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Respiratory disease of workers harvesting grain

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Darke, C. S., Knowelden, J., Lacey, J., and Milford Ward, A. (1976). *Thorax*, **31**, 294–302. **Respiratory disease of workers harvesting grain.** The incidence of respiratory symptoms caused by grain dust during harvesting was surveyed in a group of Lincolnshire farmers. A quarter complained of respiratory distress after working on combine harvesters or near grain driers and elevators, with cough, wheezing, and breathlessness, sometimes so severe as to prevent work. The airborne dust around combine harvesters contained up to 200 million fungus spores/m^3 air with *Cladosporium* predominant while drivers were exposed to up to 20 million spores/m^3 air. *Verticillium/Paecilomyces* type spores, mostly from *Verticillium lecanii*, *Aphanocladium album*, and *Paecilomyces bacillosporus*, were abundant in the dust. Extracts of these species produced immediate weal reactions in skin tests, precipitin reactions with sera, and rapid decreases in FEV_1 when inhaled by affected workers. There were no delayed reactions. Results suggest type I immediate hypersensitivity to the spores although the physical effect of a heavy dust deposit could be important. Drivers could be protected by cabs ventilated with filtered air.

Many reports of respiratory difficulty in workers handling grain have followed the first by Ramazzini (1713)—(Thackrah, 1832; Duke, 1935; Smith, Greenburg, and Siegel, 1941; Dunner, Hermon, and Bagnall, 1946; Jimenes-Diaz, Lahoz, and Canto, 1947; Cohen and Osgood, 1953; Rüttner and Stofer, 1954; Ordman, 1958; Skoulas, Williams, and Merriman, 1964; Williams, Skoulas, and Merriman, 1964; Kováts and Bugyi, 1968; Tse *et al.*, 1973; Warren, Cherniack, and Tse, 1974). Respiratory disease caused by dust during cereal harvesting has attracted less interest, apart from allergy to spores of plant pathogenic rust and smut fungi (Cadman, 1924; Harris, 1939; Jimenez-Diaz *et al.*, 1947) and some saprophytes on the straw (Harris, 1939).

New farming methods and increased mechanization create new dust hazards so, with cereal growing, dust from stationary threshing machines has been replaced by dust raised from combine harvesters or when grain is moved to driers, storage bins or silos.

In 1969, one of us (CSD) learnt of farmers who had suffered respiratory distress after exposure to grain dust before storage. They were unable to return to work during the harvest because further exposure aggravated the symptoms. Between 1970 and 1973, 16 farms of varying size were visited and investigated for such respiratory disease.

METHODS

DISEASE SURVEY After discussion with a local practitioner and a trade union official, a group of farms was visited to the north and east of Lincoln. Five farms comprised about 1200 hectares (3000 acres) each, the other 11 ranging from 120 to 280 hectares (300 to 700 acres). All grew mixed arable crops, including wheat, barley, oats, and peas. Each farm was visited during the spring of 1970, 1971, and 1972, and a full clinical description of the condition was obtained. Table I gives personal and occupational histories of the workers included in the survey. The pattern of the disease was confirmed by additional visits during and after each subsequent harvest period. A complainant was defined as a worker affected by dust generated by the combine harvester, grain elevator, and grain drier.

INVESTIGATIONS

QUESTIONNAIRE The Medical Research Council's questionnaire on respiratory symptoms (1966) was completed by 17 of the 18 complainants and by 48

TABLE I

PERSONAL AND OCCUPATIONAL HISTORIES OF FARM WORKERS INCLUDED IN THE SURVEY

Mean Values	Dust affects Chest	
	Yes (18)	No (60)
Age at interview (yr)	46	46
Number of years in farming industry	31	27
Number of years in farming industry before symptoms	13	—
% Smokers	61	57

of the 60 unaffected men at the initial interview. Questions 1, 3, 6, and 8 were supplemented by putting the same question to the individual but altering the words 'in the winter' to 'in the summer'. The answers have been identified as numbers 2, 4, 7, and 9 (Table II).

