Human Health Effects of Agriculture: Physical Diseases and Illnesses

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Abstract

Agriculture has experienced major bio-technological advances and economic and socio-cultural disruptions since the publication of the white paper "Agriculture at Risk" in 1988. At that time it was recognized that there were acute needs in the prevention of musculoskeletal conditions, agricultural respiratory disease, noise-induced hearing loss, and pesticide-related illnesses, and the excesses of cancers noted in epidemiological studies of farmers. In this paper, we will discuss the progress made in identification of new respiratory syndromes related to confined animal feeding operations, pesticide-related illnesses, cancers implicated with agricultural exposures, and ergonomics in agriculture. The focus will be upon the current state of knowledge in these areas, recommendations for further improvement in research techniques, and the potential application of this information to improve human health in production agriculture nation wide.

Human Health Effects of Agriculture

The agricultural sector has undergone immense change since the publication of Agriculture at Risk in 1988. In some respects there has been improvement in the health and safety of those working in agriculture due to improved technology, personal protection, and awareness of hazards. The establishment of the NIOSH Agricultural Health and Safety Centers as a result of that effort has provided a network for the collaboration of academic health center researchers, agricultural safety educators, and agricultural engineers to institute a multi-disciplinary approach to research, outreach, and education in agricultural health and safety. The regional centers appropriately reflect the geographic variation in farming conditions and practices. Regulatory approaches to improving occupational and environmental health in agricultural practices have included the passage of the Worker Protection Standard in 1992 and the Food Quality Protection Act in 1996, both dealing exclusively with pesticides.

There is still much to be done, however, to prevent injuries and improve the health status of those working in agriculture. Even with the consolidation of agricultural operations and the increased complexity and size of farms and other agricultural operations, there is a lack of knowledge of how many people are adversely affected by their exposures, particularly long-term, low level exposures. The majority of production operations are exempted from direct OSHA regulation and as a result the medical surveillance that occurs in other industries often does not or at best, occurs sporadically in agriculture. The reporting system for occupational illnesses is still woefully inadequate which makes it almost impossible to accurately track trends, determine accurate numbers of those with illnesses that are consequences of agricultural occupational exposures, and determine long-term adverse health effects from agricultural exposures. Farmers have an increased prevalence of many acute and chronic health conditions including cardiovascular and respiratory disease, arthritis, skin cancer, hearing loss, and amputations. Other health outcomes have been little studies in the agricultural workplace, such as stress and adverse reproductive outcomes. (Brackbill, Cameron, Behrens, 1994). Three prospective cohort studies have been launched that will help answer some of the questions: The Agricultural Health Study in North Carolina and Iowa, the Keokuk Study in Iowa, and the California Farmer Cohort Study (Alvanja, Sandler, McMaster, Zahm, McDonnell, Lynch, Pennybacker, Rothman, Dosemeci, Bond, & Blair 1996).

In this paper we describe the progress that has been made since 1988 in addressing respiratory exposures and illnesses, cancers related to agricultural chemical exposures, pesticide-related illnesses, and ergonomic issues. As other papers will address agricultural injuries, mental health, and environmental issues, the focus will be upon occupational exposures that have the potential to cause physical illnesses from occupational exposures. We will also recommend future courses of action to improve the health of those who work in agriculture, with a focus upon production agriculture. Space limitations preclude a full discussion of the topics covered.

Health studies must consider several modifying factors in agricultural exposures resulting in physical illnesses including work force age and ethnicity, type of commodity, work practices, engineering controls, and use of personal protective equipment. The work force has significantly changed and varies greatly by region. Principle operators tend to be Caucasian and older. There has been a slight increase in women principle operators. There has also been an increase in principle operators that work off the farm, which adds additional exposure issues (US Census of Agriculture, 1997). Hired farm workers are increasingly foreign born, younger males. It is thought that agriculture is now at a low point in agricultural labor and as the number of farms decrease, there will be an increase in the size of the agricultural labor force. According to the 1997 USDA Agricultural census the average age of principle operators is 54.3 years. Aging of the farm population may lead to increased susceptibility to the adverse effects of occupational exposures, on chronic diseases including respiratory and musculoskeletal illnesses. Many hired farm workers no longer have an agricultural background and use employment in the agricultural sector as an entry-level job. A language barrier exists which can impede following safety information on labels and training in proper work practices. Farm labor contractors instead of farm owners now hire large numbers of farm workers, raising new health and safety concerns. All of these changes may increase health and safety hazards in the agricultural workplace. Perhaps the hallmark of agricultural exposures is their enormous diversity in type, as well as in dose and duration. The ethnic variation in the agricultural workforce compounds the potential health hazards.

