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Safety Measures in the Application of Organophosphate Insecticides on Staked Tomato Crops Using Dragged Hoses

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Tomato crops are very demanding and require pesticide treatments, since they are attacked by a variety of phytophagous organisms such as insects, nematodes, fungi and bacteria. To control these damage-causing organisms, farmers use one ot two applications of pesticides per week and work under precarious safety conditions, mainly when applying organophosphate insecticides (Machado-Neto 1990).

Organophosphate insecticides are the pesticides most commonly used on tomato crops, because of their efficacy in the control of insect pests and their low cost. However, these pesticides are extremely toxic and pose a serious occupational hazard of pesticide poisoning. These insecticides have stimulated scientific debates due to the extensive quantities used in agriculture, frequently and abusively, placing at risk the health of workers by causing acute and chronic toxicities, besides causing the contamination of foods and environment. Throughout the life of a person, these insecticides can cause neurological problems, diminishing the function of or leading to the failure of various organs (Zambrone et al 1991 and Nava 1990).

The traditional equipment utilized for the application of pesticides on staked tomato crops consists of a pulverizer pulled by a tractor, fitted with hoses 40 to 60 m in length, which farmers drag over the crops to make applications. The application is carried out using high applications volume and high pressures, whereby the crops are sprayed to saturation and the spray drips from the leaves of the plants. In this type of application, the pesticide worker is positioned only a short distance from the spray area, approximately 0.6 m from the nozzle tips. With such features, these working conditions provide a potential dermal exposure (PDE) level of 1.3 to 2.4 L of spray per hour (Machado-Neto et al 1992), capable of reaching up to a mean of 2.8 L spray/h (Machado-Neto 1990). In these applications of organophosphate insecticides, a high risk of pesticide poisoning is expected in workers carrying out such tasks. The aim of this study was to evaluate the safety of working conditions of applicators of the organophosphate insecticides parathion-methyl, metamidophos and

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chlorpyrifos on staked tomato crops, using a pulverizer pulled by a tractor and fitted with dragged hoses.

MATERIALS AND METHODS

The potential dermal and respiratory exposure of pesticide applicators working with staked tomato crops was evaluated in a typical field in the Cravinhos region, State of São Paulo, Brazil, during the final phase of the cycle when the plants were 1.8 to 2.2 m high.

Pesticides were applied according to the conventional agricultural practice of the region. The machinery used for application consisted of a pulverizer pulled by a tractor, with a 2000-L tank equipped with dragged hoses 60 m in length. To the ends of the hoses that were dragged over the crops by workers for the application of pesticides, were attached 0.5-m bamboo stakes which served as application lances. The nozzle tip of the pulverization unit utilized was a high flow-rate Hatsuta universival.

The applications were at high application volume, delivering 800 L spray/ha. As such, the leaves of the tomato plants were sprayed up to the dripping of the spray. The concentrations of pesticide in the applied spray were those recommended for 100 L of spray: 150 mL Lorsban 480 BR (480 g /L chlorpyrifos), 100 mL Folisuper (600 g/L parathion-methyl) and 110 mL Tamaron BR 600 SC (600 g/L metamidophos). During the assessment of exposures, the ambient temperature varied 25 to 29°C, the relative humidity was 68 to 83%, and the wind velocity was up to 3.5 km/h.

The pontential dermal exposure (PDE) and potential respiratory exposure (PRE) to pesticides were evaluated with ten replicates, whereby pesticide concentrations were determined in the worker's clothes, and in tubes containing adsorption packing. The sampled clothes were gloves and overalls, both made of cotton. The period of worker's exposure was recorded by a timekeeper. At the end of the exposure, the overalls were cut with scissors into different parts: cap, sleeves, legs, front, and back. These parts together with the gloves were individually identified and placed in plastic bags and stored in a freezer until the time of pesticide measurement. Foot exposure was not evaluated since workers always wore impermeable boots that were covered by the trouser cuffs.

The pesticide-exposed clothes and gloves were extracted separately with ethyl acetate in flasks, which were closed with duraseal-lined polypropylene caps and mechanically shaken for 40 min in a water bath at 40°C. Extracts were passed through filter paper (Sartorius 0.47 µm), concentrated in a rotary evaporator, reconstituted in 5 mL ethyl acetate and stored at –20°C until the time of chromatographic analysis.
Tubes containing adsorption packing, XAD-2 (SKC), were fixed next to worker's mouth and nose. These tubes (sampling devices) were connected

to a Universal Sample Pump (SKC), and the pesticides were collected using a flow rate of 2 mL/min. After collection, the tubes were stored in a freezer until the time of analysis. The pesticides adsorbed to XAD-2 were extracted with 100 mL of ethyl acetate using a Soxhlet reflux for 12 h. Extracts were concentrated in a rotary evaporator, reconstituted in 5 mL ethyl acetate and stored at –20°C until the time of chromatographic analysis.