In addition, specific questions considered relevant to the clinical picture presented by the complainants were used. These comprised enquiry as to the incidence of sneezing, dryness or soreness of the throat, and the occurrence or increase of cough and sputum in relation to dust exposure. The incidence of wheezing and breathlessness, either separately or combined, was ascertained as well as the presence of chest pain. Finally, an assessment was made as to whether the group of symptoms occurred immediately on exposure or were delayed for some hours (Table III). Not all workers were available when subsequent tests were performed.

LUNG FUNCTION Ventilatory function was assessed using a Wright peak flow meter, and sometimes estimates of the forced expiratory volume in one second (FEV_1) and the forced vital capacity (FVC) were obtained from the 'Vitalograph' or Poulton machines. Base line measurements were made at the first interview and compared with measurements obtained after harvest in one or all of the three years. The peak flow of some workers was also recorded during harvest in short rests from driving the combine harvester. The results were expressed as percentages of average predicted peak flows of individuals according to age and height (Airmed Ltd). Comments on the adverse effects of dust during and after the harvest were recorded for comparison with statements made during the initial questioning.

RADIOGRAPHY A mobile mass miniature radiography unit, based at Wragby, was used to obtain 100 mm chest radiographs of 46 (59%) of the 78 workers surveyed, together with films of 101 other farm workers from the same area. Subsequently full-sized radiographs were taken of 10 (56%) of the group who complained of harvest dust and of others for whom the miniature film was suspect.

PREPARATION OF ANTIGENS Antigens were extracted from fungi isolated from combine har-

TABLE II

RESPONSE TO QUESTIONNAIRE ON RESPIRATORY SYMPTOMS (1966)

	Questions	Complainants (17) %	Non-complainants (48) %
Cough in the morning—winter	1	29	17
Cough in the morning—summer	(2)	47	13
Cough during the day—winter	3	24	10
Cough during the day—summer	(4)	18	6
Bring up phlegm in the morning—winter	6	41	13
Bring up phlegm in the morning—summer	(7)	41	6
Bring up phlegm during the day—winter	8	29	8
Bring up phlegm during the day—summer	(9)	29	6

Questions 1, 3, 6, and 8 are taken direct from the MRC questionnaire (1966).
Questions 2, 4, 7, and 9 are the same questions substituting 'in the summer' for 'in the winter'.

TABLE III

RESPIRATORY SYMPTOMS CAUSED BY GRAIN DUST REPORTED BY A GROUP OF LINCOLNSHIRE FARM WORKERS

	All Subjects		Smokers		Non-smokers		Ex-smokers	
Number	78		43		9		26	
	Per cent		Per cent		Per cent		Per cent	
Asymptomatic	77		79		56		80	
Symptomatic	23		21		44		20	
Immediate		15		14		33		12
Delayed		8		7		11		8
Specific symptoms:*								
Nasal (sneezing)		8		7		22		4
Throat (dry/soreness)		3		2		22		4
Cough (development or increase)		5		5		11		4
Sputum (development or increase)		5		5		22		0
Wheezing		14		26		33		4
Breathlessness		1		0		0		4
Breathless with wheezing		3		3		11		0
Pain		0		0		0		0

* Some patients reported more than one symptom.

vester dust growing on agar culture media as described by Lacey, Pepys, and Cross (1972). The freeze-dried extracts were reconstituted in carbol saline at concentrations of 100 mg/ml for skin tests and 6 mg/ml for precipitin tests. The concentration of reconstituted extract used in bronchial inhalation tests was selected from a series of skin tests on the subject using a series of 10-fold dilutions from a maximum of 10 mg/ml. The initial inhalation test was performed using a dilution that gave a weal smaller than 3 mm diameter, in our tests 0·1 mg/ml. However, this caused only a weak reaction and 1 mg/ml was used subsequently.

SKIN TESTS Sensitivity to standard solutions (Bencard) and to extracts of fungi isolated from combine harvester dust was assessed using prick and intradermal methods. Immediate and delayed responses were recorded in the usual way.