Respiratory Illnesses and Exposures

This topic has recently been reviewed in detail (Schenker, 1998). Agriculture involves potential exposure to a wide range of respiratory toxins, many in concentrations higher than in other industries. Despite low rates of cigarette smoking, farmers have an increased prevalence of several acute and chronic respiratory diseases.

Organic Dusts

The oldest and most well studied agricultural respiratory disease are from exposures to organic dusts such as grain processing and confined animal feeding operations (CAFOs), (e.g. swine confinement facilities). There has been a significant increase in the animal density found in animal production with the loss of smaller operations and the increase of facilities with animal densities of over 2000 hogs becoming common. It is estimated that there are as many as 700,000 workers in CAFOs, including owner/operators, family members, and employees, including 250,000 in hog confinement facilities (Von Essen and Donham, 1999). There has also been a significant increase in the exposure to organic dusts, bioaerosols, and toxic gases. Workers in larger hog operations spend as much as 40 or more hours per week inside the facilities. It has been suggested that long-term indoor exposure for 2 hours per day for 6 or more years in swine confinement facilities is associated with several respiratory conditions, including sinusitis, mucous membrane inflammation syndrome, non-immunogenic bronchospasm, and bronchitis (Thorne, Donham, Dosman, Jagielo, Merchant, & Von Essen, 1995). Research involving inhalation of swine dust and bronchoalveolar lavage has shown increased neutrophil counts but not eosinophils, suggesting an irritant response rather than an allergic response (Von Essen, Scheppers, Robbins, Donham, 1998).

There is increasing evidence that endotoxins, a component of organic dusts from both grain storage and CAFOs, are a significant contributor to respiratory disease. A dose-response to endotoxin and pulmonary function deterioration has been established in numerous studies (Reynolds, Donham, Whitten, Merchant, Burmeister, & Popendorf, 1996; Donham, Cumro, Reynolds, & Merchant, 2000; Schwartz, Donham, Olenchock, Popendorf, Van Fossen, Burmeister, & Merchant, 1995; Schwartz, Thorne, Yagla, Burmeister, Olenchock, Watt, & Quinn, 1995; Vogelzang, van der Gulden, Logering, and van Shayck, 1998; Zjeda, Barber, Dosman, Olenchock, McDuffie, Rhodes, & Hurst, 1994). Endotoxins are associated with the release of pro-inflammatory agents including tumor necrosis factor, interleukins, cytokines, and inflammatory cells (Jagielo, Thorne, Watt, Frees, Quinn, & Schwartz, 1996). There are associated declines in pulmonary functions, primarily FEV1 and symptoms including chest tightness, cough, dyspnea, and sputum production. Similar findings are seen in inhalational studies of swine confinement workers (Von Essen & McCurdy, 1998). Endotoxin is implicated to be the cause of the inflammatory reaction seen in byssinosis, which has clinical findings similar to grain fever (Schenker, 1998).

Most CAFO research has focused upon swine confinement operations but recent studies have indicated similar dose-response findings in poultry operations. Significant dose-response relationships were also found to occur with exposures to total dust, respirable dust, endotoxin, and ammonia and cross-shift decrements in pulmonary function in both swine confinement and poultry operations (Donham, 1995; Reynolds et al. 1996; Donham, 2000). These include total dust concentrations of 2.4-2.5 mg/m3, respirable dust of 0.16-0.23 mg/m3, endotoxin of 640-

1000 ng/m3, and ammonia of 7-12 ppm. Recommendations have been made for the establishment of threshold limit values for organic dusts, respirable dusts, and endotoxins as a result of the dose-response relationship findings. The findings for ammonia occurred at levels well below the established TLV of 25 ppm.

