The Health Effects of Agricultural Production: I. The Health of Agricultural Workers

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AGRICULTURE is the only industry in which humans apply large quantities of synthetic chemicals directly and purposely to the environment. Pesticides are injected into the land, mixed with water for irrigation, and sprayed into the air; all of these compounds are specifically utilized for their properties as biocides.

Only belatedly in the history of chemical agriculture have we begun to evaluate the potential costs of these practices for human health. In fact, we have only recently begun to contemplate the health effects of other aspects of agricultural production. The economic objectives of agricultural producers shaped the reorganization and industrialization of agriculture, the evolution of new cultivation practices replacing hand labor with machines or chemicals, the design of machinery, the development of pesticides and other chemicals, and the provision of housing, water and basic hygiene facilities for agricultural workers. Neither the producers nor agricultural scientists questioned the potential impact of these practices on the health of agricultural workers or on the larger community and physical environment.

Populist and other small farmer movements have periodically called into question the ethics and values implicit in the dominant mode of agriculture, in some cases protesting practices which they experienced as damaging to their health: exhausting physical labor for fourteen and sixteen hour days, low pay, ramshackle housing, nonexistent sanitation facilities and polluted drinking water, and crippling tools like "el cortito," the short handled hoe. Yet agricultural research and development activities within the land grant institutions and field research stations failed to address these problems.

In the 1960s, a new wave of farmworker organizing coincided with the emergence of public concern about pesticide residues in the environment. Pressure for improved environmental protection led to legislation creating

the Environmental Protection Agency in 1970. Among other charges, the EPA registers agricultural chemicals for use and must enforce or delegate enforcement of use restrictions. With the Food and Drug Administration, which monitors food products for pesticide and other contaminants, and OSHA, which has very limited responsibility for the enforcement of health and safety regulations in agriculture, the EPA shares regulatory responsibility for the impact of agricultural practices on the health of agricultural workers and that of the general public.

This article addresses the potential health impact of current agricultural practices, the regulatory approaches to pre-market and subsequent use evaluation of agricultural materials and equipment, and the need for integration of public health concerns into agricultural research and development. In studying the health externalities created by agricultural systems, there are two human "target" populations to consider: the community at large, exposed to pesticide contamination in drinking water, residues in food, and occasionally to drift from aerial application; and the agricultural workers, who face more intensive chemical exposures as well as health and safety problems related to the machinery used, the physical environment and strenuous labor, and to biologic agents such as plants and infectious organisms.

Part I reviews available information on the health of agricultural workers, data and criteria used to evaluate agricultural production materials such as pesticides for their potential health and safety effects before registration for use, and current public health monitoring of the health status of agricultural workers. Part II describes the impact of current production practices on the health of the general population: exposure to agricultural chemicals in the air as drift from treated fields, in drinking water, and as food residues; the resulting population body burdens; and associated health effects.

THE INDUSTRIALIZATION OF AGRICULTURE

Public health developed as a primarily urban phenomenon in this country, as a response to infectious disease transmission in the dense populations of new industrial cities. At the same time the rural population was beginning a precipitous decline; from 1840 to 1970, the non-urban population fell from 90% to 25% of the nation, while those living and working on farms dropped from 42% to less than 5% of the population. As a result, public health and the field of occupational health have been slow to develop an analysis of agricultural health hazards, and have barely noted the impact of

industrialization on the nature of agricultural work itself. Family farms have been consolidated into agribusinesses with hired employees, frequently seasonal or migrant, and differing in class, racial and ethnic characteristics from the original farming community. Elements of industrialization in agriculture such as the subdivision and specialization of tasks, mechanization, and the centralization of decision-making alter the traditional relationship of the farmer to the land, change the economic value of farm labor, and profoundly affect the organization of the agricultural workforce. The health effects of such changes have been studied in urban populations, but rarely in agriculture, despite a wealth of anecdotal evidence that the impact has been profound. This paucity of research has had a particularly crippling effect on attempts to regulate agricultural practices.

CHANGES IN AGRICULTURAL PRODUCTION PROCESSES

The Increasing Role of Hired, Seasonal and Migrant Labor

Although estimates of the total labor force vary in agriculture more than any other sector, 4 to 5 million persons probably work in agriculture as their primary means of earning a living. Hired, non-family farmworkers constitute between one-third and one-half of those primarily employed in agriculture. As the total farm population has declined in the United States, the proportion of hired farmworkers has risen rapidly; approximately half of all farmworkers are seasonal. Seasonal workers are at greatest risk for occupational hazards in agriculture, because they are concentrated in high-risk crops and activities (1).

