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Quantitative evaluation of liquid deposition by herbicide application systems for weed control on hard surfaces

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Summary

The liquid deposition by different herbicide application systems was tested on a hard surface facility in Wageningen in September of the year 2000. The facility consisted of experimental plots of 25 m length and 0.9 m width, differing in type of hard surface (clinkers, paving stones or gravel) and weed density (3 or 7 weeds per m^2). Dominant weed species on the plots were identified as *Artemisia vulgaris* (in Dutch: bijvoet), *Chenopodium album*, *Capsella bursa-pastoris*, *Rumex acetosella*, *Taraxacum officinale*, *Erigeron canadensis*, *Poa annua* and *Festuca ovina*.

The following sprayers were tested: Knapsack, Selectspray ®, Sprinkle bar ® and Weed IT ® in both swath (broadcast) and spot treatment modes. Selectspray and Weed IT use weed sensors to treat green areas (plants) of hard surfaces. They are modern techniques for spot treatment of weeds. The amount of liquid applied on plots per herbicide application system was quantified by collecting liquid release from sprayers four times per plot in a randomized block design.

Amounts of liquid applied ranged from 7 to 220 ml per m^2. The highest amount of liquid application was obtained by the Sprinkle bar in swath treatment mode while the lowest by the weed sensing sprayers Selectspray and Weed IT in spot treatment modes. Weed density on plots had a significant effect on the amount of liquid deposition, but not type of hard surface. It was concluded that modern weed sensing herbicide application systems allow a substantial reduction in liquid application under practical conditions. Observed reductions were on average 69%. The data presented in the report provide new input data for risk evaluation studies on use of foliar applied herbicides on hard surfaces.

Samenvatting

Het onderhavige rapport beschrijft een onderzoek naar de afgifte van spuitvloeistof door verschillende toedieningstechnieken van herbiciden. Het onderzoek werd gedaan op een proeflocatie van Plant Research International in Wageningen op 26 september 2000 in opdracht van Monsanto Europe n.v. De proeflocatie bestond uit banen met klinkers, tegels of gravel met een lengte van 25 meter lengte en een breedte van 1 meter. De onkruiddichtheid op de banen was gemiddeld 3 of 7 planten per m^2. De belangrijkste onkruidsoorten waren bijvoet, melganzevoet, herderstasje, schapezuring, paardebloem, Canadese fijnstraal, straatgras en zwenkgras. Gegevens over bodembedekking door de onkruiden, onkruidstadia en onkruidhoogte zijn beschikbaar.

Vier toedieningstechnieken van herbiciden werden getest: een rugspuit, een Selectspray ® spuit-machine, een Weed IT ® spuitmachine en een Sprinkle bar. De technieken werden toegepast op twee manieren: volvelds en pleksgewijs. Bij Selectspray en Weed IT werd pleksgewijze toediening gestuurd door onkruidsensoren. Bij de rugspuit en Sprinkle bar gebeurde dit visueel door de toepasser. De afgifte aan spuitvloeistof per oppervlakte-eenheid werd 4 keer bepaald per testoppervlak voor iedere toedieningstechniek en toepassingswijze (volvelds of pleksgewijs). Selectspray en Weed IT apparatuur werden beschikbaar gesteld door De Punt Diepenveen b.v. en Kamps De Wild b.v.

De gemiddelde hoeveelheid spuitvloeistof per oppervlakte-eenheid lag tussen de 7 en 220 ml per m^2. De hoogste hoeveelheid werd toegediend door de Sprinkle bar bij volveldse toepassing en de laagste hoeveelheid door Selectspray en Weed IT bij pleksgewijze onkruidbehandeling. Het type verharding had geen significant effect op de hoeveelheid toegdiende spuitvloeistof, maar wel de onkruiddichtheid. Een belangrijke conclusie uit het onderzoek is dat de geteste onkruiddetecterende spuittechnieken Selectspray en Weed IT een grote reductie in afgifte van spuitvloeistof op verhardingen mogelijk maakt. De reductie was gemiddeld 69% ten opzicht van volveldse behandeling (deze was 25 ml per m^2). De gegevens in het onderhavige rapport leveren nieuwe inzichten die te gebruiken zijn bij de risico-evaluatie van gebruik van contactherbiciden op verhardingen.

