HERBICIDE USE IN CITRUS PRODUCTION AND GROUND WATER CONTAMINATION IN TULARE COUNTY

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ABSTRACT

The Environmental Hazards Assessment Program of the California Department of Food and Agriculture (CDFA) surveyed ground water in Tulare County and found that 49% of surveyed wells were contaminated with detectable levels of herbicide residues. The citrus industry in Tulare County is a major user of herbicides. The Pest Management Analysis and Planning Program (PMAP) of CDFA conducted a mailing survey of citrus growers in Tulare County in 1988 to identify and characterize irrigation and herbicide practices that might be associated with reported well water contamination by three herbicides commonly used in citrus production: simazine, diuron, and bromacil.

The response rate of 41% to the questionnaire was considered good relative to attempts by others at conducting similar surveys. Success of the survey can be attributed to careful planning and execution of the survey, as well as concern by the citrus industry about the ground water problem. Except for responses to questions about dry wells, most responses agreed with previous knowledge on use of herbicides and irrigation systems. The unexpectedly low number of growers reporting dry wells on their land demonstrates the sensitivity of some issues to growers, especially those concerning ground water contamination.

Simazine was rated as the most important herbicide used in citrus production. However, the response to this question suggests a broad range of chemical weed control practices. The choice of herbicides in the fall was not affected by the type of irrigation system being used, but choice of herbicides was affected during the spring application. A significant positive regression was measured between density of citrus growers using irrigation for frost protection and frequency of well water contamination. Responses suggest irrigation practices in combination with hydrologic conditions play a role in off-site movement of herbicide residues and eventual contamination of ground water.

Low volume irrigation systems were the most widely used system among citrus growers in Tulare County (57%). The highest percentage of growers using furrow irrigation (91%) was found in a district where the price of irrigation water was one of the lowest.

Responses suggest that additional research regarding timing of herbicide applications, duration of irrigation event, type of irrigation system used, and alternative, non-chemical weed control practices could reduce the movement of herbicides to ground water.

ACKNOWLEDGEMENTS

We thank the Tulare County Agricultural Commissioner, Clyde Churchill, his staff, as well as members of California Citrus Mutual. The completion of this project would not have been possible without the assistance and cooperation of these individuals. We are grateful to Mark Pepple, John Troiano, and Bruce Johnson for their careful review and discussion of this report. We thank R.G. Martinez and J.A. Rodriguez for technical assistance.

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INTRODUCTION

In 1985, the Environmental Hazards Assessment Program of the California Department of Food and Agriculture (CDFA) conducted a study to assess the movement of the herbicides simazine and diuron through soil in citrus groves in Tulare County (Welling et al., 1986). Low levels of one or both of these herbicides were found in seven of twelve sampled wells. An expanded well sampling study in specific areas of eastern Tulare County found that 49% of well water samples had detectable levels of herbicide residues (Troiano and Segawa, 1987; Fleck, unpubl. data). These herbicides are, in decreasing frequency of contamination, simazine, diuron, atrazine, bromacil, and prometon. The citrus industry with 87,800 ac in Tulare County is a major user of simazine, diuron and bromacil (CDFA, 1987; 1988). These residues were considered the result of normal agricultural use and were thus subject to review under the Pesticide Contamination Prevention Act passed in 1985. At the conclusion of this review process, the Director of the CDFA determined that use of these herbicides could be modified to prevent ground water pollution. The Pest Management Analysis and Planning Program (PMAP) of CDFA conducted a survey of Tulare County citrus growers by mail in 1988 to identify and characterize irrigation and herbicide practices that might be associated with well water contamination. Growers responded to a series of questions dealing with irrigation and herbicide use on citrus acreage. This report summarizes the responses to this survey, examines how some of these responses are related to the spatial distribution of ground water contamination in Tulare County reported by Troiano and Segawa (1987), and evaluates the quality of information retrieved from this mailing survey (Appendix I).

SURVEY METHODOLOGY

Questionnaire Preparation

Preparation of the survey questionnaire was initiated in June, 1988. Meetings were held with citrus industry leaders, University of California citrus specialists and the County Agricultural Commissioner in Tulare County. The purpose of these meetings was to review the proposed questionnaire, elicit support from the citrus industry, and to pre-test the survey. General methodology to writing the questionnaire, its cover letter, and follow up letters (Appendices I, IIA-C) was patterned after Dillman (1978).

Number of Respondents

The mailing list for this survey was obtained from CDFA's Marketing Branch and consisted of 1,584 citrus property owners in Tulare County. However, since a portion of these growers own more than one orchard, enough additional questionnaires were mailed to describe up to three blocks of citrus (one block is a contiguous aggregate of trees). The actual number of questionnaires mailed to growers was 2060. Approximately 64 questionnaires were returned as undeliverable, leaving 1996 potential respondents. A total of 820 (41.1%) usable questionnaires were returned. This return rate was considered good in light of previous attempts by others in surveying growers by mail.

Analysis of Data

Responses to the questionnaire were initially summarized by computing the percentage of all respondents answering respective choices to questions or averaging the values reported to a question (Appendix I). All analyses were conducted with the assumption that in a township the number of respondents is approximately proportional to the total number of citrus growers.

Simple regression was used to measure the relationship between number of growers per township and citrus acreage per township. Citrus acreage was based on the total number of acres per township owned by growers responding to the questionnaire (Appendix I, p. 2). Simple regression and correlation techniques were used to determine if frequency of well water contamination was associated with either the distribution of citrus growers within Tulare County or distribution of citrus growers using specific farm practices within this County. In addition some questions were summarized using a two by two or multi-way contingency table. A Chi square (χ^2) test was then conducted to test for lack of independence between two variables.

Well water contamination in this report is based primarily on a previous Tulare County well survey (Troiano and Segawa, 1987). It is expressed as the proportion of all wells sampled in a cell (four contiguous one square mile sections as delineated by the United States Geologial Survey Public Survey Coordinate System) that had measurable amounts of any of the following herbicides: simazine, bromacil or diuron. Thus, the higher the proportion of wells with positive finds of one or more of these herbicides, the higher the local contamination of ground water. The distribution of citrus growers and users of specific farm practices were based on the number of respective individuals per township (36 square miles). In several cases, cells were composed of samples collected from more than one township. In these cases, the number of individuals per township was determined by averaging data from combined townships.

Depth to ground water, in addition to specific farming practices, could affect the presence of herbicide residues in well water samples. Examination of the depth to ground water found that cells could be divided into two groups. Nine

were in areas with ground water varying from 10 to 40 ft (cells A-I) and three others were in areas with ground water varying from 80 to 130 ft (cells J-L). The mean depth to ground water for these two sample groups was significantly different (t-test, $p = 0.01$). To remove depth to ground water as a confounding source of variation in the above regression analyses, data were examined dropping from the analyses cells in areas of deepest ground water (cells J-L). All data were examined using software from the SAS Institute (SAS, 1985).

