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# Work Patterns and Self-Reported Exposure of California Farm Operators

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**California agriculture is a gigantic industry with 76,000 farms. An estimated 1.5 million people are directly employed on these farms, and an estimated $19.9 billion worth of farm products are sold each year. Farming has been associated with a wide variety of hazardous airborne exposures. The development of respiratory disease depends, among other factors, on the duration of airborne exposures. The aim of this study was to collect information on the duration of time California farm operators personally spend on various operations and on how dusty they perceive the operations to be. The majority of farm operators (83%) reported work on crop-related operations, while a minority (27%) reported work on livestock-related operations. There were considerable differences in the duration of time California farm operators spent on various operations, some of which could be explained by the differences in commodities they grew or raised. Mechanical harvesting—in particular, of fruit and nuts—and ground preparation operations were perceived to be the dustiest operations (dust rating = 6.0 and 4.6, respectively). The farm operators estimated that their exposure to dust, gases, fumes, and pesticides had declined over the past 10 years.** NIEUWENHUIJSEN, M.J.; SCHENKER, M.B.; SAIKI, C.; SAMUELS, S.J.; GREEN, S.S.: WORK PATTERNS AND SELF-REPORTED EXPOSURE OF CALIFORNIA FARM OPERATORS. APPL. OCCUP. ENVIRON. HYG. 12(10):685–690; 1997. © 1997 AIH.

Farming has been associated with a wide variety of hazardous exposures,[1] including airborne exposures which have been associated with respiratory disease.[2–7] In general, farm work and related exposures may vary greatly throughout the year because of the cyclic nature of farming, but may also vary because of differences in local farming practices, commodities grown or raised, geography, climate, and other factors. These factors, combined with the diverse locations of farms, make assessment of hazardous exposures in agriculture very difficult.

Recently there were reports on the commodities grown and/or raised by California farm operators and the farm operators' estimates of personal exposure to dust, noise, and pesticides,[8] and on dust exposure levels and their particle sizes and determinants during various agricultural operations in California.[9,10] This work showed that high personal dust exposure levels, well above the American Conference of Governmental Industrial Hygienists Threshold Limit Values, occur in California farming and that there are considerable differences in exposure levels between various operations. However, no information was collected on the duration of time California farm operators personally spend on various operations.

The development of respiratory disease depends, among other factors, on the nature, level, duration, and particle size distribution of airborne exposures. The aim of this study was to collect information on the duration of time California farm operators personally spent on various operations and on how dusty they perceive the operations to be. This study will provide information on dust exposure for an epidemiologic study of respiratory health among California farm operators and could also be used to set priorities in health and safety in California agriculture.

In 1993 California farmers sold an estimated $19.9 billion of farm products, making it the largest agricultural state in the United States based on cash receipts.[11] That year California had some 76,000 farms[11] with up to an estimated 1.5 million people directly employed on these farms.[8]

## Materials and Methods

### *Sample Selection*

In 1993, 1947 randomly selected California farm operators were interviewed by telephone as described by Nieuwenhuijsen *et al.*[8] In 1995, 889 were randomly selected out of the 1947 and contacted by phone for more detailed questions on the duration spent working on various operations and farm operators' exposure ratings. 660 (74.2%) completed the telephone-administered questionnaire. The telephone interviews were carried out by a professional institute that routinely conducts telephone interviews. Farm operators were asked about the duration of time they personally spent on various operations (tasks), how dusty they perceived them to be (on a scale of 0 to 10), and some indicators on how their farm work has changed over the last 10 years. 114 were no longer the primary operator of the farm or sold less than $1000 in farm products (part of the California Agricultural Statistics Service's definition of a farm) and were excluded from further analyses, leaving 546 (64.4%) California farm operators for further analyses. The operators in the 1993 and 1995 studies were similar in median age (53 and 54, adjusted for study follow-up), median years of full-time farming (15 and 15, adjusted for study follow-up), median number of acres (60 and 65), gender (10.1 and 9.3% women), and type of farming (large mixed, 16.9 and 16.8%; small mixed, 12.7 and 12.5%; field crop, 7.8 and 7.7%; fruit and nut, 44.7 and 43.5%; livestock, 13.6 and 15.1%; nursery 3.4 and 3.7%; vegetable, 1.0 and 0.7%). The categorization by farming type was based on the commodities

