# Onderzoek P. Kristoffersen

## Non-chemical weed control on traffic islands: a comparison of the efficacy of five weed control techniques (2007)

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Inhoudsopgave

**Samenvatting**

***Niet-chemische onkruidbestrijding op middengeleiders; een vergelijkend onderzoek naar de effectiviteit van 5 onkruidbestrijdingstechnieken (P. Kristoffersen, 2007)***

De universiteit van Kopenhagen heeft een onafhankelijk vergelijkend onderzoek gedaan naar de effectiviteit van vijf verschillende onkruidbestrijdingstechnieken. De methoden branden, hete lucht, stoom, heet water en borstelen zijn hierbij een jaar lang door de universiteit in de praktijk getest. De effectiviteit (hoeveel onkruid staat er nog) en de efficiëntie (frequentie en hoeveel brandstof) zijn gemeten. In onderstaande tabel zijn de belangrijkste gegevens uit het onderzoek weergegeven.

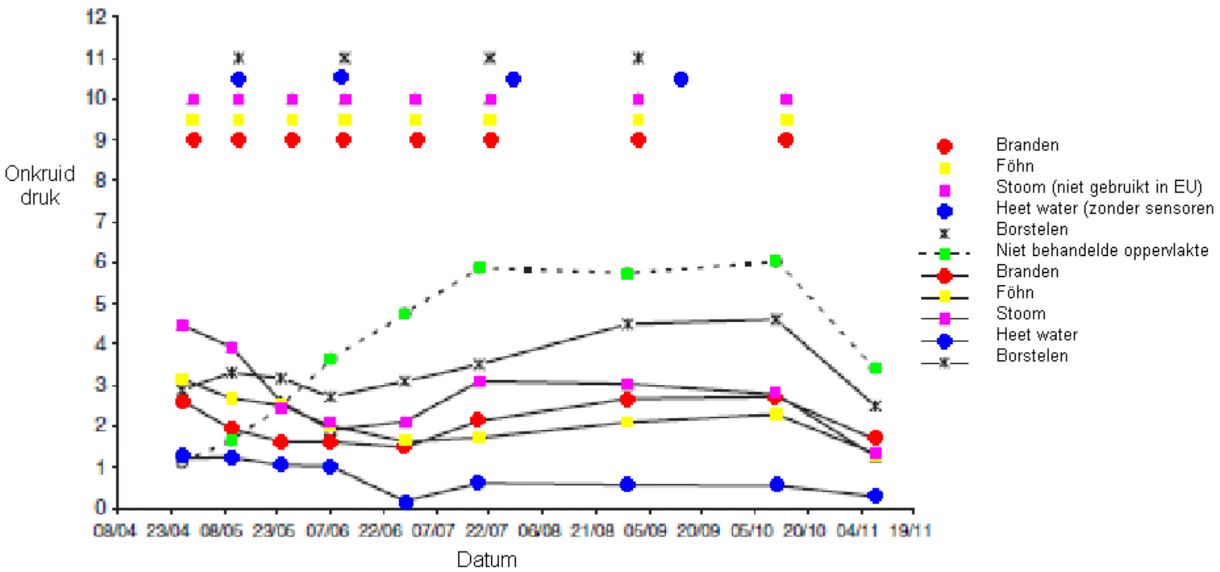
| | **gemiddeld gasverbruik per ha per beurt in kg*** | **frequentie beurten per jaar** | **gemiddeld gasverbruik per ha per jaar in kg*** |
|---|---|---|---|
| **Borstelen** | niet berekend | 4 | niet berekend |
| **Branden** | 150 | 8 | 1200 |
| **Föhn** | 335 | 8 | 2680 |
| **Stoom** | 163 | 8 | 1304 |
| **Heet water (zonder sensoren)** | 312 | 4 | 1248 |
| | | | |
| **Heet water met sensortechniek**** | 125 | 4 | 499 |

** Getallen uit onderzoek P. Kristoffersen ( pag. 126). Dieselverbruik is door Kristoffersen omgerekend naar gasverbruik in kg, zodat onderling vergelijk mogelijk is.*
*** Opgave WAVE; Heet water met sensortechniek bespaard gemiddeld 60 tot 80% energie t.o.v. techniek zonder sensoren.*