EVALUATION OF QUESTIONNAIRE PROCESS

A major concern of the survey was the quality of information retrieved from the respondents. The only check that could be made on the validity of responses was through comparison of summarized results with anecdotal information and known field measurements. In several cases, there was close agreement between "expected" and measured values. For example, simazine was considered the most widely used herbicide and was also ranked as the most important in the survey. The average amount of water use reported from our questionnaire for low volume irrigation was very close to the amount required for fruit tree production in the central valley of California. However, responses to questions dealing with dry wells indicated there were fewer dry wells than previously estimated. It is uncertain whether this was due to overestimation, unawareness of dry well locations, or reluctance to provide data on the presence of dry wells.

The number of responses required to produce a reliable estimate for a question is one factor that should be considered when designing a survey questionnaire, especially if the survey population is small. In many instances only a small group or subset of growers can respond to questions addressing very specific,

uncommon practices. For example, only 7 out of a potential 820 growers responded to a question dealing with the use of drip line irrigation, and resulted in a high coefficient of variation, 71%. Few if any conclusions could be based on a parameter estimate with that amount of variability.

RESULTS

Grower Numbers in Relation to Citrus Acreage

Size of citrus acreage showed a highly significant positive linear relationship with number of growers per township ($r^2 = 0.96$, $n = 48$, $p = 0.0001$). Therefore, within the context of this survey numbers of growers in a township can be interpreted as a surrogate measure for local citrus acreage.

Location of Citrus Growers in Tulare County

Most of the citrus growers responding to this survey were located in the north-eastern valley floor and foothill region of Tulare County (Fig. 1). The township/range 20S27E, which includes the town of Lindsay, had by far the greatest number of respondents, 139, or 19.7% of the total. The next highest count was 45 respondents and most of the remaining townships with citrus growers had less than 30 respondents. The spatial distribution of respondents in Fig. 1 shows that citrus growers are concentrated along the foothill fringe of the Sierra Nevada mountain range, an area that due to its relief has a lower risk to frost damage than the valley trough (Reuther, 1973).

Description of Citrus Orchards

Almost half of the respondents operated one block of citrus while the remaining respondents operated two or more blocks of citrus. Nine percent of growers reported that they operated over eleven blocks. Almost a third of the citrus blocks were less than 10 acres in size and 22 percent of the citrus

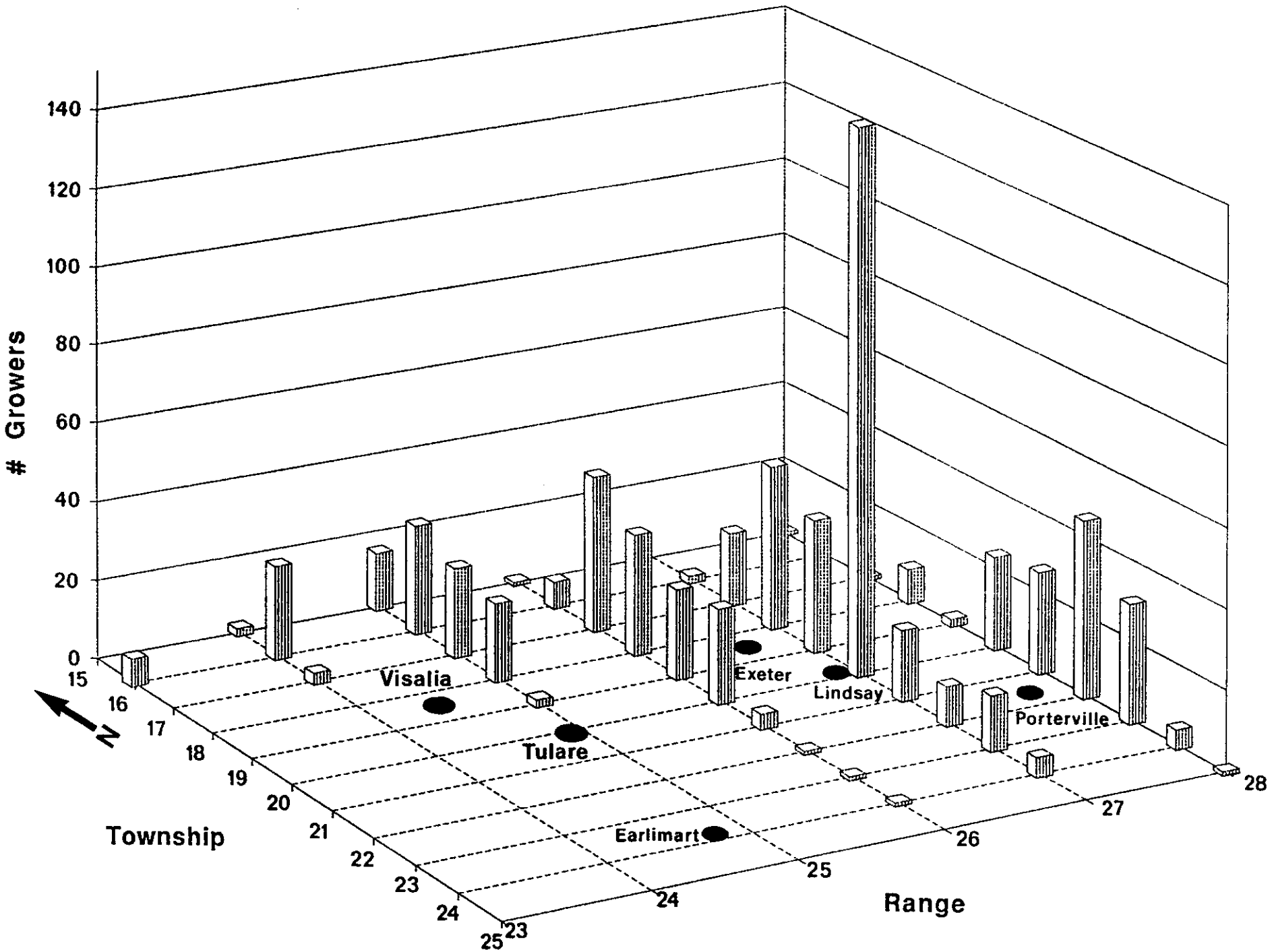


Figure 1. Distribution of citrus growers in Tulare County.

blocks were 11 to 20 acres. The remaining blocks were 31 acres in size or more. Most of the orchards (59%) have tree spacing that is either 20 ft x 20 ft or 22 ft x 22 ft. The highest percentage of growers (39%) own trees that are 21 to 30 years in age, the next highest percentage of growers own trees that are 11 to 20 years in age (15.6%). Only 5% have planted trees within the last ten years. Interestingly, a substantial percentage (14.6%) have trees that are more than 60 years old. The majority of middle-aged orchards can be found in the western central region of Tulare County's citrus area, while the older orchards are concentrated in the eastern portion (Fig. 2). The first citrus orchards in Tulare County were planted along the eastern edge of the valley because it was considered the "thermal belt" and presented the least frost risk. When growers were asked about the steepness of the slope in their orchards, 54% were on land with a moderate slope, and 2.3% were on land that was very steep, demonstrating their use of relief in reducing frost damage: air cooled by radiation tending to flow downslope because of its greater density. Although 41.8% of growers were on land considered "flat," they still lie above the valley trough.