Of the one billion pounds of pesticides used annually in agriculture in the U.S., 800 million pounds are applied to approximately 20% of the total crop acreage (2); most of these crops involve seasonal field labor. More than 50% of seasonal workers are hired for harvesting operations, which involve contact with foliage during high pesticide application periods; of the 27% which work in the cultivation of crops, more than one-third work in cotton, a crop which uses a very high rate of pesticide applications(1). There is also a geographic concentration of the workforce at highest risk: more than 50% of hired farmworkers on farms employing more than 10 workers are found in just two states, California and Florida, and 65% are employed in the production of vegetables, fruits, nuts, tobacco or sugar. Two-thirds of all vegetables are produced in California, Idaho, Michigan, Texas and Washington; California produces almost one-half of all fruit in the U.S., Florida another 20%. This pattern of seasonal and

geographic concentration is paralleled to a lesser extent by agricultural services (applicators, machinery operators and other non-field production workers) (3).

Mechanization

The mechanization of agriculture has resulted in significant decreases in occupational injuries (both in absolute terms, by replacing workers, and as a rate, because many hazardous hand labor processes have been mechanized). Mechanization has also resulted in unemployment for large numbers of farmworkers, however, and has been accompanied by other changes in agricultural production with more adverse effects on agricultural worker health. For example, the development of reduced tillage and no-till cultivation requires herbicides to kill existing vegetation prior to planting. Reduced cultivation also encourages increased insect populations and disease, resulting in increased use of chemicals to control the pests. As each new stage in agricultural technology research unfolds, the potential effects of such interrelationships on worker or general community health are rarely contemplated. As some technologies have proved themselves economically counterproductive, the adoption of alternative integrated pest management approaches including lower use rates for pesticides may incidentally serve to benefit the health of workers as well.

Agricultural Chemical Usage

The pattern of chemical use within agriculture has changed markedly since World War II. The organochlorine pesticides first used as antimalarials in the war were widely and intensively used in the 1950s. In the 1960s, they were largely replaced by the organophosphate and carbamate compounds, and later by a growing number of other chemicals such as the pyrethroids. The herbicide use rate doubled in the years 1966–1980, as farmers replaced mechanical cultivation with chemical weed control, and herbicides now account for two-thirds of the total poundage by active ingredient of all pesticides used in the U.S. In the same time period, insecticide use rate has been halved and fungicide use has decreased substantially. Total pesticide usage in the United States has reached a plateau, and significant growth is expected only in exports to developing nations (4).

In 1980, more than 45,000 individual products containing more than 1500 active ingredients were registered for use as pesticides by the EPA (5). Approximately 2.5 billion pounds of active ingredients are used annually in the United States, but more than half of this consists of chlorinated

compounds used for water treatment (anhydrous chlorine, chlorine dioxide, sodium hypochlorite). Approximately 1 billion pounds, containing slightly over 600 active ingredients, account for most chemicals used in agriculture. The general category "pesticide" includes chemicals used as insecticides, herbicides, fungicides, rodenticides, acaricides and other biocides; an even greater number of "inert" ingredients (called inert because they are not active against the target species, although they may have adverse health effects on humans) are also used in agricultural chemical formulations. Of the 45,000 individual products registered federally, not all are currently or widely used and the number registered for use in most states is much lower (4).

EVALUATION OF IMPLEMENTS AND MATERIALS PRIOR TO USE

In the USDA *Agricultural Research Service Program Plan*, the objectives of the major federal agricultural research program are outlined in some detail, including the development of equipment, pest control methods and materials, improved nutrition, animal husbandry, and more efficient work processes. Considerations of farmworker health and safety or of consumer health effects are not substantially addressed in the objectives, nor in the elements by which they are to be approached (6). This is indicative of the lack of coordination between researchers developing agricultural production technology and those studying the health of workers or communities. There is, for example, no systematic or regulated review of agricultural tools and machinery for their impact on occupational health and safety before their introduction into use. The most significant exception to this pattern is the pre-registration evaluation of pesticide chemicals for toxicologic effects.

Evaluation and Registration of Agricultural Chemicals

The Federal Insecticide, Fungicide and Rodenticide Act (also known as FIFRA, or the Federal Environmental Pesticide Control Act, PL 92-516) designates the Environmental Protection Agency as the federal body responsible for registering and regulating the use of pesticides in the United States. The EPA is also charged with enforcement of these regulations, and with conducting research on the toxicologic, environmental and public health impacts of pesticides.

When the federal registration of pesticides was initiated in 1954, the only data required of manufacturers was that for acute toxicity (the LD/50, or lethal dose for 50% of animals exposed) and subacute toxicity (adverse

effects of chronic exposure over a short time period, usually 90 days). Chronic feeding studies for oncogenicity (tumor induction) were first required in 1963, and studies on reproductive (fertility), teratogenic (birth defects) and mutagenic (genetic changes) effects were not required until 1970. The test protocols required for carcinogenicity, reproductive, teratogenic and mutagenic effects were strengthened in the 1978 FIFRA amendments and again in Proposed Data Requirements published by the EPA in 1982.

