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Fluorescent Dye and Pesticide Penetration Tested in a Computerized Spray Chamber. Part I. Nonwoven Fabrics as Barriers

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One of the important requirements for protective apparel of agricultural workers is that such fabrics resist penetration of pesticide chemicals. Testing pesticide penetration through fabrics is often time-consuming and expensive; testing all the various pesticide chemicals on all fabrics may be cost prohibitive. In addition, spraying techniques used in the field may vary depending on the crop, pest, and pesticide used. There have been many studies done on pesticide penetration through fabrics, using different pesticides and spray techniques (Freed et al. 1980; Orlando et al. 1981; Staiff et al. 1982; Easter et al. 1983; Raheel and Gitz, 1985; Raheel, 1987; and Leonas et al. 1989). These studies have used gas chromatographic (GC) analyses to estimate the penetration of pesticide chemicals; GC analyses require expensive and time-consuming extraction procedures.

Our laboratory investigated the feasibility of using a fluorescent particle (FP) tracer method to study penetration resistance of selected nonwoven fabrics. The advantages of using the (FP) tracer method are avoidance of pesticide contamination; high sensitivity of detection by the fluorometer; easy and inexpensive extraction procedures since fluorescent dye is water soluble. The FP method has been used previously to study insect control and migration (Himel, 1969) and various other spray applications. The FP method has also been used to assess dermal exposure of agricultural workers during pesticide applications (Fenske et al. 1986). The present study was performed in a computerized spray chamber. The FP tracer method was compared with the penetration of pydrin, cypermethrin, methyl parathion, and chlorpyrifos estimated by GC analysis to determine the feasibility of the FP method to mimic pesticide penetration. Differences in penetration behavior of organophosphorus and pyrethroid insecticides were also compared.

The objectives of this study were to determine if fluorescent dye can be successfully used in predicting pesticide penetration through nonwoven fabrics; to detect differences, if any, in penetration of the two chemical classes (organphosphates and pyrethroids); and to evaluate the efficiency of fluorochemical finishes in improving barrier properties of the nonwoven fabrics tested.

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MATERIALS AND METHODS

Fabrics tested were obtained through S-208 Regional Project "Textiles Fiber Systems for Performance, Protection and Comfort", and are described in Table 1. Fabric assembly consisted of test fabric on top, collector layer (100% cotton knit) and aluminum foil on underside. Swatches measured 20.5 cm^2. Fabric assemblies were mounted on metal hoops (17 cm diameter) and placed on spray platform in random order. Spray testing was done in a computerized chamber with track-mounted beam for safe and precise testing (Fig 1). Spray pressure, atomizer speed, and spray height were controlled from command console.

Table 1. Nonwoven fabrics tested for their barrier properties

Nonwoven Fabrics

1.2 oz/yd^2 Tyvek	(TCT)	Tyvek Corona (Spunbonded Polyethylene)
1.3 oz/yd^2 Tyvek	(TR)	Tyvek Regular (Spunbonded Polyethylene)
1.8 oz/yd^2 SMS RF	(S1F)	SMS(Spunbonded/Melt blown/Spunbonded Poly-propylene Laminate, Finished*)
1.8 oz/yd^2 SMS	(S1UF)	SMS (Spunbonded/Melt blown/Spunbonded Poly-propylene Laminate, Unfinished)
2.3 oz/yd^2 SMS RF	(S2F)	SMS (Spunbonded/Melt blown/Spunbonded Poly-propylene Laminate, Finished*)
2.3 oz/yd^2 SMS	(S2UF)	SMS (Spunbonded/Melt blown/Spunbonded Poly-propylene Laminate, Unfinished)
2.1 oz/yd^2 Sontara RF	(SF)	Sontara (Spunlaced, entangled composite of wood pulp and polyester staple fiber, Finished*)
2.1 oz/yd^2 Sontara	(SUF)	Sontara (Spunlaced, entangled composite of wood pulp and polyester staple fiber, Unfinished)

* Repellent Finish

Temperature and humidity were monitored at 72°F and 70% R.H. Waste liquid was collected in drums for appropriate disposal. Height of spray platform from nozzle was 90 cm. The spray nozzle (Spray Systems TX3) was operated at a speed of 2.8 km per hour and pressure of 2.5 atmospheres (37 psi). A spray uniformity test was performed with two nozzle sizes and twelve different locations prior to performing actual evaluations.

