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Minimizing Dermal Exposure to Pesticides in Greenhouses

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FINAL PERFORMANCE REPORT

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16. Abstract (Limit: 200 words)

A study was conducted to survey major variables influencing exposure during mixing and application of pesticides in greenhouses, to conduct exposure assessment studies under well defined conditions, and to field test the fluorescent tracer methodology for its utility in evaluating dermal exposure. Three types of application procedures dominated the greenhouse activity: handgunning, thermal fogging, and drenching. Thermal fogging had the highest potential for exposure, but this operation was performed by the most experienced of the workers and elaborate protective measures were followed. Drenching procedures were aimed at watering and chemically treating the roots of plants and involved application of a very coarse water stream onto the base of plants under low pressure. Handgunning was aimed at treating plant foliage and involved spraying leaves under low to high pressure. Most exposures to workers occurred during handgunning applications. Better ventilation and applicator training could help lower these exposures. Contact with treated foliage was one manner in which exposure occurred after the pesticides and other chemicals were applied to the plants. Using fluorescent tracer methodology, it was possible to visualize exposure patterns due to the presence or absence of ventilation and obtain dramatic evidence of protective clothing failures.

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Significant Findings

This research project was undertaken with three specific aims:

1. survey major variables influencing exposure during mixing and applications of pesticides in greenhouses
2. conduct exposure assessment studies under well-defined conditons
3. field test the fluorescent tracer methodology for its utility in evaluating dermal exposure

The findings of this study related to these aims were as follows:

MAJOR VARIABLES INFLUENCING EXPOSURE

A. Application Procedures

Three types of application procedures dominate greenhouse facilities: handgunning, thermal fogging and drenching. Thermal fogging involves sealing the greenhouse and producing a fine droplet aerosol throughout the structure, and is in some ways comparable to a fumigation procedure. This application procedure represents the greatest exposure potential, since the work takes place within the sealed greenhouse. However, this work is conducted by only the most experienced applicators (often the owners or managers), and elaborate repiratory protection and chemical protective clothing (CPC) are employed. This procedure is also conducted infrequently (e.g., weekly), and therefore does not necessarily represent a major contribution to total weekly exposure.

Drenching procedures are aimed at watering and chemically treating the roots of plants, and involve application of a very coarse water stream onto the base of plants under low pressure. Workers normally wear a vinyl apron to protect themselves from splashing. Most of the droplets produced by this procedure do not fall within the inspirable range, and therefore respiratory exposure is negligible. Few workers object to the use of the vinyl apron, and therefore dermal exposures tend to be low.

Handgunning procedures are aimed at treating plant foliage, and involve spraying of leaves under low to high pressure (40-200 psi). These procedures are conducted frequently on ornamentals and vegetables. In large commercial facilities handgunning occurs for several hours every day. Workers typically wear a respirator and some kind of CPC (cotton or nonwoven fabric coverall), but careful use of this equipment is not consistent. Workers find the equipment uncomfortable due to relatively high temperatures in greenhouses, and do not consider the procedures to be high risk, as they would the thermal fogging operations.

Based on our initial surveys of greenhouses, we concluded that handgunning applications represented the greatest potential for both respiratory and dermal exposures, taking into account the hazards inherent in the procedures and the attitudes and current practices of workers. We thus chose to focus our efforts on characterizing exposure to handgun applicators for the remainder of the project.

During handgunning applications several observations related to exposure potential were noted: 1) exposure to the neck and lower portions of the face are high due to the close proximity of the spraying apparatus to the body, 2) the hand-held spray cannister becomes contaminated during use

and substantial amounts of pesticide are transferred from this equipment to worker hands and clothing, and 3) spraying operations which require leaning over relatively deep benches result in substantial contamination of the stomach and groin area through contact with treated foliage.

B. Ventilation

Applications which occur outdoors are influenced by substantial natural ventilation; i.e., the air space immediatley surrounding the worker is subject to constant air exchange. This natural ventilation factor is not well characterized and is highly variable, but appears to be primarily responsible for the relatively low respiratory exposure values reported in field investigations of pesticide applications. Previous studies of outdoor applications have indicated that approximately 30% of total dose results from respiratory exposure, with the remaining 70% attributed to dermal exposure and subsequent percutanteous absorption. While this study was not able to quantify dose contributions from multiple exposure routes, it is clear from observations of the workplace that respiratory exposure values will play a relatively more important role in total dose. This conclusion assumes that no respirator is employed. If a respirator is employed, then contribution to dose from the respiratory route will be highly dependent on the fit and maintenance of the respirator. Our observations of the workplace suggest that workers are not fit-tested and do not generally invest great effort in using and maintaining respirators. Ventilation can play an important role in influencing respiratory exposures in greenhouses. Our survey of commercial applications revealed that the type and status of ventilation varied widely.

C. Applicator Training

The training and experience of applicators affects exposure potential. We observed that workers with a good knowledge of the application procedure were less likely to come into contact with the aerosol generated during spraying. Additionally, we noted that the attitude of workers toward chemical exposure influenced their behavior. Some workers considered use of protective equipment to be a burden, while others handled such equipment carefully and were meticulous in their activities.