Data Gaps. When the responsibility for registration and tolerance-setting was transferred to the EPA in 1972, all pesticides currently in registration and all tolerances set for these pesticides were based on limited acute and subacute toxicity data. The need for adequate data on the potential reproductive, mutagenic and teratogenic effects of these compounds was considered a priority. Congress directed the EPA to put all such pesticides through a re-registration process requiring registrants to submit studies addressing these concerns. Approximately 600 of the 1200 pesticide active ingredients now in use were registered prior to the 1970–1972 amended study requirements, and "data gaps" for these pesticides have been a subject of concern. In 1982 the House Agriculture Subcommittee on Department Operations, Research and Foreign Agriculture released a Staff Report on EPA's Pesticide Program, comparing information held by EPA on each active ingredient with the data required under FIFRA law (7):

- 79 to 84% of active ingredients currently registered and used commercially lacked adequate oncogenicity studies.
- 90 to 93% of active ingredients currently registered lacked adequate mutagenicity studies.
- 60 to 70% of active ingredients currently registered lacked adequate teratogenicity studies.
- 29 to 47% of active ingredients currently registered lacked adequate reproductive studies other than teratogenicity, such as fertility effects.

The National Research Council, in a major review of available toxicologic data on commercial chemicals published this year, found that no toxicity data was available for 38% of 3,350 pesticides and inert ingredients of pesticide formulations listed. Available toxicity data was judged below the minimum required for assessment of toxicity in 26% of cases, adequate for a minimal assessment in 2% of cases, for partial assessment in 24% and complete assessment in only 10% of cases (8). Moreover, because new

chemicals are put into production each year, we are losing ground on the proportion of pesticides for which adequate testing has been done.

Quality of Data Submitted. A further problem in the evaluation of pesticides for registration has been the quality of data submitted for the registration of new products. Public attention was first drawn to this issue when a commercial toxicologic laboratory, Industrial Bio-Test Laboratories, was discovered to have provided inadequate or falsified data to the EPA. The laboratory was the largest private commercial toxicologic unit involved in pre-registration testing, and the registration of more than 200 pesticides was found to be based in part on IBT data, including 90 pesticides intended for use on food crops (9). Of 801 chronic health effects studies submitted to EPA, only 3% were found to be valid and sufficient to support registration (10). Although the IBT studies are now being repeated for re-submission, this episode identified marked deficiencies in EPA's Laboratory Audit Program. At the time of the IBT scandal, the Program employed only one full-time professional; with a current staff of four and responsibility for auditing all laboratories submitting data on all toxic chemicals, including pesticides, the staff is still unequal to this oversight role.

EPA Review. The same staffing shortages which hamper the EPA Laboratory Audit Program also affect the internal review process for evaluation of toxicologic data submitted for product registration. When attention was drawn to several cases in which EPA scientific reviewers were directly incorporating information submitted by manufacturers in "cut and paste" operations, the Battelle Memorial Institute was asked to conduct a study of this problem at the EPA (11). Thirty-three percent of the 578 EPA reviews audited by Battelle were drawn directly from registrant-submitted data without independent analysis. This is a particularly critical issue because there has been no public access for independent review of studies submitted to the EPA for product registration. The FIFRA amendments in 1978 in fact addressed this problem, and mandated public access; this was not implemented until the spring of 1984 because of a court challenge by Monsanto on the basis of trade secrets protection.

Once a pesticide is registered for use, subsequent findings of toxicologic effects meeting one of the risk criteria in federal regulations may trigger an RPAR (Rebuttable Presumption Against Registration) review. EPA has moved slowly both in placing pesticides in review (Kelthane, for example, was found to be carcinogenic in mice and rats by NCI in 1978, meeting one of the criteria for review, but was not placed in RPAR until the spring of 1984), and in bringing RPAR reviews to completion.

ASSESSMENT OF THE HEALTH AND SAFETY OF AGRICULTURAL WORKERS

Farmworkers are specifically excluded from key labor laws, from almost all federal and state occupational safety and health laws and regulations, and in half the states in the U.S., from the workers' compensation system as well. Because of this, most of the information sources on working conditions, exposures, and health effects which are available for industrial, service, professional and other workers are not available for agricultural workers. In states where agricultural workers are not covered by workers' compensation, physicians lack incentives to report work-related injuries or illnesses, and are particularly unlikely to report occupational illness among field workers. Even in California, the only state to require that physicians report all possible pesticide-related illnesses to a County Health Officer within 24 hours (with a $250 fine for non-compliance), the state Department of Health Services estimates that only 1% of all pesticide-related illness among farmworkers is reported (12).