TABLE 1. Duration and Perceived Dust Ratings for Crop-Related Operations Reported by California Farm Operators (n = 546) for the Past 12 Months

| | n (%) | Number of Days* (25–75%ile) | Average Hours/Day | Dust Rating |
|---|---|---|---|---|
| Planting or seeding | 171 (31%) | 7 (3–20) | 7.3 | 2.9 |
| Supervision of field work | 312 (57%) | 80 (20–205) | 5.2 | 2.8 |
| Ground preparation (plowing, planing, discing, etc.) | 269 (49%) | 20 (10–45) | 6.6 | 4.6 |
| Mechanical mowing of weeds | 223 (41%) | 8 (4–20) | 5.5 | 3.9 |
| Manual weed control (hoeing) | 160 (29%) | 8 (4–18) | 4.2 | 2.2 |
| Irrigation | 351 (64%) | 34 (16–85) | 5.4 | 1.2 |
| Loading or spreading of manure | 86 (16%) | 6 (2–14) | 4.8 | 2.8 |
| Mixing, loading, or application of chemical fertilizers | 243 (45%) | 6 (3–15) | 4.8 | 2.4 |
| Hand harvesting | 105 (19%) | 20 (5–51) | 5.6 | 2.6 |
| Mechanical harvesting | 108 (20%) | 20 (5–42) | 7.9 | 5.4 |
| Training, pruning, suckering, thinning, and tying | 174 (32%) | 14 (6–31) | 5.3 | 1.8 |
| Transportation of the commodities from the fields | 186 (34%) | 14 (5–40) | 5.3 | 2.8 |
| Loading or stacking bales | 24 (4%) | 24 (11–159) | 3.4 | 3.1 |
| Sorting or packing of commodities | 80 (15%) | 20 (9–56) | 5.5 | 2.6 |
| Residue burning (tree, leaf, or stubble) | 215 (39%) | 4 (2–7) | 4.6 | 2.7 |

n (%) = number (as percentage of total in study) of farm operators.
*Median.

grown and/or raised and is described in detail by Nieuwenhuijsen *et al.*[8]

### Statistical Analyses

Statistical analyses were carried out using the statistical software package SAS (SAS institute, Cary, North Carolina). Proc Means, Proc Freq, and Proc Univariate were used for descriptive statistics, and Proc Corr (Spearman) was used for analyses of correlation.

## Results

The majority of farm operators (83%) reported that they personally did crop-related operations (listed in Table 1) over the last 12 months, while a minority (27%) reported work on livestock-related operations (listed in Table 3). Seventy percent of the farm operators reported general farm work (listed in Table 4), not counting pesticide work.

Of the crop-related operations, irrigation (64%), supervision of field work (57%), and ground preparation operations (49%) were reported by the largest proportion of farm operators (Table 1). Irrigation and supervision were also the crop-related operations, with the highest median number of days over the last 12 months reported by farm operators. The highest numbers of hours per day were reported for planting/seeding and mechanical harvesting. Mechanical harvesting and ground preparation received the highest average dust ratings (5.4 and 4.6, respectively), while irrigation received the lowest (1.2). Mechanical and hand-harvesting operations differ by type of farming, as different techniques and equipment are used. The reported durations and perceived dust ratings of hand and

TABLE 2. Duration and Perceived Dust Ratings by Commodity and Type of Harvesting Reported by California Farm Operators for the Past 12 Months

| Type of Farming<br>Type of Harvesting | n (%) | Number of Days* (25–75%ile) | Average Hours/Day | Dust Rating |
|---|---|---|---|---|
| Field crop | | | | |
| Hand harvesting | 3 (10%) | 34 (4–80) | 4.7 | 2.3 |
| Mechanical harvesting | 13 (45%) | 28 (15–54) | 9.5 | 4.4 |
| Fruit and nut | | | | |
| Hand harvesting | 52 (24%) | 16 (5–34) | 6.4 | 3.0 |
| Mechanical harvesting | 46 (21%) | 16 (4–40) | 8.7 | 6.0 |
| Nursery | | | | |
| Hand harvesting | 5 (26%) | 45 (20–120) | 5.0 | 0.4 |
| Mechanical harvesting | 0 (0%) | | | |
| Vegetables | | | | |
| Hand harvesting | 3 (75%) | 55 (51–360) | 6.0 | 2.3 |
| Mechanical harvesting | 0 (0%) | | | |

n (%) = number (as percentage of type of farming) of farm operators.
*Median.

