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Semiquantitative Evaluation of Dermal Exposure to Granulated Insecticides in Coffee *(Coffea arabica* L.) Crop and Efficiency of Individual Protective Equipment

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Granulated formulations of highly toxic organophosphate and carbamate insecticides are used in Brazil to control insects, mites and nematodes in coffee cultures. During application, workers are exposed to the risk of intoxication depending on the toxicity and exposure under the specific working conditions. The toxicity is an intrinsic property of a particular compound, but depends on the degree of resorption by the various routes of uptake. The exposure is largely dependent on the job being done, how it is done, the physical form of the pesticide, and the ambient conditions. The most important variables that may affect occupational dermal exposure are: type of formulation and packaging, application technique, working method (personal hygiene), and agricultural and climatic conditions (Van Hemmen 1992)

Granulated formulations in general are safer than those applied in liquid form because of the lower concentration of the active ingredient and the formation of drift during the applications. The granules that reach the body of the worker immediately fall on the soil when the surface is dry, or they adhere when the surface is damp, due to sweat, for example. This aspect can influence the efficiency of individual protective equipment (IPE). Protective equipment made of light duck and treated with teflon is impermeable to moisture and maintains the body surface of the worker dry. It reduces real dermal exposure because of the difficulty of granule adherence.

Recognition and control of dermal exposure can be enhanced significantly by an evaluation method which provides results on site without chemical analyses (Fenske 1988). This author reports on the development and testing of a visual scoring system for evaluating dermal exposure with fluorescent tracers. The system was designed to allow observers to translate subjective observations into a score based on a simple two-dimensional exposure matrix. The scoring system can serve as a basis for

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industrial hygiene recommendations related to equipment type, equipment performance, protective clothing use, protective clothing performance, work activity and work practices (Fenske 1988).

Dermal exposure has been quantified in several studies by means of fluorescent tracers and a computer-based video imaging system (Fenske et al. 1985, 1986a,b). In the present study, this methodology was adapted by replacing the fluorescent tracer with graphite powder mixed with the granules to mark the clothing of the workers. After work, dermal exposure was evaluated visually by the visual scoring system based on a simple two-dimensional exposure matrix proposed by Fenske (1988).

The objectives of the present study were to assess semiquantitatively and compare the dermal exposure of workers applying granulated insecticides to a coffee plantation using the three most common types of application equipment and to evaluate the efficiency of individual protective equipment and of clothing made of teflon-treated fabric.

MATERIALS AND METHODS

The dermal exposure of the workers applying granulated insecticides was assessed on a coffee plantation in the municipality of Pedregulho, State of São Paulo. The plants were eight years old and 2.5 m in height and planted in rows spaced 1.0 x 40 m.

A placebo formulation of the Counter insecticide (terbufos) with sand grains was used. The sand grains were coated with graphite powder (20 g/kg) and placed in 25 kg plastic bags, which in turn were placed in brass pails. The three application methods used were: 1) manually operated ladle - the worker walks between plant rows holding under one arm a plastic pail filled with 2 to 3 kg granules. Holding a metal ladle similar to a kitchen ladle in the other hand, he collects 30 g of granules from the pail and tosses them against each plant, moving the ladle to the front of his body; 2) manually operated knapsack applicator - the worker fills the knapsack with 8 kg of granules and applies 40 g to each plant. The granules come out of a rigid plastic tube with the nozzle positioned inside the leaves of the coffee plants; 3) tractor mounted applicator - the tractor driver fills the storage unit of the machine, with a capacity of 6 pails of 25 kg granules each. The granules go through flexible plastic tubes and fall close to the soil and below the leaves of the plants. Three 25 kg pails/worker were applied using each of these methods. The environmental conditions during the applications were those normally occurring in the region: temperature of 23 to 26°C, relative air humidity 48 to 55%, wind up to 4 km/h and days without clouds.

