POTENTIAL OPERATOR EXPOSURE TO HERBICIDES: A COMPARISON BETWEEN KNAPSACK AND CDA HAND SPRAYERS

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ABSTRACT

Spray treatments with low volume CDA hand sprayers generally gave lower levels of operator contamination than high volume treatments with knapsack sprayers. The majority of contamination (80 -95%) occurs on the lower leg and feet irrespective of sprayer type. There is considerable scope to greatly reduce contamination with all sprayer types by changing spray practices and avoiding holding the spray lance in front of the operator. Use of a spray management valve (SMV) with the knapsack sprayer also reduced operator contamination.

INTRODUCTION

Chemical weed control with manually carried sprayers is practised throughout the world in a variety of crop and non-crop situations. In developed agriculture manually carried sprayers are often used around field margins, for spot treatments or general use on smallholdings. They are also widely used in the industrial and amenity sector. In many other parts of the world where agriculture is still labour intensive and non-mechanised, manually carried sprayers are frequently the sole means of applying herbicides. The use of herbicides in these situations is increasing as the time and effort involved in hand weeding has often been identified as a major constraint to agricultural productivity (Matthews and Thornhill, 1993).

The conventional lever operated knapsack (LOK) sprayer with hand lance is the most widely used sprayer for this purpose, although the necessity to fetch and carry large volumes of water for spraying is itself often time consuming and laborious. In some circumstances, particularly where water is scarce, low volume Controlled Droplet Application (CDA) sprayers have been used as an alternative. These sprayers use a spinning disc to control droplet size and reduce drift. Application volumes are typically 10-30l/ha offering significant logistical advantages over conventional spraying. Normally a more concentrated spray mix is used with low volume CDA treatments therefore comparisons were made with a conventional sprayer to assess the levels of operator contamination with each system. There are four potential sources of operator contamination during the spraying process:-

- Contact during mixing and filling
- Contact with airborne spray material
- Contact with treated vegetation
- Contact with leaking or contaminated sprayer parts

The objective of these trials was primarily to examine the levels of contamination occurring with each sprayer type from contact with airborne spray material during actual spraying. Spray operators were dressed in disposable 'Tyvec' spray suits and gloves and provided with face masks. A fluorescent tracer dye, sodium fluorescein, was added to the spray solution which could be recovered from suits, gloves and mask filters. The levels of contamination on various parts of the body could then be quantified with the aid of a spectrofluorimeter. The methods used were similar to those described by Merrit (1989). An attempt was also made to examine contamination occurring during the mixing and filling process. It was considered difficult to quantify the levels of contamination due to contact with vegetation or contaminated sprayer surfaces as these are largely dependent on the particular situation/sprayer under investigation. It was hoped, however, to obtain an indication of the degree of risk to operators when using herbicides with both conventional and CDA hand sprayers and suggest what measures may be most appropriate to minimise this.

MATERIALS AND METHODS

Sprayers

For conventional herbicide applications a Cooper Pegler 'CP3' knapsack sprayer was used fitted with a Lurmark 'An 2.0' flat fan deflector nozzle. Applications were made both with and without a Spray Management Valve (SMV) from Fluid Technology, set to regulate the pressure at the nozzle to 1 bar (100 kPa). As frequently, in practise, the same sprayer and nozzle are used for both herbicide and insecticide applications some spray treatments were also made with a hollow cone nozzle (Lurmark DC05/CR-45) without SMV.

Two types of low volume CDA sprayer were also evaluated: firstly a Micron 'Microfit Herbi' sprayer which produces a circular pattern of spray droplets, around 250µm in diameter in a 1.2m band, and secondly a Micron 'Microfit Herbaflex' producing droplets, around 200µm in diameter, which are directed in a fan pattern towards the ground for narrow band treatments. Both sprayers are normally held with the spray lance in front of the operator although they can also be held to the side or rear.

Field Methodology

The trial site was a relatively large open area of short grass cover around 5cm in height. Plot sizes measured 30m x 30m separated by a distance of 20m. Consecutive spray passes were made in parallel tracks across each plot with the spray released approximately 50cm and 20cm from the ground with the LOK and CDA sprayers respectively. Flow rates for the LOK sprayer were 1.1 l/min (with SMV), 1.3 l/min (without SMV) and 0.6 l/min with the hollow cone nozzle. With the 'Herbi' and 'Herbaflex' sprayers flow rates were around 0.08 l/min and 0.04 l/min respectively. Five replicates were normally made with each sprayer configuration. During spray treatments the wind speed and direction was recorded (2m above ground) with a portable field station (Vector Instruments) positioed in the middle of two adjacent plots. Temperature and humidity were also recorded and the total volume of spray material applied measured. Temperatures were around 19 -23^0 C with windspeeds between 0.2 and 1.2 m/sec which varied from perpendicular to near parallel to the direction of travel.