TABLE 3. Duration and Perceived Dust Ratings of Livestock-Related Operations Reported by California Farm Operators (n = 546) for the Past 12 Months

| | n (%) | Number of Days* (25–75%ile) | Average Hours/Day | Dust Rating |
|---|---|---|---|---|
| Feeding of silage | 22 (4%) | 138 (23–360) | 1.8 | 2.3 |
| Feeding of hay | 126 (23%) | 150 (85–275) | 2.1 | 2.8 |
| Feeding of manufactured feed, grains, or by-products | 25 (5%) | 360 (180–360) | 1.9 | 3.6 |
| Milking | 19 (4%) | 270 (8–360) | 4.6 | 1.3 |
| Loading, unloading, herding, or moving of animals | 115 (21%) | 20 (7–41) | 3.4 | 3.2 |
| Animal handling tasks (inseminate, calving, vaccinate, etc.) | 120 (22%) | 7 (3–15) | 4.0 | 2.8 |
| Checking of animals | 130 (24%) | 153 (40–350) | 2.2 | 1.9 |
| Scraping of stalls/manure removal | 72 (13%) | 12 (4–34) | 2.4 | 3.5 |
| Handling of hay or straw | 71 (13%) | 16 (4–120) | 2.3 | 3.6 |
| Entering or checking of silos, feed storages, or pit storages | 21 (4%) | 12 (4–40) | 1.7 | 2.8 |
| Loading or cleaning of silos, feed storages, or pit storages | 11 (2%) | 8 (3–40) | 2.2 | 4.3 |
| Cleaning of stalls or houses with disinfectants | 19 (3%) | 3 (1–12) | 2.5 | 2.2 |
| Cleaning of equipment with disinfectants | 45 (8%) | 11 (2–80) | 1.7 | 1.0 |

n (%) = number (as percentage of total in study) of farm operators.
*Median.

mechanical harvesting by commodity type are shown in Table 2. Fruit and nut farm operators perceived their mechanical harvesting operations to be dustier than field crop operators (6.0 and 4.4, respectively).

For the livestock operations, checking animals (24%), feeding hay (23%), and animal handling tasks (22%) were reported by the highest proportion of farm operators (Table 3). Feeding manufactured feed and milking were livestock operations with the highest reported median number of days over the past 12 months, but they were reported by only a small proportion of farm operators (5% or less). Farm operators reported the highest number of hours per day for milking. Loading or cleaning of silos, feed storages, or pit storages received the highest average dust rating (4.3), while milking and cleaning equipment with disinfectants received the lowest (1.3 and 1, respectively).

Fifty-two percent of the farm operators reported mixing, loading, or application of pesticides, with a median of 8 days over the past 12 months (Table 4). Administrative management or office work was reported by 85 percent of the farm operators and equipment maintenance or repair by 65 percent. Tractor driving was reported by 416 of the farm operators (76%) and received a high dust rating (4.5). Of the 416 farm operators who reported tractor driving, 334 (80.3%) reported that there was never an enclosed cabin on the tractor. The remaining 82 (19.7%) reported that there was an enclosed cabin on the tractor(s) 50 percent of the time (median) they drove one. Administrative work received the lowest dust rating (0.4). A third of the farm operators (33%) reported a nonfarm job with a median duration of 20 days over the last 12 months.

The percentages of farm operators reporting certain operations varied by type of farming (Table 5). For example, 11 percent of the livestock farmers and 60.4 percent of large mixed farmers reported ground preparation operations over the past 12 months, a more than fivefold difference. Also, 19.5

TABLE 4. Duration and Perceived Dust Ratings of General Farm Operations Reported by California Farm Operators (n = 546) for the Past 12 Months

| | n (%) | Number of Days[A] (25–75%ile) | Average Hours/Day | Dust Rating |
|---|---|---|---|---|
| Mix, load, or apply pesticides | 286 (52%) | 8 (4–15) | 4.8 | — |
| Building maintenance or construction | 171 (31%) | 10 (5–20) | 5.2 | 2.4 |
| Equipment maintenance or repair | 354 (65%) | 10 (5–20) | 4.2 | 1.7 |
| Welding or grinding | 250 (46%) | 5 (2–10) | 3.2 | 2.3 |
| Wood sawing or wood sanding | 221 (40%) | 4 (2–10) | 3.7 | 3.3 |
| Spray painting of equipment or machines | 104 (19%) | 2 (1–5) | 3.6 | 2.9 |
| Wood painting | 123 (23%) | 3 (2–5) | 4.5 | 1.7 |
| Tractor driving | 416 (76%) | 30 (14–60) | 5.6 | 4.5 |
| Administrative management or office work | 463 (85%) | 41 (12–200) | 3.4 | 0.4 |
| Nonfarm job | 180 (33%) | 20 (9–30)[B] | — | 1.7 |

n (%) = number (as percentage of total in study) of farm operators.
[A]Median.
[B]Years.