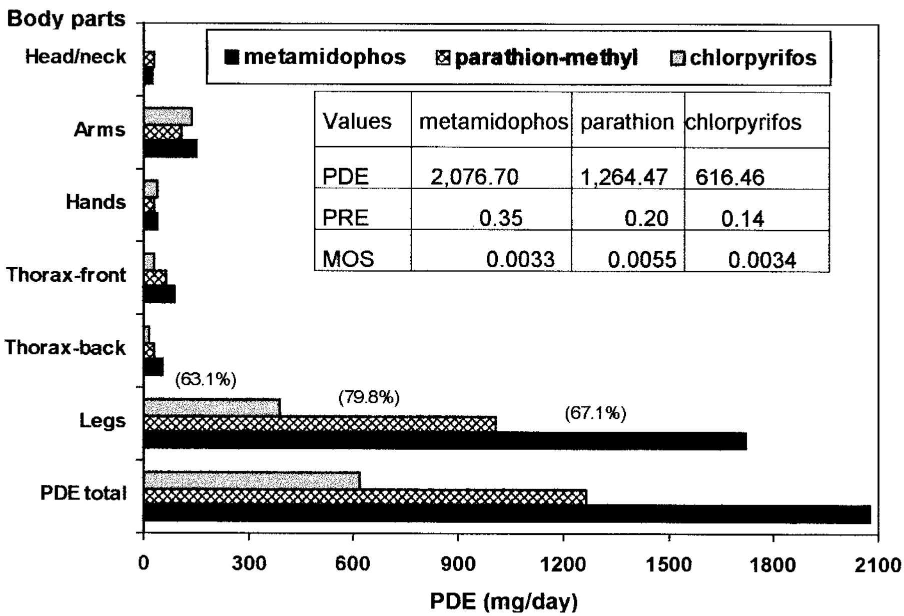
The analytical methods used for evaluation of dermal and respiratory exposure to pesticides were based on those reported earlier (Machado-Neto et al 1999, Lorberau and Pride 2000, Lonsway et al 1997, Jongen et al 1992). Pesticides were determined by gas chromatography (Varian model Star 3400 Cx) equipped with a thermionic specific detector (TSD). The GC column used was a fused-silica capillary column (30 m x 0.25 mm x i.d. x 0.1 µm film) coated with chemically bonded 5% phenyl- methyl polysiloxone DB 5 (J & W Scientific). Nitrogen was the carrier and make-up gas. Temperatures of the injector and detector were maintained at 250°C and 300°C, respectively. The pesticides were analyzed by three different programmed column temperatures. Parathion-methyl was separated using a temperature gradient that consisted of an initial temperature of 200°C for 8 min, which was increased at 15°C/min until a final temperature of 300°C was reached. Methamidophos was separated at 120°C for 5 min followed by temperature gradient of 15°C/min to 300°C, and chlorpyrifos at 220°C to 250°C at 4°C/min and to 300°C at 15°C/min.

The safety application of insecticides was evaluated by determining the margins of safety (MOS). MOS for the conditions studied and for ten agricultural workers, was calculated according to a formula described by Severn (1984) and modified by Machado-Neto (1997). MOS = (NOEL X 70) / (QAE x 10), where: NOEL = 0.1 mg/kg/day (parathion-methyl and metamidophos), and 0.03 mg/kg/day (chlorpyrifos), 70 = worker's mean body weight (kg), and QAE (quantity absorbed exposure) = 0.1 x PDE + PRE (mg/dia). MOS was estimated for 6 h of effective exposure in a day's work. The value of MOS calculated was utilized to classify the safety of insecticide applications according to the following criterion: if MOS ≥ 1 , then the working conditions are safe, exposure is tolerable and risk of pesticide poisoning is acceptable, and if MOS < 1, then working conditions are unsafe, exposure is not tolerable and the risk is unacceptable.

RESULTS AND DISCUSSION

An analytical validation of the proposed method was performed to insure the accuracy of the data obtained. The total recovery from protective clothes and gloves at different pesticides levels was 85.4 to 102.2%. The limit of detection (sensitivity of the method) was 0.02 µg mL^{-1} for parathion-methyl and chlorpyrifos, and 0.1 µg mL^{-1} for methamidophos. Inter-assay precision (coefficient of variation) was less than 6%, and a linear relationship was demonstrated between level detected and concentration in the range of 0.1 to 50 µg mL^{-1}. No compound interference was observed in the analysis.

The results of dermal and respiratory exposure of the pesticide applicators and the MOS estimated for a day's work of six hours are displayed in Figure 1. Under these work conditions, the main source of exposure to insecticides was dermal, corresponding to 99.9, 99.8 and 99.8% of the total exposure to parathion-methyl, metamidophos and chlorpyrifos, respectively. The parts of the body most exposed to insecticides were the legs, which accounted for 63.1 to 79.8% of the total PDE, followed by the arms and the chest.



Values	metamidophos	parathion	chlorpyrifos
PDE	2,076.70	1,264.47	616.46
PRE	0.35	0.20	0.14
MOS	0.0033	0.0055	0.0034

Figure 1. Distribution of PDE among the parts of the body of workers. Mean values (mg/day) of dermal (PDE) and respiratory exposure (PRE), and the margin of safety (MOS) are shown for applications of parathion-methyl, metamidophos and clorpyrifos in staked tomato crops using a pulverizer pulled by tractor and equipped with dragged hoses.

Based on the MS values calculated, 0.0055 for parathion-methyl, 0.0030 for metamidophos and 0.0034 for chlorpyrifos, these working conditions are classified as highly unsafe (MS < 1). Under these working conditions, exposure to these organophosphate insecticides during a day's work of 6 h, poses a very high risk of pesticide poisoning to these workers and can

cause acute toxicity. Therefore, there is a need to recommend active safety measures that reduce potential exposures.
One active safety measure that could be utilized is the substitution of these insecticides by others less toxic or required in lower amounts, so that the working conditions become safe (MOS $\geq$ 1), but without compromising agricultural efficiency. Another active safety measure that could be utilized is the substitution of application equipment by a safer type that would meet the criteria for an acceptable calculated MOS. This replacement equipment must provide tolerable occupational exposure levels, such as the V-shaped boom prototype, especially developed for this type of crop by Machado-Neto el al (1992). This V-shaped boom, provided for a pulverizer similar to that used in this study, reduces PDE by 91%

If these active safety measures are not sufficient to make working conditions safe, they can at least be complemented by the use of personal protective equipment (PPE) on parts of the body most exposed with areas of bare skin.

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