Use of Herbicides

Growers were asked to rank the overall importance to weed management of the four major pre-emergent herbicides: simazine, Karmex (diuron), Krovar (diuron + bromacil), and bromacil (Hyvar). Simazine was ranked as the most important herbicide and bromacil as the least important (Fig. 3). However, the response to this question suggests a potentially broad range of chemical weed control practices: 13.5% of the respondents reported simazine as "not important" to management of their citrus, while 6.5% reported bromacil was "very important" (Appendix 1, p. 1). Karmex was ranked above Krovar in importance. The use of pre-emergent material in the fall was more common than the

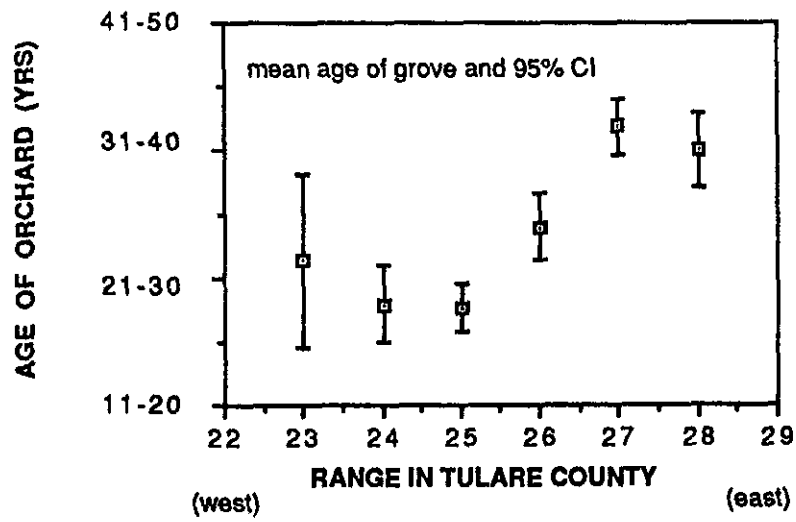


Fig. 2. Age of orchard vs. location (range).

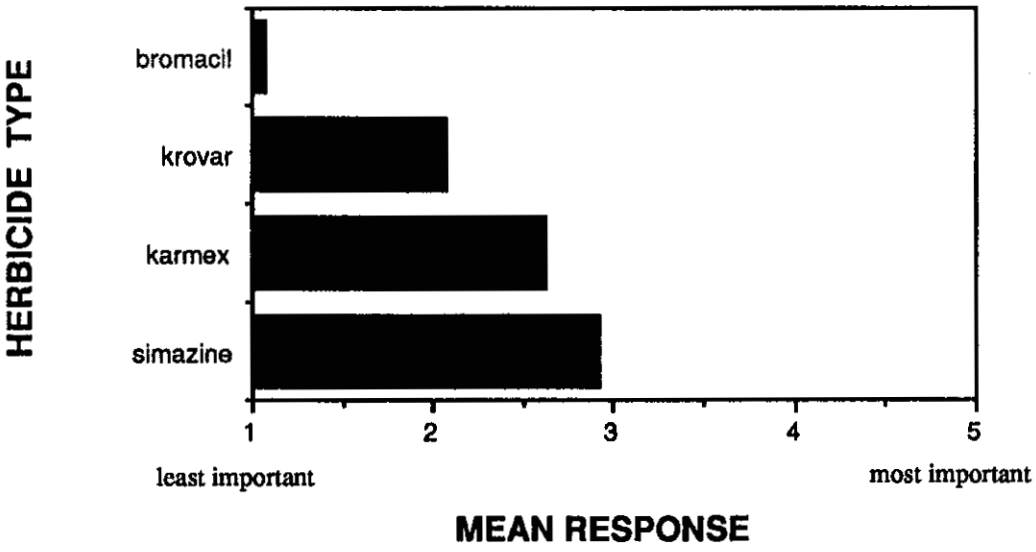
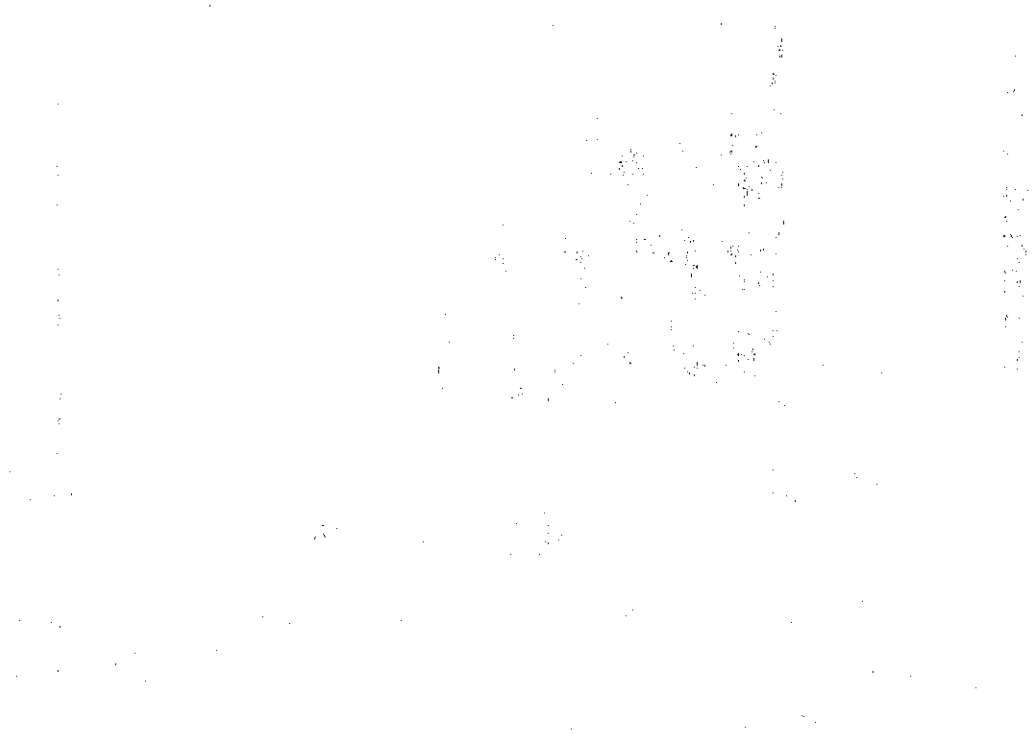


Fig. 3. Importance of herbicides to weed management program in citrus. All means were significantly different from each other based on six pairwise comparisons (t-test). Experimentwise error rate was set at alpha = 0.008.



following spring. A total of 71% of growers used herbicides in the fall and 42.2% used herbicides the following spring. Of growers who were asked which pre-emergent materials they used in fall 1988, 13% responded "none." Sixty-five percent of those growers using no pre-emergent materials in the fall, also did not use herbicides in the spring, suggesting that some growers apply sufficient rates of pre-emergent materials to provide at least twelve months of weed control. The use of post-emergent materials for spot treatments is a common practice (85% of all respondents). These products probably maintain orchards weed free in combination with the pre-emergent application.

