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Dermal Exposure of Pesticide Applicators in Staked Tomato (*Lycopersicon esculentum* Mill) Crops: Efficiency of a Safety Measure in the Application Equipment

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In tropical countries in which climatic conditions prevent the use of individual protective clothing because of the great discomfort it causes, other protective measures may be taken, such as protection by distance, by time and by changes in the working method (Copplestone 1989). Protection by distance involves modifications in the application equipment whereby the worker stands as far away as possible from the site of highest concentration of sprayed pesticide mixture. The principle of protection by distance was verified by Wolfe et al. (1961) and a modification of the knapsack hand sprayer led to a significant reduction in the dermal exposure of workers (Tunstall and Matthews, 1965).

The objective of the present study was to evaluate the efficiency of a modification in the pesticide sprayer use in staked tomato crops, whereby the worker is protected by standing at a distance from the spray nozzles.

MATERIALS AND METHODS

The potential dermal exposure of pesticide applicators in staked tomato crops was evaluated in a typical field in the region of Cravinhos, State of São Paulo, Brazil, during the final phase of the cycle when the plants were 1.8 to 2.2 m high. The equipment used is a tractor with a 200 L thank wich is parked on the track between two plots. The pesticide mixture is pumped under pressure to high-pressure hoses measuring 50 to 100 m in length and 8 mm in diameter. A spray nozzle of the Universal Hatsuta type is fitted to the end of the hoses,to which a 0.6 to 0.8 m long piece of bamboo stalk is attached to

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provide rigidity and to facilitate handling. The application is done simultaneously in the two plots on each side of the track with the tractor. The worker enters a plot walking between two rows and hauling the hose. He directs the spray vertically to drench all the leaves of one side of the plants during one trip and to drench the leaves on the other side during the return trip. He then crosses the track and repeats the same operation on the other plot at his front.

Dermal exposure sampling pads of known surface areas were attached to all parts of the worker's body (WHO 1975; Kurtz and Bode 1985; Mumma et al. 1985). Instead of the traditional alpha-cellulose pads, the samplers used were female sanitary pads of the Carefree^{TM} brand produced by Johnson & Johnson. A copper fungicide was added to the spray mixture and the Cu^{2+} cation was used as tracer. The efficiency of the analytical method of Cu^{2+} recovery from the sanitary pads was 99.88% (Machado Neto and Matuo 1989).

Extraction was performed by adding a 0.1 N HCl extracting mixture directly to the 500 mL glass flasks in which the pads were placed in the field. Dermal hand exposure was evaluated directly on new cotton gloves, and tracer recovery was similar to that from the sanitary pads. Cu^{+2} was quantified in 10 mL aliquots of the extracting mixture filtered through qualitative filter paper, using an atomic absorption spectrophotometer. Tracer concentration was also determined in the spray mixture to estimate drenching rate per hour of exposure. Data of dermal exposure and of tracer recovery may be replaced with drenching with the spray mixture a procedure accepted by the U.S. Environmental Protection Agency (Jensen 1984).

The safety measure tested in the application equipment was based on the principle of protection by distance (Copplestone 1989) and consisted of replacing the spray nozzle in its original position with nozzles distributed along a V-shaped vertical boom. With this, the spraying point was moved from 0.6-0.8 to 2.2 m away from the worker. Each side of the boom has 10 nzzles which may be open independently according to plant height. The boom is supported by 2.2 m long iron tubing 1/2 in. in diameter mounted on a bicycle wheel with a 35 cm radius. The distance between the upper tips os the boom can be regulated as needed, and is normally 0.6 to 0.8 m. The spray hose is connected to the handlebars opposite to the boom, which the worker uses to push the entire structure in the space between rows, spraying the plants on both sides simultaneously. An 80 mesh line filter and a valve were added to the hose connection for each boom.

Dermal exposure of applicators was tested under standard conditions and using the new V-shaped bar system in August and October 1989, with three replications of 1 hr of exposure with each spray system. Data relative to drenching with the spray mixture were analyzed statistically by analysis of variance by the F test in a fully randomized design and factorial experiment, and by the Tukey test for comparison of the means. The factorial scheme used was 2 x 5, where the first factor was the spray system (standard and with the V-shaped boom prototype), and the second, regions of the body, i.e., uncovered parts (head, face, V of the neck, arms and forearms), hands, front of the body (chest, front part of thighs and legs), back of the body (back torso and back part of thighs and legs), and feet.

