American Journal of Industrial Medicine 22:859–872 (1992)

Outbreak of Hypersensitivity Pneumonitis Among Mushroom Farm Workers

Wayne Sanderson, MS, Gregory Kullman, MS, Joaquin Sastre, MD, Stephen Olenchock, PhD, Alvaro O'Campo, MD, Karl Musgrave, DVM, and Francis Green, MD

Between April 1982 and August 1985, seven cases of mushroom worker's lung (MWL), a form of hypersensitivity pneumonitis, were diagnosed among workers at one mushroom farm in Florida. The cases suffered from episodic shortness of breath, cough, fever and chills, myalgia, malaise, and difficulty breathing. Pulmonary function testing revealed restrictive ventilatory impairment and reduced diffusing capacity; chest radiographs exhibited diffuse interstitial pulmonary infiltrates. The seven cases occurred among workers from different farm operations, suggesting that workers throughout the farm were exposed to the disease causing agent(s). Six of the affected workers left employment at the farm in order to remain free of symptoms. The other affected worker was able to continue working at the farm, but only by remaining in a maintenance shop which was physically separated from the rest of the farm facilities. An industrial hygiene survey demonstrated that farm workers from every work area were exposed to organic dust constituents suspected of causing MWL, but no specific antigens were identified as the cause of the cases. Of the remaining workers who participated in a cross-sectional respiratory morbidity survey at the farm, approximately 20% of the more heavily exposed workers reported occasionally experiencing symptoms consistent with MWL. Approximately 10% of the workers had below normal spirometry test results, but interpretation was hampered by the diverse racial makeup of the population and lack of an adequate comparison group. No abnormalities consistent with either acute or chronic MWL were seen on the chest radiographs. Serologic tests demonstrated that almost all workers had been exposed to antigens capable of causing MWL, but the results were not associated with health status. At the time of the cross-sectional survey, no workers were found to be suffering acute respiratory problems consistent with MWL.

Key words: organic dusts, serum precipitins, spirometry, respiratory disease, mushroom workers

Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health, Morgantown, WV (W.S., G.K., S.O., A.O., K.M.).
Department of Immunology, Tulane University, New Orleans, LA (J.S.).
Foothills Hospital, Calgary, Alberta, Canada (F.G.).
Dr. Sastre's current address is Avenue Toreros 32, Madrid, Spain.
Dr. O'Campo's current address is Department of Federal Employee Occupational Health, Kennedy Federal Building, Boston, MA 02203.
Address reprint requests to Mr. Sanderson, Division of Surveillance, Hazard Evaluation and Field Studies, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, OH 45226.
Accepted for publication March 2, 19

Outbreak of hypersensitivity pneumonitis among mushroom farmworkers

INTRODUCTION

Occasionally, mushroom farm workers develop a respiratory illness very similar to a disease seen among farmers exposed to moldy hay (farmer's lung) [Campbell, 1932]. Workers, exposed to a variety of organic antigens from other sources, have been reported to develop the same respiratory condition, generally known as hypersensitivity pneumonitis (HP). Although the etiologic mechanism by which organic dusts induce this respiratory disease is unknown, an immunologic response (precipitating antibody, circulating antigen-antibody complex, or cell mediated immunity) is most likely involved [Fink, 1973]. Mushroom worker's lung (MWL) typically affects only a minority of exposed individuals, suggesting that individual susceptibility may be important [Fink, 1986].

Reports of MWL published in English language journals have been confined to case reports and case series; a total of 33 acute cases of MWL have been reported from England, Canada, and the United States [Bringhurst et al., 1959; Sakula, 1967; Jackson and Welch, 1970; Craig and Donovan, 1970; Chan-Yeung et al., 1972; Stewart, 1974; Gilliland, 1980; Johnson and Kleyn, 1981]. Although MWL generally has onset during the first few months of employment, it sometimes occurs in workers who have been employed in the mushroom industry for many years. MWL can affect workers employed in any mushroom farm job, but has been reported most commonly among compost handlers and spawners.

The clinical features of HP are similar, regardless of the specific causative antigen [Fink, 1973]. Presenting symptoms commonly include nonproductive cough, shortness of breath, fever, chills, myalgia, and malaise. Less common symptoms include headache, nausea, vomiting, and sore throat. The initial symptoms begin 4–8 hours after exposure and persist for several hours thereafter, but recovery is usually spontaneous with abstinence from further exposure. If exposure continues, symptoms become persistent and more severe, and loss of appetite and weight loss may occur.