Irrigation Practices

Three major types of irrigation systems were addressed in the survey: (1) low volume which includes drip, mister (=fogger), and microsprinkler (=jet types) systems; (2) furrow irrigation; and (3) drag line, one or more sprinklerheads attached to a hose line pulled through the orchard. A majority of citrus growers in Tulare County (58%) use low volume irrigation, while 25% use furrow and 16% use dragline systems. The use of low volume irrigation has been widely adopted by the citrus industry and its use by growers in Tulare County corresponds to the general distribution of all citrus growers in this county (Figs. 1,4). The highest concentration of growers using low volume irrigation is just east of Visalia where the highest concentration of all respondents was measured.

Both orchard topography and the water district in which the orchard resides appear to play some role in the choice of furrow and dragline irrigation systems within Tulare County. Furrow irrigation is rarely used along the eastern edge of the citrus belt because it is a less practical approach to watering citrus in the foothills. The distribution of growers using furrow

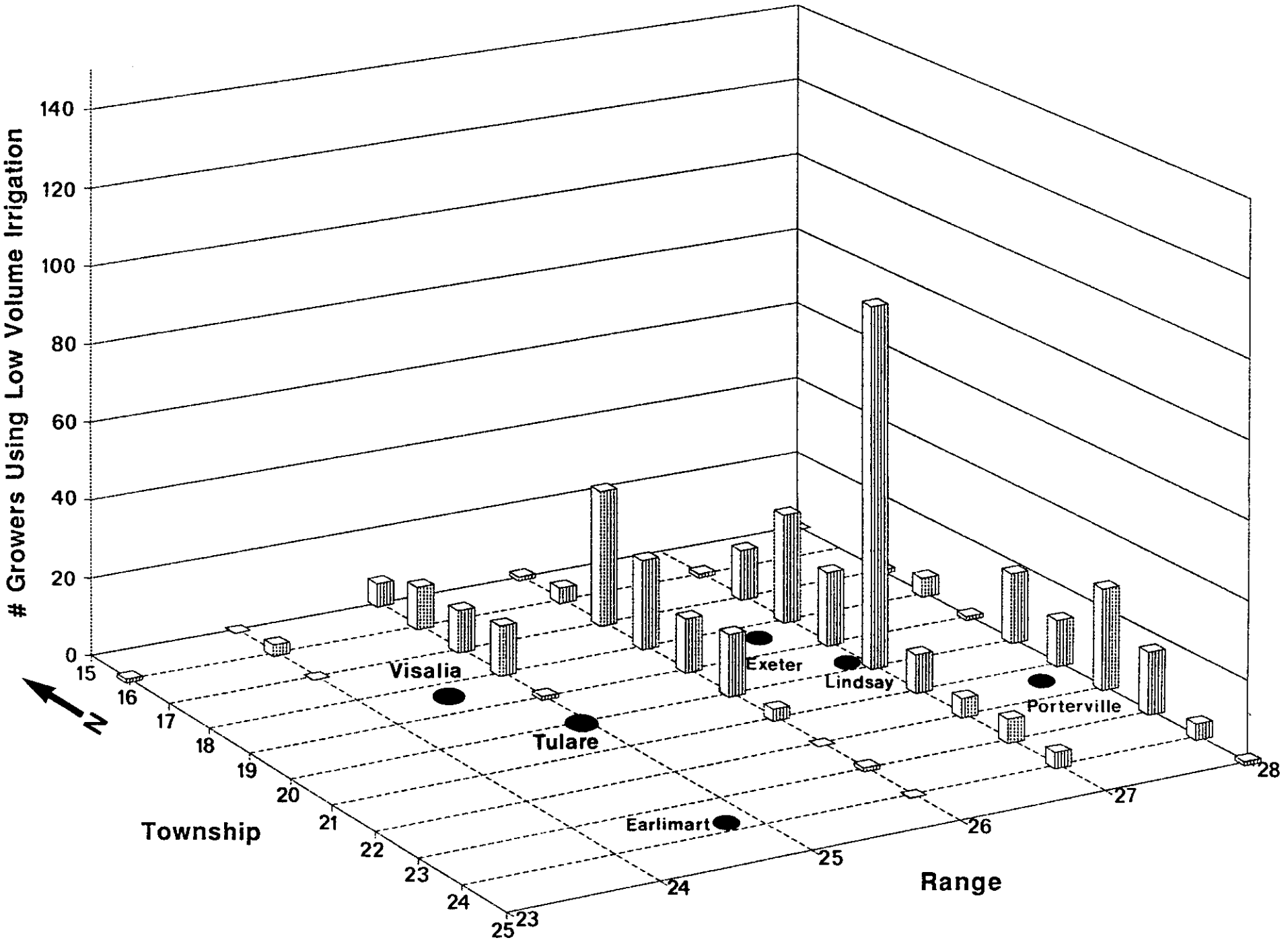


Figure 4. Distribution of citrus growers in Tulare County using low volume irrigation practices.

irrigation in Tulare County differs from the distribution of all producers of citrus (Figs. 1,5). The highest density of growers using furrow irrigation is in the northwestern area, just north of Visalia, while the highest density of all citrus growers is in the northeastern area of the county.

When partitioning growers by water district, a relationship was found between water district and type of system used for irrigating citrus (Table 1). Although 25% of growers overall in Tulare County use furrow irrigation, 91% of growers in Tulare County's Alta water district use this system. At the other extreme, none of the growers in the survey use furrow irrigation in the Terra Bella district.

The differences among water districts in use of furrow irrigation may be due in part to differing water prices between districts (Table 2). The mean price of irrigation water among water districts is weakly correlated with the percentage of growers using furrow irrigation in these areas (r = .74, p = 0.056). The lower efficiency of furrow irrigation, especially on non-level lands, makes irrigation very expensive if water is costly. Examining the extreme ends of this relationship, we found that the Alta Water District at $8.25 per ac/ft has the second lowest priced water, and Terra Bella at $68 per ac/ft has the most expensive.

The third and last type of irrigation system surveyed was dragline. Its use is concentrated in the southeastern corner of the county's citrus (Fig. 6), an area that includes the foothills of the Sierra Nevada with orchards having fairly steep slopes. Dragline provided a relatively efficient and inexpensive irrigation system in the 1950's and 60's before introduction of low volume types. It is still widely used in the highest priced irrigation water

