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Ministry of Social Affairs
and Employment

Exposure to pesticides

Part II. The cultivation of roses in greenhouses

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Labour Inspectorate

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Part II. The cultivation of roses in greenhouses

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CONTENTS

FOREWORD

The TNO Medical Biological Laboratory investigates the health risk of exposure to chemical substances in the working environment on request of the Directorate-General of Labour from the Ministry of Social Affairs and Employment. The present study is the second part of the research project 'Pesticides in greenhouses for flower culture'. The first part was performed in greenhouses for carnation culture and is also published in this series (Brouwer *et al.*, 1990). In the present part the health risk of dermal exposure to pesticides after re-entry (crop tasks after application of pesticides) of greenhouses for the cultivation of roses is emphasized.

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SUMMARY

On 18 farms for rose culture in greenhouses in The Netherlands dermal exposure of hands and forearms to abamectin, dodemorph and bupirimate during crop activities has been measured. Furthermore, dermal exposure of hands and forearms to abamectin and dodemorph during application by high-volume spraying has been measured. Only those farms have been selected which cultivate roses without thorns, so that gloves for protection against thorns were not used. Dermal exposure to abamectin, dodemorph and bupirimate during cutting by -in total - 75 workers is respectively 13 μg/h, 1.8 mg/h and 2.2 mg/h (geometric mean; active ingredient). During sorting and bundling of roses by respectively 21 and 30 workers, dermal exposure to abamectin and dodemorph is 18 μg/h and 1.9 mg/h.

Dermal exposure to abamectin during crop activities is about a factor 100 lower than dermal exposure to dodemorph and bupirimate, because of an approximately 100 times lower applied dose.

Dermal exposure during cutting as well as during sorting and bundling depends on the amount of dislodgeable foliar residue (DFR). A measure for transfer of pesticides from leaves to hands and forearms during cutting has been calculated to be approximately 1200, 4550 and 2400 cm^2/h for abamectin, dodemorph and bupirimate respectively (adjusted for application technique used). For sorting and bundling these factors are of the same order. The results suggest that working rate, expressed as harvested area per unit of time or as number of flowers handled per unit of time, is also a determinant of dermal exposure. It further appears that the between-person variance of dermal exposure during cutting accounts for approximately 30% of the remaining unexplained part of the variation in dermal exposure after regression on DFR and application technique. The final unexplained part in the variation of dermal exposure during cutting is amongst others due to the variation in the different situations measured.

An indicative prevalence of handeczema of 14% was found in 50 workers using a validated questionnaire sent by mail and an additional interview. Because of good sensitivity and specificity the questionnaire is considered to be a useful instrument for screening handeczema in large populations.

A health risk evaluation of the observed levels of dermal exposure after re-entry of greenhouses leads to the conclusion that a health risk may exist, especially after high application doses of relatively toxic pesticides with good skin penetrating properties.

SAMENVATTING

BLOOTSTELLING AAN BESTRIJDINGSMIDDELEN IN DE KASROZENTEELT
Rudi Brouwer, Hans Marquart, Gerrit de Mik en Johannes J. van Hemmen

Blootstelling aan bestrijdingsmiddelen in de land- en tuinbouw vindt plaats tijdens het zogenaamde mengen en laden (het klaarmaken van de spuit- of nevelvloeistof en het laden van de apparatuur), de toepassing van het middel en de werkzaamheden die na de toepassing in de betreffende ruimte of in het gewas worden uitgevoerd (re-entry).
In Nederland worden in de glastuinbouw tussen de 25000 en 30000 mensen potentieel blootgesteld aan bestrijdingsmiddelen tijdens werkzaamheden in met deze middelen behandelde gewassen. Slechts een beperkt aantal personen wordt blootgesteld tijdens het mengen en laden en de feitelijke toepassing van de middelen. Geschat wordt dat de meest intensieve blootstelling plaatsvindt in de sierteelt onder glas, omdat nagenoeg het jaar rond dagelijks wordt geoogst en omdat strenge eisen worden gesteld voor wat betreft afwezigheid van ziekten en plagen in bloemen voor de export.
Het doel van het in dit rapport beschreven onderzoek was het bepalen van de blootstelling van de huid aan bestrijdingsmiddelen in de rozenteelt in kassen bij met name de gewaswerkzaamheden. Op basis van de mate van gebruik en de toxiciteit van de bestrijdingsmiddelen werden abamectine, dodemorf en bupirimaat gekozen om de niveaus van blootstelling te bepalen.
De volgende vragen zouden met het onderzoek beantwoord moeten worden:

- Wat zijn de blootstellingsniveaus van de huid voor de drie geselekteerde bestrijdingsmiddelen tijdens toepassing en na re-entry?
- Welke relatie bestaat er tussen de huidblootstelling tijdens het knippen, sorteren en bossen van rozen en de hoeveelheid op het blad aanwezig bestrijdingsmiddel (afveegbaar residu)?
- Kunnen de resultaten voor de drie geselekteerde bestrijdingsmiddelen worden geëxtrapoleerd naar andere, niet onderzochte middelen in de rozenteelt?
- Vormen de blootstellingsniveaus van de huid een risiko met betrekking tot systemische gezondheidseffekten?
- Wat is de bijdrage van de tussen-persoons en binnen-persoons variatie aan de totale variatie van de gemeten huidblootstelling?
- Is een vragenlijstmethode bruikbaar voor het opsporen van handeczeem in een

agrarische populatie en geeft de prevalentie aanleiding tot nader onderzoek? Navolgend worden de resultaten, konklusies en aanbevelingen kort samengevat.