D. Contact with Treated Foliage

Greenhouse applications most often require movement up and down rows of plants placed on benchtops. In many cases foliage overhangs the benchtop and movement between benches necessarily involves leg or torso contact with the foliage. When the foliage is wet from treatment exposure potential to these regions can be high. Such applications are conducted normally while wearing CPC. Applicators assume that CPC is providing them with full protection during these activities.

EXPOSURE ASSESSMENT STUDIES

Our observations regarding ventilation, applicator training and contact with treated foliage led us to design several studies to examine these variables in greater detail. Several obstacles presented themselves in the conduct of field exposure assessment studies. First, such studies are always contingent on the recruitment and cooperation of volunteers. Growers and workers were generally reluctant to change their work schedules or lose time during busy growing seasons. Second, most greenhouses had only one or two applicators. It thus became impossible from a logistical perspective to develop a cohort of workers for continuous study. The fluorescent tracer technqiue employed required time for set up, and even with the use of a mobile laboratory investigations at multiple sites were problematic. Third, handgunning operations employed a variety of pesticides, and spraying schedules were in some cases unpredictable. The variety of pesticides used precluded

our development of adequate analytical procedures or biological monitoring techniques (insufficient time and funds), and instead we turned to the fluorescent tracer as the exclusive tool for our investigations. In light of these obstacles, our initial studies were to a great extent observational. Subsequent studies controlled various application conditions in order to examine specific variables.

Results from studies of the effects of ventilation and applicator training are reported in Appendix I. In summary, we found that workers who used the ventilation to their advantage (i.e., remained upwind from the spray aerosol) significantly reduced their dermal exposure when compared to exposures which occurred in the absence of ventilation. However, we also found that this exposure reduction only occurred among trained applicators. For inexperienced applicators the presence of ventilation could actually increase exposure when compared with no ventilation conditions.

Results from studies of the performance of CPC during contact with treated foliage are reported in Appendix II. In summary, we found that the CPC garments in use in the commercial greenhouse exhibited breakthrough within one hour. We tested three additional garments and found that all exhibited breakthrough within one hour, with exposures of varying magnitude occurring on the legs.

We were not able to conduct follow-up studies of this same population to determine the long-term impact of our recommendations regarding ventilation, training and CPC use due to time, funding and logistical constraints. However, we have learned that training at the facility studied has been improved with special attention to spraying during ventilation, and that new CPC (PVC garments) are in use.

FLUORESCENT TRACER METHODOLOGY

These studies allowed us to conduct substantial new work with fluorescent tracers, and some of our results were quite unexpected. The tracer technique allowed visualization of exposure patterns due to the presence or absence of ventilation, and provided dramatic evidence of CPC failure. We were able to categorize exposures on skin according to the intensity and extent of exposure, providing a means of ranking worker exposure. We also collected video images of fluorescent tracer exposure patterns, but analysis of these images has not been completed. We have spent the last two years revising and testing the software programs which calculate dermal exposure from video images. These programs are now in operation and we are in the process of completing the imaging analysis. We will then test our visual observation scores against the quantitative data produced by the imaging system to verify these procedures.

Fluorescent Tracer Evaluation of Dermal Exposure to Greenhouse Pesticide Applicators

I. Exposure Reduction Due to Unidirectional Ventilation

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Acknowledgments. This research was supported in part by State funds through the New Jersey Agricultural Experiment Station (Project # 07200). The extensive contributions of Shari Birnbaum to all aspects of this research deserve special thanks. Also acknowledged for their assistance in field data collection are Karen Cicero and Ian Grey. The willingness of the U.S. Environmental Protection Agency, Office of Research and Development, to provide use of a mobile laboratory during data collection is greatly appreciated.

Abstract: Nine workers conducted benchtop handgunning spray operatons in a commercial greenhouse in Florida with the ventilation system either on or off. Five workers were experienced applicators, while four had not applied pesticides previously. Applications were conducted for one hour with a fluorescent tracer substituted for the pesticide in an aqueous mixture. Dermal exposure was monitored by patches attached to the arms and legs, and by video imaging. The ventilation system produced undirectional air movement and therefore had a predictable effect on the aerosol drift pattern generated during application. Tracer deposition was reduced on 19 of 20 patch samples when ventilation was on for experienced applicators, resulting in a median applicator exposure reduction of 88.3%. For inexperienced applicators deposition was increased on 9 of 16 patches, resulting in a median applicator exposure increase of 371% due to ventilation. Median patch deposition for the inexperienced applicators was 6.4-fold greater than that of the experienced applicators with the ventilation off, but the difference was 143-fold with the ventilation on. Leg deposition was greater than arm deposition for both groups regardless of ventilation status. These results indicate that experienced applicators can employ unidirectional ventilation to their advantage by remaining upwind of the aerosol drift pattern, and that such behavior can reduce exposure dramatically during greenhouse handgunning applications.

Introduction

Ventilation has been employed to control hazardous workplace emissions and reduce occupational exposures for decades. In greenhouses, however, ventilation systems are designed and operated to maintain an atmosphere which is optimal for plant growth, primarily through temperature regulation. Air exchanges rates and specific patterns of air flow within the greenhouse will affect air concentrations and spray drift patterns, and thus can be expected to alter both respiratory and dermal exposures.