"Asthma-like syndrome" is a nonallergic respiratory condition that is identical clinically to asthma but is not associated with persistent airway inflammation or airway hyperreactivity. As the pulmonary deterioration can often be detected only by cross-shift testing, it can be difficult to document this in a typical clinic setting. The cross-shift decline in FEV1 is generally less than 10% but can be between 10-15% (Schenker, 1998). It is most common in swine confinement workers, up to 10% acutely, but can also be seen in grain workers (Von Essen and Donham, 1999). A more chronic condition with similarities to byssinosis, including Monday morning response, has been identified in 11% (Donham, 2000). A chronic form of nonallergic asthma has been identified in as many as 25% of swine confinement workers (Von Essen and Donham, 1999; Donham, 2000). It is uncertain what the long-term respiratory effects are and whether end-stage irreversible pulmonary disease will result. Acute bronchitis occurs in as many as 70% of CAFO workers and 25% develop a chronic bronchitis (Donham, 2000).

Organic dust toxic syndrome (ODTS) is common and may be seen in up to 34% of CAFO workers (Von Essen and Donham, 1999). A chronic form of ODTS in swine workers may occur with chronic fatigue, dyspnea, and possibly mild pulmonary infiltrates (Donham, 2000). Mucous membrane inflammation syndrome is a complex of nasal, eye, and throat complaints commonly found in CAFO workers. Nasal symptoms occur in as many as 50% and sinusitis in up to 25% of swine confinement workers (Von Essen and Donham, 1999). Classic allergic asthma due to IgE and IgG antibodies and Type I occupational asthma is uncommon in CAFO workers. Generally, workers with pre-existing asthma do not tolerate working in swine confinement facilities for more than several months. These illnesses and syndromes result from exposure to the myriad of antigens and irritants found in CAFO organic dust, including pollens, animal and insect feces, animal dander, fungal spores, bacterial microorganisms, pesticides, and antibiotics. Engineering controls and personal respiratory protection can decrease symptoms and pulmonary decline from the exposure. Sprinkling canola oil in a swine room decreased dust and endotoxin levels as well as human respiratory effects (Senthilselvan, Zhang, Dosman, Barber, Holfeld, Kirychuk, Cormier, Hurst, & Rhodes, 1997; Zhang, 1997). Other interventions to decrease dust levels include adding fat to feeds, increasing mechanical ventilation, using wet methods to clean, and automated feeding.

Grain dusts also include a complex mixture of organic dusts as well as inorganic dusts. Many of the same symptoms occur in grain workers as well as in CAFO workers. Grain dust is thought to be pro-inflammatory in itself, particularly grain sorghum (Von Essen, O"Neill, McGranaghan, Robbins, & Rennard 1995) and soybean dusts. A significant annual decline in FEV1 was seen in grain workers and indication of a dose-response relationship (Jagielo et al. 1996; Dosman, Pahwa, & McDuffie, 1995; Kennedy, Dimich-Ward, & Chan-Yeung, 1995). Grain sorghum appears to be the most strongly associated with respiratory symptoms (Von Essen, Fryzek, Nowakowski, & Wampler, 1999).

Other exposures of concern in CAFOs include bacterial microbials, fungal organisms and toxic gases. The primary gases of concern are ammonia and hydrogen sulfide (H2S). Ammonia is also implicated in many of the irritant respiratory conditions and may be additive or synergistic with endotoxin. It is uncertain what role low level H2S plays in the role of respiratory disease. At lower concentrations it is a respiratory irritant while it is a potentially fatal asphyxiant at higher concentrations.

Recommendations for Further Research

Medical surveillance continues to be lacking in CAFO workers. This appears to be an area where the agricultural workforce may increase in the future. Improved medical surveillance with baseline spirometry and ongoing screening for respiratory disease is important to decrease the high respiratory disease incidence. Further research on the causes and prevention of irritant chronic asthma and asthma-like syndrome, chronic ODTS, and end-stage irreversible pulmonary conditions is indicated. Larger numbers of participants are needed in prospective studies determining dose-response relationships between respiratory illnesses and pulmonary measurements and measurement of total and respirable dusts and endotoxins, ammonia and other gases associated with CAFOs.

Recommendations for the establishment of exposure limits for organic dusts, endotoxins, and microbials have been made. There is also evidence that the exposure limits for ammonia are not protective and should be decreased. At a minimum, prospective pilot studies should compare facilities at the recommended levels to controls. Exposure limits should be actively pursued and encouraged (RLVs or TLVs) as an initial step to develop regulatory limits.