Exposure Data

The 1970 Williams-Stieger Act which created OSHA, and subsequent inter-agency agreements with the EPA, specifically excluded farmworker exposure to pesticides from OSHA surveillance and enforcement programs. The EPA nationally does not conduct field monitoring of agricultural worker exposure except for research purposes. Enforcement of EPA regulations and investigation of exposure incidents has been delegated to state departments of agriculture.

The National Institute for Occupational Safety and Health (NIOSH) conducted a survey of worksites in the U.S. from 1972 to 1974. This survey, the National Occupational Hazards Survey (NOHS), did not include farmworkers but did include agricultural services workers in the Standard Industrial Classification two-digit code '07'; approximately half way through the survey, the scope was further restricted to Standard Metropolitan Statistical Areas (SMSAs) only.

In 1982–83, a second NIOSH survey entitled the National Occupational Environmental Survey (NOES) was conducted, also including agricultural services but not production workers. Of 22 worksites visited in the '07' SIC code, 2 were in crop preparation services, 10 were veterinarians, 8 were lawn and garden treatment services, and 2 ornamental plant nurseries. Rural areas were included. This data is still being analyzed, but preliminary

findings, when NOHS/NOES observations of exposures are cross-indexed with information in the Registry of Toxic Effects (RTECS), indicate that agricultural services workers are potentially exposed to a total of 175 chemicals which are potentially carcinogenic, mutagenic, teratogenic, or acutely toxic; 45 of these are carcinogenic, mutagenic, teratogenic, or some combination thereof. SIC 07 is within the upper one-third of all industries for relative health risk considering only these four health risks, according to the NIOSH model for identification of high risk occupational groups described here (13).

The California Department of Food and Agriculture (CDFA) monitors worker exposure when suspect or high-toxicity pesticides are first placed in registration. For example, chlordimeform is a potent carcinogen in animals and has caused severe cystitis (bladder inflammation) in humans; when it was re-registered for use in California in 1982, the CDFA required extensive urine sampling. The CDFA also does routine monitoring of pesticide foliage residues and worker exposure (air and dermal patch sampling, among other methods) in order to determine the adequacy of Departmental regulations and enforcement. This has provided a large body of specific data on worker exposure in California; comprehensive testing programs of this nature do not exist in other agricultural states.

All of these systems are concerned with estimating exposures to chemicals. Information on exposure to hazardous machinery (tractor hours, days of work with the short handled hoe, etc.), to biologic agents, to noise, and to other occupational hazards is not systematically collected by public health or agricultural agencies.

The General Health Status of Agricultural Workers

The general health status of many agricultural workers—not solely seasonal and migrant workers—is already significantly compromised by factors which are indirectly job-related but nevertheless derivable from occupation. In particular, low income and relative geographic and social isolation contribute to deficiencies in nutrition, housing, sanitation, education, and in access to preventive and medical care services.

Most of these factors exacerbate occupational health risks. Housing in or near fields exposes workers and their families to pesticide spray drift. Lack of adequate sanitation is associated with an increased prevalence of parasitic and infectious disease, and public health studies and migrant clinic reports have documented this pattern among migrant farmworkers. Lack of potable water in the fields and in some housing forces workers to drink irriga-

tion water which is frequently contaminated with pesticide run-off and is increasingly used as a direct method of pesticide application. Lack of education makes it difficult or impossible for workers to read pesticide labels and posted signs, a problem which is even more serious for the increasing number of non-English speaking ethnic groups now working in U.S. agriculture.

Nutritional deficiencies increase the toxicity of many pesticides (14,15). Mild water deprivation and food restriction, similar to that experienced by many farmworkers, has been found to significantly increase the acute toxicity of the widely used organophosphate parathion (16). Finally, the same economic and geographic factors which limit access to medical care for farmworkers may also delay or prevent appropriate treatment for job-related injuries and illnesses.

A 1983 survey of Hispanic migrant farmworkers used the HANES instrument to investigate the health status of tomato harvesters in Indiana, Ohio and Michigan. Upper respiratory, dental, and back and neck problems were the most frequently reported complaints. Farmworkers reported having been sprayed by or otherwise exposed to pesticides an average of 6.6 times during the preceding year; 21% reported having been sprayed or otherwise exposed 10 times or more. 97% of the sample were estimated to be in need of medical attention. Perceived problems of farmworkers in comparison with other Midwesterners included poorer housing and sanitation facilities (92%), more diseases and other health problems (84%), more child labor (76%), and greater exposure to pesticides and hazardous chemicals (79%) (17).

