Effectiveness of weed control methods on pavement

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Introduction

The policy in the Netherlands is to signifiantly reduce the use of herbicides, also on pavements. Existing non-chemical methods to control weeds are much less effective than spot spraying, the usual method at this moment. Therefore, the cost of non-chemical weed management is often estimated to be 4 to 5 times the cost of chemical weed contol. However, independently measured data on the effectiveness of spot spraying, of current non-chemical methods and of potentially improved non-chemical methods were not available. This was particularly the case for a situation under continuous non-chemical weed control. The objective of the research described here was to determine the effectiveness of existing and experimental non-chemical methods, and of spot spraying.

Materials and methods

A 3-year experiment, from 2003 till 2005, was laid out on pavement (footpath) to measure the effectivenes of spot spraying, brushing, flaming and hot water. Also two experimentat methods, joint brushing and spot flaming, were included in the experiment. Joint brushing implied brushing of the tile joints to a greater depth than usual, by means of a small steel brush working only in the joints. Spot flaming implied that only weeds were actually treated by a small open flame and that larger weeds received a higher energy dose than smaller weeds. For the sake of the experiment, both joint brushing and spot flaming was executed by hand in the absence of machinery to apply such a treatment.
Spot spraying, brushing, flaming and hot water treatment was performed over the years with different types of machinery (Figures 1A – 1D). However this did not affect the dose-effect combination selected. Regardless of the type of machinery used, a more than 95% killing of the above ground parts was targetted and the required energy dose to reach this target was applied, by controlling the working speed. Spot flaming was performed with a relatively small hand burner (Figure 1E) and joint brushing was done with a small grinding machine with a steel brush (Figure 1F). The experiment had 4 replications with the treatments randomized within 4 blocks.

The experiment was located on a foot path in Wageningen, paved with 0.3 m square concrete tiles. At the start of the experiment the pavement was moderately weedy, classified as class 4 on the weediness scale used in this experiment (Table 1). Also weeds with roots in between and under the tiles were present. The foot path was only used occassonally by pedestrians (estimated to be less than 20 passes per day). In all years, the pavement was brushed clean just before the winter, which was considered good practice in non-chemical weed control when the experiment started. In spring, brushing was only done when necessary to remove dirt from the experiment field, before the weed started to grow.

Table 1. Weediness classification used in the experiment.

Class	weediness	Weeds present
1	Clean	None
2	few weeds	Occasionally some weed growth in the joints, maximal 5% coverage of the joints; only solitary weed plants present.
3	lightly infested	5 to 25% coverage of the joints by weeds; no clustered or tillered plants and little lengthy weeds.
4	moderately infested	25 to 50% coverage of the joints by weeds; some clustered or tillered plants present.
5	Heavily infested	More than 50% weed coverage of the joints; often clustered or tillered plants present.
6	Very heavily infested	The pavement is hardly visible through the weed coverage; occasionally woody weeds present.

A

B

C

D

E

F

Figure 1. Weed control treatments used in the experiment: flaming (A), brushing (B), hot water (C), spot spraying (D), spot flaming (E) and joint brushing (F).

The effectiveness of a weed treatment method is most commonly expressed in terms of the effect that the treatment has on the weed plants. A frequently used parameter is the percentage of green parts above ground that has been killed or removed by the treatment, either directly or some time after the treatment. The effect of a single treatment depends heavily on the amount of energy put into the treatment which can be shown by the dose-effect curve. For assessing the effectiveness of weed control methods (i.e. the effectiveness of several consequetive treatments on longer term), one has to select a certain dose-effect combination of the single treatments ("energy dose") and establish a criterion for deciding when the next treatment is to be given. Once the single treatment dose-effect combination and the re-treatment

criterion have been choosen, the longer term effectiveness of a weed control method is determined by the speed of weed regrowth and the speed of growth of newly settled weeds.
In the experiment > 95% killing/removal of the above ground weed parts was established as the desired dose-effect combination for all single treatments. Weediness class 3 (lightly infested) on the scale used (Table 1) was adopted as the criterion for re-treatment. Data on the regrowth of weed were collected every week by observing the weediness class of each plot. Re-treatment took place within one week after the moment that the average weediness class of the 4 plots receiving the same treatment reached a value of 3. These data were analysed to compare the effectiveness of the various treatment methods.

Results

An example of the results obtained by weekly observation of the weediness class is presented in figure 2. In this case 4 times per year brushing (including needed treatment in November) or 3 times joint brushing was necessary to maintain the weediness at class 3. For alle methods and years, the number of treatments needed to maintain weediness class 3 is presented in table 2.