Few studies have measured greenhouse applicator exposure or addressed the role of ventilation. Two studies have examined the effect of ventilation on airborne residues in greenhouse air following pesticide applications but did not examine applicator exposure (Waldron 1985; Williams et al. 1980). Mestres et al. (1985) measured a single worker's exposure to dicofol and deltamethrin, while Adamis et al. (1985) monitored the exposure of a greenhouse handgunner and his helper, but neither study mentioned the status of the ventilation system. Fenske et al. (1987) turned off the ventilation consistently during a study of Fosetyl-Al exposure among greenhouse handgunners, but the effect of ventilation were not studied. Stamper et al. (1989) examined greenhouse handgunners' exposure to four different pesticides under normal application conditions, and noted only that ventilation was "variable"; it is unclear to what extent variable ventilation contributed to the wide range of exposures reported.

This study was designed to characterize the ventilation system operating in a commercial greenhouse and to determine the effect of ventilation on applicator exposure.

Materials and Methods

Experimental Design

The fluorescent tracer, 4-methyl-7-diethylaminocoumarin was employed as a surrogate for pesticides throughout the study. The tracer is non-toxic, non-mutagenic in bacterial assays and does not produce dermal irritation (Thomann and Kruger, 1975). This compound was handled as a wettable powder formulation and dissolved in Natural Oil (93% vegetable oil, Stoller, Inc).

In order to carefully analyze ventilation as a variable, several experimental controls were incorporated into this study. Applicators always used the same spray equipment, always completed the same numbers of work cycles and always applied the same amount of tracer.

Field Conditions

A study was conducted at a commercial greenhouse facility in southern Florida in August 1989. Two greenhouses were used during the study. One provided strong unidirectional ventilation, which we define as air moving parallel to the direction of aisles at a velocity of 5 m/sec or more. The other was tightly sealed and provided no ventilation. Both greenhouses had empty benches which were 1.8 m wide, 23 m long and elevated to a height of 23 cm. Actual greenhouse floor surface area varied somewhat. The ventilated greenhouse had a floor surface area of 2787 m^2 and a benchtop surface area of 210 m^2. The unventilated greenhouse had a floor and benchtop surface area of 426 m^2 and 263 m^2, respectively. The reason for the use of 2 different greenhouse was due to plants being grown in a portion of the ventilated greenhouse. If the ventilation system was turned off, the temperature within the greenhouse would rise and have an adverse effect on the plants.

A total of nine (9) subjects were employed during the study. Five subjects were experienced applicators who routinely apply pesticides during the course of a work day. The remaining four were inexperienced applicators who never apply pesticides. Experience level was determined by having the subjects' immediate supervisor fill out a questionnaire which determined the level of experience each subject has with respect to pesticide applications. Each applicator was asked to conduct the application as they normally would. Each subject participated in a two part experiment, in random order, and was used as his/her own control. Each of the participants operated a 125 gallon spray rig which consisted of a tank, 5 hp gas engine, pump and 100 foot detachable hose attached to a dual nozzle 1 meter long spray wand assembly. An application pressure of 13.8 Bars (200psi) was maintained throughout the study. Each tank consisted of 100 gallons of water and 60 grams of tracer dissolved in 0.25 L of Natural Oil Spray Adjuvant. Each worker applied a complete tank of water/fluorescent tracer formulation onto empty benches inside a greenhouse with the ventilation system on, and repeated the task with the ventilation off on a different day. The mean application time was 1.0 hour +/- 10 minutes with the exception of 2 experienced applicators who discharged an entire tank in 40 minutes.

Sampling

Prior to each application, each worker put on a T-shirt and athletic shorts and was outfitted with 4 inch x 4 inch polyethylene-backed alpha-cellulose patches. The location of the patches were as follows; one patch per upper arm, attached to the outer bicep area by surgical tape and one patch per leg attached to the athletic shorts by two safety pins just above the hemline of the shorts. Once the tank was empty, the subject was escorted back to a mobile laboratory where the alpha-cellulose patches were carefully removed by staff wearing surgical gloves who handled the patches at the edges. Each patch was then covered with a blank patch, wrapped in aluminum foil, labelled and stored in a cold room (0^0C) pending transportation to the laboratory.

Analysis

Each dermal monitor was center-cut on a table top paper cutter so that a 5 cm x 5 cm square remained. Both the cutting edge and blade were rinsed with pesticide grade acetone before each monitor was cut. Each alpha-cellulose square was then transferred to a 118 ml (4 ounce) glass jar using clean tweezers and capped. Samples were extracted with 30 ml of pesticide grade toluene on a flat rack shaker table (Eberbach Co.) at high speed (100 cycles/min) for 30 min. Following extraction, each patch was removed and the extract analyzed by a Turner model 430 Spectrofluorometer set at the following wavelengths; Excitation = 370 nm, Emission = 410 nm, bandwidth = 15 nm. Quantitation was achieved by a standard curve using external standards. The limit of detection was 0.12 ng/cm^2.

Quality Control Procedures

Extraction efficiencies for the dermal monitors were determined by fortifying alpha-cellulose patches with the tracer at two levels within the range anticipated in field samples. The mean recovery for the monitors was 99.9% with a standard deviation of 3.1. Field Blanks were below the detectable limit of the instrument.

Results and Discussion

Throughout the course of the study, all applicators applied the same amount of tracer which allows a direct comparison amongst workers. Outer monitors serve as indicators of depositional patterns over their respective body regions. Tables 1 and 2 present deposition rate data for experienced and inexperienced applicators, respectively. Table 3 and Figures 1 and 2 indicate the percent reduction in exposure due to ventilation by anatomical region.