Introduction

Herbicides play an important role in weed control on agricultural and non-agricultural surfaces. They are mainly applied by sprayers that consist of a herbicide tank, a pressure generator, spray nozzles, pipes and connectors, and control engineering (Southcombe & Seaman, 1990). Sprayers with several nozzles attached to a boom mounted on a carrier are used for weed control on large flat surfaces such as agricultural fields and certain pavements. In other situations, knapsack sprayers with one or two nozzles attached to a lance are mainly used.

During the past 10 years, automatized weed sensing sprayers have become available for spot treatment of weeds (e.g. Blackshaw *et al.*, 1998; Vermeulen & Hemming, 2000). Such sprayers allow a reduction in foliar applied herbicide use because weed free parts of surfaces are not treated. At least five commercial weed sensors have been marketed today. The principles behind the sensors are detection of reflection or fluorescence characteristics of plants. Weed sensing sprayers are used in practice today mainly on hard surfaces in urban areas because the advantages of weed sensing sprayers are most obvious on these surfaces.

Amongst all possible weed for control methods, the use of herbicides is principally associated with risks for human health and the environment the most. Because of this, and particularly in urban areas, there is much discussion about the use of herbicides. Risk evaluation studies on herbicide use are carried out to rationalise this discussion (e.g. Hollis, 1999). Reduction in use of herbicides will reduce associated risks. It is expected that herbicide use can be much reduced when herbicides are applied according to best possible practices (application of minimal doses of herbicides adjusted to weed, weather, herbicide and sprayer conditions by professionals using modern sprayers). To evaluate the possibilities of such practice to reduce herbicide use and associated risks under optimal conditions, data describing such practice are needed.

This report aveluates several herbicide application systems. It describes a study in which different application techniques were tested in terms of liquid release per unit of surface. The study provides new and actual input data for risk evaluation studies on herbicide use on hard surfaces.

Materials and Methods

Herbicide application systems

The amount of liquid applied was measured from four types of sprayers in swath (broadcast) and spot treatment modes. In swath treatment modes, sprays were evenly distributed over the whole surface of plots, while in spot treatment modes, sprays were directed on weeds only. The following sprayers were tested: Knapsack, Selectspray ®, Sprinkle bar and Weed IT ® (pictures see appendix).

Selectspray ® and Weed IT ® are modern herbicide sprayers for spot and swath treatments. Spray units were mounted on a small automobile vehicles (quad or tractor). During experimentation, Selectspray and Weed IT were operated by professionals from the companies De Punt Diepenveen b.v. in Diepenveen, the Netherlands, and Kamps de Wild b.v. in Zevenaar, the Netherlands, respectively. Nozzles of the sprayers were attached to a boom of 120 cm wide. In spot treatment mode, nozzles of the sprayers were opened following a positive signal from weed sensors. Each nozzle was individually connected to, and operated by a weed sensor. Selectspray sensors sense weeds on basis of light reflection characteristics of the surface to be treated, while Weed IT sensors sense on basis of fluorescence characteristics. Selectspray sensors are marketed by John Deere and Weed IT sensors by Kamps de Wild. When operated in the experiments, sensitivity of the sensors was set by the professionals to a level that gives sufficient spray liquid deposition on weeds on the surfaces (approximately 250 l/ha). Relevant operation parameters of sprayers are shown in Table 1. For achieving the 'swath treatment' in the experiment, the sensors were switched off in both systems.

Knapsack sprayer was operated by a herbicide application specialists from Plant Research International. The knapsack sprayer consisted of a tank, an air pressure unit set to constant pressure, and a 75 cm long lance with one spray nozzle at the top end. Operation parameters during experimentation are shown in Table 1.

Weedkiller Sprinkle bar ® is a device for accurate application of herbicides on domestic surfaces such as patios and lawns, mainly by non professionals. It is marketed by Miracle Garden Care Ltd in Godalming, Surrey, UK. When operated in the experiments, a 50 cm wide bar was attached onto the sprout of a 10 l watering can. The bar had 50 in line holes through which spray liquid is poured. By pouring the can, it produced a kind of shower of 50 in line streams of liquid (see Table 1).