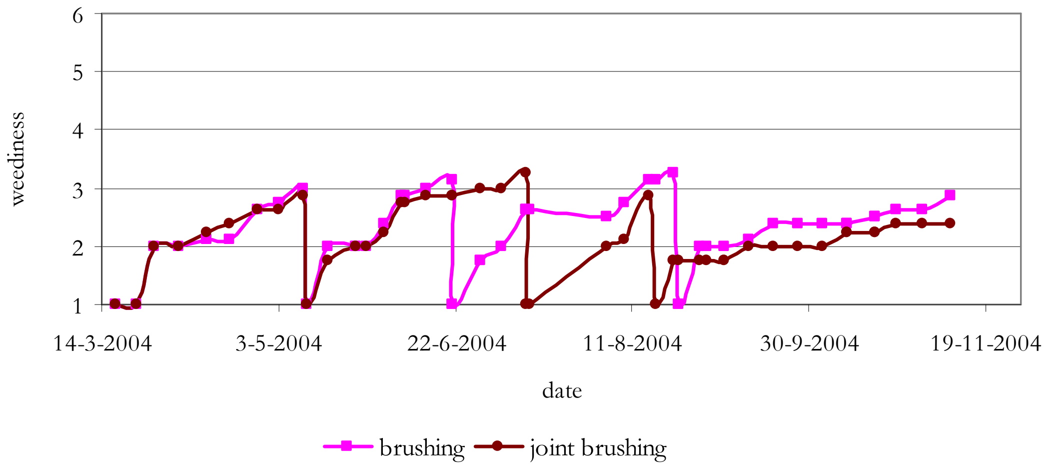

Figure 2. Average weekly weediness class observed on the brushing and joint brushing plots in 2004,

Table 2. Number of treatments per method and per year, needed for maintaining weediness class 3 during the course of the experiment.

Method	2003	2004	2005
Spot spraying	1	2	1
Brushing	5	4	4
Joint brushing	4	3	2
Flaming	6	4	2
Spot flaming	4	3	2
Hot Water	6	4	2

The number of treatments needed per season appeared to be a poor characteristic of the effectiveness of a method because:

- The duration of the first weed growth period after the winter is affected by the weed situation just before the winter (carry-over effect) and, possibly, also by the characteristics of the winter.

- In some cases we deviated from the criterion “average weediness class = 3” when the weed situation in one out of the four considered plots started to get out of hand. This affected the number of treatments per season.
- The duration of the measuring season was different for each year of the experiment, affecting the number of treatments needed. In particular the season 2005 was shorter than 2003 and 2004.

Better analysis of the effectiveness of the treatments was possible by separate analysis of the weed development in the periods following the winter and in the periods following each treatment event. The effectiveness can than be characterized by the number of days between start of season / treatment and the moment that weediness class 3 is reached again.

Weed growth after the winter

The duration of the first periods of weed regrowth after the winter, designated as the effective carry-over period (U_m) was defined as the number of days between the 1st of March and the expected moment of reaching weediness class 3. For each weed treatment separately, the development of the weediness class after the 1st of March was analysed, including the effect of the weediness at the time of applying the brushing treatment before the winter. The weed development was analysed statistically by multiple linear regression, assuming a linear increase of the weediness class with time after treatment. Values for U_m (Table 3) for each weed control method and weediness class at brushing before onset of the winter were derived from the predicted development of the weediness class. Notably, U_m is found at the time at which a weediness level of 3 is reached again.

Table 3. Expected effective carry-over period (U_m in days) per method for control target weediness class 3, as related to the weediness class at brushing before the winter.

	Weediness class at brushing before the winter			
Method	1	2	3	4
Spot spraying *)	118	99	79	-
Brushing *)	-	63	53	43
Joint brushing	-	71	56	41
Flaming	-	110	74	37
Spot flaming	-	98	83	69
Hot Water	-	92	59	26

*) Effect of weediness class at brushing before the winter not significant ($P<0.05$).

The effective carry-over period depends on the weed control method and the weediness at brushing before the winter. In all cases, the carry-over period decreased with increasing weediness before the winter. This effect was not statistically significant ($P<0.05$) for spot spraying and brushing. The carry-over period was generally shortest for the brushing treatments, but also flaming and hot water showed a short U_m when the previous year ended in a weedy situation. In all cases, the effective carry-over period of spot flaming was relatively long compared to other non-chemical methods.

Weed re-growth following a treatment event

The duration of the period of weed regrowth following each treatment event, designated as the effective control period (T_m), was defined as the number of days between the treatment event and the expected moment of reaching weediness class 3 again. For each weed treatment separately, the development of the weediness class after treatment was analysed, including effects of the weediness just before treatment and the time since the start of the experiment. The effects were statistically analysed by multiple linear regression, assuming a linear increase of the weediness class with time after treatment. Values for T_m (Tables 4 and 5) for each weed control method, weediness class just before treatment, and experiment year, were derived from the predicted development of the weediness class. Notably, T_m is found at the time at which a weediness level of 3 is reached again.

Table 4. Expected effective control period (T_m in days) per method for control target weediness class 3, as related to the weediness class just before treatment *).

Method	Weediness class just before treatment		
	2	3	4
Spot spraying	141	131	120
Brushing	51	44	36
Joint brushing	81	61	41
Flaming	55	44	32
Spot flaming **)	59	61	64
Hot Water	60	47	33

*) Results are based on all data, excluding data of first period after the winter.
**) Effect of weediness class before treatment not significant ($P<0.05$).

Table 5. Expected effective control period (T_m in days) per method and experiment year (long term effect), for control target weediness class 3 *).