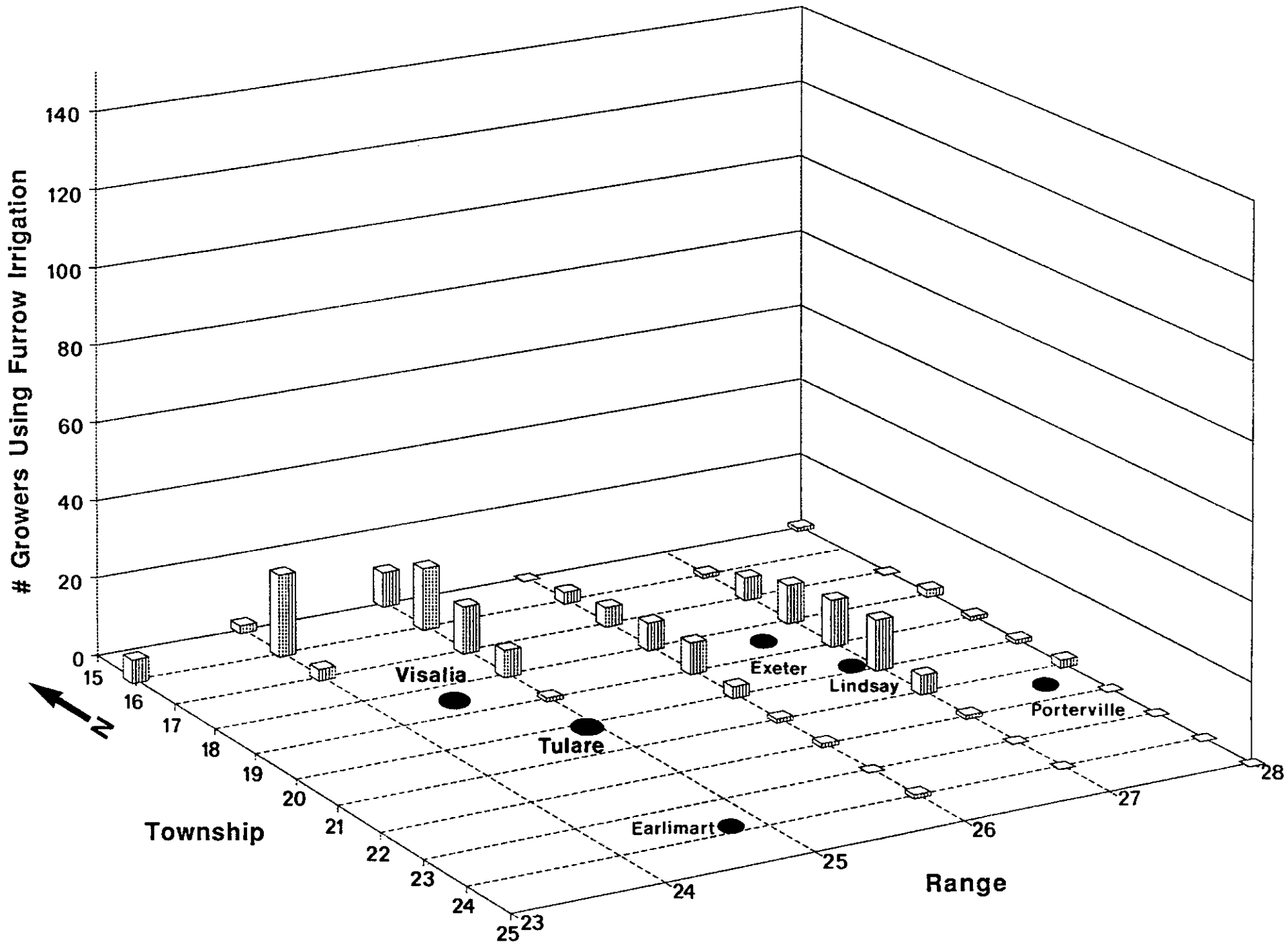


Figure 5. Distribution of citrus growers in Tulare County using furrow irrigation practices.

Table 1. Percent of growers using each of three types of irrigation systems listed by water district.

Water District[2]	Percent of Growers Using:[1] Low Volume	Dragline	Furrow
Alta	7.1	1.8	91.1
Exeter	60.0	1.1	39.0
Ivanhoe	66.3	0.0	33.7
Lindmore	61.2	20.7	18.2
Lindsay-Stratmore	73.9	23.1	3.1
Orange Cove	47.9	2.3	50.0
Terra Bella	61.7	38.3	0.0

[1]Significant association between use of irrigation system and water district (χ^2 = 261.8, $p<0.0001$, n = 610).

[2]Only water districts with greater than 5% of all respondents were used in this analysis.

Table 2. Cost of irrigation water for each water district in Tulare County, and use of furrow irrigation.

Water District	Percent of Growers Using Furrow Irrigation	Cost ($) for [1] One Acre-foot of Water
Alta	91.1	8.3
Orange Cove	50.0	27.0
Exeter	39.0	26.5
Ivanhoe	33.7	7.0
Lindmore	18.2	19.5
Lindsay-Stratmore	3.1	63.0
Terra Bella	0.0	68.0

[1] Average of high and low price within district (personal interview with District personnel).

