

Prevalence of occupational allergy to bell pepper pollen in greenhouses in the Netherlands

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Summary

Background An increasing number of allergic complaints appear to have occurred among bell pepper greenhouse employees.

Objective The aim of this study was to estimate the prevalence of work-related allergic symptoms and the prevalence of sensitization to specific occupational allergens and its determinants.

Methods We studied 472 employees who were invited to answer an extensive questionnaire and to be tested on location with inhalant allergens and home-made extracts of the bell pepper plant. In addition, peak expiratory flow monitoring and RASTs were performed.

Results Work-related symptoms were reported in 53.8% of all cases. Sensitization to the bell pepper plant was found in 35.4%. Positive reactions to leaf, stem and/or juice, however, were associated in nearly 90% with sensitization to pollen, which appeared to be most important allergen of the plant. Sensitization to the bell pepper plant and inhalant atopy were considered the most important risk factors for the occurrence of work-related symptoms of the upper airways (PRR 2.63, CI 2.11–3.25 and PRR 2.25, CI 1.82–2.79) as well as of the lower airways (PRR 4.08, CI 2.38–7.00 and PRR 3.16, CI 1.87–5.33).

Conclusion There is a surprisingly high prevalence of work-related respiratory symptoms (53.8%) in bell pepper horticulture. In two-thirds of the employees, symptoms at work were associated with an IgE-mediated allergy due to the high and chronic exposure to bell pepper pollen. Complaints at work without specific sensitization to bell pepper pollen can be caused by non-specific hyper-reactivity or atopy to other occupational allergens. The extent of this occupational allergy has important consequences for the health care of this large, still growing occupational group.

Keywords bell pepper, epidemiology, exposure, greenhouse employees, horticulture, occupational allergy, pollen, prevalence, skin test

Submitted 23 January 2001; revised 15 June 2001; accepted 10 September 2001

Introduction

Bell pepper cultivation in the Netherlands has increased enormously during the past few years. It has become the main branch of horticulture under glass, with a size of 1150 hectares, divided over approximately 1500 greenhouses, and a workforce of more than 4000 people. However, at the same time an increasing number of allergic complaints appear to have occurred among the workers. The presence of work-related allergic symptoms among bell pepper horticulturists has been described in two case reports by Gerth van Wijk and by van Toorenenbergen [1,2]. It was already mentioned at that time that the handling of bell peppers or contact with the pollen of the plant may cause an IgE-mediated allergy, with symptoms ranging from rhinoconjunctivitis to asthma.

Recently, it was demonstrated that major IgE binding occurred to allergens of about 30 and 64 kDa in bell pepper pollen extract [3]. In 1993 and 1996 two inventory questionnaire surveys were performed among bell pepper gardeners and their employees, showing that 15% and 22%, respectively, of the workforce attributed their complaints to the work environment in the greenhouses. As a possible explanation for these results the high pollen concentrations in the greenhouses were mentioned [4]. Unfortunately, the relation between exposure to pollen and the reported symptoms was not further analysed and until now no studies have been published on work-related symptoms among bell pepper horticulturists. The prevalence of work-related symptoms and determinants of specific sensitization remain largely unknown.

The described observations raised concern about health problems within this large occupational group. As a result we were asked by the Commodity Board for Horticulture to start a broad investigation among employees in bell pepper greenhouses. The aim of this study was to estimate the prevalence and determinants of work-related allergic symptoms among

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this population at risk, with a special focus on bell pepper pollen.

Materials and methods

A comprehensive cross-sectional study was carried out from March 1999 to February 2000. Bell pepper greenhouses in the western part of the Netherlands were approached at random by telephone and asked to participate in the study. The investigators paid two visits to each participating greenhouse. During the first visit the volunteers gave informed consent and were asked questions concerning age, sex, medication use, smoking habit, job and job activities, work history, symptoms at work, and atopic complaints. Symptoms present after occupational exposure comprized five categories: itching, redness and/or eczema of the skin, urticaria/angioedema, rhinitis (sneezing, rhinorrhoea, itching, obstruction), conjunctivitis (redness, itching, watery eyes), and asthma (wheezing, coughing, shortness of breath). Exacerbations during the work week and regression on weekends and holiday were considered exemplary for work-relatedness. During the second visit sensitization to occupational allergens (substances of the bell pepper plant and pollen) was determined by means of skin prick tests. Blood samples were taken to evaluate sensitization by RAST.