Method	2003	2004	2005
Spot spraying	150	132	113
Brushing **)	42	44	46
Joint brushing **)	57	62	68
Flaming	40	45	49
Spot flaming **)	60	61	63
Hot Water	44	48	51

*) Results are based on all data, excluding data of first period after the winter.
**) Long term effect not significant ($P<0.05$)

The effective control period, T_m, of a treatment decreased with increasing weediness at the time of weed treatment, except for spot flaming, for which no significant effect was found (Table 4).
On the longer term (indicated by the time after starting the experiment) the various treatments reacted differently (Table 5). There was no significant long term effect for brushing, joint brushing and spot flaming. In case of spot spraying, T_m decreased with time. The cause for this behaviour is that at the end of the experiment, weediness class 3 on the spot-spray-plots was only reached when the weed was already tough and, therefore, less susceptible to chemical treatment. The effectiveness of flaming and hot water treatment improved over time, as indicated by the increase of T_m with time.

A model for the required number of treatments per season.

Assuming a weed control season starting at the 1st of March and ending the 15th of November, the theoretically required number of treatments per season can be expressed as:

$$Y_m = 1 + \{(260 - U_m) / T_m\}$$

In which:
Y_m = number of treatments per season (excluding standard brushing before the winter).
U_m = effective carry-over period (days)
T_m = effective control period (days)

The theoretical number of required treatments needs to be truncated because the partly regrown weed population at the end of the season is removed by the brushing treatment before the winter.

It is well known that the prevailing weather in the season can strongly influence the growth of weed and, thus, the treatment frequency required. Measurements to quantify this effect were not included in the experiment, but it was evident from the observations that weed growth was significantly slower in a prolonged dry period than in a period with damp weather. Therefore, it is assumed that Y_m may be 0.5 higher than average in a year, favourable for weed growth, and that Y_m may be 0.5 lower than average in a year unfavourable for weed growth.

Y_m was calculated, using estimated values for U_m and T_m for a weed control target of weediness class 3, for years favourable and unfavourable for weed growth, and for varying weediness levels before the winter. The calculated values, both truncated and with one decimal (between brackets), are presented in table 6.

Table 6. Calculated number of required treatments per year, for 6 weed control methods*) and 4 weediness levels at brushing before the winter, to maintain a target of maximum weediness class 3 in the period 1st of March till 15th of November (260 days).

	Weediness class at brushing before the winter							
	1		2		3		4	
Year type **)	easy	difficult	easy	difficult	easy	difficult	easy	difficult
Method								
Spot spraying	1 (1,6)	2 (2,6)	1 (1,7)	2 (2,7)	1 (1,9)	2 (2,9)	-	-
Brushing	-	-	4 (5,0)	5 (6,0)	5 (5,2)	6 (6,2)	5 (5,4)	6 (6,4)
Joint brushing	-	-	3 (3,6)	4 (4,6)	3 (3,8)	4 (4,8)	4 (4,1)	5 (5,1)
Flaming	-	-	3 (3,8)	4 (4,8)	4 (4,6)	5 (5,6)	4 (5,0)	5 (6,0)
Spot flaming	-	-	3 (3,1)	4 (4,1)	3 (3,4)	4 (4,4)	3 (3,6)	4 (4,6)
Hot Water	-	-	3 (4,0)	4 (5,0)	4 (4,7)	5 (5,7)	5 (5,2)	6 (6,2)

*) excluding het borstelen vóór de winter.
**) easy means unfavourable for weed growth and difficult means favourable for weed growth.

Discussion and conclusions

It may be concluded that spot spraying with glyphosate is more effective than non-chemical control methods. When the pavement is brushed clean before the winter, 1 tot 2 treatments per season of 260 days are sufficiënt to maintain a maximum weediness level of 3.

Excluding the brushing treatment just before the winter, 4 to 6 times brushing is needed to maintain weediness class 3, depending on the weather and the situation in the previous autumn. Brushing the joints much deeper than usual, has the effect that 1 to 2 less brushing treatments are needed than with conventional brushing. Therefore, in case of joint brushing, 3 to 5 treatments are needed per season, depending on the weather and autumn weed situation.

When controlling weeds by flaming, using conventional open flame burners without spot treatment, the pavement needs to be treated 3 to 5 times per season. As the energy dose given in the experiment was probably higher than in practise, due to the target of > 95% above-ground weeds killed, the number of treatments required in practise may be usually higher. Potentially, the effectiveness of flaming can be improved by adopting spot treatment with variable dosage. With 3 to 4 required treatments per year, the effectivenes of spot flaming was better than full-field flaming, particularly when the conditions in autumn were weedy.

In case of control by hot water, 3 to 6 treatments per season are needed. Hot water was about as effective as flaming, but when the situation in autum was unfavourable, flaming performed slightly better.

An unambiguous characteristic for the re-growth of weed is essential to determine the effectiveness of weed control equipment. The weediness class used in this experiment was not completely unambiguous in situations where more criteria are involved at the same time, such as a percentage of joints covered with weeds, height of the plants and presence of clustered/tillered plants. It is recommended to further develop the classification system for weediness.