

Reentry intervals after pesticide application in greenhouses

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Workers are constantly exposed to pesticides, their residues, or degradation products in the agricultural environment. There is a potential for acute effects when highly toxic fumigants are used in closed systems such as greenhouses. It is common practice to fumigate the greenhouse, ventilate it for some hours, and then permit workers to enter. Exposure is aggravated when labor involves prolonged and continuous contact with foliar surfaces bearing pesticide residues. The dislodgable foliar residues are transferred to workers' skin and clothing. This health problem is currently referred to as the reentry problem in reference to worker reentry into a field or a greenhouse after pesticide application (3).

Reentry intervals have been established only in some countries. The California Department of Food and Agriculture has established reentry intervals for 21 organophosphate insecticides (4). A reentry interval of 48 h has been set by the US Environmental Protection Agency for 11 organophosphates and for endrin and clordimeform. The intervals are normally calculated for pesticide application in fruit orchards, and they vary from 1 to 30 d depending on the pesticide and fruit (4). Hungary has a reentry interval of 3 d, eg, for dimethoate in greenhouses (1).

The residues especially cause health problems because the degradation products could be more toxic than the parent compounds. Parathion is degraded to para-oxon, which is a 10 times more effective cholinesterase inhibitor than parathion. Carbenazime formed from benomyl is a suspected carcinogen. Organochlorine compounds enter the body easily through the skin, whereas some dithiocarbamates are potential allergens.

The aim of this study was to measure the diminishing of fumigant concentrations in greenhouse air and the dissipation of toxic foliar residues on the plant leaves so that practical reentry intervals could be established.

Methods

Pirimicarb, nicotine, and sulfur were selected as model compounds from the fumigants. Air samples were collected in five stationary sites of each greenhouse for 2, 4, and 8 h after fumigation. Samples were also taken

the next morning and after the greenhouse had been ventilated. The pirimicarb samples were collected into impingers containing 15 ml of toluene, and the nicotine samples onto XAD-2 resin. The two compounds were analyzed by gas chromatography. The sulfur samples were collected on Millipore filters and weighed.

For the dissipation studies, dimethoate and benomyl were applied in three rose greenhouses. Leaf samples were collected from four sites of the greenhouses 0, 2, 4, 16, 24, and 48 h after the spraying. Using a leaf punch sampler, we excised 5-cm² disks from each of 40 mature leaves free of surface moisture and collected them directly into a jar containing 50 ml of water. The portion of the bushes about 80 to 130 cm above the ground was sampled. Samples in transit to the laboratory were kept in an ice chest and processed within 24 h of collection. Gloves were taken from five workers harvesting during the 2 d following the spraying for a determination of dimethoate residues. After extraction, dimethoate, benomyl, and their degradation products were analyzed by liquid chromatography.

Results and discussion

The highest concentrations of fumigants were measured 1 to 4 h after the fumigation. The concentrations had dropped to acceptable levels the next morning or at least 2 h after the greenhouse was ventilated. The highest concentration of nicotine in the greenhouse air was 28 mg/m³ 1 h after the fumigation. This value is about 50 times higher than the Finnish occupational exposure limit (0.5 mg/m³). It took 8 h before the nicotine concentrations fell to 0.5 mg/m³. Two hours of ventilation were needed to refresh the greenhouse air.

The pirimicarb concentration was 1.2 mg/m³ 0.5 h after the fumigation. Pirimicarb disappeared in 3 to 4 h. The sulfur concentration rose to 0.7 mg/m³ 4 h after the beginning of the fumigation. Then the concentration decreased slowly and disappeared after 1 h of ventilation. There are no exposure limits for sulfur and pirimicarb for comparison. The gardeners and harvesters complained about irritation of the upper respiratory tract after working in the fumigated greenhouses. The results agree with those of studies in which greenhouse workers were exposed to nicotine, sulfo-*tep*, and methyl bromide (6–8).

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The sulfotep study showed that worker activity in the greenhouse significantly increased sulfotep levels in the air (7). The practice of ventilating a greenhouse for 2 h after overnight fumigation was found adequate to provide safe work conditions.