Methyl parathion (MEP), chlorpyrifos (CFS), pydrin (PYD), and cypermethrin (CYP) were selected as the representatives from organophosphorus and pyrethroid classes of pesticides, as they are often used in pest control in cotton crops (Ramaswamy and Boyd, 1991). MEP and CFS 4% emulsifiable concentrate (4EC), PYD (2.4EC), and CYP (2.5EC) were diluted to get a final spray containing 1.5% active ingredients. Basic-sulfo-flavine (BSF) dye was made at the same concentration as that recommended for each pesticide. Five treatments, one with each insecticide and the dye, were replicated four times. After exposure was completed fabric assemblies were removed and dried one hour. Samples for extraction and analysis were die cut (10.03 cm diameter).

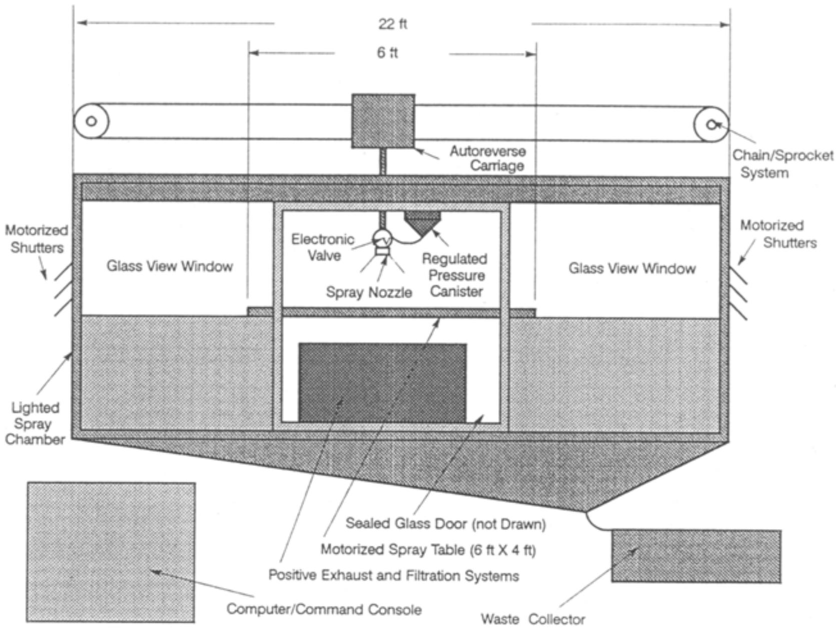

Figure 1. Diagrammatic representation of computerized spray chamber

Fluorescent dye was extracted with 40 ml of distilled water. An aliquot of extraction liquid was read in a Turner 110 Fluorometer. Standard serial dilutions were used to obtain BSF dye concentration. The dye concentration on test fabric and collector layer was calculated according to Smith, et al. (1983). The mean adjusted percent recovery of dye from each layer was used.

Pesticides were extracted from top and collector layers by placing an individual layer of fabric in a 125 ml Erlenmeyer flask. Then 50 ml diethyl ether (pesticide residue quality - Burdick and Jackson Laboratories, Inc.) was added, shaken for one minute, and left for one hour with intermittent shaking. Ether was decanted into a 200 ml flask and fabric sample was rinsed twice with 25 ml portions of diethyl ether. Extracts and rinses were combined and evaporated to near dryness on N-Evap Concentrator (Organomation Associates, Inc.) under a gentle stream of nitrogen. The chromatograph used for MEP and CFS was a Micro Tek-222, with glass column, 6' x 4 mm i.d.; 1.5% OV - 17/1.95% QF-1, 180°C, helium carrier gas flow at 70 ml/min., flame photometric detector in phosphorous mode. Confirmation GC column: 6' x 4 mm i.d.; 5% OV-210, 180°C, 70ml/min. The chromatograph used for CYP and PYD was the Varian 3400, with glass capillary 30 m x 0.25 mm i.d., DB - 1701 bonded phase column; Temperature program: initial temperature 50°C, for 4 min., programmed at 250°C to 200°C/min. for 15 min. Electron capture detector, 63 Ni, 300°C; Confirmation GC column: 30 m x 0.25 mm i.d. DB - 5.