Tracer deposition was reduced on 19 of 20 patch samples when ventilation was on for experienced applicators, resulting in a median applicator exposure reduction of 88.3%. For inexperienced applicators deposition was increased on 9 of 16 patches, resulting in a median applicator exposure increase of 371%. Median patch deposition for the inexperienced applicators was 6.4-fold greater than that of the experienced applicators with the ventilation off, but the difference was 143-fold with the ventilation on. Leg deposition was greater than arm deposition for both groups regardless of ventilation status. These results indicate that experienced applicators can employ unidirectional ventilation to their advantage by remaining upwind of the aerosol drift pattern, and that such behavior can reduce exposure dramatically during during greenhouse handgunning applications.

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Table 1

Dermal Deposition of Fluorescent Tracer with Unidirectional and No Ventilation: **Experienced Applicators**

Worker ID	Body Part[a]	Dermal Deposition Rate ($ng/cm^2/hr$) Vent On	No Vent	Exposure Reduction[b] (%)
A	LA	0.19	1.70	88.8
	RA	0.19	26.9	99.3
	LL	0.19	82.5	99.8
	RL	1.73	75.8	97.7
B	LA	2.05	7.09	71.1
	RA	0.17	1.43	88.1
	LL	0.17	3.43	95.0
	RL	0.17	19.0	99.1
C	LA	0.21	1.02	79.4
	RA	0.21	3.04	93.1
	LL	0.21	7.50	97.2
	RL	0.21	1.63	87.1
D	LA	0.12[c]	1.60	92.5
	RA	0.12[c]	2.56	95.3
	LL	7.35	10.7	31.3
	RL	5.31	1.84	-189.0[d]
E	LA	0.16	0.50	68.0
	RA	0.16	0.50	68.0
	LL	10.2	21.1	51.7
	RL	6.10	77.5	92.1

a LA = left arm; RA = right arm; LL = left leg; RL = right leg

b percent reduction = (no vent - vent on)/(no vent) x 100

c values are below limit of detection (0.12 ng/cm^2) and have been assigned l.o.d. for statistical purposes

d negative value = increase in exposure

Table 2

Dermal Deposition of Fluorescent Tracer with Unidirectional and No Ventilation: **Inexperienced Applicators**

Worker ID	Body Part[a]	Dermal Deposition Rate ($ng/cm^2/hr$) Vent On	No Vent	Exposure Reduction[b] (%)
F	LA	14.6	2.17	-573.0c
	RA	0.15	1.92	92.2
	LL	133.0	37.4	-254.8
	RL	53.0	3.50	-1414.3
G	LA	0.15	34.4	99.6
	RA	0.15	71.9	99.8
	LL	21.5	56.3	61.8
	RL	43.4	30.7	-41.4
H	LA	103.0	11.0	-836.4
	RA	4.80	42.5	88.7
	LL	122.6	67.2	-82.4
	RL	35.8	40.2	10.9
I	LA	1.43	8.24	82.6
	RA	2.54	1.81	-40.3
	LL	120.5	1.81	-6557.5
	RL	177.6	5.14	-3355.3

a LA = left arm; RA = right arm; LL = left leg; RL = right leg

b percent reduction = (no vent - vent on)/(no vent) x 100

c negative value = increase in exposure

Table 3

Dermal Exposure and Percent Reduction by Anatomical Region

EXPERIENCED APPLICATORS

WORKER ID	LEFT ARM (%)	RIGHT ARM (%)	LEFT LEG (%)	RIGHT LEG (%)
A	88.8	99.3	99.8	97.7
B	71.1	88.1	95.0	99.1
C	79.4	93.1	97.2	87.1
D	92.5	95.3	31.3	-189.0
E	68.0	68.0	51.7	92.1
Mean	80.0	88.8	75.0	37.4
Median	79.4	93.1	95.0	92.1
Std. Dev.	10.7	12.3	31.4	126.7
C.V.(%)[a]	13.4	13.8	41.9	339.0

INEXPERIENCED APPLICATORS

WORKER ID	LEFT ARM (%)	RIGHT ARM (%)	LEFT LEG (%)	RIGHT LEG (%)
F	-573.0	92.2	-254.8	-1414.3
G	99.6	99.8	61.8	-41.4
H	-836.4	88.7	-82.4	10.9
I	82.6	-40.3	-6557.5	-3355.3
Mean	-306.8	60.1	-1708.0	-1200.0
Median	-245.2	90.5	-168.6	-727.9
Std. Dev.	471.9	67.1	3235.5	1581.0
C.V.(%)[a]	-153.0	111.0	-189.0	-132.0

[a] Coefficient of Variation = Std. Dev./Mean x 100

EFFECT OF STRONG UNIDIRECTIONAL VENTILATION ON DERMAL DEPOSITION RATE
DURING GREENHOUSE HANDGUNNING APPLICATIONS
(EXPERIENCED APPLICATORS)