Dermal exposure was assessed on 28 body parts of six workers per application method. Potential dermal exposure (PDE) was assessed on the following individual protection equipment (IPE): 1) pants and long

sleeve shirt and protective hood for head, neck and shoulders made of light fabric (130 g/m^3), 100% teflon-treated cotton of white-cream color manufactured by ENGESEL Equipamentos de Segurança Ltda.; 2) white rubber boots; 3) light yellow rubber gloves, and disposable white masks. The PDE of the legs was not evaluated. In these regions the pants were impermeabilized with black plastic. Dermal exposure not controlled (DENC) by the IPE was assessed on sampling clothing such as white overalls with long sleeves and a hood, white cotton gloves and socks worn under the IPE, and in the internal part of the disposable masks. All clothing was replaced after each evaluation. Dermal exposure was assessed by the simple two-dimensional exposure matrix (Fenske 1988) with the 0 grade added to the scale of exposure intensity (Table 1). This adaptation of the matrix was necessary to evaluate the efficiency of the protective equipment on the body parts for which the PDE was of grade 1 intensity. Immediately after the exposure of each worker, three examiners separately assessed the dermal exposure by means of the two-dimensional exposure matrix adapted from Fenske (1988). The results are the means of three replications and each replication is the mean of the assessments of the three examiners. The efficiency of the IPE was obtained by means of the percentage of PDE control (%PDEC) calculated by the percent reduction of the mean PDE scores in relation to the DENC for each body part. The safety criterion adopted for these applications of granulated insecticides, which are extremely toxic, is the absence of exposure. Thus this semiquantitative method for the assessment of dermal exposure is quite advantageous since it is efficient, rapid and of low cost.

Table 1. Exposure evaluation matrix[a] adapted from Fenske (1988).

Exposed Area(%)							
80 - 100	5	0	5	10	15	20	25
60 - 80	4	0	4	8	12	16	20
40 - 60	3	0	3	6	9	12	15
20 - 40	2	0	2	4	6	8	10
0 - 20	1	0	1	2	3	4	5
	score	0	1	2	3	4	5
		Low		moderate			High
		Exposure Intensity					

[a] scores within the matrix are the product of Area Exposed and Exposure Intensity score.

RESULTS AND DISCUSSION

The mean potential dermal exposure (PDE), dermal exposure not controlled (DENC) and percentage of PDE control (%PDEC) scores for the individual protection equipment (IPE) used by the workers applying granulated insecticides with the three methods of application are

presented in Table 2. It can be seen that the hands were the most exposed body part due to the direct contact with the granules when opening the packages, filling the storage spaces and manual applying the pesticide with the ladle.

Manual application with the ladle was the most dangerous and least safe of the three methods, yielding the highest PDE scores. The maximum possible scores observed in Table 1 referred to the workers' hands, and were slightly lower on the face, breast, shoulders, abdomen and feet. These values were expected since this application system is fully open and leaves the worker in direct contact with the granules throughout the job. Among the IPE used, only the rubber boots were efficient, controlling the entire PDE of the feet. The remaining individual protection equipment failed due to the high exposures. The clothing made of teflon-treated fabric was efficient only on the thighs and legs, regions where the PDE scores were low.

The manually operated knapsack applicator can also be considered dangerous and unsafe since the worker is subjected to high dermal exposures on the hands, back and feet. These exposures occur during careless refilling of the storage container of the machine, contaminating one side of the machine which is in contact with the worker's back during the application. The feet are exposed during refilling and application. Although the granules are deposited under the leaves of the coffee plants, some may reach the worker's feet. The gloves, boots and disposable mask practically eliminated the PDE of the parts they were protecting. The clothing of teflon-treated fabric failed to protect the right forearm and arm, which holds the tube through which the granules are ejected. It also failed to protect the back due to the direct contact with the side of the machine that is usually contaminated during refilling.

The use of the tractor mounted applicator was the method that produced the least PDE. However, the hands of the tractor driver were highly exposed due to the handling of the product during refilling. There were small dermal exposures on the feet, arms, forearms, thighs and breast. These exposures may also have occurred during the refilling of the machine, since it is unlikely that they occurred during the applications. The deposit and the circuit covered by the granules inside the machine are completely closed. The granules are applied below the leaves of the plants and close to the soil surface. All individual protection equipments used by the tractor driver were efficient, fully controlled PDE and provided safe working conditions.

The semiquantitative method used to assess dermal exposure on the clothing with graphite powder mixed with the granulated insecticide formulations, which are highly toxic, and assessment by means of the adapted matrix of Fenske (1988) were efficient, rapid and practical. The

Table 2. Scores of semiquantitative assessment of PDE, DENC and %PDEC provided by the individual protection equipments in the application of granulated insecticide to coffee crop using three different types of application equipments. (n = 6).