Inorganic Dusts

Recent research has identified adverse respiratory effects of inorganic dust exposure in the agricultural workplace (Schenker, 2000; Pinkerton, Green, Saiki, Vallyathan, Plopper, Gopal, Hung, Bahne, Lin, Menache, & Schenker, 2000). This is particularly a hazard in regions with dry climate farming, such as California and the Southwest. Inorganic dusts come primarily from soil components, and are dominated by silicates but may include significant concentrations of crystalline silica (Nieuwenhuijsen and Schenker, 1999). Exposures of agricultural workers to inorganic dusts, which are often mixed with organic dusts and other components, may result in macules, nodules, and interstitial fibrosis (Schenker, 2000). The prevalence and natural history of this disorder among agricultural workers is unknown.

Other Respiratory Illnesses

Farmer's Hypersensitivity Pneumonitis (FHP), previously referred to as Farmer's Lung Disease (Schenker, 1998), has been the focus of limited recent research. Changes in feeding and bedding methods and a decrease in the traditional silos may have resulted in a decreased incidence of FHP. Current recommendations and guidelines for the diagnosis of FHP have recently been published (Schenker, 1998; Richerson, Bernstein, Fink, Hunninghake, Novey, Reed, Salvaggio, Schuyler, Schwartz, & Stechschulte, 1989). Adequate personal respiratory protection has been shown to be protective against recurrent attacks of FHP Smoking is associated with a lower prevalence of FHP but smoking may lead to a more insidious development of chronic FHP (Ohtsuka, Munukata, Tanimura, Ukita, & Kusaka, 1995). Emphysema has also been identified as an important outcome of chronic FHP (Schenker, 1998; Erkinjuntti-Pekkanen, Rytkonen, Kokkarinen, Tunianen, Rartanen, & Terho, 1998).

Drought conditions have been associated with higher nitrate in corn and resultant higher levels of nitrogen oxides in silage. "Ag bags" are seen more commonly as a method to store silage and haylage. There can also be toxic levels of nitrogen oxides at the opening of the bags that are within the immediately dangerous to life and health (IDLH) ranges leading to silo-fillers disease (Pavelchuk, Church, Roerig, London, Welles, Casey, 1999).

Recommendations

Continued efforts to decrease organic dust production and exposure to thermophillic organisms overgrowth should continue. Ongoing monitoring of individuals for the development of COPD should be a part of current research. Further evaluation of N-95 respiratory protection in lieu of respirators with higher protection factors such as helmets with powered air purifier respirators to determine if they are a safe cost-effective method to prevent progression of FHP with continued agricultural exposures.

Precautions need to be taken in dry growing conditions, even if there is not entry into a confined space such as a conventional silo. Research is needed on the long-term effects of inorganic or mixed agricultural dusts. Avoiding opening ag bags and monitoring of NO2 should be considered within the first two weeks of filling ag bags, similar to recommended practices for silos.

Agriculture Associated Cancers

Farmers have decreased tobacco- and alcohol-associated cancers (Blair and Zahm, 1995; Cerhan, Cantor, Williamson, Lynch, Torner, & Burmeister, 1998). However, many cancers have been associated with farming in epidemiologic studies, but results are inconsistent and there is no consensus on causality. A meta-analysis of cancers and agricultural associations showed only lip cancer to be elevated (Acquavella, Olsen, Colde, Ireland, Kaneene, Schuman, & Holden, 1998; Brownson, Reif, Chang, Davis, 1989; Zahm, Ward, & Blair, 1997), and another meta-analysis found a significant association of multiple myeloma and farming in men and women (Kruder and Mutgi, 1997). Other cancers showing an inconsistent association with farming include non-Hodgkins lymphoma (NHL), prostate, skin, melanoma, brain, soft tissue sarcoma (Brownson et al., 1989; Blair and Zahm 1995; Cerhan et al. 1998; Khuder, Schaub, & Keller-Byrne, 1998;Morrison, Savitz, Semenciw, Hulka, Mao, Morison, & Wigle, 1993). Some cancers have been associated with specific exposures, and may be increased in subgroups of agricultural workers. NHL and phenoxyacetic acid herbicides (e.g. 2,4 D) have shown the strongest association (Blair and Zahm, 1995), but the finding has not been consistent (Asp, Riihimaki, Hernberg, Pukhala, 1994; Perry and Layde, 1998). An increased OR was observed in one study for leukemia and dichlorvos, famphur, and natural pyrethrin but no significant increase with herbicides (Brown, Blair, Gibson, Everett, Cantor, Schumann, Burmeister, Van Lier & Dick, 1990). There has been recent concern about endocrine disrupters and cancer. Organochlorines are weak endocrine disrupters but an association of DDE and PCBs with breast cancer has not been consistently observed (Hunter, Hankinson, Laden, Colditz, Manson, Willett, Speizer, & Wolff, 1997; Krieger, Wolff, Hiatt, Rivera, Vogelman, & Orentreich, 1994; Van't Veer, Loffezzo, Martin-Morena, Guallar, Gomez-Aracena, Kardinaal, Kohlmeier, Martin, Strain, Tham, van Zooen, Baumann, Huttunen, & Kok, 1997).