Op 18 rozenteelt bedrijven is de blootstelling van handen en onderarmen aan abamectine, dodemorf en bupirimaat bepaald tijdens de spuittoepassing en tijdens gewaswerkzaamheden na een toepassing door middel van spuiten of low-volume-misting (LVM). Doorgaans worden gewaswerkzaamheden in de rozen verricht met handschoenen vanwege de doorns. Enkele cultivars (Motrea en aanverwanten) zijn echter nagenoeg doornloos. Bedrijven met deze cultivars werden geselekteerd, omdat gewaswerkzaamheden dan in het algemeen zonder handschoenen worden uitgevoerd. Van twee werkers per bedrijf werd de blootstelling gemeten gedurende de eerste gewaswerkzaamheden - knippen, sorteren en bossen - na een toepassing van een bestrijdingsmiddel. Tevens is de hoeveelheid bepaald die tijdens het knippen op het gewas aanwezig was op kniphoogte (afveegbaar residu).
De huidblootstelling aan dodemorf en bupirimaat tijdens het knippen van rozen was ongeveer 2 mg/uur (geometrisch gemiddelde; aktieve stof; spreiding: 0,6-10 mg/uur). Tijdens het sorteren en bossen van deze bloemen behandeld met dodemorf was de blootstelling gemiddeld 1,9 mg/uur (0,4-9 mg/uur). De blootstelling aan abamectine was ongeveer 13 μg/uur tijdens het knippen (3-50 μg/uur) en 18 μg/uur (1-100 μg/uur) tijdens het sorteren of bossen (tabel 2). Tijdens het knippen lijkt de blootstelling na een toepassing met LVM lager dan na het spuiten.
De hoeveelheid bestrijdingsmiddel die tijdens de gewaswerkzaamheden op de handen en onderarmen werd aangetroffen bleek samen te hangen met het afveegbaar residu. Afhankelijk van het bestrijdingsmiddel kon de variatie in de huidblootstelling tussen de 30 en 75% verklaard worden door de variatie in de hoeveelheid afveegbaar residu. Voor abamectine, dodemorf en bupirimaat konden overdrachtsfaktoren (d.i. een maat voor de overdracht van het bestrijdingsmiddel van het gewas naar de hand en onderarm) worden berekend van respectievelijk 1200, 4550 en 2400 cm^2/uur (tabel 3 en figuur 1). De overdrachtsfaktoren berekend voor sorteren en bossen na het gebruik van abamectine en dodemorf waren van dezelfde orde van grootte als die voor het knippen.
Het blijkt dat de invloed van met name de tussen-persoons variantie (d.i. variatie in huidblootstelling van verschillende werkers na een toepassing in een kas) ongeveer eenderde uitmaakt van de onverklaarde variatie in de huidblootstelling aan bupirimaat

tijdens knippen na regressie op afveegbaar residu en toepassingstechniek. Ongeveer 40% van de tussen-persoons variantie komt voor rekening van de binnen-persoons variantie (d.i. de variatie in huidblootstelling van een werker na een toepassing). De tussen-persoons variantie geeft informatie over de verschillen in huidblootstelling tussen werkers in eenzelfde situatie. Dit kan bijvoorbeeld komen door verschil in werktempo uitgedrukt als hoeveelheid geknipt oppervlak of het aantal behandelde bloemen per minuut. Het blijkt dat werktempo een (bescheiden) rol speelt in de totstandkoming van de variatie in huidblootstelling (tabel 4).
Het verschil in huidblootstelling van ongeveer een faktor 100 tussen dodemorf en bupirimaat enerzijds en abamectine anderzijds wordt toegeschreven aan het verschil in afveegbaar residu. Dit verschil kan toegeschreven worden aan de verschillen in de toegepaste dosering (tabel 5).
De huidblootstelling bij het spuiten van abamectine en dodemorf was respectievelijk 68 μg/uur en 19,2 mg/uur. Ook dit verschil wordt geweten aan het verschil in gebruikte dosering, respectievelijk 1,5 g/1000 m^2 en 300 g/1000 m^2.
Op basis van de beschikbare gegevens over de toxiciteit en de huidresorptie van de drie onderzochte middelen is een 'indicatieve limietwaarde' afgeleid, d.i. de hoeveelheid bestrijdingsmiddel per dag waarvan op grond van de huidige kennis mag worden aangenomen dat die geen nadelige gevolgen heeft voor de gezondheid. Aan de hand van de gemeten blootstellingsniveaus kan hiermee een schatting van het gezondheidsrisiko worden gemaakt.
Gezien de gemeten niveaus van huidblootstelling kan worden gesteld dat, tijdens gewaswerkzaamheden en toepassing van abamectine en dodemorf geen gezondheidseffekten worden verwacht (tabel 7). Indien de blootstelling aan dodemorf tijdens sorteren en bossen geëxtrapoleerd wordt naar bupirimaat, hetgeen op basis van vergelijkbare gebruikte dosering en huidblootstelling tijdens knippen geoorloofd lijkt, kunnen nadelige effekten voor de gezondheid niet worden uitgesloten. Meer algemeen kan gesteld worden dat huidblootstelling aan bestrijdingsmiddelen bij gewaswerkzaamheden aanleiding kunnen geven tot het optreden van gezondheidseffekten na toepassing van relatief toxische middelen met goed penetrerende eigenschappen in relatief hoge doseringen. In het licht van deze resultaten worden maatregelen aanbevolen om de blootstelling te verlagen. De dermale blootstelling kan worden verminderd door te zorgen voor een lager afveegbaar residu. Dit kan o.a. bereikt worden door het gebruik van bestrijdingsmiddelen te minimaliseren, d.w.z. door waar mogelijk te kiezen voor

lagere doseringen en door de frekwentie van toepassing te verlagen. De huidblootstelling kan worden verlaagd door zorgvuldige persoonlijke hygiëne. Over het algemeen is de gewaswerker zich niet bewust van de blootstelling aan bestrijdingsmiddelen gedurende een groot deel van de dag. De kennis van de gewaswerker t.a.v. de (toxicologische) eigenschappen van bestrijdingsmiddelen en de (persoonlijke) hygiëne die bij het werk (toepassing én gewaswerkzaamheden) in acht genomen moet worden, behoeft de nodige verbetering door training en scholing.

Een indicatieve prevalentie voor handeczeem van 14% werd vastgesteld in een populatie van 50 werkers met behulp van een toezonden gevalideerde vragenlijst en aanvullende anamnese. Gezien de goede sensitiviteit en specificiteit (respectievelijk 70% en 98%) wordt de gebruikte vragenlijst toegezonden per post als een bruikbare methode beschouwd voor het opsporen van handeczeem in een grote (agrarische) populatie.

Van het onderzoek is een samenvatting gemaakt ten behoeve van de tuinders met aanbevelingen voor de teelt (rapportnr.: MBL 1990-22).