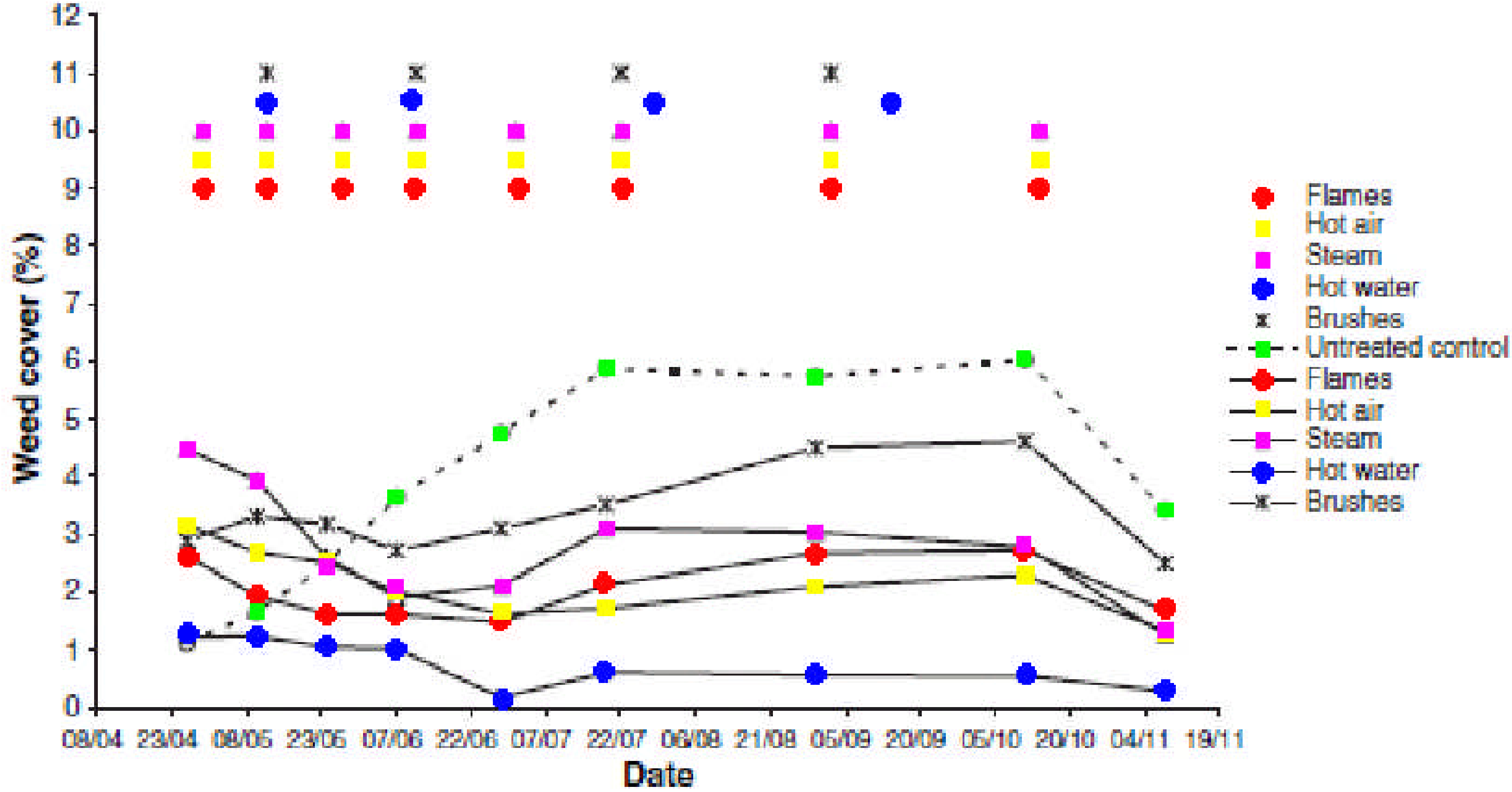
In onderstaande grafiek zijn de gegevens van het onderzoek visueel weergegeven. De grafiek is gebaseerd op de tabel uit het onderzoek van Kristoffersen (pag. 128).