{AIR VELOCITY > 5 M/S}

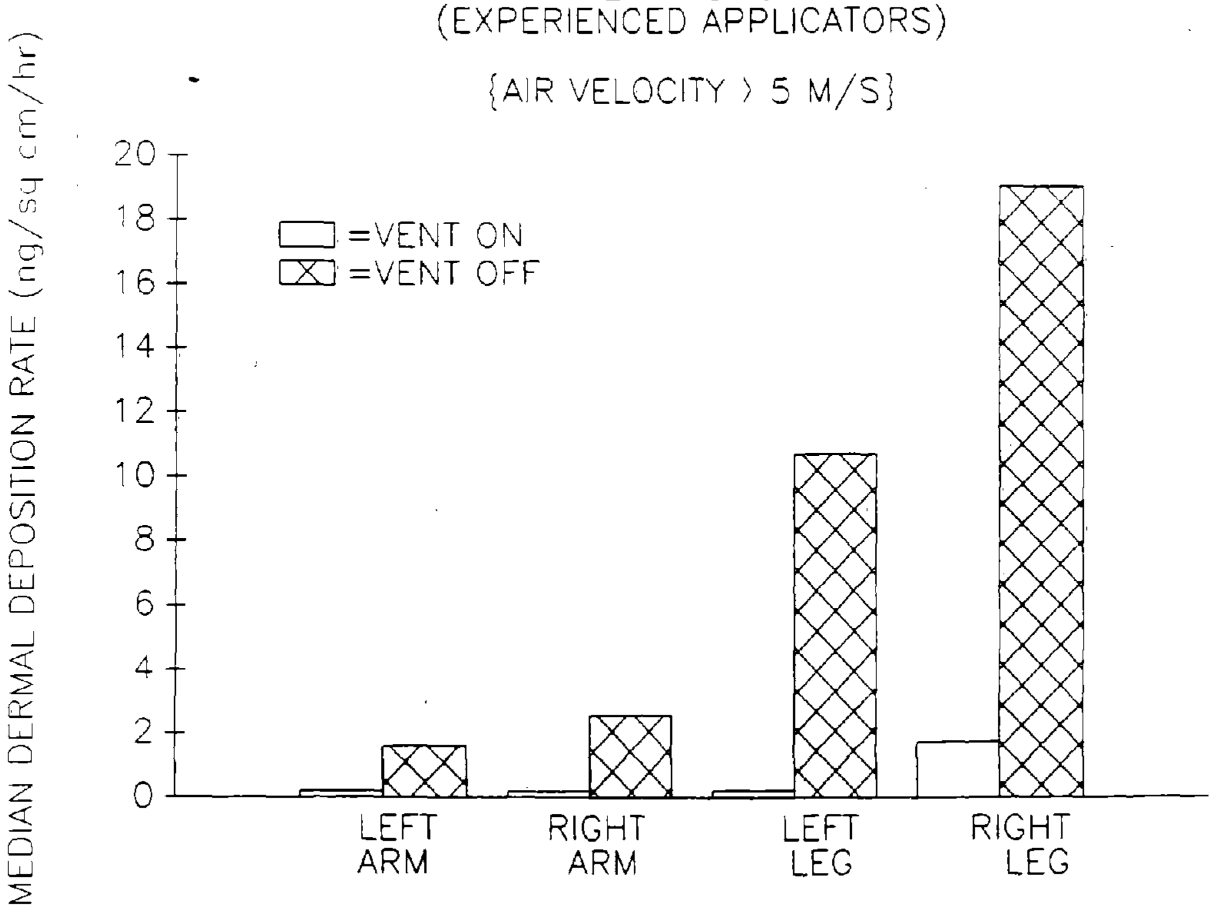

FIGURE 1

EFFECT OF STRONG UNIDIRECTIONAL VENTILATION ON DERMAL DEPOSITION RATE DURING GREENHOUSE HANDGUNNING APPLICATIONS (INEXPERIENCED APPLICATORS)