1 INTRODUCTION

Exposure to pesticides in agriculture mainly occurs during loading, mixing and application of pesticides and during manual activities in treated crops, usually referred to as re-entry. Only a limited number of persons is involved in the actual application and are potentially exposed to pesticides in this way (generally one person per farm). During manual crop activities in greenhouses for flower culture, however, nearly all workers are potentially exposed to pesticides daily. In total, approximately 30,000 persons are (potentially) exposed to pesticides in greenhouses in The Netherlands. Different tasks with frequent dermal foliar contact after application with organophosphorous pesticides have led to incidents of illness among fieldworkers in citrus and peach crops in the USA (Gunther *et al.*, 1977). Local effects such as contact dermatitis due to contact with pesticide residues have also been reported (Fregert, 1967; Ketel, 1976; Bruynzeel & Ketel, 1986). In some studies a relationship between pesticide use and prevalence of skin disorders has been found (Veien *et al.*, 1980; Peachey, 1981; Willems *et al.*, 1984). Several authors have tried to predict dermal exposure of the worker by calculating a transfer factor *i.e.* the ratio of dermal exposure and the so-called dislodgeable foliar residues (DFR) (Popendorf & Leffingwell, 1982; Nigg *et al.*, 1984; Zweig *et al.*, 1985). They state that there is a relative constancy of this factor for a variety of crops and different pesticides. A constant fraction of dislodgeable foliar residues is supposed to be transferred to the skin or clothing of workers during manual activities in treated fields.
This statement is partly supported by Brouwer and co-workers (1991[b]), who observed that dermal exposure during cutting of carnations depends -on average- for about 65% on the amount of pesticide on the foliage (DFR) and that differences in transfer factors were relatively small (range from 2900 to 10,000 cm^2/h) for four pesticides. This indicates, that for cutting of carnations these data may be extrapolated to other pesticides. Extrapolation to other manual tasks and other crops remains dubious, because the dependency of dermal exposure on DFR and the magnitude of transfer factors might be both task- and crop-specific.
The transfer of the pesticide residue from the surface of the foliage to the skin of the worker determines dermal exposure (Popendorf & Leffingwell, 1982; Popendorf, 1985; Brouwer *et al.*, 1991[b]) and depends on the amount available for transfer and the frequency and intensity of skin contact with the treated crops. The amount of pesticide

on the leaves which is available for transfer to the hands (represented by DFR) seems to depend on the dose applied per unit surface and the amount already present before application. The latter depends on frequency of use, re-entry interval and the dissipation rate of the pesticide on the crop (Brouwer *et al.*, 1991[b]). The type of formulation and the application technique may also play a role of importance. The contact of the body with the treated crops (frequency and intensity) is influenced by the specific crop (density and height), type and frequency of manual activities and by worker-dependent factors such as work practice and clothing. Uptake of pesticides may be affected by personal hygiene. Popendorf and Spear (1974) stated that all these factors do affect the uptake of pesticides to a large degree.

For commercial florists who are exposed to contaminated cut flowers (Morse *et al.*, 1979) and for workers in rose greenhouses exposed to dimethoate, benomyl (Liesivuori *et al.*, 1988) and methamidophos (Goedicke *et al.*, 1989), a health risk has been shown to exist if prolonged and continuous contact with foliar surfaces of cut flowers bearing pesticide residues occurs. From the observed levels of dermal exposure during cutting (about 10 mg/h) and sorting/bundling (about 7 mg/h) of carnations grown in greenhouses, Brouwer *et al.* (1991[a]) concluded that during crop activities a health risk may exist for pesticides with a low 'no-effect level' and good skin penetrating properties.

The aim of the present study was to assess the health risk due to dermal exposure to pesticides in greenhouses for rose culture during crop activities. On the basis of toxicity and use (frequency and amount) in rose culture abamectin, dodemorph and bupirimate were selected.

The following questions are to be answered:

- What are the levels of dermal exposure to the three selected pesticides after re-entry and during application by spraying (the major application technique in rose culture)?
- What is the relationship between the dermal exposure during the major manual crop activities (cutting, sorting and bundling) and the amount of pesticide found on the leaves (dislodgeable foliar residue) and other possible determinants?
- Is it possible to extrapolate the results of the three selected pesticides to other pesticides used in rose culture?
- May systemic health effects be expected at the observed levels of dermal exposure?

- What is the between-person and within-person variance of the dermal exposure and its influence on the total variance of dermal exposure levels measured?
- Is a recently developed questionnaire useful for screening handeczema in an agrarian population and does it give indications of an increased prevalence of handeczema compared to other occupations?

It was intented to measure also respiratory exposure of abamectin and dodemorph during application and after re-entry, especially after an application by low-volume misting. Unfortunately the developed methods for sampling and chemical analysis were not sensitive and reproducible enough to warrant use of these methods.

2 MATERIAL AND METHODS

2.1 Selection of farms

The total acreage for rose culture in The Netherlands in 1987 was about 800 ha, 23% of total acreage for flower culture, at 1000 farms (CBS, 1990). In total 2000-2500 workers are involved in the production of roses. The plants are cultured for at least 5 years. Three types of flowers are distinguished: the spray rose with a cluster of flowers and single roses with a large or a small flower. The most important daily manual crop activity is cutting by means of a pruning-shears and collecting them to a bundle on the arm. The other important activities are sorting on quality and length of the flower and bundling to a bunch of 20 flowers. From observations it appears that during these activities skin contact with the treated flowers is mainly limited to the hands and forearms. So the major part of total dermal exposure is also limited to these areas. Dermal exposure to pesticides during these activities may, amongst others, depend on the number of flowers handled per minute and the use of working gloves to prevent skin injuries by thorns. The number of flowers handled does not only depend on the worker but on the season and the variety as well, especially at cutting. During summer the production within a variety is higher and the speed of cutting is faster (more flowers are harvested per minute for less time is lost because of shorter walk distances) compared to winter. Furthermore, the flower production per unit area per year between varieties is different (100 - 330 flowers/m^2).
Situations were studied in which dermal exposure of hands and forearms was likely to occur (no use of gloves).
The following criteria for selection of farms were used:

- cultivation of roses should be the major source of income;
- two or more workers were employed;
- the small flower variety Motrea should be cultivated; this variety is giving a high production per unit surface and generally gloves are not used because the flower-containing branches are almost thornless;
- the crop should be more than one year old, because then production is at the highest level (280 flowers/m^2 per year).

The three pesticides under study (abamectin, dodemorph and bupirimate) are mainly

applied between May and September. This is also the period in which the shortest re-entry times occur and production is at the highest level of the year. Measurements were to be carried out at the first re-entry after application, so exposure was assumed to be highest for those particular situations.
The selected pesticides in rose culture are applied by high-volume spraying or low-volume misting.