During acute attacks, pulmonary function tests typically demonstrate a restrictive pattern with reductions in vital capacity, diffusing capacity, and lung compliance. Airways obstruction, indicated by reduced one-second forced expiratory volume (FEV_1) and its ratio to the total forced vital capacity (FEV_1/FVC), may also occur, especially in patients who may have endured repeated subacute attacks [Fink, 1986]. Chest radiographs may appear normal, but acutely ill patients frequently have bilateral diffuse reticulonodular shadows in the lower and mid-lung zones.

In only one published case study, has serologic testing implicated a particular antigen [Sakula, 1967]. Mushroom workers are exposed to a tremendous number of fungi, bacteria, and organic antigens, any one of which may cause HP type reactions. Therefore, if only a few select antigens are used for antibody testing, results may be negative. Serum Ig-G antibodies to antigens in extracts of compost and mushroom spawn are often present, but these are usually no more frequent in diseased individuals than in other exposed individuals.

Radiographic examination, pulmonary function testing, and serologic tests may be helpful, but the patient's symptom history is often crucial in establishing a diagnosis of MWL. If a mushroom worker presents with classic symptoms of acute HP which quickly resolve on abstinence from exposure and then recur upon return to work, the diagnosis of MWL should be seriously entertained. Individuals presenting only with manifestations of chronic disease can be much more difficult to diagnose.

SEVEN CASES OF MWL AT A FLORIDA MUSHROOM FARM

The first worker known to develop MWL at a commercial mushroom farm in Florida initially experienced symptoms in April 1982. No other confirmed cases occurred until October 1984, but during the following year, six additional workers developed MWL. The seven cases had been employed at the farm from 1 month to 12 years, and held a variety of jobs with varying degrees of exposure (Table I). In fact, an office worker, who would be expected to have a very low level of exposure, developed the disease. Ages ranged from 24–54 years, and individuals of both sexes and all smoking categories were affected. Although half of the farm population was Hispanic or Vietnamese, only white and black workers were reported to be the cases.

Onset was typically characterized by episodic occurrence of several mild symptoms in late afternoon or evening after work. With continued employment, episodes became progressively more frequent and severe over the next few weeks. Symptoms increased in number, severity, and frequency, and culminated in a severe attack, bringing the individual to medical attention. Severe episodes were characterized by shortness of breath, fever, chills, dry cough, and in some cases fatigue, malaise, muscle aches, and difficulty breathing. Four cases reported that their symptoms were first associated with spawning operations or were worse on days when spawning was done. Pulmonary function revealed restrictive impairment and reduced diffusing capacity. Chest radiographs revealed diffuse, fine reticulonodular markings.

The first five cases of MWL were initially misdiagnosed as pneumonia, bronchitis, respiratory viral infection, and coronary insufficiency. However, on return to the farm after recovering from a severe attack, the symptoms quickly recurred with equal or greater severity, resulting in referrals to appropriate medical specialists.

Fiberoptic bronchoscopy and transbronchial biopsies were performed on five of the cases. All five had histopathologic findings consistent with HP—interstitial pneumonitis characterized by diffuse infiltration of the pulmonary interstitium by plasma cells and lymphocytes, and by epithelioid noncaseating granulomata with Langhans' cells.

Six of the seven workers left work at the mushroom farm to avoid recurrence of symptoms. The other, who was diagnosed early when his symptoms were still mild, was able to continue working at the farm after transfer to a maintenance shop remote from the main farm building. Once workers were removed from further exposure, their symptoms resolved and did not recur. Chest radiographs also returned to normal, as did pulmonary function, with the exception of one worker who continued to have moderately restricted ventilatory function several months after leaving the farm.

Three of the cases had sera collected for antibody testing during their acute attack, and these three and one other had sera collected after recovery. Sera were also obtained from ten healthy asymptomatic workers employed at the same mushroom farm. Serum precipitins to extracts of antigenic material were measured by counter immunoelectrophoresis (Table II) [Gordon et al., 1971]. No obvious differences were evident between MWL cases and controls. Serum antibody reactions to various microorganisms were also tested using enzyme-linked immunosorbent assay (ELISA) (Table III) [Marx and Gray, 1982]. One case demonstrated reactivity to numerous organisms, but there were no clear and consistent differences in antibodies between cases and controls.