Table 1. Operation parameters of sprayers.

Sprayer	Operation speed [m/s]	Spray pressure [bar]	Nozzle description	Number of nozzles per 120 cm swath	Type of spray[2)]
Knapsack	0.5 [1)]	2.5	Birchmeier 1.6 mm	1	Fine droplets
Selectspray ®	1.4	2.0	Teejet 6503	4	Fine droplets
Sprinkle bar ®	0.7	-	-	-	Very coarse droplets
Weed IT ®	1.4	2.5	Teejet 65015-SS	6	Fine droplets

1) *spot treatment mode*
2) *visual interpretation*

Hard surfaces

Six plots of an experimental facility for weed control on hard surfaces were used in the study. The facility of Plant Research International b.v., located in Wageningen, was established in the winter of 1998-1999. Dominant weed species on the plots were identified as *Artemisia vulgaris* (in Dutch: bijvoet), *Chenopodium album* (melganzevoet), *Capsella bursa-pastoris* (herderstasje), *Rumex acetosella* (schapezuring), *Taraxacum officinale* (paardebloem), *Erigeron canadensis* (Canadese fijnstraal), *Poa annua* (straatgras) and *Festuca ovina* (zwenkgras). Traffic on the plots was limited to a few walks by experimentalists or visitors per year.

Three types of hard surface were tested: clinkers, gravel or paving stones. Individual clinkers had dimensions of 10 by 20 by 6 cm (length x width x height), paving stones 30 x 30 x 3 cm. Pavements were arranged in plots of 25 m long and 0.9 m wide in patterns according to common practice. Gravel was a layer of 10 cm course red gravel stones on a sandy soil.

Two levels of weed infestation were tested per type of hard surface: 3 or 7 weeds per m^2. Two months before liquid applications per unit of surface were assessed, weeds on plots were killed by an application of the contact herbicide Reglone ® at a dose of 2 l/ha. Weeds that developed afterwards, were manually thinned to the desired density. Weed infestation level was randomly divided over two available plots per type of hard surface. Mean soil cover by weeds on the experimental plots was estimated on September 26, 2000 (see Table 2). The weeds were relatively young with a maximum height of 20 cm representing a realistic situation for treatment. Mosses were observed in ridges of pavements (see Table 2) while algae were hardly observed.

Table 2. Data on weed infestation of six experimental plots on an experimental hard surface facility in Wageningen, September 26, 2000.

Experimental treatment			Ground cover by [%] [2)]		
Number	Hard surface	Weed density [1)]	Weeds	Mosses	Algae
1	Clinkers	Low	2	3	< 0.1
2	Gravel	Low	2	< 0.1	< 0.1
3	Paving stones	Low	3	2	< 0.1
4	Clinkers	High	7	3	< 0.1
5	Gravel	High	5	< 0.1	< 0.1
6	Paving stones	High	4	2	< 0.1

1) *3 (low) or 7 (high) weeds per m^2, dominant species: Artemisia vulgaris, Chenopodium album, Capsella bursa-pastoris, Rumex acetosella, Taraxacum officinale, Erigeron canadensis, Poa annua and Festuca ovina.*

2) *ground cover by different categories of weeds were determined by visual assessments of plots supported by measurements of the green surface of individual plants sampled from subplots. A LI-COR model 3100 leaf area meter was applied for green surface measurements.*

Assessment of liquid applied

On September 26, 2000, from 10.00 till 14.00 hours, the sprayer systems were tested in several runs over the six available hard surface plots in either swath or spot treatment mode. Liquid releases from nozzles were caught per run in plastic bottles mounted underneath the nozzles. The weight of liquid in the bottles was determined after each run. Liquid release by Sprinkle bar was determined by weighing the whole application unit before and after each run. Runs were made over a length of 21 m per plot with a treated area per plot of 12.6 m^2 per run (0.6 m wide). Spray drift was not observed because no wind was felt on the side during testing. So, liquid releases per unit of surface and liquid deposition per unit of surface are assumed to be similar.