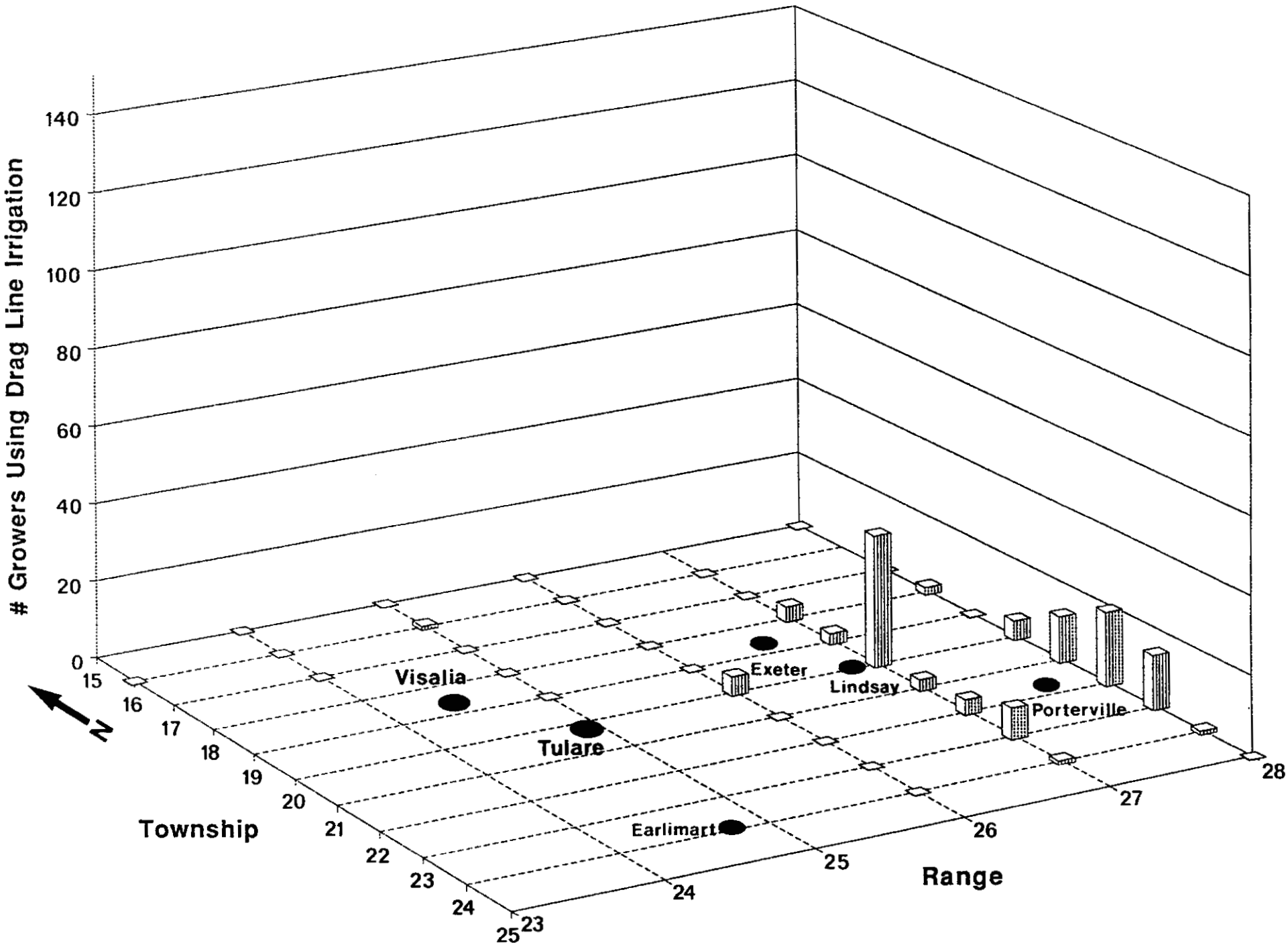


Figure 6. Distribution of citrus growers in Tulare County using drag line irrigation practices.

districts, Terra Bella and Lindsay-Stratmore (Table 2), but is frequently converted to low volume when major repairs become necessary.

Growers were asked how much water in acre-inches applied per month they used on their citrus acreage. Growers using low volume were further divided into those who used micro, drip, or mister irrigation systems. The monthly use pattern for the furrow, dragline, drip, micro, and mister irrigation systems followed a standard bell curve, with the greatest use in July and August (Fig. 7). Predicted water use, based on evapotranspiration (ET) needs, has been developed by California's Department of Water Resources (California Dept. Water Resources, San Joaquin District, 1980) and is plotted for comparison in Fig. 7. Predicted water needs typically exceeded applied water during the first half of the year for all irrigation systems. Most growers allow for uptake of winter rainfall by trees during this part of the year, reducing the need for irrigations at this time. During the latter half of the year, water applied came close to or exceeded plant needs. Furrow irrigation exceeded more than all other types of irrigation the predicted amounts needed during this time of the year.

Peak monthly water use in the summer varied from 4.04 ac/inches (drip) to 5.83 ac/inches (furrow). Growers using furrow irrigation applied more water (34.86 ac/in) over the year than growers using other types of irrigation systems and significantly more than micro and dragline irrigation (Fig. 8). Generally, more water is applied under furrow irrigation because of inefficiencies resulting from deep percolation and runoff losses. Deep percolation occurs because the head end of the furrow is over irrigated before sufficient water reaches the far end of the furrow. Except for furrow irrigation, the use of water as calculated from the survey comes very close to the amount required

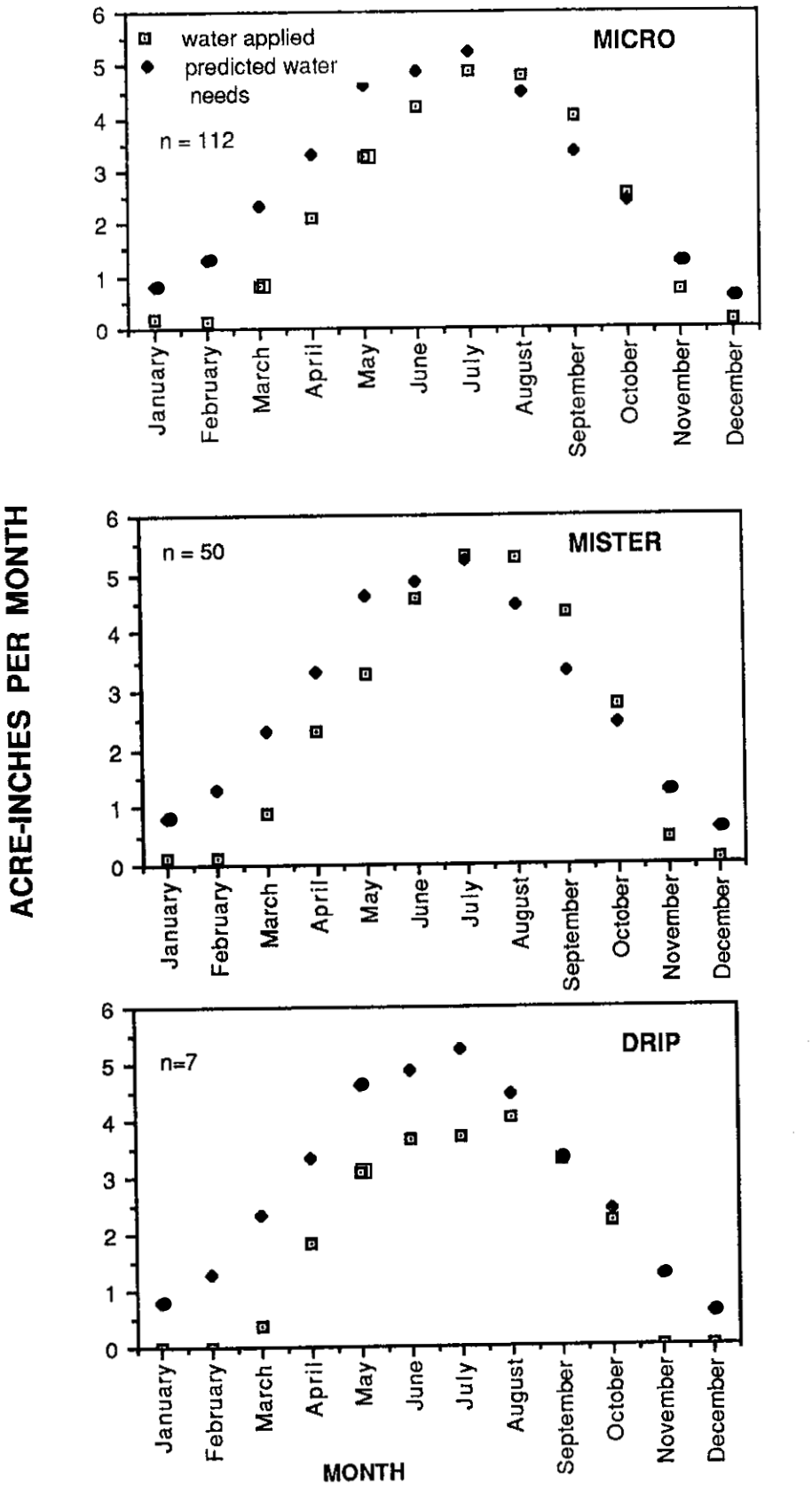


Fig. 7. Application of irrigation water in Tulare County and and predicted water needs based on ET of citrus.