BLOOD TESTS Venous blood was sampled at least once to measure immunoglobulins G, A, M, and E and to test for precipitins against the organisms implicated in farmer's lung, *Aspergillus fumigatus* and organisms isolated from combine harvester dust, by double diffusion in citrate agar. Samples from a supplementary group of farmers from near Sheffield were also tested for precipitins.

BRONCHIAL INHALATION TESTS Tests used a BLB oronasal mask with rebreathing bag connected to a standard Wright's nebulizer. Oxygen or compressed air, at 8 l/min, was used to nebulize 5 ml of antigen while the patient was encouraged to breathe normally. Nebulization of a recorded amount of antigen was divided into three periods of 1, 2, and 2 min with 10 min intervals between each. It was ensured that subjects were taking no drugs that might interfere with the tests. As a precaution, a syringe of adrenalin was drawn up ready for use before any challenge. However, there were no acute systemic reactions necessitating its use.

FEV_1 and FVC were measured three times at 5 min intervals before challenge, once at the end of each 10 min interval, and then 10, 20, 30, 45, and 60 min after challenge, and hourly up to 8 h afterwards. Temperature was recorded hourly and blood was taken before and 6 h after challenge for white blood cells, differential, and wet eosinophil counts.

DUST SAMPLING Air was sampled close to working combine harvesters to determine the spore content generated close to the pick-up reel at the front and the straw discharge chute at the back of the machine. Spore content was estimated using microscope counts of catches in a cascade impactor (May, 1945) and by isolations made with an Andersen (1958) sampler. Suction was supplied by a portable compressed air injector. Slides were prepared and mounted, as described by Gregory and Lacey (1963), and most spores were classified into types illustrated by Gregory (1973). Malt extract agar containing 40 units streptomycin and 20 units penicillin/ml was used to isolate fungi, and half-strength nutrient agar containing 50 μg actidione/ml to isolate actinomycetes and bacteria (Gregory and Lacey, 1963).

The spore dose inhaled by the combine harvester driver was assessed using a Casella personal sampler with a battery-operated pump. The sampling orifice was strapped on to the driver's left shoulder and spores were trapped in a membrane filter. This was cleared in Dioxan (Gurr's) and mounted in Eukitt (O. Kindler, Freiburg, Germany), or mounted directly in glycerol triacetate, for microscopic examination.

RESULTS

CLINICAL FEATURES The response to the MRC questionnaire and the supplementary questions revealed a higher incidence of cough and phlegm in the morning and throughout the day during the winter months in 17 complainants as compared with 48 unaffected subjects (Table II). When the same questions were put to each individual, but related to the summer months, there was an even greater contrast between the complainants and non-complainants. This gives support to the clinical observation that the problem was essentially a summer one.

Nearly a quarter of the farm workers examined were affected by grain dust (Table III), particularly while driving combine harvesters or working in confined spaces in grain bins or near grain driers and elevators. Symptoms usually developed only after several years working on farms (Table I). The clinical picture suggested a violent reaction to an inhaled irritant. The presenting symptoms and evolution of the illness were uniform, though disability varied. The individual might complain of many symptoms or only one of those listed (Table III). Sufferers felt congested in the throat during the first day's harvesting; then a mild, irritable but unproductive cough developed during the evening, with a tight feeling across the chest; later they awoke breathless and wheezy with bouts of coughing. Respiratory distress increased throughout the harvest period, breathing became difficult and laboured leading to physical exhaustion, and sometimes other work had to be found. Later, even light exposure to dust near storage bins and driers provoked symptoms and these usually recurred during subsequent harvests. Irritation of the eyes, ears, nose, and skin was minimal and unrelated to pulmonary sensitivity. Barley, wheat, and oat dusts all caused similar respiratory distress, but the worst symptoms were caused by 'dirty' grain with saprophytic fungal colonization.