Uitleg grafiek:

- Bovenste punten geven het aantal behandelingen aan;
- De punten op de lijn zelf zijn de monitoringsmomenten;
- Op de verticale as is de hoeveelheid onkruid in % weergegeven;
- Op de horizontale as is de datum weergegeven (8 april t/m 19 november).




Gegevens uit onderzoek Kristoffersen (2007) pagina 128, zie ook bijlage 1




Results research Palle Kristoffersen 2007

"Non-chemical weed control on traffic islands: a comparison of the efficacy of five weed control techniques"

# Non-chemical weed control on traffic islands: a comparison of the efficacy of five weed control techniques

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## Summary

The efficacy of five non-chemical weed control methods for reducing weed cover on traffic islands was investigated in the growing season of 2004. Three trial sites were divided into six treatment areas which were treated with either flame, steam, hot air, hot water, brushes or left untreated. The treatments were carried out at regular intervals throughout the growing season. The percentage weed cover was measured every second week using a 75 × 75 cm quadratic frame with 100 squares. In the control areas, a rapid increase in weed cover was observed, whereas all treatments reduced weed cover. Hot water was the most effective method, although not significantly better than hot air or steam. Hot air treatment was more effective than brushing, whereas hot water was more effective than both flaming and brushing. The doses that were used were relatively high (150–355 kg ha$^{-1}$), partly because of the irregular shape of the traffic islands and the treatment intervals were quite short in comparison with those in similar studies. However, the treatments could keep down the weeds only to a certain extent. The present knowledge of the efficacy of various weed control methods, as well as an increase in our knowledge of adequate treatment intervals, supports an optimisation of hard-surface weed control. Data and experience gained from these trials were used to develop further calibrated application studies.

**Keywords:** non-pesticide management, weed cover, hard surfaces, thermal weed control, steaming, flaming, hot water, hot air, brushing.

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## Introduction

Traffic islands and other elevated hard surface areas are built to guide and separate traffic at intersections or roundabouts. In Denmark, they are typically constructed as hard surfaces surrounded by kerbstone. The hard area can be surfaced with concrete or asphalt without joints or, as in this trial, with granite setts placed on a foundation of gravel. Weeds on traffic islands are not subject to wear by trampling, as opposed to footpaths or squares, and weed control is complicated because of the presence of traffic signs and an often irregular shape. Additionally, the working environment, safety and traffic flow need to be considered, as traffic islands are often situated in heavy traffic areas.

There are several reasons for the undesirability of weeds on traffic islands. They can reduce the visibility of traffic signs and thereby cause accidents or mislead the road users. Weeds can cause damage to the hard surfaces by breaking up asphalt or by enlarging cracks (Holgersen, 1994; Schroeder, 1994). Accumulation of plant residues can impede storm water run-off to drains along the road, as well as provide a substrate for new weed establishment. Furthermore, as traffic islands are

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situated where the motorists and other road users are standing or driving slowly, weeds are very visible on these locations.

Previously, hard-surface weed control was carried out with herbicides, primarily glyphosate in recent years (Holgersen, 1994; Schroeder, 1994; Kristensen *et al*., 2004). However, the risk of pollution of drinking water reservoirs and surface water has led to several restrictions on the use of herbicides in urban areas in Denmark (Kristoffersen *et al*., 2004), as well as in many other countries (e.g. Lefevre *et al*., 2001; Hansson, 2002; Augustin, 2003b). Therefore, the need for alternative control methods has increased substantially and new equipment for hard-surface weed control has been developed recently (Hansson, 2002; Tvedt & Kristoffersen, 2002; Kempenaar & Spijker, 2004; Rask & Kristoffersen, 2007). Several studies have been conducted to test and improve thermal and mechanical equipment, e.g. brushing (Hein, 1990), flaming (e.g. Storeheier, 1994; Ascard, 1995, 1998) and hot water (Hansson, 2002; Hansson & Ascard, 2002). However, only a few studies have compared the effect of various alternative methods on hard surfaces during an entire growing season (Lefevre *et al*., 2001; Augustin, 2003a; Kempenaar & Spijker, 2004; Kristensen *et al*., 2004). The aim of the present study was to evaluate the effect of four thermal and one mechanical weed control method on three traffic islands during an 8-month growing season with a fixed number of treatments per year.