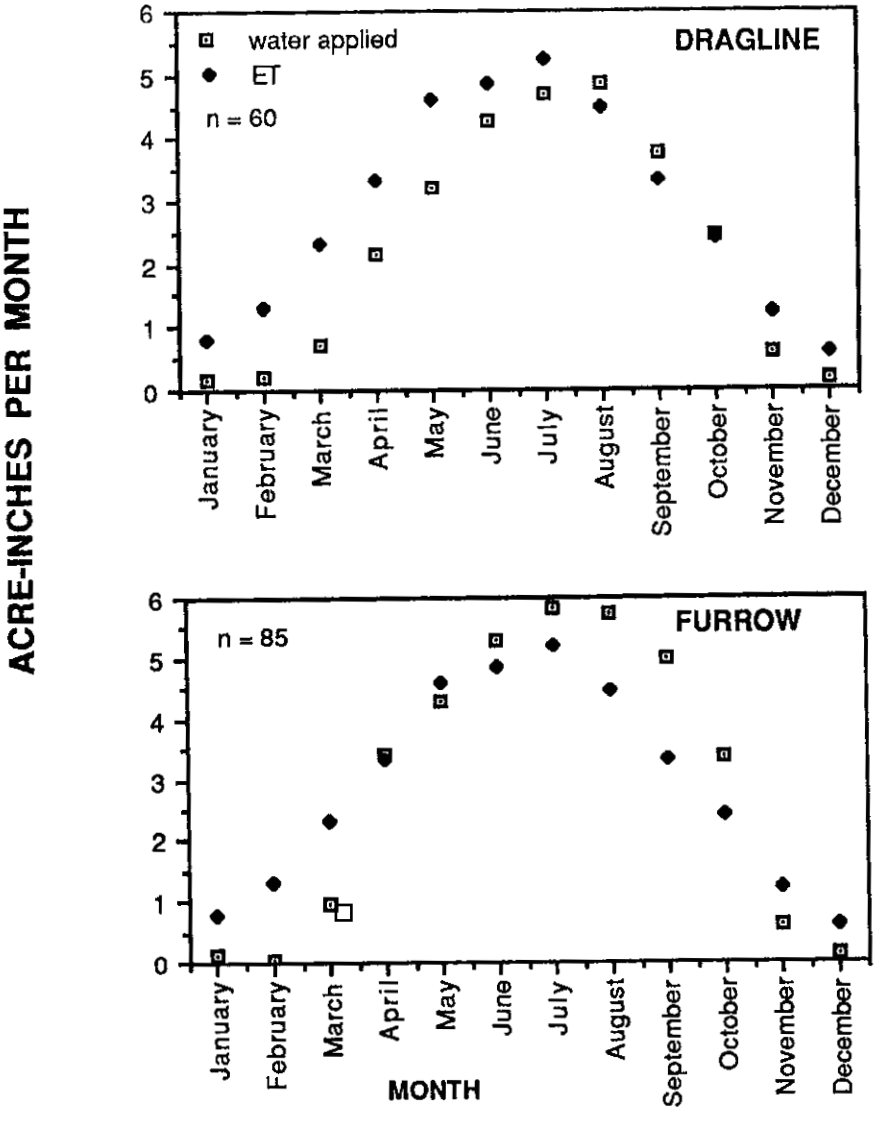
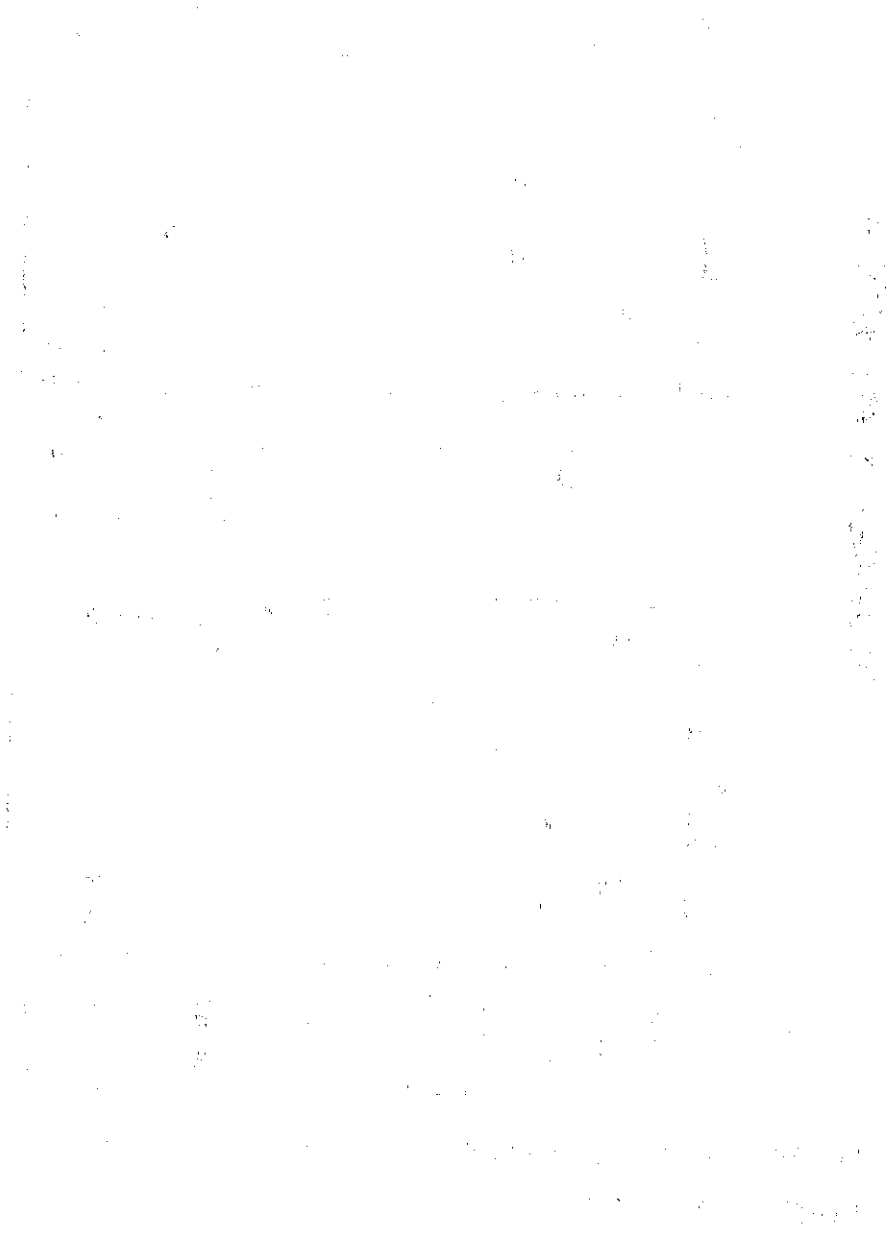


Fig. 7 cont. Application of irrigation water in Tulare County and predicted water needs based on ET of citrus.