Dye solutions of sodium fluorescein were usually prepared on the same day as the spray treatments. High volume applications with the LOK sprayer used a concentration of 0.5 - 1.0 g/l of water with 0.1% 'Agral 90' surfactant. Applications at low volumes with the CDA sprayers used a dye concentration of 5-10 g/l. Spray treatments took around 5-10 minutes for each replicate and thereafter any spray deposit was allowed to dry on the 'Tyvec' suits before these were cut into sections and placed in labelled polythene bags. Samples were then stored in black plastic bags to minimise degradation of the fluorescein tracer by sunlight. A sample of spray liquid was also taken from each sprayer and, with a micropipette, 100μl of spray solution transferred onto an unsprayed piece of suit section. This 'reference' sample was then left in daylight for 10 minutes to dry before being placed into labelled bags with the other sample materials. These 'reference' samples were subsequently used to prepare the 'known standard' dye solutions for calibration of the fluorimeter.

In trials to examine contamination during mixing and filling, four operators dressed in 'Tyvec' suits with gloves and respirators, performed a standard routine using a 'concentrate' solution (10 g/l) of sodium fluorescein dye in water. The 'concentrate was supplied in a 5 litre 'Plysu Multigaurd' container and operators required to measure out 500ml of 'concentrate' and transfer this to the sprayer tank/bottle adding water as necessary. Tank lids or spray bottles were secured and the sprayers positioned ready for spraying. This routine was repeated ten times by each operator before the suits, gloves and mask filters were removed for analysis.

Laboratory Methodology

One litre of water containing 0.1% 'Agral 90' surfactant and 0.02 M NaOH solution was added to each plastic bag containing the suit section, gloves or mask filters to extract the tracer material. Samples were shaken and left to stand for a period of 1 hour being agitated routinely throughout. A sample of each solution was then transferred into a cuvette from which a reading could be taken with the spectrofluorimeter (Sequoia Turner model 450) to determine the concentration of tracer recovered. For both the LOK and CDA sprayers a calibration curve was plotted using known dilutions of the spray mix and thereafter any corrections to the readings made accordingly.

RESULTS

Results for operator contamination are expressed as the mean amount of spray material recovered from the various suit sections in μl per litre of spray applied. Expressing the contamination levels as a proportion of the spray applied allows for a direct comparison between sprayers irrespective of differences in volumes applied (refer to Table 1). From this an estimate of the quantity of active ingredient deposited can be calculated for a particular dosage rate usually expressed as mg/ha treated (refer to Figure 1 for a comparative example).

Results indicated that with all sprayers the majority of contamination occurs on the operators feet and lower leg (below the knee). Unfortunately measurements of contamination of the feet proved unreliable as spray deposits were brushed off the 'Tyvec' boots by the grass. With the LOK sprayer and deflector nozzle, around 80% of contamination occurred on the lower leg and 16% on the thighs. Some contamination was also found on the left hand which held the spray lance. The LOK sprayer with hollow cone nozzle provided some of the highest deposits on the lower leg but less on the thighs in comparison to the LOK with standard deflector nozzle. Otherwise the two treatments were comparable. Using the Spray Management Valve (SMV) reduced operator contamination. Spray treatments with the 'Herbi' sprayer held to the front provided significantly lower contamination levels than either the standard LOK with deflector or hollow cone nozzle, confirming earlier studies by de la Fuente (1991), but gave comparable results to those with the LOK fitted with SMV. The 'Herbaflex' gave the lowest levels of contamination of all treatments where the spray head/lance was held in front of the operator. Contamination was again largely confined to the lower leg. Where the 'Herbi' spray head was held to the side or rear this virtually eliminated any contamination with a 50 fold reduction in contamination of the lower leg. For all treatments spray deposits on the upper torso were negligible, as was the inhalable fraction of the spray which was at the limits of detection using this methodology. An ANOVA test confirmed highly significant differences were found between sprayers ($p<0.001$) and within different body areas ($p<0.001$).