To study possible work-related asthmatic reactions peak expiratory flow (PEF) monitoring was performed during the 2 weeks following the medical survey. For reasons of feasibility bronchial provocation tests with histamine were not performed during the visit on site. However, the decline in PEF over a working day or between days away from and at work can also be used as a tool to detect occupational asthma [5]. Each participant was given a mini-Wright peak flow meter (Glaxo Wellcome, Zeist, the Netherlands) and they were asked to record PEF twice a day: before and just after work during working days and during the weekend or days away from work on waking and at bedtime. On each occasion they were asked to blow after maximal inspiration three times into the peak flow meter; the highest of the three attempts was used for analysis. On each day the use of medication and symptom scores (rhinitis and asthma symptoms) on a four-point scale (0 = no symptoms, 1–2 = moderate symptoms, 3 = severe symptoms) were noted by the participant in a diary. For each day the mean PEF and the absolute difference between morning and afternoon were calculated. In the statistical analysis the two indices used were the average PEF (PEFMEAN), calculated as average over the mean PEF on 14 days, and the average PEF difference, calculated as average over the PEF difference on 14 days (PEFDIF). The study was approved by our hospital medical ethical committee. Confidentiality was maintained.

Reference group

Ten non-atopic volunteers without allergic complaints who had never been in contact with bell pepper plants were skin tested to detect irritative, non-specific reactions to our home-made occupational allergen extracts.

Prick tests

Prick tests were performed by application of one drop of allergenic extract to the skin of the volar side of the forearm. Subsequently, the dermis was punctured with a standardized

skin test needle and the results were read after 20 min. Reactions were expressed (mm) of mean weal diameter (adding the longest diameter to the orthogonal diameter and dividing by 2). A diameter of 3 mm or more was considered positive [6]. Dilution buffer was used as a negative control, histamine chloride 10 mg/mL as a positive control.

Allergens

Skin prick tests were performed with *botrytis cinerea* (SQ 412) as one of the moulds found in greenhouses and six common inhalant allergens from ALK Abelló, Nieuwegein, the Netherlands: *Dermatophagoides pteronyssinus* (SQ 503), tree mix (SQ 108), grass mix (SQ 293), mugwort (SQ 312), dog dander (SQ 553) and cat dander (SQ 555). Pollen from flowers of the bell pepper plants were collected in a greenhouse in the period February–March. The flowers were in full blossom and biological control by predatory mites (*Amblyseius Cucumeris*) was not used yet. A 10% (w/v) extract was prepared in phosphate-buffered saline pH 7.4, containing 0.03% human serum albumin and 0.5% phenol (PBS). In the same period a fresh bell pepper plant was supplied by a bell pepper gardener. Stems and leaves were collected and a 25% (w/v) extract in PBS was prepared. Stamen from the bell pepper flowers were collected in August. We prepared a 25% (w/v) extract in PBS. All extracts were centrifuged for 10 min at 2000 *g* and supernatants were passed through a 0.22- μ m Millex GS filter (Millipore, Bedford, MA, USA).

To prepare bell pepper juice, a red bell pepper (inside flesh and seeds were removed) was homogenized in a food processor, the slurry was filtered and the fluid was subsequently passed through a 0.22- μ m filter. Protein concentrations were determined by the method of Watanabe et al. with pyrogallol red molybdate complex [7]. The protein concentrations of the 25% extract of the stem, leaf and stamen were 0.28 g/L, 0.35 g/L and 1.01 g/L, respectively, whereas the protein concentration of the 10% pollen extract was 0.59 g/L. All extracts were stored in appropriate aliquots at -20°C until use in skin tests. Before use, extracts were defrosted for 1 h before skin test and mixed.