By means of a questionnaire, sent to 103 Motrea growers, geographically situated in the region around Aalsmeer (the major production area for roses) and 'Het Westland', the farms which met the criteria were selected. From the 60 farmers (58%) who returned the questionnaire 25 did not want to participate for various reasons such as 'no time' and fear of withdrawal of one of the pesticides from the market when results would be 'negative'. A further four farms did not grow Motrea anymore and five farms were hesitating to cooperate. Finally 26 farms remained. Measurements were carried out in 18 rose (Motrea) production farms. The selected farms had on average 0.83 ha of greenhouses for the cultivation of rose and employed on average 4 workers.

2.2 Assessment of dermal exposure

Dermal exposure of the applicator(s) was measured during spraying and of two workers during cutting, sorting and bundling on every selected farm. Dermal exposure was measured using (pre-washed) cotton gloves which covered hands and forearms (stretch-cotton: 200 g/m^2, surface (one sided) 370 cm^2; J. van der Wee B.V., Riel, The Netherlands). Measurements were performed in the treated crop during the whole period of cutting, sorting and bundling. A pair of gloves was used for a maximum period of one hour, in order to prevent breakthrough of the pesticide through the glove to the hand. In a previous study the breakthrough for chlorothalonil was found to be about 5% after 1 hour (Brouwer *et al.*, 1991[a]). After a break in the work period or when the work period took more than one hour, a new set of gloves was given to the workers. The sets of gloves used during one activity were treated as one sample. In order to estimate the within-person variance, dermal exposure of two persons per farm per situation during cutting was measured twice consecutively for a maximum period of one hour each after an application of bupirimate.
Dermal exposure during spraying was measured only for abamectin and dodemorph

over the whole application period including loading and mixing of the pesticide. Dermal exposure was not measured in case low-volume misting, a non-thermal fogging method in which pesticide containing aerosols are sprayed and distributed into the greenhouse using one or more fans, was used. The applicator is usually not present during this type of application, but only during mixing and loading of small volumes, therefore levels of dermal exposure were thought to be low compared to other application techniques. Samples were stored in the dark at 4°C until they were chemically analysed for the amount of pesticides.

2.3 Assessment of dislodgeable foliar residue

Just before application and after re-entry eighteen leaves were sampled in duplicate from six adjacent beds at the height the flowers are harvested (contact zone). After collection dislodgeable residues were obtained as described by Iwata *et al.* (1977). Total leaf surface (one-sided) was measured with a surface area meter (LI-COR, 3100). The solution containing the dislodgeable residue was analysed for the pesticides. The coefficient of variation (CV_t) for leaf sampling and chemical analyses was 17-30%, depending on the pesticide.

2.4 Assessment of determinants of dermal exposure

The harvested area per worker was assessed by dividing the total harvested area by the number of workers cutting in the exposure period. After sorting and bundling the total number of flowers was counted and divided by the number of workers sorting, respectively bundling, in the considered period.

2.5 Chemical analyses of pesticides

Abamectin

Dislodgeable foliar residue solutions or methanol solutions (gloves) containing abamectin were extracted with n-hexane. Extraction efficiency of gloves using methanol was 95%. Extraction of abamectin from methanol or dislodgeable foliar residue solution into n-hexane was 100%. After derivatization with trifluoroacetic anhydrate, the derivative was quantified by reversed-phase liquid chromatography with fluorescence detection. Excitation and emission wavelengths were respectively 365 and 480 nm. Between-day precision was estimated from methanol extracts of gloves and from dislodgeable foliar residue solutions. In all cases the coefficient of variation was less than 6% (Jongen *et al.*, 1991[a]).

Dodemorph

Dislodgeable foliar residue solutions containing dodemorph were extracted with n-hexane. Extraction of dodemorph from dislodgeable foliar residue solutions was virtually complete. After evaporation of a part of the n-hexane, dodemorph residues were redissolved in heptane for on-column injection into the gas chromatograph. Cotton gloves were extracted with methanol. Subsequently, the methanol was extracted with heptane for gas chromatographic determination. Extraction of dodemorph from gloves was complete. Detection was performed with a nitrogen/phosphorous detector. The between-day coefficient of variation was determined in glove extracts and was less than 7% (Ravensberg, 1990)

Bupirimate

Dislodgeable foliar residue solutions containing bupirimate were injected directly onto the HPLC system. They had to be analysed within one day. Methanol extracts from gloves were diluted with one volume of water before injection. Extraction of gloves with methanol was 100%. Reversed phase HPLC was carried out with a cyano-modified column and ammoniumsulphate solution/methanol (4/6 by volume) as the eluent. UV detection was performed at 310 nm. The between-day coefficient of variation could not be calculated for dislodgeable foliar residue solutions because of instability of bupirimate in these solutions. For glove extracts, the between-day variation was less than 7% (Jongen *et al.*, 1991[b]).

2.6 Data on skin disorders and personal protection

From every of the 26 selected Motrea farms, two workers were asked to participate in pilot study on skin disorders among flower growers. They were asked to complete a questionnaire (Smit & Coenraads, 1990) sent by mail about skin disorders, especially handeczema. All responders were also medically examined with special emphasis on handeczema. They were further asked about the use of gloves, masks, rubber boots and special clothing during application, mixing and loading, cutting, sorting and bundling.

2.7 Statistical analyses

The exposure data were statistically analysed using SOLO Statistical System (BMDP Satistical Software Inc., Los Angelos, USA, 1988) for personal computer. The dermal exposure data were log-transformed to meet the normal distribution. Results are expressed as geometric mean (GM) and geometric standard deviation (GSD).

The association between dermal exposure and dislodgeable foliar residue and other variables was studied using (multiple) linear regression using least squares estimates (Snedecor & Cochran, 1982; Draper & Smith, 1981). The between-person variance was determined by measuring two people in an identical situation. The within-person variance for cutting was estimated by measuring two persons twice consecutively in an identical situation. The analysis of variance was carried out according to the 'lack of fit'-method (Draper & Smith, 1981).

3 RESULTS

3.1 Dermal exposure after re-entry

Dermal exposure of 49 workers to abamectin or dodemorph was measured during cutting. They worked 74 and 96 min in crops which were treated -on average- 34 h earlier with abamectin or 17 h earlier with dodemorph, respectively. Of 13 workers in crops treated with bupirimate two consecutive measurements were performed with an average exposure time of 42 minutes each. In the exposure period the workers harvested approximately 400 m^2. Dermal exposure during sorting and during bundling was measured for abamectin and dodemorph only. In total 21 workers during sorting and 30 workers during bundling were involved. About 1900 and 1400 flowers were handled respectively in -on average- 75 min (table 1).