The symptoms suggested a type I immediate hypersensitivity reaction with bronchospasm, but sometimes delayed breathlessness without wheezing suggested alveolar involvement and type III delayed hypersensitivity. Symptoms soon disappeared after the end of exposure.

Workers, both atopic and non-atopic, were affected on both small and large farms, smokers and non-smokers in similar proportions. The incidence of winter bronchitis or other respiratory infections was unrelated to the incidence of the complaint, although winter cough and phlegm was more common in complainants than in non-complainants (Table II). However, during summer, the incidence of morning cough in complainants nearly doubled, while in non-complainants both cough and phlegm declined.

RESPIRATORY FUNCTION TESTS Peak flow measurements varied widely in both groups (Table IV). No significant changes occurred in workers tested during the harvest period and again later nor during the course of the working day.

Measurements of FEV_1, FVC, and the ratio between them in 39 subjects indicated no significant restrictive or obstructive ventilatory defects, but serial measurements over 24 h are necessary to exclude these as symptoms often occurred at night.

TABLE IV

% OF PREDICTED PEAK FLOW VALUES PRE-HARVEST

	Complainants (18)	Non-complainants (60)
Number tested	11	49
% of predicted value:		
100+	0	3
90–99	2	8
80–89	2	16
70–79	3	11
60–69	4	5
50–59	0	5
40–49	0	0
30–39	0	1

RADIOLOGY No radiographic changes were found except for nodular opacities compatible with occupational lung disease on standard radiographs from two complainants.

SKIN TESTS Immediate type I weal reactions were produced in most complainants and many non-complainants both to routine Bencard skin-testing solutions and to extracts of fungi isolated from the combine harvester dust (Table V). Complainants reacted most often with Bencard grass pollens, tree pollens, hay dust, mixed moulds (A13, but not M10 or M11), and *Candida albicans*

TABLE V

IMMEDIATE REACTIONS IN COMBINE HARVESTER OPERATORS TO SKIN TESTING WITH DIFFERENT SOLUTIONS

	Complainants %		Non-complainants %	
Bencard extracts				
No. tested	17		44	
No. reacting to one or more extracts	10	(59·0)	12	(27·7)
Grass pollens	6	(35·3)	0	(0)
Shrub pollens	3	(17·6)	0	(0)
Tree pollens	4	(23·5)	2	(4·5)
Hay dust	4	(23·5)	1	(2·3)
Mixed moulds	5	(29·4)	4	(9·1)
Alternaria alternata	3	(17·6)	3	(6·8)
Aspergillus fumigatus	3	(17·6)	0	(0)
Botrytis cinerea	3	(17·6)	0	(0)
Candida albicans	5	(29·4)	0	(0)
Cladosporium fulvum	2	(11·8)	2	(4·5)
C. herborum	1	(5·9)	4	(9·1)
Fusarium spp	3	(17·6)	16	(36·4)
Mucor spinosus	1	(5·9)	4	(9·1)
Extracts of fungi from dust				
No. tested	14		25	
No. reacting to one or more extracts	5	(35·9)	8	(32·0)
Aphanocladium album	5	(35·7)	5	(20·0)
Botrytis sp	2	(14·3)	0	(0)
Cephalosporium sp	2	(14·3)	0	(0)
Cephalosporium sp	1	(7·1)	0	(0)
Fusarium culmorum	2	(14·3)	1	(4·0)
Fusarium sp	1	(7·1)	0	(0)
Hyalodendron sp	2	(14·3)	0	(0)
Mucor spinosus	1	(7·1)	0	(0)
Mucor sp	3	(21·4)	0	(0)
Paecilomyces bacillosporus	3	(21·4)	0	(0)
P. farinosus	6	(42·9)	7	(28·0)
P. ochraceus	3	(21·4)	0	(0)
Sporobolomyces sp	1	(7·1)	0	(0)
Verticillium lecanii	5	(35·7)	7	(28·0)

and with *A. album*, *Mucor* sp, *Paecilomyces farinosus*, *P. ochraceus*, and *V. lecanii* among the fungi from combine harvester dust. Non-complainants reacted most frequently to the Bencard *Fusarium* extract and only to *A. album*, *F. culmorum*, *P. farinosus*, and *V. lecanii* from combine harvester dust. No delayed reactions were found. Four of the six workers complaining of delayed pulmonary symptoms caused by grain dust gave immediate reactions to several extracts, usually including *A. album*, *V. lecanii*, and *P. farinosus*.