Table 1. Operator contamination on different parts of the body * (µl/litre applied)

	Suit Section (area in cm²)											
	Hood (1200)	Mask (172)	Ftorso (6250)	Rtorso (6250)	R arm (1350)	L arm (1350)	Glove (900)	R thigh (1900)	L thigh (1900)	R Leg (1250)	L Leg (1250	Total (23772)
LOK (F)												
mean	0.65	0.03	7.09	3.39	2.41	2.48	2.79	54.70	33.35	206.04	227.19	540.12
std deviation.	0.50	0.03	12.64	3.38	2.32	3.73	3.69	94.26	48.83	65.29	70.79	294.32
LOK SMV (F)												
mean	0.16	0.02	0.32	0.32	0.23	0.23	0.52	1.66	4.62	87.42	99.55	195.05
std deviation.	0.10	0.01	0.09	0.17	0.04	0.08	0.40	0.99	5.71	39.78	28.19	60.00
LOK HC (F)												
mean	0.26	0.05	1.60	1.02	0.30	0.39	0.80	4.60	2.55	175.18	294.60	481.35
std deviation.	0.07	0.06	0.78	0.69	0.09	0.20	0.24	2.58	1.29	102.51	167.36	267.77
HERBI (F)												
mean	0.71	0.03	3.40	0.49	0.69	0.96	1.48	1.74	1.79	77.38	86.63	175.62
std deviation.	0.45	0.04	1.76	0.41	0.66	0.41	1.29	0.91	0.91	86.06	54.26	140.98
HERBI (S)												
mean	0.24	0.00	0.84	0.11	0.44	0.06	0.86	0.26	0.62	0.68	0.50	4.68
std deviation.	0.19	0.00	0.50	0.11	0.27	0.11	0.44	0.33	0.41	0.63	0.86	2.25
HERBI (R)												
mean	0.00	0.00	0.77	0.00	0.00	0.97	0.58	0.19	0.19	3.95	5.17	11.82
HFLEX (F)												
mean	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.26	78.34	44.04	122.72

* mean of 5 replicates except for Herbi (R) and Herbaflex (F) with only 2 replicates each.

Key:

LOK	Lever operated knapsack with deflector nozzle
LOK SMV	Lever operated knapsack with deflector nozzle and SMV set for 1 bar.
HERBI (F) (S) (R)	Herbi with spray head held to the front (F), side (S) or rear (R)
HFLEX (F)	Herbaflex held with spray head to the front
LOK (HC)	Lever operated knapsack with hollow cone nozzle at around 2 bar

The results for contamination levels during the mixing and filling process are given in Table 2. These represent the mean contamination levels from four different operators performing the same mixing routine ten times expressed as µl/litre of 'concentrate'. On this occasion only one example of each sprayer type was examined as the mixing process is similar for the different knapsack configurations and similar for both the 'Herbi' and 'Herbaflex'. These results suggested that the gloves received the highest contamination during mixing and filling accounting for around 30% and 64% of the total contamination for the LOK and CDA sprayers respectively. Contamination levels were, however, much lower than reported elsewhere (Craig and Mbevi, 1993) and it is likely that this methodology underestimates contact with herbicides during mixing and filling. These tests were performed under laboratory conditions which is unlikely to accurately reflect the field situation.

Figure 1. Contamination on various parts of the body expressed as mg a.i./ha treated. (Assumes a dose rate of 500g a.i./ha)