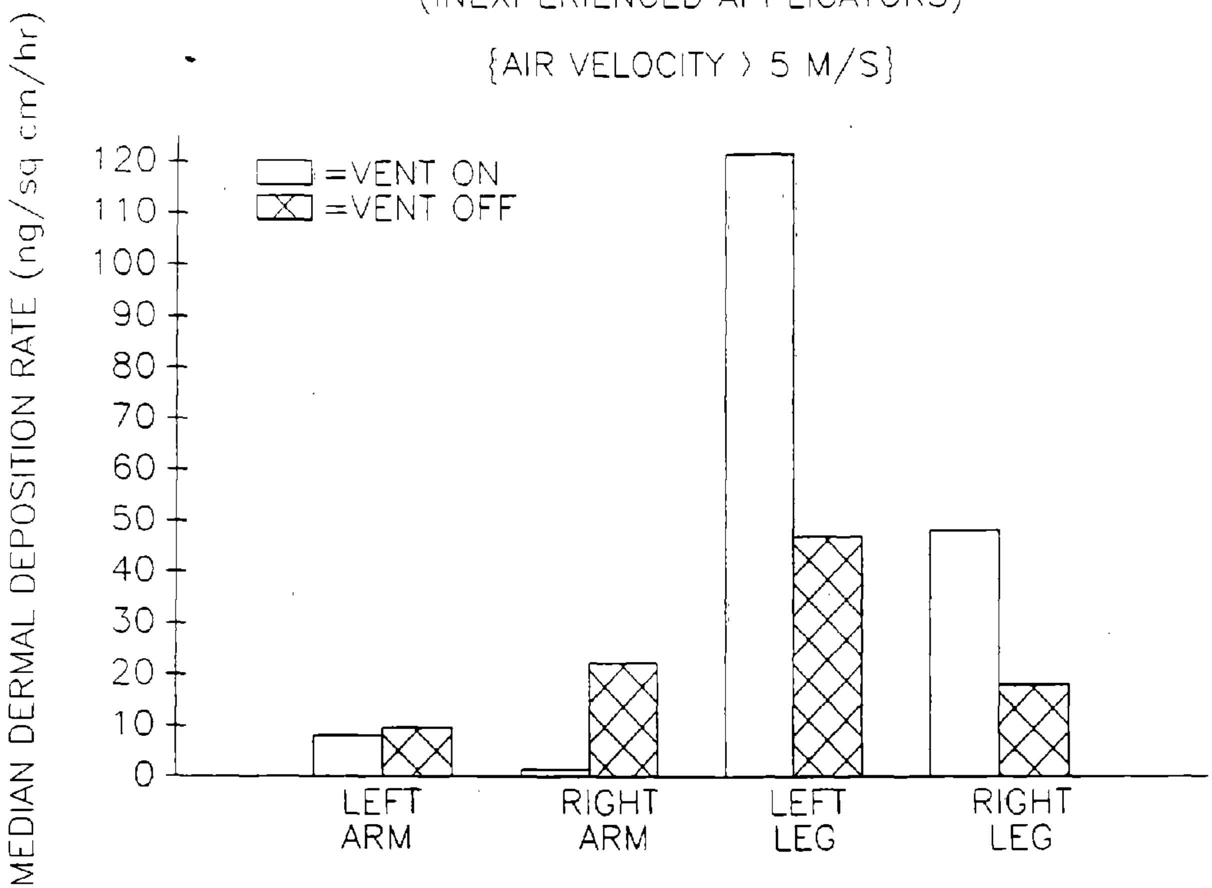

FIGURE 2

[MANUSCRIPT IN PREPARATION]

Fluorescent Tracer Evaluation of Dermal Exposure to Greenhouse Pesticide Applicators

II. Failure of Chemical Protective Clothing Due to Foliar Contact

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Abstract. Protective clothing performance under greenhouse conditions was evaluated by adding a fluorescent tracer to the spray tank during handgunning applications. A modification of the traditional patch technique where patches made of alpha-cellulose were attached outside and inside a protective garment at mid-thigh level was utilized. This technique allows the evaluation of protective clothing which comes in contact with wet foliage during greenhouse handgunning applications. Sixteen handgunning applicators were asked to wear 4 different types of protective clothing. The garments evaluated were; Untreated Tyvek coverall (non-woven), Saranex coated Tyvek pants, Kimberly-Clark Kleenguard coverall and an experimental Gore fabric pants. All garments exhibited breakthrough to varying degrees after one hour of application. Percent penetration for each garment was calculated by dividing the mean deposition rate for the inner patches by the mean deposition rate for the outside patches and multiplying this value by 100. Performance for each garment was as follows; Saranex coated Tyvek pants (0.2%), Gore fabric pants (0.3%), Untreated Tyvek coverall (3.0%) and Kimberly-Clark Kleenguard Coverall (14.0%). These results indicate that garments normally considered chemical-resistant during applications may provide inadequate protection when wet foliage is contacted repeatedly during application.

Introduction

Dermal exposure to pesticides has been determined to be the primary route of exposure in agriculture and constitutes a serious occupational health hazard. These hazards have been recognized for quite some time and has prompted the use of protective garments while applying/mixing pesticides. However, some garments are used for both outdoor airblast and greenhouse handgunning applications even though the hazards associated with each application are different. Most chemical protective clothing performance analyses are conducted under laboratory conditions where a mechanical spray device deposits a pesticide onto swatches of material (Leonas et al. 1988). This type of device can simulate both heavy and light drift that occurs during airblast applications as well as a splash received while mixing a pesticide (Staiff et al. 1982). Protective clothing performance under actual field conditions has been recommended (Berardinelli and Roder, 1986).

Only one study has examined the performance of protective clothing worn during a handgunning application under greenhouse conditions (Stamper et al. 1989). This study suggested that contact with foliage may have contributed to high levels of pesticide found on thigh patches. Wet foliage contact appears to be unavoidable in greenhouses where benches are up against the walls and no exit is provided at the end of the aisle. Also, benches are usually packed tightly with plants, often resulting in foliage extending into the aisles. This type of greenhouse interior design forces the handgunning applicator to walk through and contact foliage in an area he/she has just sprayed. The use of fluorescent tracers as a surrogate for a pesticide during field testing of protective clothing offers a two advantages over traditional methods. The first advantage is that the tracer is non-toxic. Second, the analysis and equipment required is relatively straightforward and inexpensive.

This study was designed to compare the efficiency of four types of protective garments used during greenhouse handgunning applications. One of these garments (Gore fabric) is experimental and not currently available to the agricultural worker. Several study parameters were controlled so that equal exposure potential amongst workers was maintained: All applicators conducted normal spraying episodes and never mixed or handled the tracer. The same equipment was employed throughout the study. Each applicator completed the same number of work cycles (i.e. same number of tanks applied). Each applicator applied the same amount of tracer. Bench height and bench width were constant throughout the study. The major uncontrolled variables were actual time worked and individual work practices.