SERUM IMMUNOGLOBULINS AND PRECIPITIN TESTS Serum samples from 22 individuals in 1972, another 18 in 1973, and from 14 farm workers near Sheffield were tested for immunoglobulins and the presence of precipitins. Seven (13%) had significantly increased immunoglobulins but only two (4%) had IgE in excess of 1000 IU/ml. Twelve (22%) showed decreased levels of serum IgA.

Precipitins to farmer's lung hay antigens were not found, but those to *A. album*, *V. lecanii*, *P. farinosus*, and *P. bacillosporus* were frequent (Table VI). Their incidence was similar in both complainants and non-complainants from Lincolnshire and in the Sheffield group. Changes in six workers tested in both years were slight; three showed an additional reaction and one reaction was lost. *A. album* and *V. lecanii* showed cross reactions of partial identity but cross reactions with *Paecilomyces* and *Fusarium* species were absent.

Precipitin reactions were correlated neither with amounts of serum immunoglobulin nor with positive skin tests. Most sera reacted to at least two and often three antigens, but only two individuals also had increased IgE. Positive precipitin and skin tests to *A. album*, *P. farinosus*, and *V. lecanii* occurred only occasionally in the same individual. Only one of the four people tested who had delayed symptoms at harvest also had precipitins to any fungi.

BRONCHIAL INHALATION TESTS Five selected complainants with skin sensitivity to the test fungi, one with precipitins also, inhaled aerosols of *A. album*, *P. farinosus*, *V. lecanii*, and a mixture of all three.

TABLE VI

INCIDENCE OF PRECIPITINS IN FARM WORKERS

	Lincolnshire Farm Workers		Supplementary Group*
	Complainants	Non-complainants	
No. tested	11	23	14
% with precipitins	64	74	64
% with precipitins to:			
Aphanocladium album C1802	55	61	64
Fusarium culmorum C1812	—	—	7
Paecilomyces bacillosporus C1659	18	26	25
Paecilomyces farinosus C1811	64	52	57
Verticillium lecanii C1803	55	61	57

* A group of farm workers from the Sheffield area.

Within 1 h of inhaling the test solution all felt tight in the chest and their FEV_1 had significantly decreased, but they recovered rapidly and symptoms did not recur. Control carbol-saline aerosol caused no reaction. Two non-complainants with precipitins to the test fungi were unaffected by inhaling the antigens.

AIR SAMPLING RESULTS Airborne dust from combine harvesters was composed mostly of fungus spores and fragments of fungal hyphae. Spores numbered from 3·5 to more than 200 million/m^3 of air (Table VII) and hyphal fragments from 0·7 to 43·6 million/m^3 air. However, to prevent too dense deposits, cascade impactor samples were short (10 s) and some variability could be caused by changing wind direction. Dust was generated both by the pick-up reel and at the rear of the machine where straw was discharged. On average, 40% more spores were found at the rear of the machine than near the reel, although sometimes the difference exceeded 150%.

Drivers were exposed to fewer spores than occurred close to the sources of dust, especially in 1972 when the weather was cool and cross winds were strong. Concentrations at driving level rarely exceeded 20 million spores/m^3 of air, although a few small hyaline spores, with refractive index close to that of the mountant, were found, suggesting this is an underestimate. In 1970 and 1971 the weather was warmer with less wind than in 1972 and dust sometimes rose in a cloud above the combine harvester. Spores were then numerous on the personal sampler filters.