The statistical analyses were done using arcsin transformation of the mean percent of pesticide/dye recovered. ANOVA was run for the five experiments combined as one data set. Then data were sorted by insecticide and dye; effect of finish and fabric were analyzed. Further, data were sorted by fabric type; effect of finish and chemical were analyzed. Analyses were done with SAS/STAT program (1986, SAS Institute, Inc.) using the 5% level of significance, with the mean separation done by Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

The spray uniformity test indicates that the location of fabric swatches on the spray platform and nozzle size do not significantly alter amount of spray deposited (Table 2).

The average percent recovery of BSF dye in fluorometric analysis was higher than recovery of MEP, CYP, PYD, and CFS in the GC analyses (Table 3). This may be due to the extraction solvent having varying affinity for the fabrics. All values were adjusted for recovery.

Table 2. Analysis of variance for spray uniformity test

Source	DF	SS	MS	F-Value	p
Factor A (Nozzle size)	1	2.784	2.784	12.964	>0.10
Error	3	0.644	0.215		
Factor B (Location)	11	0.354	0.033	0.915	>0.10
Error	33	1.161	0.035		
A * B	11	0.643	0.059	2.525	>0.10
Error	33	0.764	0.023		

Table 3. Average percent recovery of pesticides, and dye

Fabric Type	MEP	CFS	PYD	CYP	Dye
Tyvek (TCT)	78.3	67.8	86.8	88.8	67.3
Tyvek (TR)	61.7	48.6	91.2	94.4	68.7
SMS (1.8 oz/yd^2) RF	81.7	68.6	108.8	88.0	101.3
SMS (1.8 oz/yd^2)	72.7	56.6	96.8	89.6	104.4
SMS (2.3 oz/yd^2) RF	73.9	86.4	105.6	86.5	98.2
SMS (2.3 oz/yd^2)	69.8	63.1	88.4	96.2	101.1
Sontara RF	42.5	38.0	95.6	83.2	90.4
Sontara	40.9	38.7	90.0	84.0	94.7
TS*	76.4	81.4	90.0	73.6	93.7
Aluminum Foil	45.8	22.7	81.6	65.2	99.1

* Collector Layer - Cotton knit fabric

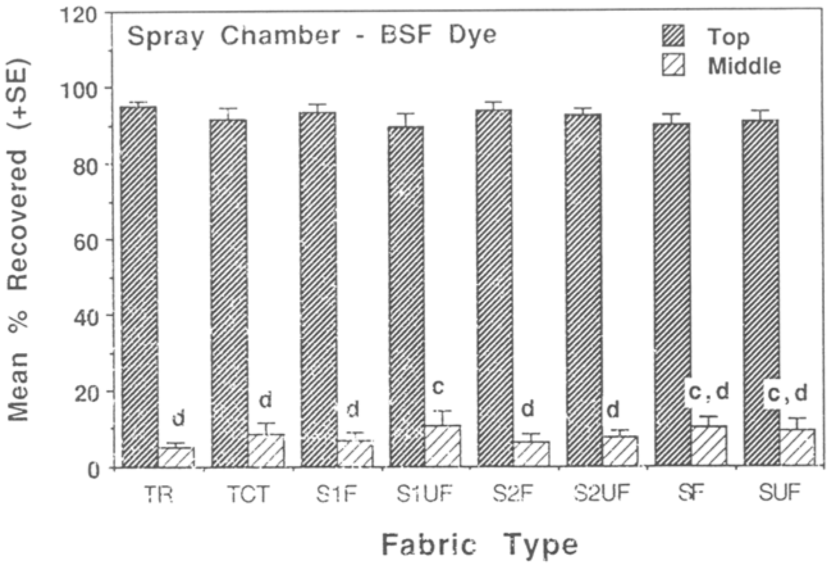

Figure 2. Mean percent of dye (BSF) recovered (+SE) from layers. Similar letters above bars signify no statistical differences among fabrics by Duncan's Multiple Range Test ($p<0.05$).