RAST

Pollen from flowers of the bell pepper plant were obtained from a greenhouse. Allergen-specific IgE was determined by RAST by the use of agarose beads as allergen support, as described by Adkinson et al. [8]. An amount of 10 mg of pollen was extracted with 2 mL coupling buffer (0.1 mol/L NaHCO_3 and 0.5 mol/L NaCl, pH 8.5) for 1 h at room temperature. After centrifugation for 10 min at 1400 *g*, protein in the supernatant was coupled to 100 mg of CNBr-activated Sepharose 4B (Sigma Chemical Co., St Louis, MO, USA), according to the manufacturer's instructions. An amount of 2 mg per test of bell pepper pollen Sepharose preparation was incubated overnight with 0.05 mL patient serum. After four washes, radio-iodinated rabbit anti-human IgE antibodies (Pharmacia & Upjohn, Uppsala, Sweden) were added. After overnight incubation and four washes, the percentage of bound radioactivity was measured.

Statistical analysis

In the statistical analyses differences between continuous variables were tested with the unpaired Student *t*-test. The differences between frequencies of categorical variables were tested

with the chi-square test (χ^2). Multiple linear regression analysis was applied to study the influence of several individual characteristics, respiratory symptoms and work history on the peak-flow outcomes. A generalized loglinear model with a binominal distribution was used to present associations between work-related risk factors and respiratory symptoms. Prevalence rate ratios (PRR) were estimated as a measure of association between risk factors and respiratory symptoms. The PRR is a better approximation of the relative risk than the often-used odds ratio in situations where the disease prevalence is high [9]. As age appears strongly to influence the probability of respiratory symptoms, it was included in each logistic model, regardless of the level of significance. For the initial selection of variables in multivariate loglinear models a significance level of $P < 0.10$ was used. In the final models only variables with a P -level below 0.05 were retained. The statistical analysis (esp PROC REG and PROC GENMOD) was executed using the SAS computer package.

Results

Population characteristics

Of the 110 greenhouses approached by telephone, 79 participated in the study. Moreover, six additional greenhouses announced they would take part. Reasons for refusal to participate were lack of time and/or lack of interest because of absence of work-related symptoms, fear of losing (hard to find) employees with allergic complaints and other individual causes. The invited group of workers in 85 greenhouses comprised 487 employees, of which 472 participated (response rate of 96.9%). The greenhouses in the study together cover an area of 1 888 363 square metres, nearly 10% of the total bell pepper horticulture in the Netherlands. Population characteristics and characteristics of the participating greenhouses, concerning the number of regular and seasonal employees and the area, are given in Table 1.

Symptoms at work were highly prevalent among the greenhouse workers. One or more symptoms were reported by 254 employees (53.8%), of whom 208 (44%) notified a substantial

improvement or complete regression on weekends and holidays. Complaints consisted of rhinitis in 233 individuals (49.4%) and of conjunctivitis in 143 individuals (30.3%). Redness, itching and/or eczema of the skin were mentioned by 83 individuals (17.6%), asthma by 63 individuals (13.3%) and urticaria and/or angioedema by 42 individuals (8.9%). In subsequent analyses work-related rhinitis and conjunctivitis are analysed together as symptoms of the upper airways (51.3%) and compared with work-related symptoms of the lower airways (13.3%), considered as the most serious manifestation of an occupational allergy.

One parameter was used as indicator of atopy: the presence of a positive skin prick test result (defined as a weal size of 3 mm or more) to at least one of the common inhalant allergens. This was found in 177 employees (37.5%). Sensitization to occupational allergens was also highly prevalent. Of all employees, 167 (35.4%) were sensitized to various substances of the bell pepper plant, 129 of them (27.3%) to the pollen as shown in Table 2. In addition, all control subjects showed negative responses in the skin prick test.