Farmworker organizations petitioned OSHA to regulate the provision of sanitation and hygiene facilities at agricultural worksites in 1974. OSHA standard §1910.141 has required basic sanitation facilities in all permanent workplaces in the U.S. since 1971, and facilities for sanitation have also been required in the construction industry and in temporary labor camps. There is no evidence that field laborers differ in physiological and hygienic needs from other workers. Studies conducted during the development of rural water supply systems demonstrated that the availability of water for personal hygiene may significantly reduce disease transmission, and strategies promoted by the Centers for Disease Control for the control of acute enteric diseases emphasize the importance of hand washing. In response to a Supreme Court ruling which ordered the agency to propose a standard or show cause for failure to comply, OSHA issued a proposed Field Sanitation Standard in 1984; hearings were held in May, 1984, and in April,

1985. OSHA announced that the evidence was not sufficient to warrant promulgation of a standard.

Injury Data

Injury and death rates rank agriculture consistently among the three most hazardous industries in the United States. The death rate for agricultural workers is 54 per 100,000 workers, in comparison with 57 and 63 for construction and mining, and the rate of disabling injuries is 54 per 1,000 workers, versus 53 and 50 for construction and mining respectively. In considering the comparison between agricultural work and mining and construction, it is important to note that the latter two sectors are highly organized, and are uniformly covered by workers' compensation, enhancing the likelihood that work-related death and injury will be reported. Furthermore, since almost half of all farmworkers in labor surveys have worked less than 75 days per year, the death and injury rate per work hour in agriculture is presumably even higher in comparison with industrial occupations (18).

The relative position of agricultural worker safety described above still holds, despite a steady decline in occupational injury rates for many sectors of agriculture. The fall in injury rates is due to mechanization of harvesting, changes in cultivation practices which reduce stoop labor and other crippling physical labor, and redesign of tools and implements. In a review of occupational injuries in California agriculture, Whiting showed a close correlation between the rate of decline in sprain- and strain-type injuries, including back strain, and changes in the physical demands of work in various crops. Field vegetable crops traditionally utilized stoop labor, but as the short-handled hoe was finally replaced in California in the late 1960s, these injuries fell by 34%. Workers on fruit and nut tree farms, where there is less stoop labor but much lifting, experienced an intermediate decrease of 19%. Workers on dairy, livestock and poultry farms, and in nursery and greenhouse work, showed almost no decline in such injuries for the same period because mechanization of these farms had taken place much earlier (19).

Machines themselves remain the primary cause of reported work-related injuries in agriculture, however. Tractors alone are responsible for an estimated 40 to 60% of farm accidents and fatalities, and factors including the complexity of many new machines, heat stress, and the effects of pesticide residues may contribute to accidents involving machinery. Mechanization may actually represent potentially increased health risks for equip-

ment operators, because harvesters and other equipment shake large amounts of foliage rapidly, dislodging pesticide residues and creating a substantial risk of inhalation exposure. Aerial application pilots are at particularly high risk, because equipment failure may be compounded by the neurologic effects of low-level pesticide exposure, resulting in decreased ability to compensate for mechanical problems.

Illness Data

Like injury rates for agricultural workers, occupational disease rates rank among the most hazardous. In California, they are the highest of all sectors in the state labor force: occupational illnesses per 100 full-time workers in 1979 were 0.3 for all industries combined, 0.5 for manufacturing, 0.3 for mining, 0.3 for construction, and 0.6 for agriculture (0.7 for agricultural production, and 0.5 for agricultural services) (20). While injury rates have been declining, occupational disease rates have not, and represent a rising proportion of all morbidity among agricultural workers. In public health terms, this resembles the broader shift in developed industrial societies to predominant patterns of chronic disease.

Mortality. The mortality from all causes is lower among farmers than the general population, probably as a result of two factors: the 'healthy worker effect,' i.e., the self-selection of healthy workers into physically strenuous occupations such as farming; and the lifestyle of farmers, which includes vigorous exercise and markedly low tobacco use. The excess mortality rates most consistently encountered in studies of agricultural workers have included cancers of the lymphatic and hematopoietic system, particularly leukemia, cancers of the prostate, skin and stomach, and motor vehicle accidents (farm machinery) (21).

Early studies comparing mortality rates among agricultural workers and other occupational groups or national rates have identified excess death rates among farmers and farm laborers for such potentially work-related causes of death as leukemia, motor vehicle accidents, machinery accidents and cancer of the skin (22,23,24,25). More recently, NIOSH published a further study by Milham in which a correlation between specific types of cancer and agricultural subgroups (e.g., nurserymen, dairy farmers, poultry farmers) was noted (26), and Stubbs reported excess proportionate mortality rates for deaths due to motor vehicle accidents, all respiratory disease, and all infective and parasitic diseases among farmworkers and farm owner/managers in California, with deficits for deaths due to arteriosclerotic heart disease (27). More studies of this type have been conducted for

pesticide applicators than for farmworkers, because it is easier to establish and follow cohorts (groups) of registered applicators; excess lung cancer death rates have been reported in these studies (28,29).