TABLE I. Characteristics of Confirmed Cases of Mushroom Worker's Lung (MWL) in Florida, 1982–1985

Case no.	Sex/age	Race	Smoking status	Job	Tenure	Onset symptoms	Symptoms
1	M/24	W	Ex-smoker	Grower	3 years	04/82	Flu-like symptoms, short of breath, dry cough, fever
2	F/36	W	Smoker	Packer	3 months	10/84	Fatigue, muscle aches, headache, fever, chills, cough, short of breath
3	M/52	W	Ex-smoker	Maintenance	11 years	12/84	Fever, chills, muscle aches, malaise, dry cough, short of breath, wheezing
4	F/54	W	Nonsmoker	Packer	10 years	01/85	Difficulty breathing, chest pain, short of breath, fever, chills
5	F/26	W	Smoker	Office worker	4 months	01/85	Headache, malaise, dry cough, short of breath, fever, chills, sweats, muscle aches
6	M/41	B	Ex-smoker	Wharf/spawning	12 years	04/85	Fever, cough, difficulty breathing, muscle aches, malaise, short of breath, chills
7	M/31	W	Smoker	Maintenance	1 month	08/85	Dry cough, short of breath, fever, chills, muscle aches

TABLE II. Serum Precipitin Reactions to Extracts of Antigenic Material Encountered at the Mushroom Farm, Measured by Counter Immunoelectrophoresis*

	Antigenic material						
Case no.	Chicken manure	Pre-fill	Pre-dip	Pre-spawn	Pre-flush	Spawn	Spawn mate
Recovery serum							
3	+[a]	+	+	+	+	+	+
5	−[b]	+	+	+	+	−	−
6	−	+	+	+	+	−	−
7	+	+	+	−	+	−	−
Total no. positive	2/4	4/4	4/4	3/4	4/4	1/4	1/4
Acute serum							
5	−	+	+	+	+	−	−
6	−	+	+	−	+	−	−
7	+	+	+	−	+	+	−
Total no. positive	1/3	3/3	3/3	1/3	3/3	1/3	0/3
Controls							
Total no. positive	8/10	10/10	10/10	2/10	10/10	2/10	0/10

*Prefill, compost before loaded into trays; Predip, compost before steam and aeration treatment; Prespawn, compost before mushroom mycelia added; Preflush, compost before picking mushrooms; Spawn, mushroom mycelia; Spawnmate, soybean nutrient.
[a]+ = positive reaction.
[b]− = no reaction above control.

RESPIRATORY HEALTH SURVEY OF WORKERS AT THE MUSHROOM FARM: METHODS

After investigating the seven known MWL cases, a cross-sectional industrial hygiene and medical study was conducted at the mushroom farm. The industrial hygiene results are reported separately [Kullman and Sanderson, 1989]. Every current employee at the mushroom farm was asked to voluntarily participate in the cross-sectional health study, which included a symptomatology questionnaire, pulmonary function test, posteroanterior chest radiograph, and serologic testing.

Questionnaire

The questionnaire obtained information on each worker's age, race, gender, smoking history, and employment history both at the farm and elsewhere. The workers were asked whether they had any of the following symptoms while employed at the mushroom farm: chills and/or fever; shortness of breath; cough; fatigue; chest tightness; muscle aches; loss of appetite; unexplained weight loss; runny, stuffy nose; nausea/vomiting; wheezing; and/or numbness in the face or arms. If workers responded affirmatively to one of these symptoms, they were asked to state the approximate date when they first noticed the occurrence of the symptoms, how often the symptom occurred (everyday; sometime every week = frequently; every once in a while = occasionally; or once or twice per year = rarely), what time of day the

TABLE III. Serum Antibody Reactions to Various Microorganisms Measured by Enzyme-Linked Immunosorbent Assay (ELISA) in Mushroom Workers*