Symptoms vs. sensitization

In order to investigate associations between respiratory symptoms and sensitization the study population was divided into four subgroups based on the presence of work-related symptoms and sensitization to occupational allergens (Table 3). The majority of the sensitized employees appeared to have work-related symptoms (84%), whereas only 55% of the employees with work-related symptoms were sensitized to the bell pepper plant (group A vs. group B). A high proportion of the employees in group A (128) were sensitized to bell pepper pollen and/or stamen (91.4%), which also contain a certain amount of pollen. The majority of them (93) also had positive reactions in the skin prick test to leaf, stem and/or juice of the plant. In group C 22 employees appeared to be sensitized to the pollen and/or stamen (81.5%) but only five of them were also sensitized to one of the other tested substances of the bell pepper plant.

Sensitization to those substances without sensitization to pollen was only seen in a relatively small number of employees: in group A eight employees showed an isolated positive reaction

Table 1. Characteristics of the bell pepper greenhouses and their employees ($n = 472$)

	Mean	SD	Range
Age (yr)	36.6	11.5	13–79
Duration of employment (yr)	8.5	6.1	0–31
Regular employees (n)	6.0	2.6	1–13
Seasonal employees (n)	3.7	3.1	0–15
Area of the greenhouse (m^2)	24710.5	10425.9	6500–50000
	n	%	
Sex: male	387	82	
Sex: female	85	18	
Smoking	153	32.4	
Job classification			
Owner	133	28.2	
Supervisor	14	3.0	
Full-time employee	235	49.8	
Part-time employee	60	12.7	
Sorter	30	6.4	

Table 2. Prevalence of work-related symptoms and results of the skin prick tests

Symptoms	Symptoms at work		Symptoms at work, less or absent in weekends	
	<i>n</i>	%	<i>n</i>	%
Skin (itching/redness/eczema)	83	17.6	71	15.1
Urticaria and/or angioedema	42	8.9	38	8.1
Rhinitis	233	49.4	190	40.3
Conjunctivitis	143	30.3	124	26.3
Asthma	63	13.3	55	11.7
<i>Skin prick test positive:</i>				
Inhalant allergens				
<i>Dermatophagoides pteronyssinus</i>	122	25.8		
Tree pollen	53	11.2		
Grass pollen	90	19.1		
Mugwort	35	7.4		
Cat dander	41	8.7		
Dog dander	63	13.3		
Botrytis	24	5.1		
Occupational allergens				
Leaf bell pepper plant	74	15.7		
Stem bell pepper plant	52	11.0		
Pollen bell pepper plant	129	27.3		
Stamen bell pepper plant	139	29.4		
Bell pepper juice	97	20.6		

Table 3. Results of the skin prick tests of greenhouse employees grouped by work-related symptoms and sensitization to occupational allergens (proteins of the bell pepper plant and pollen) (*n* = 472). Group A: symptoms at work and occupational sensitization. Group B: symptoms at work without occupational sensitization. Group C: asymptomatic workers with occupational sensitization. Group D: asymptomatic workers without occupational sensitization

Group	A	B	C	D	Total
Work-related symptoms	+	+	-	-	
Sensitization to occupational allergens	+	-	+	-	
<i>n</i>	140	114	27	191	
Positive skin prick test					
Bell pepper leaf	72	-	2	-	74
Bell pepper stem	51	-	1	-	52
Bell pepper pollen	116	-	13	-	129
Bell pepper stamen	120	-	19	-	139
Bell pepper juice	87	-	10	-	97
Inhalant allergens	107	36	9	25	177

to bell pepper juice and one to the leaf of the plant, while one and two employees, respectively, were found positive to the leaf and bell pepper juice and to the stem and bell pepper juice. Five employees in group C were only sensitized to the bell pepper juice. A high proportion of the employees in group A were also sensitized to at least one of the common inhalant allergens (76%). The presence of specific IgE to common allergens was less prevalent in the other three groups, ranging from 32% and 33%, respectively, in group B and C to only 13% in group D.