TABLE 5. Percentage of California Farm Operators Reporting Work on Various Operations Over the Past 12 Months by Type of Farming

| | Type of farming | | | | | | |
|---|---|---|---|---|---|---|---|
| Operation | Large Mixed | Field Crop | Fruit and Nut | Livestock | Nursery | Small Mixed | Vegetables |
| Number (%) of farm operators | 91 (16.8) | 42 (7.7) | 236 (43.5) | 82 (15.1) | 20 (3.7) | 68 (12.5) | 4 (0.7) |
| Seeding/planting | 50.5 | 40.4 | 28.8 | 9.8 | 45.0 | 26.5 | 75.0 |
| Supervision | 74.7 | 47.6 | 71.6 | 12.2 | 70.0 | 38.2 | 75.0 |
| Ground preparation | 60.4 | 52.4 | 59.7 | 11.0 | 30.0 | 48.5 | 50.0 |
| Hand harvest | 23.0 | 7.1 | 22.0 | 2.4 | 25.0 | 26.5 | 75.0 |
| Mechanical harvest | 35.2 | 31.0 | 19.5 | 3.7 | 0 | 20.6 | 0 |
| Checking animals | 48.4 | 7.1 | 0.5 | 75.6 | 0 | 29.4 | 0 |
| Load, mix, and apply pesticides | 46.2 | 47.6 | 63.6 | 19.5 | 75.0 | 55.9 | 75.0 |

percent of the livestock farm operators reported mixing, loading, or application of pesticides, while 75 percent of the nursery and vegetable farm operators did.

In general, there were weak to moderate correlations between the number of days farm operators personally spent on various operations ($r_s < 0.5$), except for some livestock operations. Table 6 shows the livestock operations for which there were stronger correlations between the number of days spent on these various operations. These operations are done by a relatively small percentage of farm operators on a routine basis. Besides these operations, fairly strong correlations were found between the number of days milking and feeding manufactured feed ($r_s = 0.69$), cleaning and entering silos ($r_s = 0.61$), disinfecting stalls and cleaning silos ($r_s = 0.56$), mixing, loading, and applying pesticides and of fertilizers ($r_s = 0.53$), welding and equipment repair ($r_s = 0.60$), and building maintenance/construction and sawing wood ($r_s = 0.54$). The potential for exposure to pesticides depends, among other things, on the method of application. The application method used personally by the largest percentage of California farm operators appears to be the vehicle-mounted boom sprayer (20.9%), followed by the vehicle-mounted airblast sprayer (19.4%) (Table 7). Of the 286 farm operators who said they mixed, loaded, or applied pesticides over the past 12 months, 43.0 percent reported that they never or rarely wore a mask or cartridge respirator, 10.8 percent reported that they wore one up to half the time, and 45.8 percent reported that they wore one more than half the time. One farm operator did not know.

The farm operators were asked to rate their exposure over the past 10 years. They reported a decline in dust, gas, fume, and pesticide exposure and the percentage of time spent in dusty jobs over the past 10 years, while reporting that their median numbers of farm hours remained the same (Table 8).

## Discussion

This article described the duration of time California farm operators personally spent on various agricultural operations and how dusty they perceived them to be. The sample confirms the enormous diversity in California agriculture. The majority of farm operators reported work on crop-related operations, while a minority reported work on livestock-related operations. There were considerable differences in the duration of time California farm operators spent on various operations, some of which could be explained by the differences in commodities they grew or raised. Mechanical harvesting—in particular of fruit and nuts—and ground preparation were perceived to be the dustiest operations. The farm operators estimated that their exposure to dust, gases, fumes, and pesticides had declined over the past 10 years.

The development of respiratory disease depends, among other factors, on the nature, level, duration, and particle size distribution of airborne exposures. Recently there were reports on the level, particle size distribution, and determinants of dust exposure in California agriculture[9,10,12] and the commodities that were grown or raised.[8] This article provides valuable information on the duration of exposure. Currently we are undertaking a study to measure the dust, endotoxin, and silica levels for various operations in a small subgroup of the farm operator cohort. Together they will provide unique information on exposure to evaluate California farm operators' risk of developing respiratory disease.