Recent studies raise questions about other cancers, but more research is needed to establish causality. Childhood brain tumors were associated with mothers exposure to pigs and horses during pregnancy, working on a livestock farm, and the child's living on a farm for over one year beginning when under 6 months of age (Holly, Bracci, Mueller, and Prestin-Martin, 1998). Atrazine is the most extensively used herbicide in the Unites States. There is no evidence for increased risk of colon cancer, soft-tissue sarcoma, Hodgkin's, multiple myeloma, or leukemia (Neuberger, 1995). Another study found no association of atrazine and ovarian cancer. (Stump, Hopenhayn-Rich, and Browning, 2000).

Recommendations

The meta-analyses suffer from heterogeneity of studies, type of farming, geographic area, and time period and limitations in exposure assessment (Acquavella et al. 1998). Farmers and farm workers are exposed to multiple hazardous exposures including pesticides, fertilizers, paints, solvents, welding fumes, dusts, infectious microorganisms, and endotoxins. Generally the studies have been done on white farmers and to a much lesser degree, spouses. Very little research has been done on hired farm workers, who may have a greater exposure, (Blair and Zahm, 1995). The focus of the various studies has generally been on crop production farmers who are exposed to each pesticide only a few times each year (Kruder and Mutgi, 1997). Research needs include more information on inert ingredients. Studies focusing on agricultural workers with more intense exposure to pesticides, such as small vegetable and fruit workers, are needed. The development of improved biomarkers and increased use of biological monitoring to establish dose-response relationships are needed. Improved homogeneity of the studies and standardization of the endpoints will also improve the reliability of the studies.

Non-Cancer Pesticide Related Illnesses

Pesticide fatality rates in the U.S. have been steadily decreasing each year (Litovitz, Klein-Schwartz, Caravati, Youness, Crouch, & Lee, 1999; Blondell, 1997; Caldwell, Barker, Schuman, and Simpson, 1997; Klein-Schwartz, Smith, and Gordon, 1997). Hospitalizations and acute poisonings have decreased due to improved worker education, better technology of application and mixing methods, formulations, better labeling and regulation, more IPM, and stricter registration including de-registration of the most toxic agents (Schuman and Simpson, 1997; Woodruff, Kyle, and Bois, 1994). There are considerable unreported exposures with up to 29-44 % of farmers reporting dermal or respiratory exposures with associated symptoms (Perry and Layde, 1998; Reynolds, Merchant, Stromquist, Burmeister, Taylor, Lewis, & Kelly, 1998). There is less use of personal protective clothing with pesticide use for farmers who are unlicensed pesticide applicators, even though licensed applicators do not routinely use appropriate protection (Garry, Kelly, Sprafka, Griffith, Hansen, McMullen, Richness, & Burroughs, 1995; Lexau and Heins, 1994; Mandel, Carr, Hillmer, Leonard, Halberg, Sanderson, & Mandel, 1996). Skin reactions are generally the most common adverse reaction (O'Malley, 1997).