Determinants of work-related symptoms

Tables 4 and 5 show the association between work-related respiratory symptoms and the significant determinants in the univariate as well as in the multivariate analysis. The two

most important variables strongly associated with work-related symptoms were sensitization to substances of the bell pepper plant and inhalant atopy. These associations, however, were clearly more pronounced for symptoms of the lower airways. A third positive association was found between the age of the employee and work-related symptoms of the upper airways and although significant, the prevalence rate was much lower compared with the other two determinants. The number of reported work-related symptoms decreased by age ($P = 0.005$), with the lowest prevalence for the group employees of 40 years and older (28.6% vs. 36% for the group of 30 years and younger).

Several other determinants were tested but none of them was significantly associated with work-related symptoms of upper and lower airways: sex (PRR 0.97 and 1.01), job classification (PRR 0.91 and 1.38), years of education (PRR 0.99 and 1.01), hours per week (PRR 1.27 and 0.84), size of the greenhouse (PRR 0.99 and 1.02) and smokers (PRR 0.88 and 0.71). Addition of any of these variables to the multivariate model did not change the results as presented in Table 5. Furthermore, inhalant atopy appeared to be an important determinant of sensitization to the bell pepper plant, with a highly significant prevalence rate ratio (PRR 3.79, 95% CI 2.89–4.97). Of all common inhalant allergens, sensitization to grass pollen and house dust mite were most prevalent in our study population. However, as suspected, the association between sensitization to grass pollen and sensitization to bell pepper pollen (PRR 4.88, CI 3.76–6.32) was stronger than the association between the house dust mite and bell pepper pollen (PRR 2.27, CI 1.72–3.00).

Peak-flow results

Completed PEF readings and symptom diaries over 14 days were returned by 448 employees (94.9%). Twelve participants, however, had PEF records without any difference between

Table 4. Univariate analysis of work – related respiratory symptoms in relation to age, atopy and allergen specific sensitization

Determinants	UA		UAW		LA		LAW	
	PRR	95% CI	PRR	95% CI	PRR	95% CI	PRR	95% CI
Age (yr)	0.99	0.98–1.00	0.98	0.98–0.99	NS		NS	
Atopy	2.17	1.83–2.59	2.25	1.82–2.79	2.70	1.69–4.35	3.16	1.87–5.33
Sensitization to bell pepper plant	2.23	1.88–2.64	2.63	2.11–3.25	3.65	2.24–5.95	4.08	2.38–7.00

UA = symptoms at work of upper airways; LA = symptoms at work of lower airways; UAW/LAW = symptoms at work of upper and lower airways, with an improvement during the weekends; NS = non-significant; PPR = prevalence rate ratio; CI = confidence interval.

Table 5. Multivariate analysis of work-related respiratory symptoms in relation to age, atopy and allergen specific sensitization

Determinants	UA		UAW		LA		LAW	
	PRR	95% CI	PRR	95% CI	PRR	95% CI	PRR	95% CI
Age (yr)	1.00	0.99–1.00	0.99	0.98–1.00	NS		NS	
Atopy	1.57	1.28–1.94	1.48	1.16–1.88	1.59	0.93–2.71	1.82	1.00–3.29
Sensitization to bell pepper plant	1.70	1.39–2.08	2.10	1.65–2.69	2.88	1.64–5.05	3.01	1.62–5.58

UA = symptoms at work of upper airways; LA = symptoms at work of lower airways; UAW/LAW = symptoms at work of upper and lower airways, with an improvement during the weekends; NS = non-significant; PPR = prevalence rate ratio; CI = confidence interval.