Materials and Methods

This study was conducted at a commercial greenhouse facility in Florida in August, 1989. The study group consisted of 16 individuals who normally apply pesticides during the course of a workday. Prior to the application, each applicator put on a pair of black athletic shorts and a T-shirt. Alpha-cellulose patches (10 cm x 10 cm) were attached to the shorts just above the hemline of each leg. The protective garment was then put on and two more patches were attached to the outside of the garment at a position just above the inside patches so that no overlap occurred. This method of patch placement is identical to the method used in the greenhouse handgunner study by Stamper et al., (1989). Each of the participants operated a 125 gallon spray rig which consisted of a tank, 5 hp gas engine, pump and 100 foot detachable hose attached to a dual nozzle 1 meter long spray wand assembly. An application pressure of 13.8 Bars (200psi) was maintained throughout the study. Each tank consisted of 125 gallons of water and 75 grams of tracer dissolved in 0.25 L of Natural Oil Spray Adjuvant (Stoller Inc.). Each worker applied a complete tank of water/fluorescent tracer formulation onto mature poinsettias or chrysanthemums which were densely packed on benches inside a ventilated greenhouse. The application time ranged from 58-95 minutes with 75 minutes appearing to be the mean value. Once the tank was empty, the subject was escorted back to a mobile laboratory where the alpha-cellulose pads were carefully removed by staff wearing surgical gloves who handled the pads at the edges. Each pad was then covered with a blank pad, wrapped in aluminum foil, labelled accordingly and stored in a cold room (32^0 F) pending transportation to the laboratory.

Four different protective garments were analyzed for protection against chemical breakthrough during contact with wet foliage. The garments which were studied were; untreated Tyvek (non-woven), Saranex coated Tyvek pants, Kimberly-Clark Kleenguard coveralls(non-woven polypropylene) and Gore experimental fabric pants. The control study for each of the protective garments consisted of 4 individual subjects, each wearing one of the four garments. Each subject applied 125 gallons of water using the same spray technique. Once this was complete, the individual was examined under UV-A light to determine if there were any fluorescent compounds present in the garment which might contaminate the inner pads. Also, each garment was examined under UV-A light to determine if the garment posesses any compound(s) that fluoresce when illuminated by UV-A light.

Analysis

Each dermal monitor was center-cut on a table top paper cutter so that a 5 cm x 5 cm square remained. Both the cutting edge and blade were rinsed with pesticide grade before each monitor was cut. Each alpha-cellulose square was then transferred to a 118 ml (4 ounce) glass jar using clean tweezers and capped. Extraction consisted of the addition of 30 ml of pesticide grade toluene to each jar and shaking at high speed (100 cycles/min) for 30 minutes on a flat rack shaker table (Eberbach Co.). Following extraction, each pad was removed and the extract analyzed by a Turner 430 Spectrofluorometer set at the following wavelengths; Excitation = 370 nm, Emission = 410 nm, bandwidth = 15 nm. Quantitation was achieved by a standard curve using external standards. The limit of Detection was found to be 0.12 ng/cm^2.

Quality Control Procedures

Extraction efficiencies for the dermal monitors was determined by fortifying alpha-cellulose patches with the tracer at two levels within the range anticipated in field samples. The mean recovery for the monitors was 99.9% with a standard deviation of 3.1. Field Blanks were below the detectable limit of the instrument.

Results and Discussion

Each patch was extracted and analyzed individually but outer deposition values were grouped together and combined for the statistical analysis. The same procedure was followed for the inner patches. Patch deposition rates are presented in Table 1 and summary statistics of percent penetration are presented in Table 2. Mean outer deposition rates were consistent for all but the untreated Tyvek coverall which was found to be 3 times less. This could be attributed to one applicator who sprayed in a greenhouse which had less plant extension into the aisle. Figure 1 illustrates the marked differences in protection amongst the different garments. The Kimberly-Clark Kleenguard garment provided the least amount of protection (14%) penetration. The Tyvek garment also exhibited breakthrough but to a lesser degree (3%). The remaining garments (Saranex coated Tyvek and Gore experimental fabric pants) both exhibited less than 1% penetration. All controls were blank and all garments had tight fitting openings so the only route of exposure was across the protective barrier. The penetration through each garment appears to be due to contact with wet foliage which extended into the aisles. Overall, it appears that none of the tested garments were impermeable under greenhouse saturating conditions. This study clearly demonstrates that the protection afforded by garments used during greenhouse handgunning applications varies widely and further research which will evaluate other protective garments appears necessary.