Symptoms of pesticide exposure include headache, skin irritation, eye irritation, and fatigue. Over one-half of private applicators with a high pesticide exposure event had symptoms. Of these only one-half sought medical treatment from a health care provider (Alavanja et al. 2000). Respiratory and flu-like symptoms were associated with pesticide exposures in Iowa farmers when applying livestock insecticides and with hand or arm exposures (Sprince, Lewis, Whitten, Reynolds, and Zwerling, 2000).

There is recent concern regarding chronic pesticide exposure and adverse reproductive effects. Miscarriages have been associated with thiocarbamates, carbaryl, and unclassified pesticides and chemical activity, and preterm delivery with mixing or applying yard herbicides (Savitz, Arbuckle, Kaczor, and Curtis, 1997). There was no strong or consistent pattern of association with pesticide exposure and time to pregnancy (Curtis, Savitz, Weinberg, and Arbuckle, 1999). However, women working in agriculture-related industries and women residing on farms had an association with infertility (Fuortes, Clark, Kirchner, & Smith, 1997).

Several pesticides that are male reproductive toxicants are no longer registered in the US, including kepone, dibromochloropropane (DBCP), and ethylene dibromide (Sever, Arbuckle, and Sweeney, 1997). An ecologic study found increased prevalence of congenital birth defects in the children of pesticide applicators in the area of Minnesota with the highest fungicide and chlorphenoxy use. The findings included a more pronounced effect with infants conceived in the spring, an increased male:female ratio, and an association with trifluralin and 2,4-D but not atrazine (Garry, Schreinmachers, Harkins, & Griffin, 1996). Cryptorchidism was significantly increased in male offspring of mothers employed in gardening, including greenhouse workers, orchards, and nurseries (Weedner, Moller, Jensen, and Skekkebek, 1996). Other developmental defects associated with pesticide use include oral-facial clefts (Nurminen, 1995) and limb reduction defects associated with other organ system anomalies (Lin, Marshall, & Davidson, 1994). As with most of these studies, these ecologic findings require further research before etiologic conclusions can be reached.

The acute findings of organophosphate poisonings have been well described, including organophosphate induced polyneuropathy (OPIDP) and intermediate syndrome. The role of pesticide mixtures may be an important issue as neuropathy can be induced in animals at a less than neuropathic dose when given in a specified order (Kiefer and Mahurin, 1997). Permanent neurological deficits have been reported as a sequelae of organophosphate pesticide poisoning, including neuropsychiatric effects, peripheral neuropathy, poor performance on neuropsychiatric testing, and multiple chemical sensitivity (Meggs and Langley, 1997). A dose-response relationship is suggested as the severity of effects increases with more severe poisonings, as measured by length of hospitalization, lost work days, and decreased cholinesterases (Steenland, Jenkins, Ames, O'Malley, Chrislip, & Kurso, 1994; Rosenstock, Keifer, Daniell, McConnell, and Claypoole, 1991). Chronic exposures also demonstrate subtle neuropsychiatric findings such as lower reaction time of the dominant hand in higher OP exposure group (Fiedler, Kipen, Kelly-McNeil, and Fenske, 1997). A subset of nine applicators had clinical evidence of peripheral neuropathic dysfunction out of 90 applicators with increased vibration sensitivity (Horowitz, Stark, Marshall, & Mauer, 1999). Other studies have raised the issue of Parkinson's Disease and pesticide exposure (Battlefield, Valanis, Spencer, Lindeman, and Nutt, 1993; Fleming, Mann, and Bean, 1994).

Recommendations

A significant issue that remains to be addressed is establishing causal linkages and dose-response relationship between chronic illnesses and pesticide exposure. The development of improved biomarkers of organochlorine pesticides and metabolites, such as DDE and DDT, would help improve this, but the short half-life of OP biomarkers limits their usefulness. The groups that have the highest exposures to pesticides, hired farm workers, particularly those working in the vegetable and fruit commodities, should be targeted. A significant issue is the accurate evaluation of acute and chronic cholinesterase depression. Presently, there is difficulty comparing data from one clinical laboratory to another, variable reporting units and normal values range, and different assay methods. Wilson et al (1997) have called for the standardization of enzyme of enzyme assays by the American College of Pathologists, development of a standardized sampling and storage conditions to maintain activity and reduce reactivity, and consistent use of a portable inexpensive field test to monitor cholinesterases (Wilson, Sanborn, O'Malley, Henerson, and Biltilli, 1997). Further research into the endocrine disrupter effects of pesticides is an area of critical importance. Prospective studies such as The Agricultural Health Study and the review of pesticides under the Food Quality Protection Act will help address this. Improved medical surveillance and reporting of pesticide-related illnesses will be important to further describe the epidemiology of pesticide illnesses. A nation-wide effort to improve and standardize medical surveillance of pesticide applicators and others exposed to pesticides on a regular basis and reporting of pesticide-related illnesses is indicated.

