Also thanks to Thomas and Steen Michael for helping with all the mechanical treatments.

I also acknowledge the many inputs to all the small extra experiments from Håkan Rasmusson (Värpinge), Per Rasmussen (Smørum), Antoine Challe (Hørsholm) and Thomas Pihl (Furesø).

Project publications (including accepted publications 'in press')

A number of articles and IPM fact sheets have been produced where knowledge created in this research project was included. Additionally knowledge collection was performed on related subjects after the Ph.D. student skipped the project. These articles are also included on the list.

Jensen A. M. D. og Krogholm K. S. (2008)
Pesticidfri pleje af fairways – nystartet ph.d. projekt. Greenkeeperen 3; 10-13

Jensen A. M. D. (2010)
STERF's forsknings- og udviklingsprogram om IPM. Greenkeeperen 3; 61-6.

Jensen A. M. D. (2010)
Kort nyt fra Skov & Landskab: Følgende aktiviteter omkring græs og golf er i gang på Skov & Landskab. Greenkeeperen 1; 67-67

Jensen A. M. D. og Nielsen J. P. (2010)
Dokumentation af IPM – lad os se fordelene. Greenkeeperen 2; 34-

Jensen A. M. D. og Sintorn K. (2010)
Får: et miljøvenligt alternativ til ukrudtsbekæmpelse. Greenkeeperen 4; 62-64

Jensen A. M. D. og Petersen T. K. (2010)
EU får betydning for de danske golfbaner: EU direktiv om bæredygtig anvendelse af pesticider vil sætte standarten på de danske golfbaner. Greenkeeperen 1; 72-74

Jensen A. M. D. og Sintorn K. (2010)
Får: et miljøvenligt alternativ til bekæmpelse af ukrudt på golfbanen. Videnblad, Park og Landskab. 5.6-44.

Jensen A. M. D. og Sintorn K. (2010)
Får: ett miljövänligt alternativ som ogräsbekämpning. Greenbladet 4; 56-57.

Jensen A. M. D. og Sintorn K. (2010)
Møde mellem svenske og danske greenkeepere: erfaringsudveksling om pesticidfri pleje. Greenkeeperen 3; 12-15

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Svenskt/danskt greenkeeperutbyte om pesticidfri skötsel. Greenbladet (4) 44-4

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Jensen, A. M. D. (2012)
Ukrudtsbekæmpelse på græsarealer – oversigt. Bioforsk FOKUS 5(2); 174-176s

Jensen A. M. D. (2012)
Bekæmpelse af tidsler. Greenkeeperen 3; 24-26

Jensen A. M. D. og Nielsen J. P. (2012)
Danmarks mest populære greenkeeper. Greenkeeperen 2; 14-15
Jensen A. M. D. og Petersen S. (2011)
Nye beboere på Hornbæk golfbane. Greenkeeperen 2; 20-23
Strandberg M., BlomBäck K., Jensen A. M. D. and Knox, J. W. (2012)
Priorities for sustainable turfgrass management: a research and industry perspective. Acta Agriculturae Scandinavica. Section B. Soil and Plant Science. Supplement 1; 3-9

Submittes:
Abstract for the 4th ETS conference in Germany 2014. Title; *Pesticide free management of weed on golf course fairways*. It is a review article. It is probably accepted as a full paper.

In prep:
An article to the Danish greenkeeper association's journal in 2014. Title: Mechanical control of weed in grass – how do we move forward? It will also be submitted to the Norwegian and the Swedish greenkeeper journal.

Talks on field days, meetings etc.

Teaching where the project and pesticide free management has been presented and discussed:

September	2008	Landscape architect course, Plant and Technology, University of Copenhagen
September	2009	Landscape architect course, Plant and Technology, University of Copenhagen
October	2010	Landscape architect course, Plant and Technology, University of Copenhagen
September	2011	Landscape architect course, Plant and Technology, University of Copenhagen
September	2012	Landscape architect course, Plant and Technology, University of Copenhagen
October	2013	Landscape architect course, Plant and Technology, University of Copenhagen
February	2010	Greenkeeper course at Alnarp, Sweden: *Weed control and pesticide free management of golf courses.*
September	2010	Garden and Park engineers, Forest school, University of Copenhagen
September	2011	Garden and Park engineers, Forest school, University of Copenhagen
September	2012	Garden and Park engineers, Forest school, University of Copenhagen

Presentations at meetings

Date	**Year**	**Meeting**
Fall	2008	Scandinavia golf course architect meeting: *Golfbaneskötsel utan växtskydsmedel*.
November	2008	Golf course and Environment seminar DGU. *Pesticide free management.*
Fall	2008	Bioforsk Norway – Seminar on climate change challenges on golf courses. *Development of methods for non-pesticide weeds control on fairway*

January	2009	Greenkeeper education week, Sandemosen
Fall	2009	Grass seminar for municipalities at University of Copenhagen. *Pesticide free management.* *Turf composition in relation to environmental restrictions.*
January	2010	Greenkeeper education week. *Pesticide free management* *IPM – EU directive*
January	2010	Modern banskötsel – *Nya EU-direktiv kräver integreret växtskydd"* Held by The Swedish Golf Federation and STERF, Goteborg, Sweden.
February	2010	Modern banskötsel – *Nya EU-direktiv kräver integreret växtskydd"* Held by The Swedish Golf Federation and STERF, Malmo, Sweden.
May	2010	Meeting with Swedish greenkeepers, Group "Miljöoptimerad banskötsel", at Hoffgård golf course, Sweden2010
Oct	2010	Meeting with Swedish greenkeepers, Group "Miljöoptimerad banskötsel", at Mölndal golf course, Theme IPM, Sweden 2010
June:	2010	ETS conference, Field day, Landvik, Norway (Kvalbein) 2010
September	2010:	STERF conference on multifunctional golf courses: *Weed control without pesticides*
Fall	2010:	STERF IPM workshop: *Pesticide free management of fairways*.
February	2012	Bioforsk conference, Gardemoen, Norway, (Jensen). *Golfbanan arena för idrott, naturvård och allmänhet – bekæmpelse af ukrudt uden pesticider*
Spring	2013	Seminar held by the Danish Environmental Protection Agency. *Pesticide free management of golf courses*.

Field days

October	2008	MST visit at Furesø golf course

Other activities related to the project

STERF IPM group: Hours used for meetings in Uppsala in 2011.

Meeting at Furesø golf course where the project was discussed and the experimental field was visited, 2010.