## Materials and methods

### *Experimental design*

The trial was carried out during the growing season from April 2004 to November 2004. It was designed as a block design including three trial sites (Høng, Ugerløse and Kalundborg), in which trial site corresponded to the block factor. The trial sites were situated in western Zealand, Denmark (55°N; 12°E) and the size of each trial site was 362, 166 and 186 m$^2$, respectively. All traffic islands were paved with granite setts and an attempt was made to select traffic islands with similar density and type of weed vegetation. However, the traffic islands were selected before there was any weed growth and the selection was based on the recollection of the road managers. Therefore, there were some differences. Additionally, the joint filling in Ugerløse consisted of gravel which usually facilitates an even distribution of weeds, mainly grasses (Table 1). Dicotyledonous weed species are relatively rare, perhaps because of the high risk of desiccation. The other two traffic islands had joint filling consisting of a mixture of gravel and concrete, on which weed growth is predominantly along the edges and in cracks. This construction facilitates increased rain water run-off to the weeds along the edges, as the joints in the middle are usually sealed.

All sites were cleared around the kerbstones, but not on top of the traffic islands, six to eight times during the growing season. Two of the sites (Ugerløse and Kal-

**Table 1** Weed species composition on each trial site in July 2005, i.e. the following growing season. The weed species are firstly divided in monocotyledonous and dicotyledonous weeds and then listed alphabetically

| Scientific name | English common name | Høng | Ugerløse | Kalundborg |
|---|---|---|---|---|
| *Agrostis* spp. | Bent grasses | 14* | | |
| *Dactylis glomerata* L. | Cock's-foot | 11* | | |
| *Elytrigia repens* (L.) Desv. ex Nevski | Couch grass, quack grass | 5* | 3 | 4 |
| *Festuca rubra* L. | Red fescue | 4 | | |
| *Poa annua* L. | Annual meadow-grass | | 2 | 5 |
| *Poa pratensis* ssp. *pratensis* L. | Smooth meadow-grass | 2 | | |
| *Puccinellia distans* (Jacq.) Parl. | Reflexed saltmarsh grass | 1 | 1 | 2 |
| *Artemisia vulgaris* L. | Mugwort | | 9* | 6* |
| *Atriplex patula* L. | Common orache | 12* | 5 | |
| *Chenopodium album* L. | Fat-hen, common lambsquarters | 7* | | 1 |
| *Chenopodium glaucum* L. | Oak-leaved goosefoot | 3 | 7* | |
| *Cichorium intybus* L. | Chicory | | 4 | 7* |
| *Hypochaeris radicata* L. | Common catsear | 13* | 10* | |
| *Lepidium ruderale* L. | Narrow-leaved pepperwort | | | 3 |
| *Plantago major* L. | Greater plantain | | 8* | |
| *Polygonum aviculare* L. | Knotgrass | 9* | 6 | |
| *Rumex acetosa* L. | Common sorrel | 8* | | |
| *Sonchus oleraceus* L. | Smooth sow-thistle | 6* | | |
| *Taraxacum* spp. | Dandelion | 10* | | |

*Less than 0.1 plants per square metre.

The numbers correspond to the ranking of frequencies of the species, where 1 is the most frequent species.

undborg) were cleared with a mechanical sweeper before the beginning of the trial in April and dirt removed from the traffic islands.

### *Treatments*

Five treatments and one untreated control were included in the trial (Table 2). The treatments comprised four thermal control methods, one mechanical method and one untreated control. The number of treatments was fixed from the beginning of the trial, based on strategies developed from previous experiments of 3 year duration (Hansen *et al.*, 2004).