Experimental set up and statistical analysis

Four experimental factors (4 types of sprayers, 2 modes of application, 3 types of hard surface and 2 levels of weed infestation) were tested in a non orthogonal split plot scheme. The experimental factors hard surface and weed infestation level were assigned to the main plots, and type of sprayer and mode of application to subplots. There were 28 treatments and 4 replicates per treatment. Runs to determine liquid application in spot treatment mode were repeated four times per experimental plot. Runs to determine liquid application in swath application strategies were repeated four times per system. The order of the runs per plot was randomly determined.

The Genstat 5 statistical package was used for statistical analysis (Payne *et al.*, 1987). Treatment effects were determined by multiple comparisons tests in analysis of variance at $P<0.05$ (Sokal & Rohlf, 1981).

Results

Large differences were observed in the amount of liquid applied per unit of surface by the different herbicide application systems tested. Table 3 shows experimental means of the amount of liquid applied per herbicide application system. Mean liquid application ranged from 7 to 220 gram per m^2, differing a factor 30. Lowest amounts of application were obtained by Selectspray and Weed IT in spot treatment modes, while highest by Sprinkle bar. Coefficients of variation were larger in spot treatment mode than in swath treatment mode (Table 3).

Table 3. Amount of liquid applied by different herbicide application systems on plots of an experimental hard surface facility in Wageningen, September 26, 2000. Plots differed in type of hard surface and level of weed infestation.

Application system	Liquid applied gram/m^2] [1)]	Coefficient of variation [%]	Reduction relative to swath treatment [%]
Swath treatment:			
- Sprinkle bar ®	220	10	
- Knapsack sprayer	76	4	
- Selectspray ®	25	3	
- Weed IT ®	27	3	
Spot treatment:			
- Sprinkle bar ®	200	18	9
- Knapsack sprayer	43	5	43
- Selectspray ®	9	8	64
- Weed IT ®	7	16	74

[1)] *Experimental means of 4 and 24 replicates per sprayer for swath and spot treatments, respectively.*

Statistical analysis showed a significant interaction between mode of application (swath or spot treatment) and type of sprayer (Sprinkle bar, Knapsack, Selectspray and Weed IT). The liquid deposition by Sprinkle bar was not significantly affected by mode, while application by the other types of sprayers was. Within each mode, knapsack sprayer applied significantly more liquid on plots than Selectspray and Weed IT, but significantly less than Sprinkle bar. Differences in amount of liquid applied between Selectspray and Weed IT were not significant. Experimental data of Weed IT showed more variation than those of Selectspray.

Statistical analysis also showed a significant effect of weed infestation level on liquid application. Table 4 shows treatment means of liquid application by Knapsack sprayer, Selectspray and Weed IT when applied in a spot treatment mode. Type of hard surface did not have a significant effect on liquid application by these sprayers.

Table 4. Amount of liquid applied by three herbicide application systems in spot treatment modes on an experimental facility in Wageningen, September 26, 2000.

Hard surface	Weed density	Liquid application [gram/m²] [1] by		
		Knapsack	Selectspray	Weed IT
Clinkers	Low	29	5	3
Gravel	Low	25	4	4
Paving stones	Low	32	9	7
Gravel	High	62	11	13
Clinkers	High	59	12	10
Paving stones	High	51	16	14

[1] *Treatment means of 4 replicates are presented.*

Reduction in amount of liquid applied by spot treatments relative to swath treatments was significantly affected by sprayers and weed infestation level, but not by type of hard surface. Experimental mean reduction percentages for amount of liquid application in spot treatment mode per sprayer are presented in Table 3, ranging from 9% to 74%. Highest reductions were obtained by the modern weed sensing sprayers. A significant correlation between weed infestation level and reduction percentage for liquid application was observed for Knapsack, Selectspray and Weed IT (see Figure 1).