Case-control studies have compared the incidence of agricultural occupations among persons dying of potentially work-related diseases with that for persons dying of presumably non-occupational diseases. A series of such studies has repeatedly found an excess risk of leukemia among farmworkers in several midwestern states; in each case, the risk has been associated with particular crops or livestock and with high insecticide or herbicide usage, although the specific patterns have not always been consistent (30,31,32). Stemhagen has reported that persons dying of liver cancer in New Jersey were twice as likely to have worked as farm laborers as a matched control population; the probable periods of employment suggest a possible association with arsenical compounds (33).

In some studies, there is a significant difference in death rates between farm owners/managers and farm laborers. Stemhagen found that the risk of liver cancer was associated exclusively with the job title identified as 'farm laborer,' and Carlson found that farm laborers had a three times greater rate of death from respiratory diseases than farm owners and managers (34).

There is no standard death certificate or approach to obtaining information on usual occupation, and coding that information, across all states. Partly because of this, and partly because it is even more difficult to establish cohorts (groups to follow over several decades) in agriculture than in other sectors, there are no reliable estimates of the mortality experience of farm laborers.

Heat Stress. Substantial medical evidence of the adverse health effects of work without adequate water intake under hot environmental conditions exists, although studies of the rate and limit of acclimatization among farmworkers in varying climates and occupational activities within the United States have not been done. Heat stress may lead to heat exhaustion, cramps, and stroke, and, in its earlier stages, is frequently treated symptomatically by the worker and therefore is not reported (35, 36). Rest periods and drinking increased quantities of water are the primary means of preventing heat stress, yet potable water is frequently unavailable to field workers; one study found that fewer than half of the agricultural employees interviewed were provided with drinking water (or handwashing or toilet facilities) in the field (37).

Musculoskeletal Disease. The national Health Interview Survey data file

contains information on self-reported conditions and injuries from a sample of U.S. households. Analysis of this data reveals that farmworkers have a higher prevalence of arthritis than white collar, blue collar, service, or all workers combined. 17% of all conditions reported among farmers and farm managers during the period 1969–1977 were musculoskeletal and connective tissue diseases, versus 12% for all occupations combined. Musculoskeletal conditions were the most frequently reported ailments among both male and female farmers and farm managers; farmers reported over 50% more musculoskeletal disease than farm managers. Arthritis represented 68% of musculoskeletal disease reported by male farmers, and 74% of that reported by female farmers.

Social Security Administration data shows that 17% of disability awards granted to male farmers, and 23% of those made to females, were attributable to musculoskeletal and connective tissue disease, making it the second leading cause of disability among farmers of both sexes. The rigorous physical work of farming is presumed to be responsible for this excess in musculoskeletal disease, although no studies have been done to identify equipment, tools or work practices which are specifically associated with these adverse outcomes (38).

Dermatitis. The most frequently reported occupational disease, for agriculture as for all industries, is dermatitis. The rate of occupational skin disease for all California industries combined was 2.1 per 1,000 workers in 1977. The rate for agriculture was 8.6, for manufacturing 4.1, for construction 2.5, and for mining 2.0. While agriculture represented only 3% of state employment, it accounted for more than 13% of all occupational dermatoses. The majority of cases are due to plant exposures, primarily poison ivy; 16% were attributed to agricultural chemical exposure (39). Because 26% of these pesticide-related dermatoses are reported to require disability leave, however, the economic as well as the health consequences of pesticide-related dermatitis are significant for farmworker families.

Pesticide-Related Illnesses. Systemic pesticide illness is markedly underreported, for reasons which include the nonspecific nature of early and mild symptoms of pesticide exposure, the sociology and political economy of agriculture and its field labor force, and the lack of physician knowledge regarding occupational disease in general and pesticide-related disease in particular. Of those with reported illnesses in California, applicators, mixers, loaders and field workers comprise the greatest proportion, approximately one-third. Greenhouse and nursery workers have relatively high rates, presumably because their workplaces are largely enclosed and pesticide

applications are concentrated. Truck drivers, who handle highly concentrated pesticide formulations, and firemen, who are exposed in uncontrolled emergency situations, have rates only slightly lower than the greenhouse and nursery workers.

The pattern of systemic poisonings has also changed over the past two decades, perhaps most remarkably in California, where strengthened re-entry period regulations were introduced in the early 1970s as part of a vigorous pesticide monitoring and enforcement program. Until that time, a large proportion of reported cases involved entire crews of field workers, frequently harvest crews in citrus orchards, who entered the orchard or field while high concentrations of pesticide residues were still present on the foliage. Cases of systemic illness reported in the last 5 to 7 years have more frequently been individual or small groups of workers encountering re-entry violations or accidental exposures; almost all illnesses reported except dermatitis, however, are still acute illnesses (symptoms developing immediately after and directly referable to moderate or high exposures to pesticides).