The maximum amount of dimethoate on the leaves (720 ng/m^2) was measured 2 to 4 h after the spraying. The dissipation was quick. The dimethoate level was 190 ng/cm^2 on the third day. The dissipation of dimethoate on the rose leaves followed first order kinetics. The mean half-life was 21 h. Only trace amounts of dimethoxon were detected on the leaf samples, whereas the dimethoxon concentration on the gloves was 1.1 mg/cm^2 . There was a dimethoate concentration of 0.48 mg/cm^2 in the glove samples. The analysis of the residues on the gloves proved that protective gloves should be used in greenhouse work.

Many studies on reentry intervals have indicated that the dissipation curves are characterized by an initial rapid residue decrease as a pesticide decomposes, and this decrease is followed by a slower residue decline when compounds persist on leaves, sometimes even for weeks (3). When dimethoate was applied to citrus trees in dry open air, the dislodgable foliar residue levels were 50 times higher than those found on rose leaves (3). Dimethoxon was present on the citrus leaves, but no sample contained more than 50 ng/cm^2 . The half-life for dimethoate was 2.6 d on citrus foliage and 2.6 d on orange foliage. The half-lives indicate that dimethoate decomposes faster under warm and humid greenhouse conditions.

The same trends were found for the concentrations and half-lives of benomyl and carbendazime as for dimethoxon. The benomyl concentrations were over 900 ng/cm^2 24 h after the spraying but declined to 370 ng/cm^2 during the next 24 h. The carbendazime concentrations rose to 310 ng/cm^2 during the first 24 h and then decreased to 170 ng/cm^2 on the second day. The mean half-lives for benomyl and carbendazime were 44 and 53 h, respectively. When benomyl was sprayed on apple trees, benomyl residues on the foliage dissipated quickly during the first 3–7 d. Twelve days after the application at least 15 % of the original deposit ($950\text{--}1\,200 \text{ ng/cm}^2$) existed as intact

benomyl. The maximum concentration of carbendazime, $17 \text{ } \mu\text{g/cm}^2$, occurred 8 d after the spraying (2).

Mathematical models developed to calculate reentry intervals are theoretical and difficult to apply for different pesticides, plants, and work conditions (5).

According to the results of the present study some practical instructions could be given to prevent greenhouse workers' exposure to pesticides or their degradation products. Fumigations should be made in the evening, and the greenhouse must be ventilated for 2 h before work in the morning. Pickers, harvesters, and packers must wear protective gloves when handling treated flowers.

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References

1. Adamis Z, Antal A, Füzesi I, Molnár J, Nagy L, Susán M. Occupational exposure to organophosphorus insecticides and synthetic pyrethroid. *Int Arch Occup Environ Health* 56 (1985) 299–305.
2. Chiba M, Veres Darrel F. Fate of benomyl and its degradation compound methyl 2-benzimidazolecarbamate on apple foliage. *J Agric Food Chem* 29 (1981) 588–590.
3. Iwata Y, Dusch ME, Carman GE, Gunther FA. Worker environment research: Residues from carbaryl, chlorobenzilate, dimethoate, and trichlorfon applied to citrus trees. *J Agric Food Chem* 27 (1979) 1141–1145.
4. Knaak JB. Minimizing occupational exposure to pesticides: Techniques for establishing safe levels of foliar residues. *Res Rev* 75 (1980) 81–96.
5. Popendorf WJ, Leffingwell JT. Regulating OP pesticide residues for farmworker protection. *Res Rev* 82 (1982) 125–201.
6. Roosels D, Van Den Oever R, Lahaye D. Dangerous concentrations of methyl bromide used as a fumigant in Belgian greenhouses. *Int Arch Occup Environ Health* 48 (1981) 243–250.
7. Williams DT, Denley HV, Lane DA. On site determination of Sulfotep air levels in a fumigating greenhouse. *Am Ind Hyg Assoc J* 41 (1980) 647–651.
8. Williams IH. Dissipation of sulfotep and nicotine in a greenhouse atmosphere following their use as fumigants. *J Environ Sci Health B13* (1978) 235–241.