Exposure to inorganic dust and pesticides tends to be higher

TABLE 6. Spearman Correlation Coefficients ($R_s$) Between the Number of Days per Year Conducting Various Operations During Livestock Farming Among California Farm Operators

| | Handling Animals | Checking Animals | Scraping Stalls | Handling Hay/Straw | Loading Animals |
|---|---|---|---|---|---|
| Checking animals | 0.87 | | | | |
| Scraping stalls | 0.60 | 0.65 | | | |
| Handling hay/straw | 0.54 | 0.58 | 0.57 | | |
| Loading animals | 0.86 | 0.83 | 0.60 | 0.54 | |
| Feeding hay | 0.81 | 0.83 | 0.66 | 0.62 | 0.79 |
| Disinfecting equipment | 0.53 | 0.51 | | | |

TABLE 7. Number of Farm Operators (%) Reporting Personal Use of Pesticide Application Methods

| Application Method | n (%) |
|---|---|
| Crops | |
| Soil injection | 21 (3.8) |
| Irrigation system | 26 (4.8) |
| Portable hand-held sprayer | 92 (16.8) |
| Vehicle mounted hand-held sprayer | 89 (16.3) |
| Vehicle mounted airblast sprayer | 106 (19.4) |
| Vehicle mounted boom sprayer | 114 (20.9) |
| Livestock | |
| Dipping | 0 (0.0) |
| Foot bath | 2 (0.4) |
| Ear tag | 3 (0.5) |
| Pouring on | 13 (2.4) |
| Dust pack | 13 (2.4) |

n (%) = Number of farm operators (percentage of the total number of farm operators).

in crop farming (field crop, fruit and nut, vegetable, and nursery farming) than in livestock farming, while exposure to organic dust and gases tends to be higher in livestock farming.[13] The different exposures are associated with different respiratory diseases.[13] Dust exposure levels vary with the type of operation.[9,10,12,14] High dust levels, well above the American Conference of Governmental Industrial Hygienists Threshold Limit Values,[15] have been measured for crop-related operations such as ground preparation and harvesting in California agriculture.[9,10,12,14] Some of the highest inhalable dust levels were measured for discing (geometric mean = 81.9 $mg/m^3$) and land planing (geometric mean = 47.0 $mg/m^3$).[10] Respirable dust levels were generally below 1 $mg/m^3$. The presence of an enclosed cabin considerably reduced (up to sixtyfold) the dust levels,[9,10,12] but only 20 percent of the farm operators in this study used tractors with enclosed cabins. The results of this study show that California farm operators do many different operations with varying duration, while other studies have shown that the nature, level, and particle size distribution vary among operations in California agriculture.[9,10,12,14] One could appreciate that the risk of developing respiratory disease also varies among California farm operators.

Reports have shown that workers are able to estimate their occupational exposure with reasonable success, particularly when viewed as a group rather than on an individual basis.[16–21] Although self-reported exposure estimates might not be as good as actual exposure measurements, they are much easier to obtain and could be used at least as an indicator of some level of exposure. Personal dust measurements are difficult to obtain in agriculture because of the varied and cyclic nature of the farmers' work and the diverse locations of the farms. Currently we are undertaking a study to validate the self-reported dust exposure estimates with personal dust measurements in a small subgroup of this farm operator cohort.

TABLE 8. Average Farm Operator Exposure Ratings for Dust, Gas, and Pesticide, Farm Hours, and Percentage Time in Dusty Job for the Past 10 Years

| | Last Year | 5 Years Ago | 10 Years Ago |
|---|---|---|---|
| Dust rating | 2.8 | 3.4 | 3.8 |
| Gas and fume rating | 1.7 | 2.2 | 2.4 |
| Pesticide rating | 1.9 | 2.3 | 2.6 |
| Percent time in dusty job | 11% | 13% | 15% |
| Farm hours/week | 32 | 32 | 33 |

In this study California farm operators perceived ground preparation and mechanical harvesting of fruit and nuts to be the dustiest operations, while they perceived irrigation and milking as some of the least dusty operations, which is consistent with the measurement results of a previous study.[9] However, it is important to note that dust was regarded as one exposure when in fact it has various constituents such as inorganic quartz, various silicates, organic allergens, pesticides, or endotoxins which are likely to vary among operations and can cause different illnesses.

The farm operators reported a decline in their exposure to dust, gases, fumes, and pesticides over the past 10 years. This might be because they are getting older and are leaving the farm work more often to their farm workers. These farm workers need more attention in the future. California agriculture is a gigantic industry with 76,000 farms, employing an estimated 1.5 million people directly and selling an estimated $19.9 billion worth of farm products.[11] It is surprising that relatively little health and safety research has been carried out in California agriculture, particularly in the area of dust exposure and respiratory disease, although recent studies have shown adverse respiratory health effects.[6,7] More research is needed, and this and other articles[9,10,12,14] have identified areas where the risk of developing respiratory disease might be the highest.

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