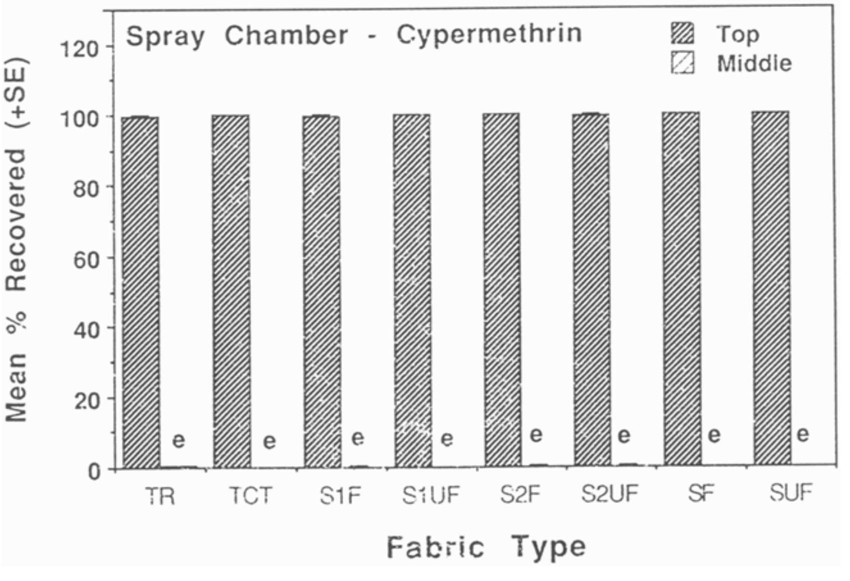

Figure 3. Mean percent of CYP recovered (+SE) from layers. Similar letters above bars signify no statistical differences among fabrics by Duncan's Multiple Range Test ($p<0.05$).

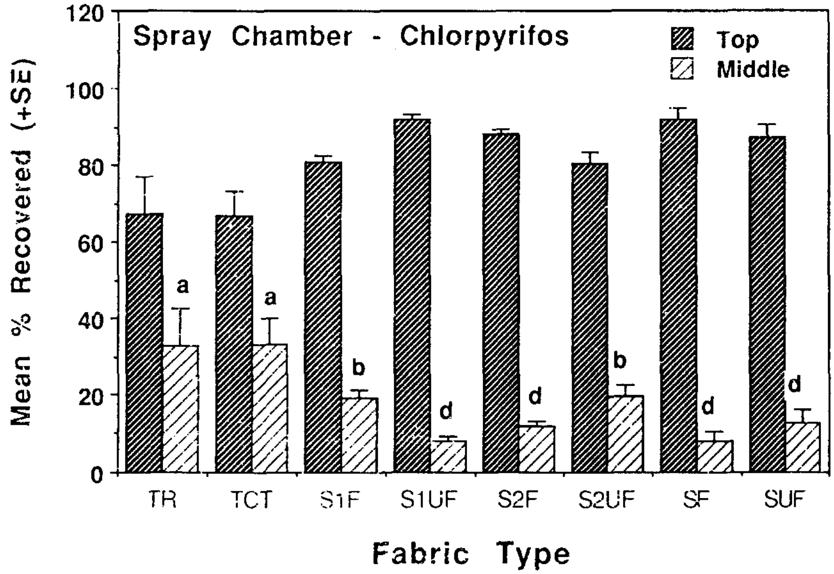

Figure 4. Mean percent of CFS recovered (+SE) from layers. Similar letters above bars signify no statistical differences among fabrics by Duncan's Multiple Range Test ($p<0.05$).

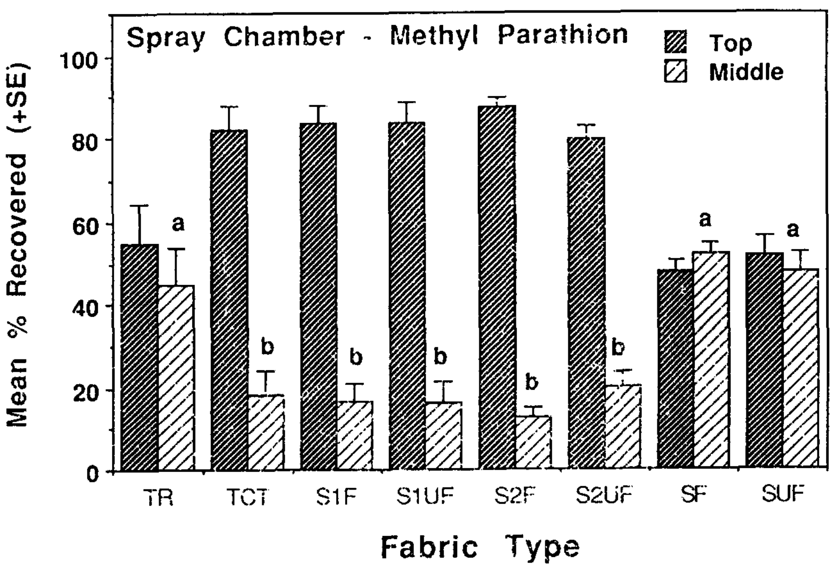

Figure 5. Mean percent of MEP recovered (+SE) from layers. Similar letters above bars signify no statistical differences among fabrics by Duncan's Multiple Range Test ($p<0.05$).