Body part	Manual ladle			knapsak applicator			Tractor-mounted applicator		
	PDE	DENC	%PDEC	PDE	DENC	%PDEC	PDE	DENC	%PDEC
1. Head	14.2	2.0	85.9	2.2	0.0	100.0	1.5	0.0	100.0
2. Face	25.0	2.5	90.0	8.5	0.0	100.0	6.5	0.0	100.0
3. Neck-front	15.5	9.0	41.9	1.7	0.0	100.0	2.0	0.0	100.0
4. Neck-back	10.5	1.7	83.8	3.2	0.0	100.0	0.0	0.0	0.0
5. Right shoulder	16.7	5.0	70.1	7.7	0.0	100.0	0.0	0.0	0.0
6. Left shoulder	21.2	5.5	76.4	9.7	0.0	100.0	1.0	0.0	100.0
7. Right arm	11.5	7.5	34.8	3.5	0.0	100.0	1.0	0.0	100.0
8. Left arm	12.0	3.7	69.2	2.0	0.0	100.0	0.0	0.0	0.0
9. Right forearm	15.7	12.5	20.4	5.2	3.7	28.8	3.5	0.0	100.0
10. Left forearm	11.0	6.7	39.1	2.5	0.0	100.0	3.5	0.0	100.0
11. Right hand	25.0	4.0	84.0	25.0	0.0	100.0	25.0	0.0	100.0
12. Left hand	25.0	3.0	88.0	25.0	1.0	96.0	25.0	0.0	100.0
13. Right breast	21.2	12.0	43.4	4.0	0.0	100.0	0.7	0.0	100.0
14. Left breast	22.5	13.5	40.0	7.0	0.0	100.0	2.2	0.0	100.0
15. Right abdomen	14.5	10.5	27.6	3.7	0.0	100.0	3.0	0.0	100.0
16. Left abdomen	14.5	9.7	33.1	2.0	0.0	100.0	2.0	0.0	100.0
17. Right back	8.7	0.5	94.2	12.0	2.7	77.5	0.7	0.0	100.0
18. Left back	4.7	0.5	89.4	12.0	2.0	83.3	0.7	0.0	100.0
19. Right thigh-front	3.2	0.0	100.0	2.5	0.0	100.0	3.0	0.0	100.0
20. Right thigh-back	1.5	0.0	100.0	3.0	1.2	60.0	1.2	0.0	100.0
21. Left thigh-front	4.0	0.5	87.5	2.2	0.0	100.0	2.7	0.0	100.0
22. Left thigh-back	0.5	0.0	100.0	2.2	0.0	100.0	1.5	0.0	100.0
23. Right leg-front	-	0.0	100.0	-	0.0	100.0	-	0.0	100.0
24. Right leg-back	-	0.0	100.0	-	0.0	100.0	-	0.0	100.0
25. Left leg-front	-	0.0	100.0	-	0.0	100.0	-	0.0	100.0
26. Left leg back	-	0.0	100.0	-	0.0	100.0	-	0.0	100.0
27. Right foot	25.0	0.0	100.0	17.2	0.0	100.0	5.2	0.0	100.0
28. Left foot	16.2	0.0	100.0	13.0	0.0	100.0	2.5	0.0	100.0
Total score	339.9	109.8	67.7	177.0	10.6	94.0	93.4	0.0	100.0

PDE = potential dermal exposure, DENC = dermal exposure not controlled, and %PDEC = percentage of PDE control

method permitted the assessment and comparison of the safety of the methods of application of these insecticides to coffee cultures and of the individual protection equipment, in agreement with other studies (Fenske 1988; Fenske et al. 1985, 1986a,b). The safety of the workers was extremely affected by the methods of application, in agreement with the information reported by Van Hemmen (1992). The methods of application with a manually operated ladle and a manually operated knapsack applicator should not be used because they are dangerous and unsafe, even with the use of the individual protection equipment tested. The method of application with a tractor mounted applicator is safe if all the IPE evaluated is used. However, this method was the least effective in the control of the coffee tree cicadas compared with the first two methods (Yamada et al. 1993). On this basis, the machine should be improved in order to increase its efficiency. The individual protection equipment was efficient only when the tractor mounted applicator was used, as shown by the occurrence of low potential dermal exposure.

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