Similar spore and colony types were found each year, *Cladosporium* always predominant and *Alternaria* abundant but least common following the cool harvest in 1972 (Tables VIII and IX). Other spore types varied more in abundance between harvests and cereal crops, but the relative frequency of different colony types could not be determined accurately because plates were overloaded. The small hyaline spores of the *Verticillium/Paecilomyces* group were least abundant in 1972, and scarce also in barley dust in 1971, but colonies of *V. lecanii* were still grown from all samples (Table IX). Actinomycetes and bacteria usually accounted for less than 10% of the total spores in the dust. Although bacteria were sometimes common on Andersen sampler plates, actinomycetes were few.

Dust from grain being handled after combining, but before storage, was similar to that found before. Up to 75 million spores/m^3 of air were

TABLE VII

CONCENTRATION OF SPORES (10^6 SPORES/m^3 AIR) IN COMBINE HARVESTER DUST CLOSE TO THE SOURCES AND AT THE DRIVING POSITION WHILE HARVESTING GRAIN

	Cascade Impactor				Personal Sampler on Driver	
	Carried by Pick-up Reel		Carried behind Machine			
	Range	Mean	Range	Mean	Range	Mean
1970	—	—	49·9–117·4	72·0	3·8–19·2	13·1
1971	—	—	12·6–110·5	57·2	0·6–34·0	18·7
1972	27·7–86·9	53·4	3·5–212·6	74·9	0·5–14·6	4·2

TABLE VIII

RELATIVE ABUNDANCE OF DIFFERENT SPORE TYPES IN COMBINE HARVESTER DUST

	1970		1971		1972	
Crop	Various	Wheat	Barley	Oats	Wheat	Barley
No. of samples	5	21	3	6	15	16
	Percentage of total spore content					
Spore type:						
*Cladosporium**	56·0	46·8	45·7	58·8	65·2	75·4
*Alternaria**	27·8	23·8	17·9	9·0	12·5	8·9
*Epicoccum**	1·8	0·9	1·2	0·5	1·4	0·3
*Botrytis**	3·8	0·3	—	0·3	1·7	0·8
*Verticillium/Paecilomyces**	8·9	5·8	1·5	7·2	2·3	2·7
Puccinia* (Rusts)	0·3	2·7	3·9	0·1	0·7	0·7
Ustilago* (Smuts)	0·2	1·9	0·2	0·4	9·9	0·5

*Reported as allergens (Hyde, 1972).

TABLE IX
FREQUENCY OF ISOLATION OF DIFFERENT COLONY TYPES FROM COMBINE HARVESTER DUST

Colony Type	% of Air Samples yielding Colonies
Verticillium spp*	100
Cladosporium spp*	100
Penicillin spp*	97
Hyalodendron spp*	92
Alternaria spp*	90
Botrytis cinerea*	66
Paecilomyces spp*	61
Mucor spp*	55
*Epicoccum purpurascens**	53
Fusarium spp*	42
*Aureobasidium pullulans**	40
Acremoniella atra	34
Yeasts*	32
Gonatobotrys sp	29
Sporobolomyces spp*	26
Papularia sp	16
Sporotrichum sp*	11

In fewer than 10% of samples: *Stephanosporium cerealis*, *Aspergillus fumigatus*,* *Helminthosporium* sp,* *Chaetomium* sp,* *Torula* sp,* *Trichoderma* sp,* *Gliocladium* sp,* *Phoma* sp*.
* Reported as allergens (Hyde, 1972).

found when trailers were unloaded and 12 to 30 million spores/m³ of air close to grain driers in farm buildings. By contrast, only 1·4 million spores/m³ of air were found above the grain in a ventilated grain bin.

DISCUSSION

More occupations are being discovered where exposure to fungi and their spores leads to various forms of allergy (Emanuel, Wenzel, and Lawton, 1966; Riddle *et al.*, 1968; Weck, Gutersohn, and Bütikofer, 1969; Avila and Lacey, 1974). In Britain many farm workers suffer respiratory distress during harvesting, but not all complain. Persistent cough and phlegm occurred more often in complainants than in non-complainants, but unexpectedly workers who stated that they were unaffected by grain dust more often had breathlessness worse than grade 2. Cough, wheezing, and breathlessness were all much more common in non-smokers than in comparable unexposed populations, but, surprisingly, these symptoms were not enhanced in smokers. The tests of respiratory function showed no evidence of ventilatory impairment during harvesting, but frequent peak flow measurements during harvesting are necessary to prove this.