morning and evening during 7 days or more. Those records were considered unreliable and as a consequence left out for analysis. Multiple regression analyses were performed with the two PEF indices as dependent variables. The PEFMEAN of the entire group ($n = 436$) was 508.5 L/min ($SD \pm 27.00$) and the PEFDIF, assessing PEF variability, -12.07 L/min ($SD \pm 37.8$). Slight to moderate symptoms of the upper airways were mentioned by 306 employees and severe symptoms by 179 employees. Considering the lower airways, slight to moderate symptoms were reported by 198 subjects during the 2-week period of peak flow measurements, while 98 mentioned severe symptoms in the accompanying diary. Workers with complaints of the upper airways during the peak flow measurement period had similar PEFMEANs and PEFDIFs than those without these complaints. However, for subjects with lower respiratory complaints on at least 7 out of 14 days the PEFMEAN decreased by 52.4 L/s (10.3%) for those with moderate symptoms and 66.9 L/s (13.2%) for those with severe symptoms. Workers with asthmatic complaints in the baseline survey had a significantly lower PEFMEAN of -40.2 L/s (7.9%). Sensitization to substances of the bell pepper plant was not associated with the peak flow measurements.

RAST

Bell pepper pollen specific IgE was demonstrated in 88 employees, ranging from 0.36 to 80.7 E/mL. Of this group, 83 employees had a positive skin prick test result to pollen, indicating that in 64% (83/129) of the employees sensitized to bell pepper pollen the presence of specific IgE to these pollen could be confirmed by skin prick testing as well as by RAST. In the other five employees only the RAST test was found positive. Of nine employees with a positive skin prick test to pollen serum samples were not available. The other 37 employees with a positive prick test were RAST negative, as were all the other individuals with negative skin test results for bell pepper pollen.

Discussion

In this study a high prevalence of work-related respiratory symptoms among employees of bell pepper greenhouses was found (53.8%), the main symptoms being rhinitis and conjunctivitis in 49.4 and 30.3%, respectively. Local dermatitis and asthma were reported to a lesser extent: 17.6 and 13.3%, respectively. Asthma is considered the most serious manifestation of an occupational allergy, mostly preceded by rhinoconjunctivitis [10]. Sensitization to proteins of the bell pepper plant, confirmed by skin prick testing and RAST, appeared to be the most important and strongest determinant for the occurrence of work-related symptoms. This association was even more pronounced for asthma symptoms than for symptoms of nose, eyes and skin. Of all tested substances of the bell pepper plant, the pollen appeared to be the most important allergen. Pollen are not only responsible for a large proportion of the work-related complaints mentioned but probably also for the more severe symptoms. A higher percentage of workers with asthma complaints was found in the group of symptomatic employees with sensitization to pollen and/or stamen than among symptomatic employees without sensitization (30% vs. 18%).

The established association between sensitization to pollen and lower airway symptoms is also supported by the results of the PEF measurements. Work-related respiratory symptoms caused a 10% decrease of the average PEF. The fact that full-time working employees with a daily exposure to the pollen have an increased PEF might be due to a selection process: a considerable number of symptomatic employees with subsequently a lower PEF will change job or reduce their number of working hours. The prevalence rate of work-related respiratory symptoms in this study was surprisingly high compared with the previous surveys among bell pepper horticulturists in 1993 (15%) and 1996 (22%). The prevalence rate of sensitization to occupational allergens in this study was also high compared with previous epidemiological studies on occupational allergies:

rat/mouse urinary allergens in laboratory workers were found positive in 18.2% and in 10.7%, respectively [5], wheat-flower/ α -amylase in bakers in 10% and in 7%, respectively [11], and natural rubber latex in operation room personnel in 14.1% [12].

Apart from sensitization to the bell pepper plant inhalant atopy was also considered a significant risk factor for symptoms of the lower airways. However, its effect on the development of work-related symptoms is less strong than the effect of sensitization to the bell pepper pollen and plant. Atopy has been identified as an important risk factor for work-related symptoms in several other studies [5, 11–13]. In this study 116 (69.5%) of the 167 employees sensitized to the bell pepper plant were also sensitized to one or more common inhalant allergens, 71 to grass pollen. This illustrates a clear association between sensitization to the bell pepper pollen and inhalant atopy, in particular to grass pollen.