	Microorganism[a]											
Case no.	1	2	3	4	5	6	7	8	9	10	11	12
Recovery serum												
3	—	—	1:320	1:80	—	—	1:320	1:160	1:320	1:80	1:80	1:320
5	—	—	—	—	—	—	—	—	—	—	—	—
6	1:160	—	—	—	—	—	—	—	1:80	—	—	—
7	—	—	—	—	—	—	—	—	—	—	—	—
Acute serum												
5	1:320	—	—	—	—	—	—	—	1:640	—	1:160	1:80
6	1:80	—	—	—	—	—	—	—	1:80	—	—	—
7	—	—	—	—	—	—	—	—	—	—	—	—
Controls												
No. positive reactions and median antibody titer	0/10 —	0/10 —	0/10 —	0/10 —	0/10 —	0/10 —	2/10 1:120	0/10 —	6/10 1:120	3/10 1:80	1/10 1:160	2/10 1:80

*Positive reactions are expressed as the highest dilution ratio for which a positive reading was obtained.

[a]Microorganism corresponding to numeral heading: 1, *Micropolyspora faeni;* 2, *Thermoactinomyces vulgaris* I; 3, *T. vulgaris* II; 4, *Thermoactinomyces sacchari;* 5, *Saccharomonospora viridis;* 6, *Thermoactinomyces candidus* I; 7, *T. candidus* II; 8, *T. candidus* III; 9, *Aspergillus fumigatus* I; 10, *A. fumigatus* II; 11, *A. fumigatus* III; 12, *Aspergillus niger.*

symptom began or was made worse (morning; afternoon; evening; night; or unrelated to time of day), and if they had seen a physician because of the symptom.

Spirometry

Spirometry was performed according to American Thoracic Society guidelines [American Thoracic Society, 1979], except that workers' results were eliminated if their two largest FVCs or FEV_1s varied by more than 10%. Five maximal expiratory maneuvers were recorded for each person. A worker's FVC, FEV_1, and ratio of FEV_1/FVC were expressed as percent of predicted value [Knudson et al., 1983]. Spirometry results were compared only within racial categories or adjusted statistically for the effect of race, since predicted values were estimated from a study of white subjects only.

Chest Radiographs

Each chest radiograph was read independently by three radiologists, who interpreted the films without knowledge of subjects' ages, occupations, or smoking histories.

Serologic Analysis of Blood

Sera were analyzed by double diffusion for precipitating antibodies to extracts of 13 different materials used in mushroom growing, 15 species of microbes (two thermophilic actinomyces and 13 fungi) isolated from agar samples collected at the farm, *Agaricus bisporus* mushrooms, *A. bisporus* spores, and the pesticide pyrethrum [Marx and Gray, 1982]. Sera were also analyzed by ELISA for precipitating antibodies to *A. bisporus* spores [Wide et al., 1967] and by radioallergosorbent test (RAST) for immunoglobulin-E (IgE) antibody reaction to *A. bisporus* spores [Pharmacia Diagnostics, 1984].

Case Definitions

For purposes of this cross-sectional survey, the following criteria were used to define abnormalities and categorize workers as possible cases of MWL.

1. Questionnaire responses—To be considered a possible case of MWL by questionnaire responses, a worker had to have reported having (at least occasionally and resolving while away from work on weekends or vacation) two or more of the following symptoms: cough; fever/chills; shortness of breath; chest tightness; muscle aches; fatigue; loss of appetite; and unexplained weight loss.
2. Spirometry results—To be considered a possible case of MWL by spirometry test results, a worker had to have a restrictive ventilatory impairment (i.e., FEV_1/FVC $>70\%$ and FVC less than 80% of predicted) [Knudson et al., 1983].
3. Chest radiograph—To be considered a possible case of MWL by chest radiographic findings, a worker's chest radiograph had to show evidence of diffuse reticular or reticulonodular shadows [Morgan and Seaton, 1984].

RESULTS

From a total of 282 current mushroom workers, 259 (91.8%) elected to participate in the cross-sectional health study. Of these, one participant chose not to undergo spirometry testing, six chose not to undergo radiographic examination, and 32 chose not to have blood drawn for serologic analysis.

TABLE IV. Number of Workers Reporting Symptoms Associated With Mushroom Worker's Lung (MWL)

No. of symptoms	No. of employees (%)	Cumulative no. of employees	Cumulative (%)
Possible cases of MWL[a]			
≥5	7 (3)	7	3
4	14 (5)	21	8
3	16 (6)	37	14
2	17 (7)	54	21
Noncases			
1	49 (19)	103	40
0	156 (60)	259	100

[a]To be considered a possible MWL case, workers had to report having (at least occasionally and resolving while away from work) two or more of the following symptoms: cough; fever/chills; shortness of breath; chest tightness; muscle aches; fatigue; loss of appetite; or unexplained weight loss.

