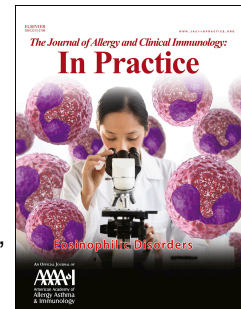


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Prevalence of tomato and cucumber sensitization among greenhouse workers

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Conflict of interest statement

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23 Clinical Implications

24 Over one fifth of exposed greenhouse workers were sensitized to tomato and cucumber, and the
25 sensitized workers presented more work-related asthma and rhinitis symptoms. Preventive
26 measures and regular health surveillance are needed to prevent occupational allergic diseases
27 among these workers.

28 Key words

29 Allergy, cucumber, exposure, greenhouse, occupational, tomato

30

In recent decades, greenhouse cultivation of tomatoes and cucumbers has increased in temperate areas, enabling higher quality and longer production periods. Greenhouse workers are exposed to plant material such as pollen, fruit, leaves, and stems, and other agents including mites and insects. Tomato (*Lycopersicum lycopersinum* or *Solanum lycopersicum*, botanical family Solanaceae) and cucumber (*Cucumis sativus*, Cucurbitaceae) can cause oral allergy syndrome. Vegetables have been reported to cause occupational allergic diseases for example in kitchen and food industry work (1, 2). Cases of occupational asthma, rhinitis and contact urticaria due to tomato and cucumber sensitization has been found among greenhouse workers (3, 4). Handling plants in greenhouses can also cause occupational irritant and allergic contact dermatitis on the hands (5). Nevertheless, the prevalence of sensitization to tomato and cucumber among greenhouse workers is poorly known. We aimed to study sensitization, work-related respiratory and skin symptoms, and eosinophilic airway inflammation among tomato and cucumber greenhouse workers.

The study was approved by the Helsinki University Hospital Ethical Committee (HUS/3372/2017). Each participant gave their written informed consent. The cross-sectional study was conducted among the workers of eight Finnish greenhouse companies growing tomato and/or cucumber, as reported earlier (6). The structured interview was performed before testing the workers, the questions covered demographic information, work history, smoking, and airway and skin symptoms. The workers' hands were inspected to detect eczema. Asthma symptoms were defined as having at least two asthma symptoms (prolonged coughing, dyspnoea, wheezing, chest tightness) and rhinitis as at least two nasal symptoms (rhinorrhoea, nasal obstruction, nasal itching, sneezing), excluding symptoms during respiratory infection over the last 12 months. Hand eczema was defined as self-reported hand and/or forearm dermatitis, and urticaria as self-reported contact urticaria on the hands and/or forearms. The symptoms were regarded as work-related if they eased during days off or holidays or worsened because of factors at work.

The skin prick tests (SPT) with ALK Lancet (ALK-Abello, Hørsholm, Denmark) included a negative control and a positive control (histamine). Fresh flower, leaf stem, and fruit of tomato and cucumber were tested separately, 1 ml of crushed plant parts were diluted in 0.5 ml of potassium phosphate buffer (100 mmol/l, pH 7.4) and then used for prick-to-prick testing. The common environmental allergens panel included birch, timothy grass, mugwort pollen, dog, cat, and house-dust mite *Dermatophagoides pteronyssinus* (ALK-Abello, Hørsholm, Denmark). The test was read 15 minutes after pricking, a wheal at least 3 mm larger than the negative control was considered positive (7). Fractional exhaled nitric oxide (FeNO) was measured at the workplace using an online chemiluminescence analyser (NIOX mino; Aeroctine AB, Solna, Sweden).

We used SPSS version 27.0 (IBM Corporation, Armonk, NY) for our analyses. Continuous measures were summarized by medians and interquartile range and categorical variables by their frequencies and proportions. We analysed the differences between the groups using the Mann–Whitney U test for continuous variables and chi-squared tests for categorical variables. Logistic regression analysis was used to calculate odds ratios (ORs). Variables were tested in a multivariate logistic regression model and adjusted for sex, age, smoking, and atopy.

Of the 118 participants, 91 worked in tomato and 72 in cucumber greenhouses, 45 worked in both. Altogether 21% of the exposed workers were sensitized to some part of the tomato plant and 24% to the cucumber plant. The workers were sensitized most commonly to the flower part (Table 1). Of the workers, 14% presented work-related symptoms of asthma, 33% rhinitis, 17% hand eczema, and 6% urticaria (Table 2). Those sensitized to tomato were younger ($P = 0.011$), more atopic ($P = 0.029$) and reported more symptoms of work-related asthma ($P \leq 0.001$), rhinitis ($P = 0.013$) and urticaria ($P = 0.011$) than the unsensitized. Cucumber-sensitized workers reported more symptoms of work-related asthma ($P = 0.001$) and hand eczema ($P = 0.020$) than the unsensitized. No-one had hand eczema on inspection. In the logistic regression model, after adjusting for sex, age, smoking, and atopy, sensitization to tomato remained a significant risk factor for work-related asthma (OR = 22.8;

95% confidence interval [CI], 4.6-113.2) and rhinitis (OR = 3.5; 95% CI, 1.1-10.8) symptoms, and sensitization to cucumber for work-related asthma symptoms (OR = 16.3, 95% CI 2.3-113.7). FeNO $\geq$ 25ppb significantly associated with symptoms of work-related asthma (OR = 6.5; 95% CI 2.0-20.3) and rhinitis (OR = 3.4; 95% CI 1.4-8.9).