RESULTS AND DISCUSSION

The potential dermal exposures recorded are presented in Table 1. We would like to emphasize the marked reduction in potential dermal exposure provided by the V-shaped bar system for all parts of the body. The efficiency of this safety measure applied to the spray equipment in terms of total exposure was 94.1 and 85.6% for the first and second determination, respectively. Statistical analysis showed significant differences within the factors tested, i.e., spray system ($F = 97.55^{**}$; $P < 0.01$) and regions of the body ($F = 13.28^{**}$; $P < 0.01$). The significance of the spray system factor is due to the great efficacy of the V-shaped boom system which achieved safet simply by being based on the principle of protection by distance (Copplestone 1989).

The levels of exposure still persisting with this prototype may be considered to be negligible in terms of acute intoxication during a normal working day of four to six hours. For example, in the application of metamidophos (whose dermal LD50 is 50 mg/kg for male albino rats) at the dose of 20 g/100 L water, with an exposure of 1.2 L mixture per 6-hr period, the risk of intoxication would be a maximum of 7.5% of its toxic dose per working day as calculated by the formula proposed by the WHO (1975). For less toxic products such as propargite (whose dermal LD50 is 300 mg/kg for rabbits) at the dose of 60 g/100 L water, the risk of intoxication would be a maximum of 0.38% of its toxic dose per working day. However, as pointed out by Tunstall and Matthews (1965), this consideration does not apply to chronic intoxication, mainly because the applications reported here are performed at four -day intervals and during two crops per year (Provesa 1987).

Table 1. Mean drenching rates (mL/hr) of pesticides applicators in staked tomato crops with and without the use of a V-shaped boom system for spraying. Cravinhos, SP, 1990.

Body parts	Drenching rates (mL/hr) of different parts of the applicator			
	1st determination		2nd determination	
	Standard	V-shaped boom	Standard	V-shaped boom
Head	8.5 ± 3.6*	3.6 ± 1.8	29.6 ± 13.7	4.0 ± 1.8
Face	4.8 ± 2.1	2.1 ± 1,1	14.6 ± 4.6	1.6 ± 1.0
V of the neck	0.7 ± 0.2	0.7 ± 0.4	4.5 ± 1.4	0.4 ± 0.1
Arm (right)	8.5 ± 4.9	3.2 ± 1.8	26.0 ± 7.5	7.9 ± 3.0
Arm (left)	34.4 ± 2.7	3.4 ± 1.9	55.8 ± 2.7	6.4 ± 4.0
Forearm (right)	8.7 ± 4.9	3.1 ± 1.4	11.9 ± 1.1	11.0 ± 3.8
Forearm (left)	20.2 ± 4.3	3.4 ± 1.8	43.0 ± 11.5	12.4 ± 5.7
Hand (right)	171.9 ± 163.5	7.9 ± 2.6	42.2 ± 23.7	11.4 ± 2.8
Hand (left)	130.5 ± 120.9	4.8 ± 3.6	27.3 ± 14.3	10.3 ± 2.8
Back	21.8 ± 8.4	7.0 ± 3.5	38.8 ± 8.2	4.6 ± 1.8
Chest (right)	5.5 ± 2.0	1.2 ± 0.4	14.7 ± 2.5	1.0 ± 0.4
Chest (left)	11.3 ± 1.5	1.7 ± 0.9	21.9 ± 5.0	1.0 ± 0.2
Thigh (right/front)	29.4 ± 5.7	6.1 ± 1.7	51.8 ± 11.0	16.4 ± 10.4
Thigh (right/back)	3.2 ± 0.9	1.5 ± 0.4	3.6 ± 0.8	4.5 ± 3.9
Thigh (left/front)	53.3 ± 10.8	7.7 ± 3.1	76.2 ± 1.5	9.5 ± 4.3
Thigh (left/back)	4.0 ± 1.2	2.0 ± 0.9	4.3 ± 1.5	1.1 ± 0.8
Leg (right/front)	70.2 ± 22.7	15.4 ± 5.6	59.1 ± 12.5	6.7 ± 0.8
Leg (right/back)	12.9 ± 3.5	4.2 ± 2.1	11.5 ± 2.9	2.3 ± 0.6
Leg (left/front)	117.1 ± 39.3	4.2 ± 1.1	76.7 ± 15.5	7.8 ± 2.2
Leg (left/back)	14.9 ± 4.0	4.5 ± 3.1	12.0 ± 2.7	2.5 ± 0.9
Foot (right)	550.7 ± 297.7	28.9 ± 14.6	277.3 ± 52.2	35.5 ± 4.1
Foot (left)	1103.0 ± 431.0	23.8 ± 10.8	440.2 ± 87.6	35.2 ± 6.5
Total	2385.5	140.4	1343.0	193.5

*: Value represents mean ± standard error, n = 3.