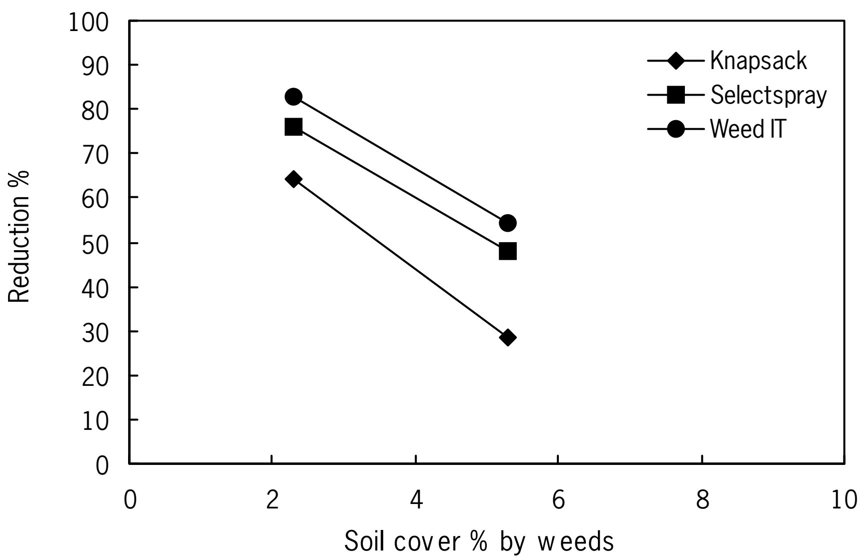

Figure 1. Relationship between weed infestation level of hard surfaces and reduction in liquid application by three herbicide application systems in a spot treatment modes and relative to swath treatment modes.

Discussion

The data presented in this report show that the amount of liquid applied is much affected by herbicide application systems. Lowest amounts per unit of surface were obtained by modern sprayers Selectspray and Weed IT, equiped with weed sensors for spot treatment of weeds. The sprayers applied a mean of 8 gram spray liquid per m^2 (8 ml per m^2 or 80 l per ha) in spot treatment mode, which is a reduction 69% when compared to swath treatment mode (swath treatments generally deposit 250 to 300 l/ha). These figures are representative for deposition of spray liquid on hard surfaces (e.g. paving stones) and semi hardsurfaces (e.g. gravel) according to this best new practice. The sprayers were tested on common urban situations in the Netherlands which require weed control measures. Sluijsmans & Drijver (1996) have reported a reduction in liquid application by Selectspray on hard surfaces in urban areas of 57% relative to swath treatment, which is in line with the data presented in this report.

The reduction in herbicide use by modern sprayers such as Selectspray and Weed IT is determined by weed density and spacial distribution. In Figure 1, relationships between weed density and reduction were shown for these professional herbicide application systems in spot treatment modes. Figure 1 allows some extrapolation. A soil cover by weeds of greater than 20% probably does not allow much reduction by spot treatment anymore. This extrapolation is supported by additional observations on the experimental hard surface facility where the sprayers applied 25 gram liquid per m^2 on a plot with a density of 20 weeds per m^2 and a soil cover by the weeds of 25%.

The presence of 3% soil cover by mosses on the hard surface had little effect on liquid application by Selectspray and Weed IT. Though the mosses will produce reflection and fluorescence signals, the sensors were hardly affected by their presence when comparing liquid application on the pavements with gravel that had no mosses. It is expected that a soil cover by mosses much larger than 3% this will effect liquid application by weed sensing sprayers.

Knapsack sprayers are best suited for chemical weed control on small surfaces and on locations where construction elements or other obstacles such as lampposts prevent the use of spray booms. When used in a spot treatment mode, the knapsack sprayers applied 43 gram per m^2 (430 l per ha), a reduction of 43% when compared to swath treatment. The knapsack sprayer applied approximately five times less liquid per unit of surface than the Sprinkle bar.

The observation of reduced liquid application by modern sprayers in spot treatment mode brings new elements into the discussion and evaluation of risks of foliar herbicide use on hard surfaces. The reduction potential is indicated. Therefor, the data presented are input for risk evaluation studies such as presented by Hollis *et al.* (1999) and those to be carried out by pesticide registration authorities.

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Appendix I.

Herbicide application techniques in action on experimental facility

Selectspray machine

Weed IT machine

Sprinkle bar

Knapsack sprayer

Appendix II.

Hardsurfaces and weed densities (low or high) on experimental facility