Table 1 Dermal exposure measurements during cutting, sorting and bundling of roses: general data

	Cutting	Sorting	Bundling
Number of measurements	75	21	30
abamectin	23	10	15
dodemorph	26	11	15
bupirimate	26	n.d.(2	n.d.(2
Exposure period (min)(1	70 (35)	78 (37)	70 (34)
abamectin	74 (26)	62 (27)	62 (16)
dodemorph	96 (39)	92 (41)	79 (44)
bupirimate	42 (9)	n.d.(2	n.d.(2
Re-entry time (h)(1	23 (24)	28 (24)	31 (32)
abamectin	34 (41)	28 (25)	35 (40)
dodemorph	17 (6)	28 (24)	27 (20)
buprimate	19 (4)	n.d.(2	n.d.(2
Area harvested (m^2)(1	391 (204)	--	--
Number of handled flowers(1	n.d.(2	1879 (728)	1387 (695)

1 Mean and standard deviation (in parentheses)

2 n.d. = not determined

The results on dermal exposure to abamectin, dodemorph and bupirimate after re-entry are presented in table 2.

Table 2 Dermal exposure of hands and forearms to pesticides after re-entry in greenhouses for rose culture.

Pesticide	Application technique	Dermal exposure (mg/h)[1]					
		n[2]	Cutting	n[2]	Sorting	n[2]	Bundling
Abamectin	spraying	15	0.013 (2.2)	7	0.033 (2.0)	9	0.034 (3.0)
Dodemorph		20	1.9 (1.8)	8	1.8 (2.2)	11	1.7 (2.1)
Bupirimate		22	2.7 (1.8)		n.d.[4]		n.d.[4]
Abamectin	lvm[3]	8	0.011 (1.8)	3	0.004 (2.1)	6	0.007 (4.2)
Dodemorph		6	1.5 (1.5)	3	2.3 (2.8)	4	2.8 (2.7)
Bupirimate		4	0.8 (1.3)		n.d.[4]		n.d.[4]
Abamectin	total	23	0.013 (2.0)	10	0.018 (3.3)	15	0.018 (4.3)
Dodemorph		26	1.8 (1.7)	11	1.9 (2.3)	15	1.9 (2.2)
Bupirimate		26	2.2 (2.0)		n.d.[4]		n.d.[4]

1 Geometric mean (GM) and geometric standard deviation (GSD; in parentheses)
2 Number of observations
3 Low volume misting
4 n.d. = not determined

The geometric mean (GM) of dermal exposure rate to abamectin during cutting (13 μg/h, GSD: 2.0) is about a factor 100 lower than the GM of dermal exposure to dodemorph and bupirimate. This is also observed for dermal exposure rate during sorting and bundling. From this table some differences between groups of observations can be seen. These differences have not been tested on significancy because of the small number of observations. Dermal exposure during sorting and bundling after spraying of abamectin is higher than during cutting. This difference is not found after application of dodemorph and is reversed after an application of abamectin by LVM. Differences in dermal exposure after application by different techniques are small. Levels of exposure during cutting tend to be lower after application by LVM. Dermal exposure to abamectin during sorting and bundling after low-volume misting was lower

than after high-volume spraying.
In order to investigate to what extent dermal exposure after re-entry depends on dislodgeable foliar residue (DFR) linear regression analysis was carried out. This analysis was stratified by pesticide because dermal exposure and DFR of abamectin were 'out of range' compared to those of dodemorph and bupirimate. The relationship between dermal exposure and DFR was studied after adjusting for application technique. It appears that application technique was a confounding factor in the relationship between dermal exposure and DFR. Too few observations after an application using LVM were available, however, for separate analysis. For exposure to abamectin during cutting the results are shown in figure 1.

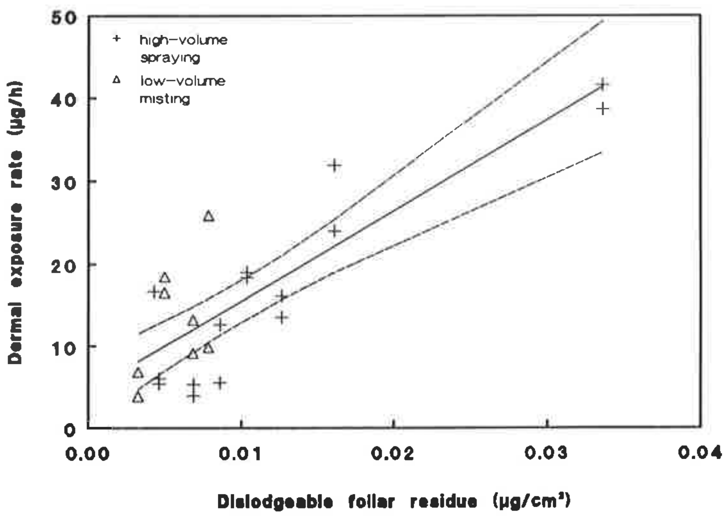

Figure 1 Association of the exposure rate of hands and forearms to abamectin, applied by two application techniques, during cutting of roses and dislodgeable foliar residue.

The regression coefficient or transfer factor appears to be approximately 1200 cm^2/h with 95% confidence limits of 850-1550 cm^2/h. The regression equation with DFR and application technique as independent variables explains about 74% of the variation found in dermal exposure to abamectin during cutting of roses. The transfer factors adjusted for application technique for dodemorph and bupirimate during cutting of roses are 4550 and 2400 respectively. The 95% confidence intervals of these transfer factors were wide, especially for dodemorph (1500 to 7600). The amount of explained variation was small compared to the explained variation for abamectin, 32% and 55% respectively (table 3).

Table 3 Association between dermal exposure of hands and forearms to pesticides (μg/h) during cutting, sorting and bundling of roses and dislodgeable foliar residue (μg/cm^2) adjusted for application technique.

Task	Pesticide	n[1]	Regression coefficient[2]	95% Confidence limits LCL[3]	UCL[3]	R^2[4]
Cutting						
	abamectin	23	1200 (150)	850	1550	0.74
	dodemorph	26	4550 (1000)	1500	7600	0.32
	bupirimate	26	2400 (600)	1250	3550	0.55
Sorting						
	abamectin	10	2400 (500)	1250	3550	0.86
	dodemorph	12	2400 (2650)	- 3700	8500	0.15
Bundling						
	abamectin	15	2250 (1200)	- 400	4900	0.38
	dodemorph	15	6250 (2350)	1150	11,350	0.49

1 Number of observations
2 Regression coefficient and standard error of estimate (s.e.) in parentheses
3 LCL = lower confidence limit; UCL = upper confidence limit
4 The amount of variation in the dependent variable explained by the fitted regression equation.