The farm population was relatively young, with half the workers younger than age 31. Males slightly outnumbered females (58% vs. 42%). Asians (27%), mainly from Vietnam, and Hispanics (25%), from various Latin American countries, represented greater proportions in the study population than in the general population. Blacks (10%) and whites (38%) comprised the rest of the studied population. Smokers and nonsmokers each represented 44% of the overall group. Median tenure was 3.7 years, reflecting fairly rapid workforce turnover.

Farm employees were divided into seven work groups: 1) wharf department workers, who prepare the compost trays and operate the tray filling, casing, and spawning lines; 2) growing/watering department workers, who water and check the temperature, moisture content, and environmental conditions of the compost throughout the entire mushroom growing process, and who evaluate the quality of compost ingredients; 3) pickers, who cut the mushrooms from the compost and sort them by size; 4) packing department workers, who wash and package the harvested mushrooms; 5) maintenance workers, who generally work in all areas of the farm to repair and maintain facilities, equipment, or vehicles, but sometimes work exclusively as mechanics in a garage separated from the main farm building; 6) night workers, who clean the farm facilities, monitor growing conditions during the evening and night, and apply pesticides; and 7) office workers, who perform administrative and clerical duties in a typical office environment attached to the main farm building.

Picking and packing work groups were the largest, comprising 68% of the study population. Women worked almost exclusively in the picking, packing, and office areas. White males were generally in supervisory and maintenance positions. The wharf and growing/watering work groups were staffed mainly by young Hispanic males. Asians worked almost exclusively as pickers.

Symptoms

At the time of the survey, none of the 259 workers were experiencing acute symptoms consistent with HP. However, some workers were complaining of one or more of the eight MWL symptoms asked about in the questionnaire, and 54 (21%) were considered possible cases (Table IV). The symptoms most frequently reported by the mushroom farm workers were cough (17%), fatigue (16%), myalgia (13%),

TABLE V. Percentage of Workers Reporting Symptoms Associated With Mushroom Worker's Lung (MWL) by Work Group*

	Wharf	Grow/ water	Pick	Pack	Main- tenance	Night	Office	Total
% ≥ 2 symptoms	36	28	18	18	18	27	0	21
No. of workers	14	18	121	55	28	15	8	259

*$\chi^2 = 5.76$, $p = 0.46$.

chest tightness (11%), and shortness of breath (10%). Possible cases did not significantly differ (chi-square statistic $p > 0.10$) from noncases on the basis of age, sex, race, smoking status, or tenure.

Possible cases and noncases are stratified by work group in Table V. Workers from the wharf, growing/watering, and night groups complained of symptoms somewhat more frequently than workers from other areas. However, this difference in prevalence of complaints did not achieve statistical significance (chi-square statistic $p = 0.46$). None of the eight office workers was categorized as a possible case by questionnaire response.

Spirometry

Of the 258 workers who had spirometry tests, results from 247 were technically acceptable. Approximately 10% ($n = 22$) of the population had spirometry test results consistent with restrictive ventilatory impairment ($FEV_1/FVC > 70\%$ and FVC less than 80% of predicted). Since race-specific predicted values were not used for blacks, Hispanics, and Asians, it is possible that prevalence of abnormal ventilatory function was overestimated.

There were no obvious differences in the prevalence of abnormal pulmonary function or differences in spirometric parameters by work area. The mean FVC, FEV_1, and FEV_1/FVC (each adjusted for age, sex, race, height, and smoking status by analysis of covariance) are presented by work area in Table VI. Also, even within racial categories, possible cases (as defined by questionnaire responses) did not differ from noncases with regard to ventilatory function. Approximately 10% of both the possible MWL cases and noncases had below normal spirometry tests. Adjusted mean spirometric parameters for possible cases and noncases are presented in Table VII. The mean FEV_1/FVC ratio was significantly lower for possible cases, suggesting somewhat more airways obstruction.

Chest Radiographs

None of the 253 chest radiographs was found to have abnormalities consistent with acute or chronic HP.