Evidence has accumulated to suggest that the vast majority of pesticide-induced illnesses among agricultural workers in all job categories are in fact moderate and chronic rather than severe or acute—that is, continuous or intermittent symptoms in response to continuous or intermittent low-level exposures. A series of studies in California, New Jersey, Canada, Nebraska and other agricultural regions have examined the blood cholinesterase levels of farmworkers in comparison with either their own pre-season baselines or with groups of non-agricultural workers (cholinesterase enzyme activity is inhibited (decreases) upon exposure to organophosphate and carbamate pesticides). In each case, seasonal shifts correlated with pesticide application periods or significant differences from non-exposed population norms have been reported (40,41,42).

Low-level exposure to organophosphate pesticides may produce a variety of nonspecific central nervous system symptoms, that is, symptoms which also occur with influenza and many other common non-occupational diseases. These symptoms include headache, fatigue, drowsiness, insomnia and sleep disturbances, mental confusion, disturbances of concentration and memory, anxiety and emotional lability. Studies of farmworkers, and in some cases applicators and farmworkers separately, have found many of these symptoms to be prevalent at a higher rate than among comparable non-agricultural groups (40,43).

The most detailed study of the prevalence of potentially pesticide-related

morbidity among farmworkers was conducted by the California State Department of Health Services in 1974. Farmworkers reported physicians' visits for potentially pesticide-related symptoms 15 times more frequently than a control population of the same ethnic background and socieconomic status (12). Based on a further investigation of the physician reporting for these cases, and on a similar study in another California county, the director of pesticide programs for the Department of Health Services estimated that as little as 1% of all pesticide-related illness in farmworkers is reported in California—despite the fact that a state regulation requires physicians to report such cases to their County Health Officer within 24 hours of diagnosis (12). In 1982, 235 cases of pesticide-related illness among farmworkers were reported; if this represents 1% of actual illnesses, the 'true' prevalence would be 23,500 cases among the estimated 300,000 farmworkers in the state. If this rate is applied to a conservative estimate of the national farmworker labor force, or 4 million workers, the prevalence may be 313,300 cases; if we apply the rate only to hired seasonal farmworkers who are at greatest risk for field residue exposures, the case prevalence would be 156,600.

These studies indicate that cholinesterase inhibition, taken as an index of exposure, is widely prevalent among a variety of agricultural work groups, and that certain nonspecific but potentially pesticide-related symptoms are also more prevalent among farmworkers than the general population. While the extent of cholinesterase inhibition reflects organophosphate and carbamate exposure only, we must assume that low level chronic exposure to other pesticide residues also occurs.

Partly as a result of increased publicity about the potential toxicity of chronic pesticide exposure, many farmers and farm laborers have become more concerned about agricultural chemical usage. Of 1,959 Missouri farmers polled in a 1983 survey, 30% reported that "high use of chemicals" was "very important" as an issue. Out of a list of eight selected government programs including agricultural research, soil conservation, and cooperative extension programs, farmers reported that they perceived less benefit from farm safety programs than most other programs (only price support programs and farm credit programs ranked lower) (44).

There is no regular biologic monitoring of agricultural worker exposures to pesticides, except for periodic cholinesterase tests required of certified pest control operators handling organophosphates and carbamate compounds on a regular basis in the state of California. There are no regular examinations or surveys to identify the adverse health effects of pesticide or pesticide residue exposures.

Other Agricultural Diseases. A wide range of other diseases are associated with agricultural work, although the total numbers of persons affected are significantly less than for the three categories discussed above. Biologic agents cause 'valley fever' (coccidioidomycosis), anthrax, brucellosis, tetanus, tularemia, leptospirosis, Rocky Mountain spotted fever, Q fever, rabies, psittacosis and ornithosis, orf, histoplasmosis, sporotrichosis, and ringworm. Hypersensitivity pneumonitis, a form of allergic sensitization, is known as farmer's lung, and is also found among mushroom workers. Toxic gases accumulate in stored fodder and cause silo filler's lung. Vibration may cause circulatory and musculoskeletal system changes, and ultraviolet radiation causes skin cancer at excessive rates among farmers. Hearing impairment has also been found at high rates among agricultural workers, the result of operating machinery without ear protection.