Transfer factors of abamectin and dodemorph during sorting and bundling were also calculated. The independent variables that were used for this calculation were DFR during cutting and the application technique. As can be seen from table 3 the transfer factors were within the range calculated for the transfer factors during cutting. The regression model for abamectin explains more than 80% of the variation in dermal exposure during sorting, while the regression model for dodemorph does not (significantly) explain the observed variation in exposure. The models for bundling are not better. It is obvious that some of the preceeding models are not perfect and some are useless. A significant part of the variation in exposure remains unexplained.
In order to investigate the influence of within-person and between-person variance on

the total variation of dermal exposure rates an analysis of variance on the bupirimate data for cutting was carried out. From the analysis it appears that the between-person variance accounts for almost one-third of the total unexplained variation (*i.e.* 1 - 0.55 = 0.45; see table 3) of the model for bupirimate. The within-person variance accounts for almost 40% of the between-person variance. The between-person variance also provides information on the variance in dermal exposure between workers. This can be explained partly by differences in working rate of the workers in that situation. In table 4 the results are presented of a regression analysis with dermal exposure as dependent variable and as regressors DFR, application technique and working rate. The latter is expressed as harvested area or number of flowers handled per unit of time.

Table 4 Association between exposure of hands and forearms to pesticides and working rate adjusted for dislodgeable foliar residue and application technique.

	n[1]	Regression coefficient[2]		R^2[3]
Dermal exposure rate (μg/min) during:		Harvested area (m^2/min)	Number of flowers (flower/min)	
Cutting				
abamectin	23	0.015 (0.005)*	n.d.[4]	0.81
dodemorph	26	3.1 (1.9)	n.d.[4]	0.39
bupirimate	26	- 3.6 (2.2)	n.d.[4]	0.60
Sorting				
abamectin	8	---	0.020 (0.006)*	
dodemorph	7	---	1.0 (3.8)	
Bundling				
abamectin	12	---	0.039 (0.015)*	
dodemorph	12	---	1.2 (1.5)	

* $p < 0.05$

1 The number of observations for some models is lower compared to table 3 due to missing values for number of flowers handled per min.

2 Regression coefficient and standard error of estimate in parentheses

3 The amount of variation in dependent variable explained by the fitted regression equation.

4 n.d. = not determined

From table 4 it appears that for cutting only the regression coefficient of the harvested area after application of abamectin is significantly different from zero. This means that, after an application of abamectin, dermal exposure of hands and forearms of the workers will differ -on average- 0.015 μg per harvested square meter. Also the regression coefficients for the number of flowers handled in the two other models (table 4) are only significant for abamectin and not for dodemorph. For all regression models for cutting the amount of explained variation in dermal exposure increased compared to the models presented in table 3. The models for sorting and bundling in table 3 and 4 are incomparable, because of differences in the number of observations. As can be seen from table 3 dermal exposure during cutting strongly depends on dislodgeable foliar residue (DFR). The observed difference in dermal exposure to abamectin and the other two pesticides after re-entry (table 2) is probably due to a difference in DFR after application (DFR_1). The difference in DFR_1 and applied dose of abamectin on one hand and of dodemorph and bupirimate on the other hand (table 5) are of the same order of magnitude as the observed difference in dermal exposure during cutting (table 2).

Table 5 Dislodgeable foliar residue after application (DFR_1), dislodgeable foliar residue before application (DFR_0) and applied dose differentiated by application technique.

Pesticide	Application technique	DFR_1 [1] ($\mu g/cm^2$)	DFR_0 [1] ($\mu g/cm^2$)	Applied dose [2] ($g/1000\ m^2$)
Abamectin	spraying	0.0098 (2.0)	0.0002 (3.1)	1.5 (0.9)
Dodemorph		0.24 (1.7)	0.06 (2.5)	297 (150)
Bupirimate		0.78 (1.8)	0.03 (2.2)	154 (38)
Abamectin	lvm	0.0055 (1.5)	0.0002 (2.1)	0.7 (0.3)
Dodemorph		0.32 (2.5)	0.10 (1.8)	113 (49)
Bupirimate		---	---	----

1 Geometric mean (GM) and geometric standard deviation (GSD; in parentheses)
2 Mean and standard deviation (in parentheses)

The applied dose of dodemorph and bupirimate were 297 $g/1000\ m^2$ and 154 $g/1000\ m^2$, respectively and of abamectin 1.5 $g/1000\ m^2$.

An association between DFR and applied dose for each seperate pesticide appears to be very weak for bupirimate and absent for abamectin and dodemorph. Dislodgeable foliar residue already present before application (DFR_0) is not related to DFR_1 for the pesticides under study.

3.2 Dermal exposure during application

Dermal exposure during application was measured during high-volume spraying of abamectin and dodemorph. Spraying was performed with hydraulic sprayers, mostly the spray gun, using - on average - 270 l spray solution per 1000 m^2. On the average spraying of 1000 m^2 took 30 min. The applied dose used for abamectin was 1.5 g/1000 m^2 and for dodemorph approximately 300 g/1000 m^2. The GM of dermal exposure during spraying abamectin was 68 μg/h (GSD: 2.9; n=8), during spraying of dodemorph 19.2 mg/h (GSD: 2.4; n=11).

3.3 Skin disorders

Fifty of the 52 approached persons were willing to participate in this pilot study. Of these subjects with a mean age of 38.7 yrs (SD: 11.4), 48 were male and 2 were female. On average they worked approximately 17.1 years (SD: 10.6) in greenhouses for flower culture. Five of the 50 participants met the defined criteria for handeczema as defined by Smit and Coenraads (1990) by questionnaire. Two cases, who did not fully complete the questionnaire, were found to be positive only after the additional interview. One of the participants was false positive. The remaining 42 respondents were truly negative. Therefore, when using the questionnaire, a sensitivity of 70% with regards to diagnosing handeczema, can be reached. This sensitivity will rise to 100% if additional questions to complete the gaps in the questionnaire are asked directly to the respondent. The specificity of the questionnaire was 98%, rising to 100% when additional questions are asked. The positive predictive value of the questionnaire for the small population under study was 83%.