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Table 1

Fluorescent Tracer Deposition Rates on Outer and Inner Patches

PROTECTIVE GARMENT	WORKER ID	OUTER PAD (ng/cm^2)	INNER PAD (ng/cm^2)	APPL. TIME(hr)
UNTREATED TYVEK	6-LL	511.4	12.8	1.08
	6-RL	75.0	114.0	
	16-LL	1434.0	4.40	1.07
	16-RL	3920.0	110.2	
	20-LL	818.3	0.14[a]	0.83
	20-RL	1188.0	0.14[a]	
SARAN COATED TYVEK PANTS	1-LL	6280.0	8.30	0.97
	1-RL	1061.0	0.14[a]	
	17-LL	19.2	0.14[a]	1.02
	17-RL	101.0	0.14[a]	
	28-LL	7555.0	11.5	1.25
	28-RL	3539.0	13.3	
GORE EXPERIMENTAL FABRIC PANTS	12-LL	5626.0	0.14[a]	1.58
	12-RL	17.9	0.14[a]	
	15-LL	2886.0	72.4	1.33
	15-RL	3653.0	0.14[a]	
	23-LL	14274.0	0.14[a]	1.17
	23-RL	302.0	1.63	
	26-LL	113.4	0.60*	1.25
	26-RL	9.30	0.14[a]	
KIMBERLY CLARK KLEENGUARD COVERALL	51-RL	8282.6	3166.9 **	1.25
	51-LL	12545.7	3288.7 **	
	52-RL	511.6	4.50	1.05
	52-LL	176.6	2.30	
	53-RL	3.20	0.80	1.25
	53-LL	3.00	0.30	
	54-RL	35.2	1.40	1.00
	54-LL	15.5	0.30	
	60-RL	9987.8	2.50 ***	1.25
	60-LL	13885.5	9.60 ***	
	71-RL	71.9	2.00	1.25
	71-LL	71.9	1.40	

Limit Of Detection= 0.14 ng/cm^2
* = Lower than field blank sample of 1.60 ng/cm^2 obtained during that sampling period.
RL = RIGHT LEG
LL = LEFT LEG
[a] Denotes value was below limit of detection.
** Indicates worker who wore a "washed" garment(used previously, then washed and used).
*** Indicates same worker as #51, but wore a new garment.

Table 2

Protective Clothing Breakthrough Analysis: Percent Penetration to the Ventral Thigh Region

	Deposition rate Outer Patch ($ng/cm^2/hr$)		Deposition rate Inner Patch ($ng/cm^2/hr$)		Percent[a] Penetration
Garment	mean	C.V[b]	mean	C.V[b]	mean
Tyvek (n=3)	1325	103	40.3	139	3.0
Saranex Coated Tyvek (n=3)	3093	105	5.6	111	0.2
Gore Expt'l Fabric Pants (n=4)	3360	145	9.42	270	0.3
Kimberly Clark Kleen-guard Coverall (n=6)	3799	148	540	233	14.0

[a] denotes "percent penetration" which is defined as the inner pad deposition rate divided by the outer pad deposition rate x 100.

[b] denotes Coefficient of Variation (%) = Std.Dev/mean x 100

FLORIDA GREENHOUSE PROTECTIVE CLOTHING BREAKTHROUGH ANALYSIS
PERCENT PENETRATION TO VENTRAL THIGH REGION OF HANDGUNNERS

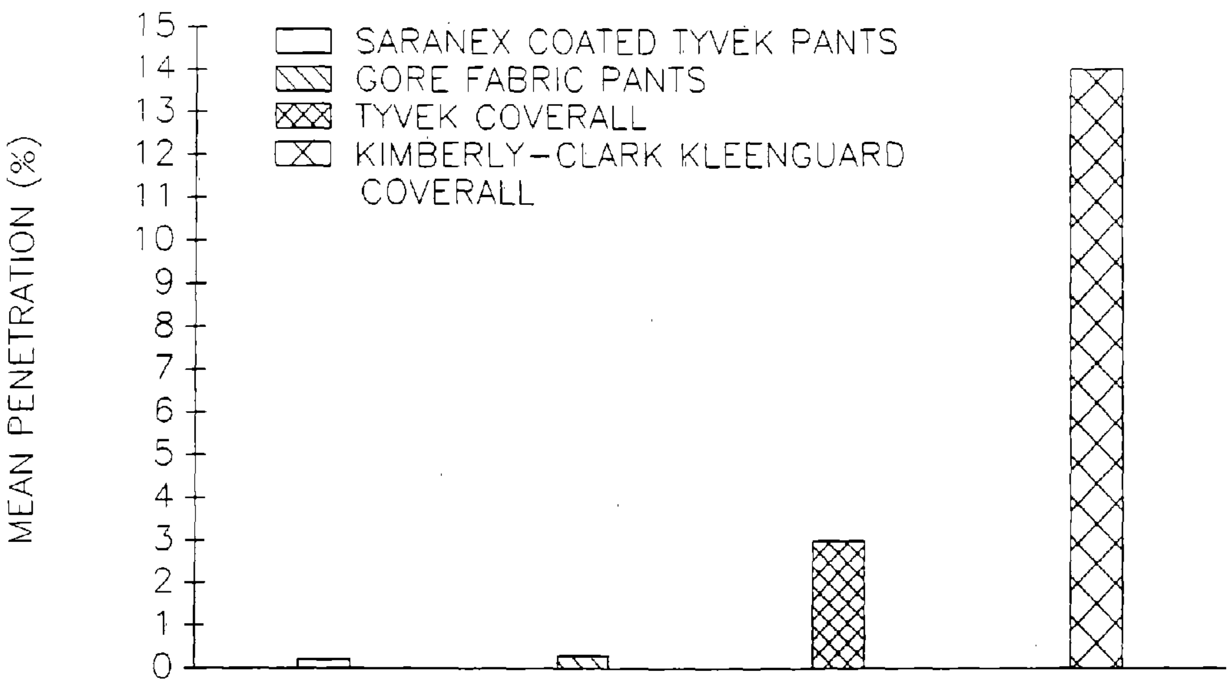

FIGURE 1