The energy dose applied by the thermal weed control equipment was regulated by the driving speed. Before the trial was started, each treatment dose was planned on the basis of how these treatments are commonly used (e.g. 1000 kW h $ha^{-1}$ for flames and steam). However, in practice, the used doses were generally higher than planned, because of the irregular shape of the traffic islands, overlap and impediments such as traffic signs (Table 2). The dose used was calculated based on previous experience, to ensure that all above-ground plant parts were damaged (tested by the thermal fingerprint test as described by Schroeder & Hansson, 2006). No attempt was made to 'equalise' the treatments on basis of energy consumption or thermal energy content. The differences in gas consumption of the equipment also had a significant impact on the resulting doses. On small traffic islands, the reduction in working speed and thereby increasing dose will have a relatively higher impact when the machines have high gas consumption (e.g. the hot air equipment in this trial).

The flame treatment was carried out using a HOAF (HOAF Infrared Technology; NL-7575 ED Oldenzaal, the Netherlands) hand-pushed gas-burner (Table 2). To accomplish sufficient heat transfer to weeds with growth meristems located at the axilla of the basal leaves (grass species such as *Poa* spp., several Plantaginaceae, like *Plantago major* L., or Asteraceae at the rosette stage), the leaves of these weed plants were burned off. Hot air treatments were carried out with a hand-pushed machine from Zacho Products A/S (DK - 8660 Skanderborg, Denmark), a machine that is based on a high-temperature hot air system with a turbo blower. Steam treatments were carried out using a small hand-held aggregate linked by a hose to a large steam-producing machine.

The Waipuna system (Waipuna, Auckland, New Zealand) used for the hot water treatments also consisted of an aggregate linked by a hose to a machine. This system is based on a combination of hot water (95°C) and foam (consisting of maize and coconut oil).

**Table 2** Treatments, equipment specifications, treatment frequency and mean doses used per treatment and per year

| Treatment | Machine type | Capacity ($m^2$ $h^{-1}$) | Gas consumption (kg gas $h^{-1}$) | Energy consumption (kW h $h^{-1}$) | Working width (cm) | Treatment number ($year^{-1}$) | Working speed* (km $h^{-1}$) | Mean dose (kg gas $ha^{-1}$) | Mean dose per year (kg gas $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| Flames | HOAF weedmaster, hand-pushed | 320–350 | 4.8–5.3 | 61.4–67.2 | 50 | 8 | 0.64–0.7 | 150 | 1200 |
| Hot air | Zacho Turbo Weedblaster, UKB 650 | 350–400 | 11.7–13.4 | 150.1–171.5 | 65 | 8 | 0.53–0.61 | 335 | 2680 |
| Steam | Dansteam + handheld aggregate | 250–300 | 4.1–4.9 | 52.2–62.6 | 50 | 8 | 0.5–0.6 | 163† | 1304 |
| Hot water | Waipuna hand-held aggregate | 200 | 6.2 | 79.9 | 20 | 4 | 1 | 312‡ | 1240 |
| Brushes | DUKS FM-BS | | | | 50 | 4 | | | |

*The working speed is calculated by use of the total time spend on the respective treatments.
†Corresponding to 209 L diesel oil $ha^{-1}$ = 176 kg diesel $ha^{-1}$ (density of diesel approximately 0.84 kg $L^{-1}$).
‡Corresponding to 400 L diesel oil $ha^{-1}$ = ca. 336 kg diesel $ha^{-1}$ (thermal value of diesel = 11.9 kw h $kg^{-1}$, thermal value of propane gas = 12.8 kw h $kg^{-1}$).

 

It is a direct contact method as the heat energy is bound to the water in liquid phase. To achieve an optimal effect, sufficient water must surround the weed plant for a sufficient length of time to release the heat energy and thereby lower the energy losses. Brushing was carried out with a DUKS FM-BS petrol-powered machine (Machinefactory Intho A/S, 8643 Ans By, Denmark) with vertically rotating cylinder brushes made of steel.

### Measurements

Each trial site was divided into six similar treatment areas, and on each treatment area three sample plots ($75 \times 75$ cm) were determined at the beginning of the trial. The position of each sampling plot was marked with paint, and all measurements were carried out on the same plots throughout the trial. The sample plots were selected to represent parts of the traffic island, with the highest weed density within the treatment area.