With the standard spray equipment, total potential dermal exposure was 77.8% higher during the first than during the second determination (Table 1). This difference was mainly due to the occurrence of stronger and more frequent winds in August than in October in this region. The wind is the environmental factor that most affects the intensity of occupational exposure of pesticide applicators in the field (Wolfe et al. 1967). When the V-shaped boom prototype was used, however, the difference between the two determinations was very small, demonstrating that the safety measure tested here also controlled the effect of wind on potential dermal exposure of applicators.

Mean potential dermal exposure was 1864.7 mL/hr with the standard spray equipment and was reduced to 166.8 mL/hr with the use of the V-shaped boom prototype, corresponding to 91.0% mean efficiency of the proposed equipment in the control of worker drenching. If the use of individual protective clothing for the most exposed parts (boots and a long apron) were combined with the safety measure proposed here, this efficiency would reach 94.7%, and if gloves were also used, it would reach 95.6%. It can be seen that the three additional types of garments only added a total of 4.6% protection to the 91.0% rate provided by the V-shaped boom system alone. In the 1960's, Wolfe et al. (1961) noted that the driver of an herbicide spraying truck fitted with a front boom in an apple orchard was more exposed than tractor drivers applying with a front or back boom because he was sitting at a lower height from the ground and because the truck had no driver's compartment. Tunstall and Matthews (1965) reported that the potential dermal exposure of a pesticide applicator using a manual knapsack sprayer for cotton crops was reduced by 93.3% by simply moving the spray tube and nozzle from the front to the back of the worker's body.

The V-shaped boom prototype had other practical advantages in addition to excellent control of potential dermal exposure. Spraying can always be performed down the wind since the plants of both sides are sprayed at the same time in one direction. A return trip without spraying is much more rapid, and the presence of filters in the system virtually eliminates the frequent occurrence of nozzle clogging, with a 75% increase in treated area per hour. During the tests, it was also noted that the workers preferred to spray with the V-shaped boom system since this made their work lighter, more comfortable and more rapid.

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REFERENCES

Copplestone JF (1989) Pesticides. In: Parmeggiani L (ed) Encyclopaedia of occupacional health and safety. 3 ed. V2., L. International Labour Office, Geneva, p. 1616-1619.

Jensen JK (1984) The assumptions used for exposure assessments. In: Siewierski M (ed) Determination and assessment of pesticide exposure. Elsevier, New York, p. 147-152.

Kurtz DA, Bode WM (1985) Application exposure to the home gardener. In: Honeycutt RC, Zweig G, Ragsdale NN (eds) Dermal exposure related to pesticide use. Amer Chem Soc, Washington, Symp Ser 273, p. 139-161.

Machado Neto JG, Matuo T (1989) Avaliação de um amostrador para o uso da exposição dérmica potencial de aplicadores de defensivos agrícolas. Ciência Agronômica - Jaboticabal, 4(2): 22.

Mumma RP, Brandes BA, Gordon CF (1985) Exposure for applicator and mixer-loader during the application of mancozeb by airplanes, airblast sprayer and compressed-air back-pack sprayer. In: Honeycutt RG, Zeig G, Ragsdale NN (eds) Dermal exposure related to pesticide use. Amer Chem Soc, Washington, Symp Ser 273, p. 201-210.

Provesa. Program of Epidemiology and Health Vigilance in the use of Pesticides of Ribeirão Preto (1987) Report of the first survey (April/1987). Provesa, Ribeirão Preto, Brazil. 34 p.

Tunstall JP, Matthews GA (1965) Contamination hazards in using knapsack sprayer. Emp Cot Grow Rev 17: 193-196.

WHO. World Health Organization (1975) Survey of exposure to organophosphorus pesticides in agricultura standard protocol. WHO, Geneva (Document VBC/75.9).

Wolfe HR, Durham WF, Batchelor GS (1961) Health hazards of some dinitro compounds. Arch Environ Hlth 3: 468-475.

Wolfe HR, Durham WF, Armstrong JF (1965) Exposure of workers to pesticide. Arch Environ Hlth 14: 622-633.

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