The sensitization rates to tomato (21%) and cucumber (24%) were slightly lower than those to bell pepper (35%) among Dutch greenhouse workers handling these plants (8). In our study, the workers showed most positive SPTs to pollen-containing flower parts. Similarly, bell pepper pollen was the most significant allergen of the plant. In bell pepper greenhouses, the prevalence of work-related rhinitis (49%) was higher, but that of asthma (13%) and urticaria (9%) symptoms was in line with our study. The Dutch study found an association between atopy and bell pepper sensitization, similarly to our study. Atopy has also been found to be a risk factor for IgE-mediated sensitization and occupational contact urticaria in the food industry (1). Workers sensitized to tomato and cucumber were at a higher risk of work-related airway symptoms, although the small sample size caused uncertainty in the point estimate and wide CI. FeNO $\geq$ 25ppb associated with tomato sensitization and work-related asthma and rhinitis symptoms, suggesting eosinophilic airway inflammation and Type 2 inflammatory processes typical of allergic airway diseases (9). Our findings propose that sensitization to tomato and cucumber in greenhouse work is related to occupational allergic airway diseases. Although 17% of the workers reported work-related hand eczema, no-one had this on inspection, like the Danish gardeners and greenhouse workers (5). The cucumber-sensitized workers reported more work-related hand eczema than the unsensitized. Cucumber leaves are sharp and irritating, and may have initially provoked hand eczema and made the workers prone to sensitization. Indeed, pre-existing contact eczema with an impaired skin barrier function has been considered a risk factor for IgE-mediated sensitization (1).

Further studies are needed to identify tomato and cucumber allergens involved in airway sensitization in order to allow quantification of airborne exposure in greenhouse facilities.

Preventive measures, including the use of protective gloves, clothing and equipment, work modifications to minimize dust exposure, and education of workers should be considered to prevent work-related allergic diseases among greenhouse workers. Regular health surveillance and testing of specific sensitization among those with work-related allergic symptoms is recommended.

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Tables

Table 1. Skin prick test results of 118 greenhouse workers exposed to tomato and/or cucumber

	Cases with positive skin prick test to	
	tomato, N = 91	cucumber, N = 72
Flower, N (%)	17 (19)	15 (21)
Leaf stem, N (%)	12 (13)	11 (15)
Fruit, N (%)	10 (11)	12 (17)
Any part, N (%)	19 (21)	17 (24)

Table 2. Characteristics, work-related symptoms, and eosinophilic airway inflammation of 118 tomato and/or cucumber greenhouse workers.

	All, N = 118	Tomato greenhouse workers, N = 91			Cucumber greenhouse workers, N = 72		
		SPT positive to tomato N = 19	SPT negative to tomato N = 72	P value	SPT positive to cucumber N = 17	SPT negative to cucumber N = 55	P value
Male, N (%)	72 (61)	15 (79)	41 (57)	0.080	14 (82)	33 (60)	0.091
Age, median (IQR), N=117	39 (31- 50)	33 (24- 41)	43 (32- 52)	0.011	39 (28- 51)	37 (29- 45)	0.716
Current smoking, N (%)	41 (35)	7 (37)	19 (26)	0.370	8 (47)	24 (44)	0.804
Duration of greenhouse work in current employer, years, median (IQR)	4.8 (1.6- 4.8)	4.0 (1.7- 10.1)	4.8 (1.4- 10.4)	0.872	9.3 (4.0- 10.3)	4.1 (1.6- 10.3)	0.210
Duration greenhouse work, median (IQR)	5.9 (2.6- 5.9)	4.2 (3.9- 10.2)	6.4 (2.4- 13.3)	0.516	9.3 (4.0- 10.3)	4.8 (2.2- 12.3)	0.529
Atopy*, N (%)	30 (25)	9 (47)	16 (22)	0.029	8 (47)	13 (24)	0.063
Atopic skin constitution**, N (%)	14 (12)	4 (21)	8 (11)	0.265	2 (12)	8 (15)	0.753
Work related symptoms, N (%)							
Asthma	16 (14)	10 (53)	6 (8)	<0.001	6 (35)	3 (6)	0.001

Rhinitis	29 (33)	12 (63)	23 (32)	0.013	7 (41)	16 (29)	0.350
Hand eczema, N = 117	20 (17)	5 (26)	13 (18)	0.438	7 (41)	8 (15)	0.020
Contact urticaria, N = 117	7 (6)	4 (22)	3 (4)	0.011	2 (13)	3 (6)	0.332
FeNO $\geq$ 25ppb, N (%), N = 117	25 (21)	7 (37)	9 (13)	0.017	7 (41)	11 (20)	0.078

* At least one positive SPT to common environmental allergens, ** infantile eczema or Besnier's prurigo. FeNO = Fractional exhaled nitric oxide; IQR = Interquartile range; SPT = skin prick test