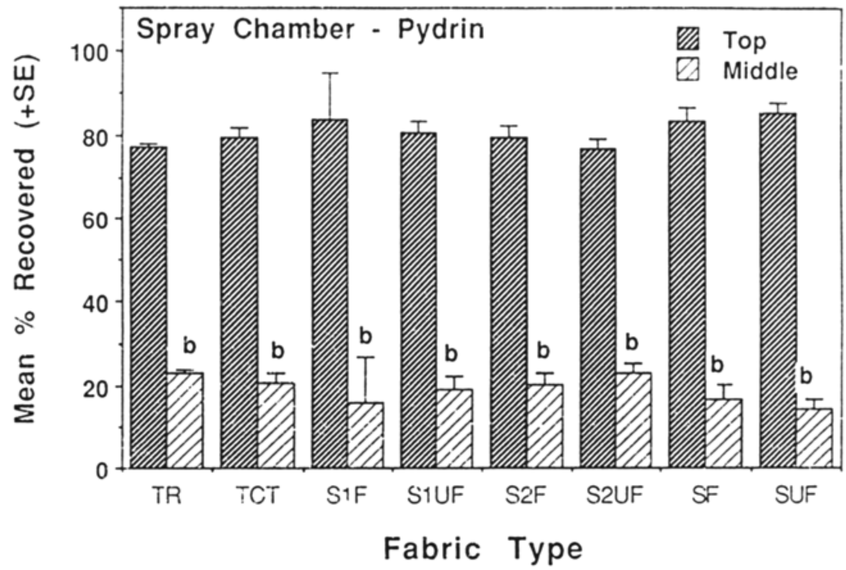

Figure 6. Mean percent of PYD recovered (+SE) from layers. Similar letters above bars signify no statistical differences among fabrics by Duncan's Multiple Range Test ($p<0.05$).

When experiments were combined as one data set, there was a significant interaction among fabric, chemical, and finish with respect to penetration of chemicals. Due to this interaction, data were sorted by chemical. Analysis of variance procedure was used to determine differences between fabrics for each pesticide/dye. Results indicate that differences between fabrics were significant at the 0.05 percent level for CFS and MEP, but not significant for PYD, CYP, and BSF dye. The mean percent of pesticide/dye recovered on the collector layer and Duncan groupings are shown in Figures 2-6. Fabric groupings were done according to Leonas, 1985. Fabrics in Duncan's group 'a' allowed 40% or greater pesticide penetration providing least protection. Fabrics in group 'e,' allowed negligible penetration (less than 2%), providing best protection. Fabrics in groups 'b,' 'c', and 'd' were classified as having below average (16-25% of pesticide recovered), average (11-15%), and above average (3-10%) protection, respectively.

Results showed that for CYP all fabrics provided excellent protection. For MEP, regular Tyvek and Sontara provided least protection. All other fabrics falling under group 'b', provided below average protection. Leonas (1985) showed that Tyvek provided excellent protection against MEP, but in our studies regular Tyvek proved to be a poor barrier against MEP and CFS. This may be due to a different source of Tyvek, pesticide, or spray conditions, or the fiber webs may not have been laid uniformly, thus affecting barrier properties of Tyvek. Against PYD, all fabrics provided below average protection. Finally, against BSF dye, all fabrics provided average or above average protection. Mean percent of pesticides recovered from collector layers suggest that barrier properties of the fabrics depend on pesticide.

The fluorescent tracer can be used only to predict the barrier performance of fabrics. However, since the penetration of the dye does not mimic the penetration of pesticides, one must exercise caution while making conclusions regarding barrier properties of fabrics. The presence of repellent finish on these fabrics did not significantly improve the barrier performance of nonwovens. Both weights of SMS were the better barriers against all pesticides and dye tested. These fabrics should also be tested in spill situations. More work needs to be done using field evaluation of prototype garments made of these fabrics.

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