Serology

Sera from 227 workers were analyzed for precipitin reactions (Table VIII). Extracts from compost materials elicited the most prevalent responses, with workers from every work area having positive reactions to compost extracts. Over 40% of the serologically tested farm workers reacted positively to extracts of stockpiled compost.

TABLE VI. Adjusted Mean Spirometry Parameters Among 247 Mushroom Workers by Work Group (Adjusted for Age, Height, Sex, Race, and Smoking Status)

Spirometry parameters	Work group							p value
	Wharf	Grow/ water	Pick	Pack	Main- tenance	Night	Office	
FVC (liters)	4.04	4.08	3.95	3.84	3.89	4.33	4.26	0.08
FEV_1 (liters)	3.13	3.33	3.23	3.17	3.10	3.32	3.52	0.22
FEV_1/FVC (%)	78.2	81.6	81.9	82.9	80.3	77.2	83.1	0.08
No. of workers	14	18	113	53	28	14	7	

TABLE VII. Adjusted Mean Spirometry Parameters by Mushroom Worker's Lung (MWL) Case Status (Adjusted for Age, Height, Sex, Race, and Smoking Status)

Spirometry parameter	MWL case status		p value
	Noncases	Possible cases[a]	
FVC (liters)	3.96	4.06	0.26
FEV_1 (liters)	3.23	3.21	0.79
FEV_1/FVC (%)	81.9	79.5	0.02[b]
No. of Workers	199	48	

[a]To be considered a possible MWL case, workers had to report having (at least occasionally and resolving while away from work) two or more of the following symptoms: cough; fever/chills; shortness of breath; chest tightness; muscle aches; fatigue; loss of appetite; or unexplained weight loss.
[b]$p < .05$.

However, few workers had positive reactions to extracts of the selected thermophilic actinomyces or fungi. Packers and pickers reacted more frequently to *A. bisporus* extracts, and workers on the night crew reacted more frequently to pyrethrum.

There were no differences between the possible MWL cases and noncases (as defined by questionnaire) in proportion to positive precipitin reactions to the various antigens. There were also no differences between the possible MWL cases and noncases (as defined by spirometry) in proportion of positive precipitin reactions.

Compared to other groups, higher proportions of pickers and packers had positive reactions to *A. bisporus* spores, as measured by double diffusion and ELISA. As measured by RAST, however, the prevalence of antibodies to *A. bisporus* spores was no greater among pickers and packers. Positive reactions to spores were also more frequent among women, Asians, nonsmokers, and workers with higher tenure; but, since women and Asians were most commonly pickers or packers, this association is probably explained by work area exposure. There were no differences between possible cases of MWL and noncases (as defined by questionnaire or by spirometry) in terms of positive serologic reactions to *A. bisporus* spores.

DISCUSSION

A variety of lung reactions and diseases may result from exposure to organic dusts in the farm environment [Rylander, 1986]. Although the symptoms and onset of MWL are similar to organic dust toxin syndrome (ODTS), which has been related

TABLE VIII. Percentage of Mushroom Workers With Positive Precipitin Reactions to Various Antigens by Work Area

	Work area							
	Wharf	Grow/ water	Pick	Pack	Main- tenance	Night	Office	Total
Antigenic materials								
Cotton seed meal	8	—	—	—	—	7	—	1
Spawnmate	8	—	—	3	—	—	—	1
Chicken manure	23	6	9	5	—	14	20	8
Spawn	15	6	12	18	—	—	—	11
Prespawn compost	39	6	24	20	21	14	—	21
Spent compost	15	6	28	13	33	21	60	24
Postspawn compost	46	31	37	33	25	21	40	34
Compost + mycelia	46	31	40	35	21	21	20	35
Stockpiled compost	31	31	47	40	50	43	60	44
Thermophilic actinomyces								
M. faeni	—	6	7	13	17	7	20	9
T. vulgaris	—	6	—	3	4	—	—	1
Fungi								
A. fumigatus	—	6	3	3	4	—	—	2
Penicillium	—	—	2	3	—	—	—	1
Mucor	—	—	2	—	—	—	—	1
Tricoderma sp.	—	—	—	—	—	—	—	—
Neurospora	—	6	1	—	4	—	—	1
Cladosporium	—	—	—	—	—	—	—	—
Doratomyces sp.	8	6	1	—	—	—	—	1
Yeast	—	6	—	—	4	—	—	1
A. bisporus	8	6	17	23	13	—	—	15
Pesticide								
Pyrethrum	8	—	18	15	21	36	—	17
No. of workers	13	16	115	40	24	14	5	227