On each sample plot the percentage weed cover was measured within a frame ($75 \times 75$ cm), which was divided into $10 \times 10$ squares (this method has previously been used to estimate grass cover on sports areas as described in DS/EN 12331, 2003). Within each square the weed cover was estimated (e.g. 3/10 or 30% of one square is covered with green) and the result was the sum of weed cover of 100 squares for the entire frame (0.3% weed cover in this case). Data were entered into a portable computer.

The first weed cover measurement was made before the first treatment and repeated approximately every second week throughout the growing season (Table 3). The measurements were made just prior to the next treatment and 4 weeks after the last treatment with flames, steam and hot air. Because the measurements were carried out prior to the treatments, and not immediately following the treatments, each measurement aimed at recording the effect of the treatment on the regrowth of weeds up to the next treatment.

**Table 3** Measurement dates and the time span from each treatment to the subsequent measurement date

| Measurement number | Date | Number of days after treatment: Flames/ steam/ hot air | Hot water | Brushing |
|---|---|---|---|---|
| 1 | 26 April | No previous treatment | | |
| 2 | 10 May | 12 | No previous treatment | |
| 3 | 24 May | 12 | 12 | 12 |
| 4 | 7 June | 11 | 26 | 23 |
| 5 | 28 June | 17 | 18 | 17 |
| 6 | 19 July | 18 | 39 | 35 |
| 7 | 30 August | 39 | 32 | 39 |
| 8 | 11 October | 39 | 27 | 39 |
| 9 | 8 November | 64 | 55 | 64 |

Weed cover was the only parameter that was measured and no distinction was made between the constituent weed species. Except for regular sweeping, no weed control had been carried out on the trial sites in preceding years and according to the road managers the sites were densely overgrown with weeds (especially grasses) in 2003. When the first measurement was made in April 2004, the growing season was just beginning. The vegetation was dominated by established perennial grasses as the salt-tolerant grass species, *Puccinellia distans* (Jacq.) Parl., *Poa* spp. and *Elytrigia repens* (L.) Desv. ex Nevski. By the second measurement in mid-May several dicotyledonous weed species, mainly *Chenopodium album* L., *Chenopodium glaucum* L. *Lepidium ruderale* L. and *Taraxacum* spp. were at early developmental stages (primarily one- to four-leaf stage). A quantitative analysis of the weed species on all treatment areas was carried out in July 2005, i.e. the following growing season (Table 1). There was generally little variation in the species present in 2004 and 2005. However, there was a considerably higher density of *Taraxacum* spp. and *Sonchus oleraceus* L. in Høng in 2004 in comparison with 2005.

### Statistical analysis

The statistical analysis for percentage weed cover was carried out using the proc mixed procedure of the SAS package 8.2 (Anonymous, 2000) in order to take account of random effects and repeated measurements. All systematic factors were tested against variation between the trial sites, which was considered a random effect. The model also took into account repeated measurements, as repeated measurements in the same plot are correlated and therefore not independent. To adjust for the time span between measurements, day numbers within the year were used. The mean of the three sample plots within each treatment area was calculated for the statistical analysis. The treatment and number of measurements factors, and the interaction between these two factors were class variables in the systematic part of the model. Weed coverage at the beginning of the trial was covariate to adjust for the weed cover of each treatment area before the first treatment. The number of days between the latest treatment and each measurement was also included in the model. Measurements before the first treatment and measurements in the untreated areas were given the value 0 days. To compare the effect of each treatment, pair-wise comparisons were made by use of $t$-tests. $P$-values below 0.05 were considered significant.

 

**Table 4** Analysis of variance of weed cover

| Factor | Degrees of freedom | F-value | P-value |
|---|---|---|---|
| Treatment | 5 | 21.52 | <0.001 |
| Measurement date | 7 | 3.37 | 0.012 |
| Days from treatment to measurement | 1 | 6.33 | 0.013 |
| Weed cover before first treatment | 1 | 63.34 | <0.001 |
| Treatment × measurement date | 35 | 1.45 | 0.074 |