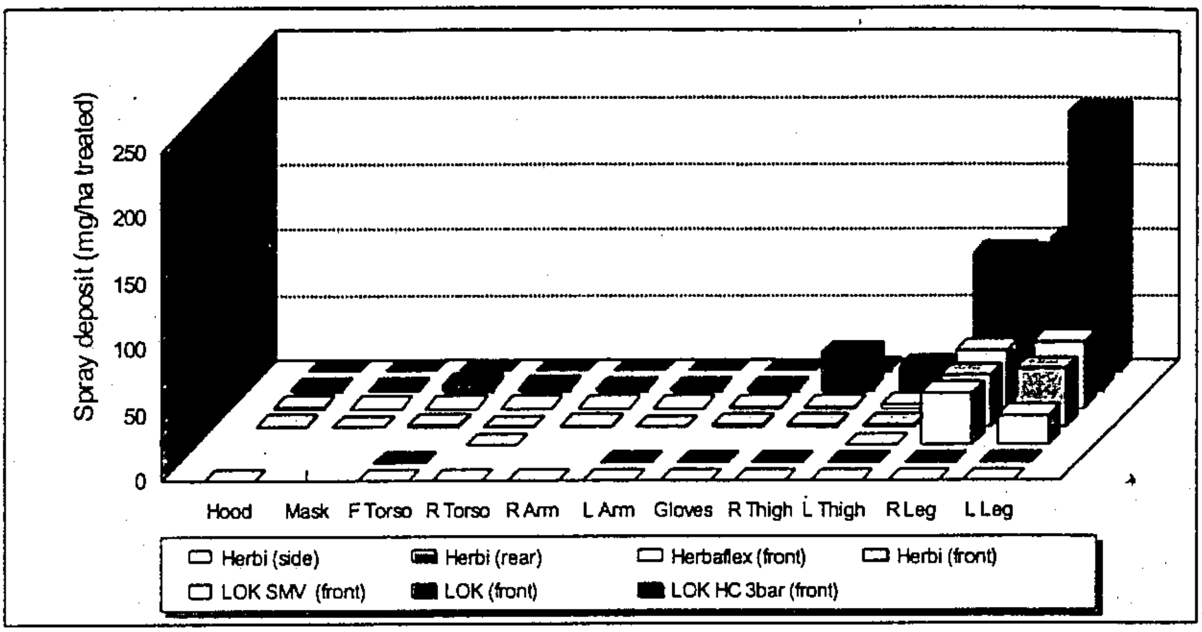

Table 2 Operator contamination during mixing and filling (µl/litre applied).

Sprayer	Hood	F Torso	R Torso	R Arm	L Arm	Gloves	R Thigh	L Thigh	R Leg	L Leg	Total
L.O.K. mean	0.22	3.98	2.74	1.34	1.4	8.52	2.58	3.34	3.24	1.92	29.28
HERBI mean	0.00	2.21	0.14	1.72	1.4	24.06	1.24	0.54	1.3	2.78	35.79

DISCUSSION

The contamination levels found in these trials represent the potential dermal exposure, as defined by Chester (1993), to herbicides by spray operators. Whilst these levels are unlikely to present any risk of acute dermal toxicity there is the possibility of some chronic effects such as skin irritation and sores with certain herbicides if spray treatments are made in bare feet or short trousers and operators do not wear gloves or wash their hands after handling the concentrate. Obviously such malpractices are to be discouraged but can and do occur in some situations where spray operators have not been trained, are unsupervised or do not have access to proper footwear or gloves. Training both by local extension services and agrochemical suppliers together with clear label instructions provide one of the most effective means of combating misuse of pesticides. Improved packaging and formulations can also reduce the risks to operators as well as encouraging the use of safer less hazardous products or actively prohibiting the use of some products. Where CDA sprayers have been used in small scale tropical agriculture these have generally been introduced through local extension services, agrochemical suppliers or into managed plantation estates, in part due to the requirement to train users in the use of such techniques. These types of applicator are also not recommended for use with toxic products, such as paraquat, at concentrations higher than those recommended on the label.

Irrespective of sprayer type, where boots, long trousers and gloves are worn there is likely to be little risk to spray operators when applying herbicides from contact with airborne spray material. The majority of contamination during herbicide treatments occurs due to the operator holding the spray lance to the front whilst walking forward and therefore deposits either impinge directly on the legs and feet or are transferred from the treated vegetation. Holding the spray head to the side of the operator can therefore significantly reduce any contamination simply by not walking through the area being sprayed. In these trials, the use of a spray management valve (SMV) also reduced the levels of contamination from the knapsack sprayer presumably by avoiding higher pressures during pumping and thereby the creation of smaller droplets which are more prone to displacement by the wind.

Experiments to evaluate the levels of contamination which may occur during mixing and filling were inconclusive due to the difficulty of simulating essentially chance accidents.

In these trials there was no attempt to assess the contamination occurring from leaking sprayers or contact with contaminated surfaces. Often poor quality materials or inappropriate designs can lead to significant operator contamination. One example is manufacturers omitting tank lid seals and non return air bleed valves for reasons of cost, which can lead to leakage on the operators back. Such a source of contamination should not be overlooked and may often exceed any contamination occurring during actual spraying (Turnbull 1985). Similarly transfer of spray deposits from treated vegetation can be a significant source and will largely be dependent on the height of the vegetation. Holding the spray head/nozzle as low as possible to the ground will reduce operator contamination although this may not always be possible in tall weeds and therefore extra care is required in such situations.

CONCLUSIONS

It can be concluded that with the CDA sprayers examined there was no increased risk to spray operators due to the higher concentration of active ingredient in the spray mix and in these trials the levels of contamination were lower than standard practices with the LOK sprayer. The majority of contamination will occur on the feet and lower legs irrespective of which type of sprayer is used when spraying in front of the operator therefore adequate footwear, long trousers and gloves are essential for safe application. There is considerable scope for reducing operator contamination simply by changing spray practices by holding the spray lance to the side or rear where possible.

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