3.4 Personal protection

The 50 participants of the pilot study on handeczema were also asked for the use of personal protection. The results are reported in table 6. Application was performed by

36 workers for on average 3.1 hours per week (SD: 1.8). Most of these workers (64 to 90%) never used hand protection. Rubber boots and special clothing were seldomly used. Most commonly used protection during application is a mask: 66 to 90% used allways or sometimes a mask dependent on the application technique. Mixing and loading was done by 31 workers 2.6 times a week (SD: 2.1). During mixing and loading approximately 60% never used any protection at all. If gloves were used they are only replaced if they were worn out.

Table 6 The use of personal protection during application, mixing and loading, and croptasks in rose culture.

Task	n	Number of workers that states **NEVER** to use:			
		Gloves	Mask	Rubber boots	Special clothing
Spraying	36	23	12	16	17
Dusting	22	20	2	20	17
Cold fogging	22	19	6	21	21
Mixing & loading	31	22	18	--(1	--(1
Harvest tasks	50	35	--(1	--(1	--(1

1 Not asked for

In rose culture gloves are commonly used during crop handling (cutting, sorting and bundling) as protections against thorns. From the 50 workers in the almost thornless cultivar Motrea 70% never uses gloves during the mentioned activities. Of the 15 workers who admitted the use of gloves, eight used gloves on both hands and 7 on one hand.

4 DISCUSSION

4.1 Re-entry

The levels of dermal exposure to dodemorph and bupirimate of about 2 mg/h, during cutting of roses grown in greenhouses are in order of magnitude comparable with those found by Davis *et al.* (1982; 1983) in apple thinning and Brouwer *et al.* (1991[a,b]) in cutting of carnations grown in greenhouses using the same method of assessment. Liesivuori *et al.* (1988), using gloves, reported levels of dermal exposure of 1.1 mg/cm^2 for dimethoxon and 0.48 mg/cm^2 for dimethoate. These results can not be compared with the results presented in this study, because the authors did not mention the exposure period and the surface area of the glove monitors. On average, however, the levels of exposure to dodemorph and bupirimate are somewhat lower, than observed for cutting of carnations, although the applied doses were within the same range (Brouwer *et al.*, 1991[a,b]). This is probably due to the method of cutting: roses are cut using a pruning-shears instead of a knife used in carnation culture, leading to less contact with the crop. Furthermore, the DFR in roses was found to be lower than in carnations, which may be due to lower residues present before application and to a faster dissipation on foliage of the pesticides under study. The level of dermal exposure to abamectin, however, is totally different from the level of exposure to dodemorph and bupirimate. This is ascribed to the difference in applied dose. Abamectin is applied in a dose about 100 times lower than dodemorph and bupirimate resulting in a DFR which is about 100 times lower. This confirms the results described by Brouwer *et al.* (1991[b]) that applied dose is an important determinant of DFR. For the individual pesticides, however, the association of applied dose and DFR could not be proven, probably because the variation in applied dose was too small within the series of measurements for a single compound. Differences in dissipation on foliage and time of sampling after application between abamectin and the other two pesticides may also cause a difference in DFR.

Remarkable is the higher level of exposure after high-volume spraying of abamectin during sorting and bundling compared to cutting. This is not found for dodemorph and for abamectin after low-volume misting. No explanation for this finding can be given. Levels of dermal exposure during cutting tend to be lower after application of a pesticide using LVM than after application using high-volume spraying. This may be expected from a lower applied dose and lower DFR. But too few data for a LVM application were available (because this technique was introduced only a year ago and therefore not available to a large enough extent in the selected farms) to confirm this finding properly. LVM is a non-crop-directed application method, so pesticides will not only deposit on the crop.

The reported transfer factors of the three pesticides under study are comparable to those reported by Brouwer and co-workers (1991[b]) for carnation culture (4500 cm^2/h), although -on average- lower, which may be due, amongst others, to a smaller degree of contact during cutting. From the results it still remains unclear, to what extend the lower transfer factors are due to the nature of the pesticides under study and to crop-specificity. Further research is needed *e.g.* by using a pesticide in different crops. The transfer factors are also of the same order of magnitude as the factor established for different kinds of fruit by Zweig *et al.* (1985) and Popendorf and Leffingwell (1982), who calculated a factor of around 5000 cm^2/h. Recently Spencer *et al.* (1991) reported transfer factors of 450 cm^2/h for mechanically harvested tomatoes, characterizing low-contact harvest tasks up to 40,000 cm^2/h for harvesting grapes representing high-contact harvest tasks.

The variation in dermal exposure during cutting can be explained for about 75% and for about 55% by DFR (adjusted for application technique) after application of, respectively, abamectin and bupirimate. These findings are comparable with those reported from carnation culture (Brouwer *et al.*, 1991[b]). For dodemorph the amount of explained variation in dermal exposure by DFR was much smaller. It appears that for the data on this compound the between-person variance is large, for which at present no explanation can be given. For abamectin and bupirimate it is possible to predict dermal exposure from DFR and application technique within a narrow range of a factor 2-3. For bupirimate the between-person variance is about 30% of the unexplained 45% ($\approx$15%) of the total variance. This means that using this model the maximum R^2 that can be explained will be around 70% ($R^2_{max} = R^2$ + between-person variance: 55% + 15%). The remaining unexplained part is due to the between-situation variance, for which determinants are difficult to assess, and to random variation in the observations (Draper & Smith, 1981). Prediction of dermal exposure during other crop activities such as sorting and bundling from DFR and application technique, is far more difficult, although the transfer factors are comparable to those

for cutting. Only for sorting after application of abamectin the presented model is suitable. For the other models the 95% confidence interval of the transfer factor is too wide because of large variation in small numbers of observations. It is likely, however, that the DFR during cutting is not the proper measure for the amount of residue available for exposure during sorting and bundling, because the contact zone with the crop during these activities is different from the zone where the samples were taken and DFR was established. Furthermore, DFR during sorting and bundling might be different due to preceeding activities and prolonged time between application and sorting and bundling. But results from a pilot study in carnation culture (data not shown) indicate, however, that the DFR during sorting/bundling is not very much different from the DFR during cutting. Therefore it is concluded from the present results that the transfer factors of pesticides (within a crop) calculated for different manual activities will be comparable.
The between-person variance provides some information on the variation in dermal exposure during manual crop activities between different workers in the same situation. Differences in for example the intensity of contact with the treated crop, working rate, work practice, clothing and so on can bring about differences in dermal exposure (Popendorf & Leffingwell, 1982; Popendorf, 1985; Fenske *et al.*, 1989). As appears from the results working rates during different manual crop tasks may play a role in explaining differences in dermal exposure between workers. In predicting individual levels of dermal exposure during a crop activity within a crop, its role is, however, modest. The amount of explained variance increases with about 5% for the range of working rates observed in practice.