The age of the employee was also identified as a risk factor for the development of work-related rhinoconjunctivitis and/or local dermatitis. There was a significant decrease in the prevalence of these symptoms in different age groups, with the lowest prevalence of work-related symptoms in the group of 40 years and older. This might indicate a so-called healthy worker effect as a result of selection processes. Greenhouse workers who develop severe symptoms due to exposure to the bell pepper plant have changed their jobs because of their health problems. Casuistic information from current employees confirmed this hypothesis. A better estimate of this selection bias can only be studied in a longitudinal survey over several years. Duration of employment, job classification and full-time vs. part-time are proxies for exposure that appear not to capture the relevant exposure characteristics for the occurrence of work-related symptoms.

Although work-related symptoms in bell pepper greenhouses are obviously associated with contact with the pollen of the plants, not all symptoms could be explained by an IgE-mediated response to this allergen. In this study 53.8% of the employees reported work-related allergic symptoms but in only 65.7% of these workers IgE-sensitization to the bell pepper plant and pollen could be demonstrated. The question is what may have caused the work-related symptoms in the group of employees without sensitization. During the collection of pollen for our pollen extract, the presence of large amounts of predatory mites in the flowers of the plant was noticed. The predatory mite *Amblyseius Cucumeris* (AC) was introduced in bell pepper greenhouses in 1985 as an effective biological control agent for common thrips species, the most important pest in bell pepper horticulture. It has been used for year-round biological control ever since. Reports on sensitization to AC or an antigenic relation between the common house dust mite and the predatory mite AC are hardly found in scientific literature. However, the relation between allergic complaints and sensitization to mites in general is well known. An increased exposure to AC, as currently observed in bell pepper horticulture, might very well lead to sensitization and subsequently to work-related symptoms from the skin, nose, eyes and lower airways. The role of AC is discussed in more detail in another publication.

However, there are other possible explanations for work-related symptoms without sensitization. First, our skin prick test may have failed to detect sensitization in some individuals,

although the method used was comparable to other studies performed by our research group. Secondly, the involved employees might be specifically sensitized to other occupational allergens, not identified yet. A non-specific reaction to the humid and warm environment in greenhouses is probably a third (additional) explanation.

The described relationship may have important consequences for health care in this large, still growing occupational group. It provides important evidence of causation and suggests that work-related symptoms are to some extent preventable by reducing exposure levels to pollen. The continuing fertilization process of the self-pollinated bell pepper plant requires the maintenance of high pollen concentrations throughout the greenhouse during the season. Besides, the necessary daily activities during the cultivation process, like heading of the bell pepper plants, cause the release of large amounts of pollen from the flowers. These pollen, well-known as rather large and heavy particles, are falling down towards the ground, immediately causing a peak exposure for the employee who is working on the crop. To perform the work-task properly, it is necessary that the employee stands very close with his face towards the plant and so contact with the pollen is hardly avoidable. Inhalation of these pollen may cause immunological sensitization with subsequent allergic symptoms in sensitized workers. Personal contact with employees in bell pepper greenhouses confirmed that the mentioned activity on the plants often initiate the onset of symptoms or aggravate existing symptoms.

Measures should be taken at different levels at the same time. First, personal protection of the employee to avoid inhalation of pollen. Secondly, new upgrading methods to create plants with a good setting of bell peppers with as little pollen as possible. Finally, exploring the possibilities of genetic engineering of the bell pepper plant to create flowers without pollen. We fully realize that these solutions are relatively time-consuming to develop. Furthermore, we would like to emphasize the need for follow-up (longitudinal) survey to see whether sensitized employees without work-related symptoms will develop allergic complaints and whether sensitized employees with rhinoconjunctivitis will develop asthma during continuation of their current job.

In conclusion, there is a surprisingly high prevalence of work-related respiratory symptoms and sensitization to bell pepper pollen in bell pepper horticulture. The extent of this occupational allergy has important consequences for health care in this large, still growing occupational group.

Acknowledgements

We thank Glaxo-Wellcome B.V., the Netherlands, for supplying the mini-Wright peak flow meters. The fruitful discussions with F.Th.M. Spieksma, Laboratory of Aerobiology, Department of Pulmonary Diseases, University Hospital Leiden, are also gratefully acknowledged.

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