to airborne endotoxin exposure [Rylander, 1986], the conclusion that seven farm workers had HP is clear. ODTS is often represented by a high prevalence in the exposed population, but only seven cases (prevalence = 2–3%) were reported among the mushroom farm workers. Also, the airborne endotoxin measurements at the mushroom farm were lower than have been reported in silos and grain handling operations wherein exposed workers had developed ODTS [Olenchock, 1988]. In addition, transbronchial biopsies from five of the cases showed histopathologic findings consistent with HP.

Although a specific antigen or antigens were not identified as the cause of the seven MWL cases, causal association between the mushroom farm environment and these MWL cases is clear. Symptoms, pulmonary function changes, and radiographic abnormalities consistent with MWL resolved while away from work, but recurred when the workers returned to the farm.

The cases came from all work areas except the picking and night crew, indicating that virtually every work group was exposed to disease-causing agents. The results of the serologic studies and an industrial hygiene investigation [Kullman and Sanderson, 1989] both demonstrated that farm workers in all work areas were exposed to organic dust constituents capable of causing HP. The pesticide pyrethrum has

been documented to cause HP [Carlson and Villaveces, 1977], but it is an unlikely cause of any of the MWL cases because it was used only by the night workers, and airborne concentrations were low.

It is unknown why most cases in this apparent outbreak of MWL disease occurred between October 1984 and August 1985, but it is speculated that exposures to disease-causing antigens may have been higher during this time period. Company officials reported no process/materials changes during this time period. However, spawn area ventilation practices were changed in May 1985, and likely reduced the airborne organic dust concentrations during spawning in both the spawn area and emission to other farm areas.

Although half of the working population was Hispanic or Asian, only white and black workers were noted to be MWL cases. It is possible that because most Asians and many Hispanics were pickers, they were exposed to lower concentrations of antigens than the rest of the work force. It is also possible that Asian and Hispanic workers may tend to leave employment at the mushroom farm without seeking medical care when they develop symptoms. These workers would effectively remain unknown as cases, since symptoms resolve after leaving the farm environment.

In the cross-sectional study, it was discovered that approximately 20% of the population had at least occasionally experienced symptoms consistent with MWL, and the most heavily exposed workers experienced the greatest prevalence of symptoms. About 10% of the population had below normal pulmonary function tests, but interpretation of the pulmonary function tests is hampered because predicted normal values were not available for blacks, Hispanics, and Asians (together comprising 62% of the study population), and no adequate control group was studied for comparison. No worker was observed to suffer acute respiratory problems at the time of the survey, and the lower pulmonary function tests were not associated with any particular work area or level of MWL symptoms. Cross-sectional pulmonary function tests probably do not serve as useful predictors of workers encountering exposure to antigens or having symptoms of MWL. This is supported by the fact that the cases often had normal pulmonary function in the early stages of MWL, and developed a restrictive pattern only during a severe acute attack. Therefore, periodic spirometry testing may not serve as a useful screening tool for workers at potential risk to MWL.

The serologic analyses provided useful markers of exposure to antigens, but did not serve as predictors of disease status. These tests clearly demonstrated that virtually every employee was exposed to disease-causing antigens at this particular mushroom farm. There is little, if any, evidence that precipitating antibodies have a pathogenic role in HP, but they have been used to identify agents in the environment to which workers were exposed [Burrell and Rylander, 1981].

Unique to this farm was the occurrence of MWL in an office worker. Although all workers at the farm were exposed to numerous antigens capable of causing HP, exposure was much lower in the office than in other work areas. This case demonstrates the importance of individual sensitivity in the development of MWL.

Because of variations in individual susceptibility, several different antigens in wide ranges of concentration may be responsible for causing MWL. At present, there are no tools available to predict who will become sensitized to what antigens and in what concentrations. In this study, spirometry, chest radiographs, and serology were not useful in identifying workers who were experiencing symptoms possibly related to their work environment. All mushroom farm workers should, therefore, be coun-

seled about the risk of developing MWL, and advised on the symptoms and warning signs of MWL and the potential severity of the disease. Precautions should be taken to keep exposures to airborne antigens as low as possible. In addition, the initial misdiagnosis of five of the seven MWL cases underscores the admonition for physicians to routinely inquire about their patients' occupations.