**Table 5** Estimates of the relative effect of each treatment on weed cover and pair-wise comparisons

| Treatment | Weed cover (%) | P-values (differences between treatments) | | | | |
|---|---|---|---|---|---|---|
| | | Hot water | Hot air | Steam | Flames | Brushes |
| Hot water | 0.9 | | | | | |
| Hot air | 1.1 | 0.252 | | | | |
| Steam | 1.2 | 0.198 | 0.682 | | | |
| Flames | 1.6 | 0.007 | 0.072 | 0.205 | | |
| Brushes | 1.8 | <0.001 | 0.037 | 0.082 | 0.452 | |
| No treatment | 8.4 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

Homogeneity of variance was assessed on the basis of plots of standardised residuals against predicted values by use of proc GLM in SAS (8.2). In order to achieve homogeneity of variance percentage weed cover was subjected to a square root transformation. For presentation and analyses of differences between treatments, the estimates (lsmean values) were back-transformed.

## Results

### Variation in weed cover

The mean weed cover was 5.4% in Høng, 1.7% in Ugerløse and 1.1% in Kalundborg before the first treatment (mainly established grass weeds). A lower weed cover in Kalundborg and Ugerløse was primarily a result of the sweeping with brushes carried out in the middle of April on these locations. The percentage weed cover before the first treatment significantly affected weed cover during the trial (Table 4). However, the regular treatment intervals at the beginning of the growing season tended to compensate for the differences in weed cover, compared with weed cover before the first treatment. After two to four treatments the differences in treatment effects increased (Fig. 1).

No weed control resulted in a rapid increase in weed cover at the beginning of the growing season. Even though weed infestations were quite low at the beginning of the growing season on untreated areas, a substantial increase was recorded. From the end of July the weed growth did not increase on the untreated areas. Between 11 October and the last measurement date, the growing season ended and the plants began to senesce.

### Effects of treatments

All treatments significantly reduced weed cover compared with the untreated areas (Table 5). Hot water and hot air were the most effective and no significant differences between these treatments were observed. Hot air treatment was more effective than brushing, whereas hot water was more effective than both flaming and brushing. There was no significant difference between treatment with steam or any other method.

A rapid decrease in weed cover was especially noticeable on areas with a high initial weed infestation, after the first thermal treatments had been carried out. Areas treated with hot water had almost no weed cover after two treatments (middle of June). From the end of July, the weed cover was relatively constant on most treatment areas (except brushed areas) until the end of the growing season at the end of October. Weed cover was generally higher on brushed areas and the effect was

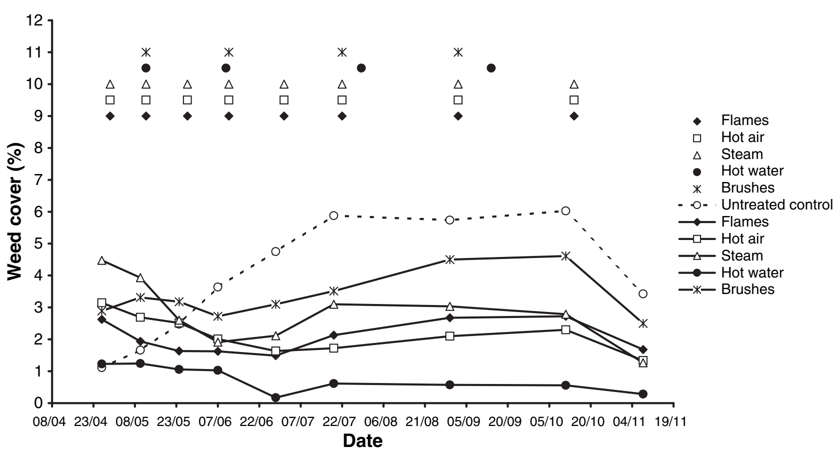


**Fig. 1** Mean weed cover (all trial sites) on the traffic islands measured nine times during the growing season. Each point is a mean value of nine measurements. The points above the lines correspond to the treatment dates for each treatment.

 

more variable between trial sites, in comparison with thermally treated areas. On one of the trial sites (Ugerløse), brushing did not have a significant effect on weed cover as compared with the untreated control area.

The measurement date and the time between treatment and measurement had a significant effect on weed cover (Table 4). However, there were no clear interactions between treatment and measurement date, reflected by the relatively parallel curves during the main part of the growing season (Fig. 1).