Ergonomic Issues

Farming and other production agricultural activities are recognized as being hard physical work. Musculoskeletal disorders (MSDs) are common in production agriculture and may increase as labor intensive agricultural work has increased over the last 20 years (Villarejo and Baron, 1999). Chronic back pain was identified in 26% of farmers and ranchers in one survey, and increased with age and years worked (Xiang, Stallones, and Keefe, 1999). As many as 71% of swine producers report chronic back pain (Von Essen and McCurdy, 1998). The recently instituted OSHA ergonomic program standard 29 CFR 1910.900 will not apply to production agriculture and nursery growing operations but will affect other agriculture-related industries including food processors, landscapers, and lawn and garden services. Arthritis of the hips and knees has been associated with dairy farming and driving tractors (May, 1998). Studies of the orchard fruit harvesting have identified ergonomic stressors such as working with raised arms, repetitively forceful lifting, and pressure on the shoulders from straps of the fruit bags (Fulmer, Punnett, Slingerland, & Earle-Richardson, 2000). Evaluation of California nurseries identified

49% of injuries due to sprains and strains with 46% of these affecting the back (Meyers, Bloomberg, Faucett, Janowitz, & Miles, 1995). Ergonomic stressors identified include forceful exertions, pinching, stooping, prolonged static postures, awkward positions, continual bending and twisting at the waist while handling excessive or asymmetrical weights (Meyers, Miles, Faucett, Janowitz, Tejeda, & Kubashimi, 1997). It is difficult to apply standard ergonomic interventions throughout agricultural industries as agricultural operations involve varied duties at multiple locations (Meyers et al. 1995).

Studies of nursery workers have been a model for ergonomic evaluation and intervention. Some of the interventions include use of handles on pots to decrease pinch grip, automatic washers, adding pallet trucks and a track and raising loading ramps to reduce forceful repetitive lifting, and smaller pots to decrease weights. Other interventions involve developing lighter equipment, more flexible protective clothing, new tools, and raising beds (Meyers et al. 1995). Research and ergonomic interventions are recommended for other commodities. The goal is to develop simple solutions that are inexpensive to produce and apply.

Other Health Issues

Numerous studies have found hearing loss to affect over 50% of the farming population (Beckett, Chamberlain, Hallman, May, Hwang, Gomez, Eberly, Cox, & Stark, 2000; Lexau and Heins 1994; May, 1998). Noise levels are elevated with mean noise levels of tractors, vacuum pumps, feed unloading area above the OSHA standard for hearing protection requirements (Marvel, Pratt, Marvel, Regan, & May, 1991; Holt, Broste, and Hansen, 1993). Cabs on tractors and other equipment have greatly lowered the noise levels but significant exposure still occurs. Increased use of personal hearing protection is recommended, as well as improved noise reduction techniques that can be economically applied on all agricultural operations.

Hired farmworker (including migrant and seasonal worker) health problems remain an important issue (Mobed, Gold, & Schenker, 1992). M. tuberculosis, both latent tuberculosis infection and tuberculosis disease, is increasing in the migrant work force, predominately in Mexican and Central American workers, and is highest in the US-Mexican border communities (Lobala and Cegielski, 2001). Prevalence rates are significantly higher than the US rates. Recommendations include improved surveillance, diagnosis and treatment, and ensuring completion of treatment to decrease multi-drug resistant strains of M. tuberculosis.

There are many other health issues of concern that were not addressed in this paper including dermatitis and other zoonotic infections. The topics discussed in detail were chosen because of the focus of current research and their potential to be the most affected by the changes occurring in agriculture. Advances in biotechnology, genetic modified organisms (GMOs), new agrochemicals, and an evolving work force will continue to have an impact on the human health in agriculture, and need to be addressed by future research.

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