Psychosocial Effects of Agricultural Work. Several studies of mental illness in rural communities have found prevalence rates to be significantly higher than in urban communities; this prevalence rate has consistently been in the range of 10% of the rural population, defining cases as those probably in need of psychiatric care (45). In Mazer's detailed study of a Massachusetts rural community, general physicians reported that 51.5 per 1,000 patient visits—or 1 out of 20 visits—were for psychiatric care (46). An NIMH review of mental health and rural America concluded that these studies identify a marked "slippage" between the existence of mental illness in rural areas and the treatment of such disease (45).

Many sociological descriptors of rural farm populations are consistent with these findings. Rural residents are poorer than urban residents, and rural farm families are poorer than non-farm families residing in rural areas. There is a higher ratio of dependent persons—those under age 18 or age 65 or over—to productive age group persons in rural areas. While the general health status as well as the mental health status of rural residents is below that for urban residents, the quality of health facilities and services, the availability of transportation to reach health care centers, and the smaller number of practitioners working in rural areas results in less access to care for rural communities as well (45).

More recently, sociologists and economists investigating rural communities have identified patterns which are known to contribute to mental illness in other settings. Changes in the structure and control of agriculture have concentrated not only ownership, but also managerial control over production practices. In the Missouri Farm and Rural Life Poll, 47% of the respondents felt that agricultural decisions are made predominantly by

persons other than farmers. These structural changes are not only occurring in the family farm sector of agriculture; the contracting of hired labor through marketing corporations rather than by individual growers has substantially changed job stability and work relations for many seasonal workers. Unemployment is an increasingly critical problem for both groups as well; for family farmers who fail financially and cannot find employment in their communities, and for seasonal workers displaced by mechanization. Despite these many indicators of distress among rural farmers, there are almost no studies of the potential relationship between agricultural production systems and mental stress and disease.

SUMMARY

The relationship between agricultural production and health is a 'special case,' unlike that existing in other sectors of economic production. A much higher rate of injury and illness appears to exist among farmworkers than most other sectors of the workforce. Workers' compensation does not cover farmworkers in half the states in the country. Farm workers are also excluded from general benefits such as social security. Regulations which entitle other workers to basic worksite sanitation, the 'right to know' the name of chemicals used in a workplace, and other occupational health and safety programs routinely exclude agricultural workers.

The criteria used to evaluate and regulate agricultural chemicals differ from those used for industrial pollutants, and EPA is required to consider the economic benefit derived from use of chemicals as well as the potential health risks in registration and use decisions. The reporting and monitoring of health effects associated with agricultural practices are much weaker than for industrial, service and other sectors of the workforce. All of these issues are health 'externalities'—costs not accounted for in the economy of the individual agricultural producer, costs borne instead by the agricultural laborers and by the larger society.

There is no single explanation for this phenomenon. I have already noted the urban roots of public health, and the delayed response of public health professionals and agencies to the occupational health problems of agricultural workers. Given the evidence reviewed in this article for very high rates of occupational injury and disease among workers in agriculture, however, we may ask why these externalities were not identified and addressed by occupational health or agricultural researchers.

Part of the problem in recognition of these externalities stems from the narrow definition of agriculture as a technological intervention in nature, rather than a social process of production. Cost/benefit analysis is therefore

encapsulated within the triad of land, labor and implements as units of production cost. Because structural constraints such as workers' compensation and unionization of the workforce are greatly reduced in the agricultural sector, agricultural managers encounter neither economic nor social pressures to incorporate health externalities into their evaluation of costs and benefits. This situation has begun to change over the past decade, as environmental groups, farmworker unions and advocate organizations have pressed regulatory agencies for improved standards and stricter enforcement.

Fundamental questions about the desirability of pesticide use on surplus crops or in situations where continued cultivation may be counterproductive for the larger agricultural ecosystem have received increasing attention. In California, this issue was raised during regulatory consideration of Bolero and Ordram use on rice; there was already a one year supply of the crop in storage and large payment-in-kind allotments had been made. It also was considered when use of the suspect carcinogen chlordimeform was permitted again on cotton in the Imperial Valley, because of the large cotton surplus and the fact that the Imperial Valley crop serves as a land bridge for pest movement between Arizona and the more productive, valuable and uninfested crops in the Central (San Joaquin) Valley.

Increased research on the health effects of agricultural production and improved reporting systems for injury and illnesses would markedly improve the quantity and quality of information available for assessment of costs which have been externalized from agriculture. Strengthened premarket evaluation of agricultural production materials and technology for their potential health impact would encourage the incorporation of health concerns into earlier stages of research and development. Extension of workers' compensation coverage and increased utilization of economic policies (such as the mill tax on pesticide sales which finances health and safety research and regulation in California) may result in the 'internalization' of some of the health costs of past and present practices. Finally, there has been increasing interest in agricultural technologies which utilize lesser amounts of pesticides (loosely referred to as integrated pest management programs), a development which may substantially reduce the potential for both worker and community exposures.

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