## Discussion

A common feature of non-chemical weed control methods is that effective control requires more frequent repeated treatments than chemical weed management (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, such as glyphosate, kill the entire plant and therefore only require one or two treatments per year (e.g. Augustin, 1990; Popay *et al*., 1992). In the present study the thermal treatments were applied four to eight times during the growing season and the mechanical treatment (brushing) was carried out four times. These treatment intervals were selected on the basis of previous studies; however, increasing the treatment frequency of brushing may improve the efficacy of this treatment. On the other hand, brushing causes wear to the surface and may even destroy vulnerable surfaces (Lefevre *et al*., 2001; Wood, 2004) and should therefore preferably be used in combination with other weed control methods.

The results of this study show the importance of carrying out repeated weed control with these types of methods. Untreated areas had a rapid rise in weed infestations on all trial sites, even Kalundborg, where weed cover was quite low at the beginning of the season. The high weed infestation may increase the weed pressure in the following years, as the annuals spread their seeds and the perennial weeds had a good opportunity to increase their root or rhizome biomass. Further studies are needed to investigate these issues and to investigate the long-term effects of using the respective weed control methods.

Treatment with hot water worked well on weed cover, although not significantly better than hot air or steam. The development of equipment using hot water, hot air and steam is relatively new compared with flaming. These methods have the advantage of eliminating the fire risk; however, the energy use of hot water (Hansson, 2002; Wood, 2004) and hot air (Table 2) is relatively high. According to Hansson and Ascard (2002) 340 kJ $m^{-2}$ [calculated by the authors to about 126 kg or 150 L diesel $ha^{-1}$ when the equipment had a thermal efficiency of 75% (D. Hansson, pers. comm., SLU, Alnarp, Sweden)] was required to achieve 90% control of *Sinapsis alba* L. at the two-leaf stage, whereas almost three times as much energy was required when the plants had six leaves. In comparison, Ascard (1995, 1998) carried out dose–response studies on flaming and propane doses of 10–40 kg gas $ha^{-1}$ were required to achieve 95% control of sensitive species such as *Chenopodium album* L. with zero to four leaves, whereas plants with four to 12 leaves required 40–150 kg gas $ha^{-1}$. Species with protected growth meristems such as *Capsella bursa-pastoris* (L.) Medik., *Matricaria discoidea* DC and *Poa annua* L. required markedly higher doses to achieve the same control level. The relatively high doses (150–335 kg gas $ha^{-1}$, Table 2) that are used in this experiment may not be representative for hard surface areas in general, but are applicable to areas that are not easily accessible. They can therefore be considered as a 'worst case scenario' and probably not comparable with the doses that may be adequate for weed control on footpaths, road verges and bicycle lanes. On these areas, tractor-mounted equipment may be used, whereas on traffic islands and similar hard-to-reach areas small handheld or hand-pushed aggregates are favoured, as the 'Dansteam' aggregate and Waipuna hose used in this study. These types of application equipment had an obvious advantage on the irregular traffic islands in comparison with the other treatment equipment and therefore were more economic to use. As regards the hot water method (Waipuna), a high run-off was observed on some of the traffic islands, as they were built with a sloping profile and with relatively compacted joint material.

Repeated use of any weed control method is likely to cause a shift in the weed flora to resistant or more tolerant species. Thermal methods often favour the growth of grasses and dicotyledonous species with growth meristems close to the ground (Parish, 1989; Ascard, 1995, 1998; Hansson, 2002; Rask & Kristoffersen, 2007). In this study, the weed flora was dominated by well-established grasses and this may reduce the effectiveness of the thermal treatments. A combination of weed control methods, e.g. by brushing or sweeping at the beginning of the growing season to remove dirt and destroy the aboveground plant parts, followed by thermal treatments at regular intervals throughout the season, may be advantageous.

In the present trial the number of treatments was fixed from the beginning of the trial. In 2005 and 2006, the trial was continued with a calibrated approach, adjusted according to the density of weed cover, in order to estimate the number of treatments that were sufficient to maintain a given control level. Data analysis of these results is currently in preparation. This succeeding trial may also resolve questions such as whether, in the course of time, the number of operations with the respective methods can be reduced.

## Acknowledgements

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