All workers harvesting and drying grain were exposed to concentrations of fungus spores many times greater than those usual in outdoor air, where 10^6/m³ of air is exceptional. Such exposure throughout the working day presents the lungs with a heavy load to clear. This might have physical effects on farm workers, but most damage seems to be caused by disease resulting from hypersensitivity. Most affected workers react at once, complaining of persistent wheezing suggesting a type I immediate reaction leading to varying degrees of airway obstruction. This agrees with the prevalence in the group of immediate skin reactions to extracts of known allergenic fungi abundant in combine harvester dust (Hyde, 1972).

Occasionally, symptoms developed slowly after exposure, and complaints of breathlessness, combined with some constitutional upset, suggested an Arthus type III allergic response to inhaled antigens. However, there were no delayed reactions from inhalation challenge tests, and delayed skin reactions were not recorded, nor was there evidence of precipitins to *Aspergillus fumigatus* or the organisms that cause farmer's lung and few reactions to the 17 other extracts of commonly occurring fungi. By contrast, there were often precipitins to isolates of *V. lecanii*, *A. album*, *P. farinosus*, and *P. bacillosporus* from the combine harvester dust. Precipitins indicate only that an individual has been exposed to a particular antigen. Provocation inhalation tests confirmed that specific fungi in grain dust could cause the condition. Inhalation of an aerosol of the fungus extract to which the individual was skin sensitive provoked symptoms resembling the natural condition. Five subjects developed variable degrees of airway obstruction that subsided quickly after withdrawal of the aerosol.

Few of the spores were as small as those of the actinomycetes involved in farmer's lung, but most were small enough to reach the respiratory bronchioles and many might reach the alveoli. Spores classified as *Verticillium/Paecilomyces* type and produced by fungi such as *V. lecanii*, *A. album*, and *P. farinosus* were only 1–3 μm in diameter and up to 5 μm long and so were well suited to penetrate to the alveoli. *Cladosporium* and other common fungi had spores small enough not to be trapped in the nose but that were deposited in the bronchi and bronchioles, so perhaps accounting for the scarcity of hay fever and other nasal symptoms and the frequency of a bronchospastic response. Although the disability was generally mild, sufferers were concerned that permanent lung damage might result from repeated attacks, as in farmer's lung. Two individuals had abnormal chest radiographs, but generally no evidence of permanent change was shown by clinical, functional or radiographic investigations.

It is difficult to prevent fungi sporing on cereal crops; fungicides or resistant varieties may decrease pathogens, but most spores come from fungi growing saprophytically on the straw and ear as the grain ripens and may be only slightly affected by earlier fungicide application. Premature death of crops, often resulting from root diseases, may increase these fungi, but they are dependent on dew and rain for growth. At this stage application of fungicides would be undesirable, expensive, and damaging to the crop. Earlier harvesting with greater reliance on driers would have only a marginal effect.

A more promising way to decrease respiratory diseases is to isolate the farm worker from the dust by advising him to wear a respirator, by fitting cabs to combine harvesters or by providing a curtain of filtered air around the operator. Respirators are unpopular because of resistance to breathing and discomfort, particularly if the weather is warm. Cabs and 'air curtains' restrict the movement and view of the operator, so some compromise between safety and comfort may be necessary. Exposure of drivers to airborne dust might also be decreased by harvesting across the wind and by design modifications to direct more dust away from the driver. Closer liaison between agricultural engineers, microbiologists, and doctors is necessary to reduce the risks of exposure and to reverse the trend towards increasing dust hazards with increasing mechanization. Farm workers must also be taught about the risks and how they may be prevented or avoided.

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