ACKNOWLEDGMENTS

The authors wish to thank Dr. Robert Castellan and Dr. Daniel Lewis for review of the manuscript and helpful comments. This study was conducted in response to a health hazard evaluation request initiated by the mushroom farm. We appreciate the assistance of farm management and the cooperation of farm employees who spent their workday with us.

REFERENCES

American Thoracic Society (1979): ATS statement—Snowbird workshop on standardization of spirometry. Am Rev Respir Dis 119:831–838.

Bringhurst L, Byrne R, Gershon-Cohen J (1959) Respiratory disease of mushroom workers. J Am Med Assoc 171:101–104.

Burrell R, Rylander R (1981): A critical review of the role of precipitins in hypersensitivity pneumonitis. Eur J Respir Dis 62:332–343.

Campbell JM (1932): Acute symptoms following work with hay. Br Med J 2:1143–1144.

Carlson JE, Villaveces JW (1977): Hypersensitivity pneumonitis due to pyrethrum. J Am Med Assoc 237:1718–1719.

Chan-Yeung M, Grzybowski S, Schonell M (1972): Mushroom worker's lung. Am Rev Respir Dis 105:819–822.

Craig D, Donovan R (1970): Mushroom worker's lung. Can Med Assoc J 102:1289–1293.

Fink J (1973): Organic dust-induced hypersensitivity pneumonitis. J Occup Med 15:245–247.

Fink J (1986): Hypersensitivity pneumonitis. In Merchant JA, Boehlecke BA, Pickett-Harner M (eds): "Occupational Respiratory Disease." Washington, DC: DHHS (NIOSH) Publication No. 86-102, pp 481–497.

Gilliland J (1980): Mushroom worker's lung: report of case. J Am Osteopath Assoc 79:411–414.

Gordon MA, Almy RE, Greene CH, Fenton JW (1971): Diagnostic mycoserology by immunoelectroosmophoresis: A general, rapid, and sensitive microtechnic. Am J Clin Pathol 56:471–474.

Jackson E, Welch K (1970): Mushroom worker's lung. Thorax 25:25–30.

Johnson W, Kleyn J (1981): Respiratory disease in a mushroom worker. J Occup Med 23:49–51.

Knudson R, Lebowitz M, Holberg C, Burrows B (1983): Changes in the normal maximal expiratory flow-volume curve with growth and aging. Am Rev Respir Dis 127:725–734.

Kullman G, Sanderson W (1989): Health hazard and technical assistance report. Morgantown, WV: US Department of Health and Human Services; Public Health Service; Centers for Disease Control; National Institute for Occupational Safety and Health; NIOSH report MHETA 85-083-1976.

Marx JJ Jr, Gray RL (1982): Comparison of the enzyme-linked immunosorbent assay and double immunodiffusion test for the detection and quantitation of antibodies in farmer's lung disease. J Allergy Clin Immunol 70:109–113.

Moller B, Halberg P, Gravesen S, Weeke B (1976): Precipitating antibodies against Micropolyspora faeni in sera from mushroom workers. Acta Allerg 31:61–70.

Morgan WC, Seaton A (1984): "Occupational Lung Disease." 2nd ed. Philadelphia: W.B. Saunders Company, pp 564–608.

Olenchock S (1988): Quantitation of airborne endotoxin levels in various occupational environments. Scand J Work Environ Health 14:72–73.

Pepys J, Jenkins P (1965): Precipitin (FLH) test in farmer's lung. Thorax 20:21–24.

Pharmacia Diagnostics (1984): "Rhadebas Rast Radioimmunoassay." Piscataway, NJ.

Rylander R (1986): Lung diseases caused by organic dusts in the farm environment. Am J Ind Med 10:221–227.

Sakula A (1967): Mushroom-worker's lung. Br Med J 3:708–710.

Stewart C (1974): Mushroom worker's lung—two outbreaks. Thorax 29:252–257.

Wide L, Bennich H, Johansson SGO (1967): Diagnosis of allergy by an in vitro test for allergen antibodies. Lancet 11:1105–1109.