4.2 Application

Dermal exposure to dodemorph during application of roses with high-volume spraying is about the same as that during application by high-volume spraying of carnations with chlorothalonil and thiophanate-methyl (Brouwer *et al.*, 1991[b]). The variation in the exposure is smaller which may be explained by the fact that in roses nearly all measurements were carried out during application using a spray gun, while in carnations measurements were done for different kinds of hydraulic sprayers. Dermal exposure to abamectin during spraying is lower because of the very low applied dose compared to dodemorph and the four pesticides studied for carnation culture.

4.3 Potential health risk due to the exposure to pesticides

The present results indicate that the potential dermal exposure for manual activities in roses grown in greenhouses which are treated with pesticides is relatively high when compared to application of pesticides, although the levels are lower than in carnation culture. Furthermore, for all workers the frequency of manual crop activities occur daily whereas application is limited to one person, up to a few times a week for a relatively short period of time. It should be noted that the levels of exposure have been determined for unprotected hands and forearms to which pesticides are accumulated during the day. In the rose variety under study about 70% of the workers never uses hand protection during manual crop activities, whereas in other varieties workers wear gloves on one or both hands to protect against sharp thorns. This does, however, not necessarily mean that the gloves protect the worker against dermal exposure to pesticides. Also during mixing and loading, and application the majority of the workers say they never use hand protection to prevent exposure.
The health risk due to the levels of exposure to the specific pesticides in this study can be estimated according to the method described by Brouwer and co-workers (1991[a]), which is based on toxicological data: 'no-effect levels' (NEL), absorption data, and so-called safety factors (Genderen *et al.*, 1988). In table 7 'indicative limit values' (ILV: the amount of pesticide considered to be the highest level of daily exposure which does not lead to an adverse health effect) for the three pesticides in this study are presented.

Table 7 Measured average dermal exposure per task on a working day in greenhouses for rose culture and indicative limit values (ILV) for dermal exposure.

Pesticide	NEL (mg/kg*day)	ILV(1 (mg/day)	Dermal exposure(2 (mg/task)			
			A(3	C	S	B
abamectin	0.2	14	0.085	0.050	0.035	0.036
dodemorph	20	1400	25	8	4	5
bupirimate	5	35	n.m.	9	n.m.	n.m.

ILV = indicative limit value; A = application; C = cutting; S = sorting; B = bundling
n.m. = not measured

1 ILV is calculated for a man of 70 kg, using of a safety factor 10, except for abamectin(= 100); dermal absorption is assumed to be 1% for abamectin, 10% for dodemorph and for bupirimate 100%.

2 Average task times on a day used: spraying 75 min (2500 m^2); cutting 4 h; sorting and bundling 2 h.

3 Dermal exposure for high-volume spraying (including mixing and loading) only.

The ILV's are based on data obtained from Campell (1989) for abamectin and largely from confidential toxicological reports and professional toxicological judgement for dodemorph and bupirimate, since some required data are lacking. For dodemorph and bupirimate a safety factor of 10 was used because of intra- and interspecies differences. Only for abamectin a safety factor of 100 was used because of reported effects on the reproductive system in mice.In table 7 the observed average potential levels of dermal exposure to the selected pesticides are compared with the ILV's. It is concluded that for abamectin and dodemorph no health risk exists due to dermal exposure after re-entry and during application. Comparing the obtained data on applied dose and dermal exposure during cutting for bupirimate and dodemorph, the dodemorph data on sorting and bundling may be extrapolated to bupirimate. Dermal exposure of workers who apply bupirimate and also perform harvest tasks in treated crops may occasionally exceed the ILV. In the preceeding part only the dermal exposure is evaluated, but one should realise that respiratory and oral exposure occur simultaneously. It should further be considered that the analysis is based on average levels of exposure. Ninety-percentiles for levels of dermal exposure are a factor 2-3 higher. Besides, it is assumed that dermal exposure to the mentioned pesticides occurs daily, since it is at present unknown whether dodemorph and bupirimate present in dislodgeable foliar residu do dissipate to an appreciable extent. From abamectin it is known that the half-life of decay of DFR in different crops is up to a few days[1] dependent from the presence of sunlight (Campbell, 1989).
A risk for chronic health effects appears to exist after re-entry of greenhouses for rose culture after application of pesticides that are relatively toxic (say, NEL < 1 mg/kg) and have a relatively good dermal absorption and are applied with a relatively high dose. From the results it is obvious that data on dermal exposure after re-entry and skin-penetrating properties, as well as on cumulation and dissipation of pesticides on foliage are required for proper health risk evaluation.
From the presented data and those described for carnation culture (Brouwer *et al.*, 1991[a]) it is evident that the levels of dermal exposure have to be decreased. This can be achieved by minimizing the use of pesticides, lowering the applied dose and the frequency of application. This will lead to a lower DFR and thus to lower dermal exposure after re-entry.

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[1] **Personal communiction; FB Dirkse, Merck-Sharp and Dohme AGVET Division, Haarlem, The Netherlands.**

4.4 Skin disorders

The sensitivity and specificity in screening this agrarian population for handeczema by means of a questionnaire are comparable with those reported by Smit *et al.* (1990) in their validation study. They reported a sensitivity of 100% and a specificity of 65% for a population of 109 nurses. Therefore the questionnaire sent by mail is considered a useful instrument in screening handeczema in large populations. Gathering additional information from persons who did not fully complete the questionnaire may be worthwhile to enhance the sensitivity and specificity.

The indicative prevalence of handeczema found in this population is 14%. Compared to the prevalence of eczema in the Dutch population (6.2%; Coenraads *et al.*, 1983) and the prevalences of handeczema in workers exposed to epoxy resins (19.3%; Putten *et al.*, 1984), metal workers (14%; Boer *et al.*, 1989), construction workers (7.8%; Coenraads *et al.*, 1984), kitchen personel in hospitals (18%; Kavli *et al.*, 1987) and shrimp peelers (10.6%; Kavli *et al.*, 1985) the need for further investigations in a population of workers in horticulture in greenhouses is considered justified.

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