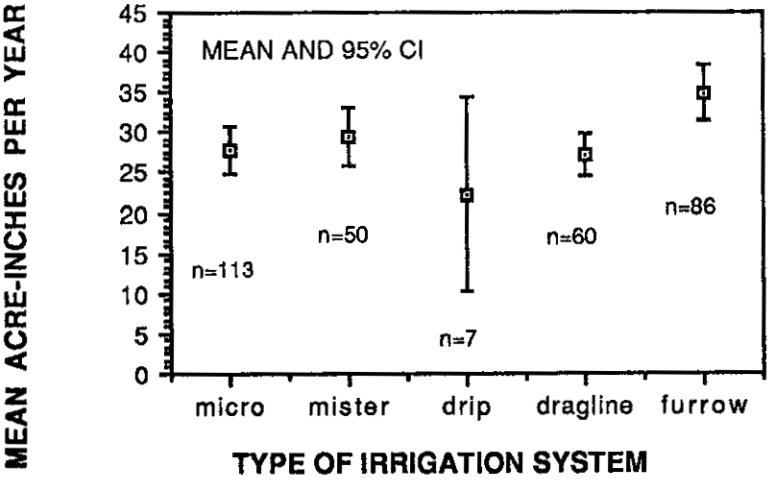


Fig. 8. Water use in relation to irrigation system.

for citrus tree growth, 26 ac/in per year (Fig. 8; Pehrson, 1975). Growers using drip irrigation reported the least use of water, 22.3 ac/in per year, however this estimate is unreliable due to the small sample size (n = 7).

The survey questioned growers of microsprinkler or jet type systems about the duration of individual irrigations. Forty-six percent of growers irrigated for 24 hr, 36% for 48 hr, 13% 72 to 96 hr and 1.1% for longer than 96 hr. This use pattern (24 hr $\geq$ 48 hr > 72-96 hr) was the same for all water districts except Lindmore (Table 3). The most frequently used irrigation duration in this district was 48 hr, followed by 24 hr, and 72-96 hr. This pattern suggests that in the Lindmore Water District factors other than irrigation efficiency may play a role in an irrigation practice. Perhaps a longer duration reduces the labor costs associated with the more frequent operation of irrigation systems. The mixed results from this question point out a need for additional research on the importance of water use efficiency relative to leaching, water costs, and labor costs.

A χ^2 analysis was used to test if the choice of pre-emergent material was affected by the type of irrigation system employed on an orchard. In the fall, choice of materials by growers using low volume, furrow, and dragline irrigation systems was relatively the same, indicating a similar preference towards pre-emergent materials (χ^2 = 9.86, p = 0.628; Table 4). The most frequently selected herbicide for all three groups of growers was a mixture of simazine and diuron, followed by the mixture diuron plus bromacil (Krovar), simazine alone, diuron alone, the mixture of simazine and bromacil, and bromacil alone. In the spring, however, growers using dragline systems showed a different preference for pre-emergent materials than those using low volume and furrow irrigation (χ^2 = 25.99, p = 0.011). Growers using dragline systems

Table 3. Percent of growers using three different lengths of time for irrigating citrus using low volume equipment.

Water District[1]	Percent of Growers: Duration of Irrigation Event: 24 hr.	48 hr.	72-96 hrs.
Exeter	50.0	50.0	0.0
Ivanhoe	57.1	28.6	14.3
Lindmore	33.3	44.4	22.2
Lindsay-Stratmore	51.5	31.8	16.7
Orange Cove	55.6	33.3	11.1
Terra Bella	45.7	45.7	8.6

[1]Only water districts with greater than 5% of all respondents were used in this analysis.

Table 4. Relationship between type of irrigation system used by citrus growers and choice of fall and spring herbicide treatments.

	Percent of all growers, partitioned by type of irrigation systems employed, using each herbicide treatment.					
	Fall 1988			Spring 1989		
	Furrow	Dragline	Low Volume	Furrow	Dragline	Low Volume
None	20.9	18.2	17.0	52.8	46.4	48.9
Simazine	17.8	15.5	17.0	8.0	4.6	10.1
Bromacil	0.0	0.9	0.3	0.0	0.9	0.5
Diuron	4.3	4.6	3.2	0.13	8.2	6.4
Diuron + Bromacil	10.4	20.2	19.2	8.0	**24.6**	11.2
Simazine + Bromacil	1.8	1.8	1.6	2.5	1.8	1.1
Simazine + Diuron	**44.8**[1]	**39.1**	**41.8**	**22.7**	3.6	**21.8**
	$\chi^2 = 9.9$. df = 12, p= 0.63			$\chi^2 = 26.0$, df = 12, p = 0.01		

[1]Values in bold represent the most frequently used herbicide treatments.

most frequently selected the mixture of diuron plus bromacil, followed by the mixture of simazine and diuron, diuron alone, simazine alone, the mixture of simazine and bromacil, and bromacil alone. Growers using low volume and furrow irrigation showed the same order of preference for materials as they did in the fall. Information about target weeds is needed to interpret these results.

Downward Flow of Surface Applied Waters

In some areas with shallow or 'perched' water tables collection systems have been installed that are permitted to discharge into ground water and established water courses. For this reason, growers were asked a number of questions dealing with direct movement of surface water to ground water. Only 6.6% and 5.4%, respectively, reported dry wells and tile drainage systems in their citrus orchards. Only 12.4% reported dry wells associated with their septic tanks, and 4.6% reported dry wells on adjacent property. These results may not reflect the number of dry wells in the area. Typically associated with each parcel is a septic tank that often empties into leach lines and dry wells. The smaller the average parcel, the higher the density of associated dry wells and drainage systems in any given area. Of eleven orchard size categories presented in the survey, the one most frequently designated (31%) was of smallest acreage, less than 10 ac.

A substantial portion of all orchards, 67%, were planted on hardpan soil. To improve internal drainage and increase rooting depth, 46% of all growers have ripped their soil. Growers with hardpan were more likely to rip their soil than those without (χ^2 = 40.9; p = 0.0001). The hardpan soils are located along the eastern foothills (Storey 1940, 1942).

During winter months well water is often pumped and applied to the surface for frost protection. The most common method of frost protection in Tulare County was the combination wind machines and water, 45% of respondents, and water alone, 19% of respondents. If several nights of protection are necessary irrigation water may result in deep percolation of water and movement of herbicides below the zone of soil where herbicide degradation can occur and eventually movement down to ground water. Even short duration frost protection could have an affect since the soil is frequently saturated from winter rainfall.

Alternative Practices

Several questions were directed to the use of alternative farming practices. When asked about non-chemical weeding practices, 77.6% of respondents did not answer the question, 13.3% tilled the soil, 5.2% used ground cover, and 3.8% mowed. Because the level of organic matter in soil affects leaching of many herbicides (Rao and Davidson, 1980), growers were asked about the percent of organic matter in their soil. Most growers did not answer the question (68.2%), and 16.8% did not know this value. The low response rate to these questions (Appendix I, p. 9) suggests that most Tulare County citrus growers use herbicides as the only method of weed control.

The primary reasons for maintaining a weed-free orchard are to prevent frost damage, minimize compaction from farm equipment, reduce root competition, and maintain low costs. Ground cover in the winter lowers the night air temperature increasing both the risk of frost damage, and the cost of frost protection (Reuther, 1973). Cover crops compete with the shallow rooted citrus trees for both water and nutrients and thus represent an expense for these inputs. Studies on the evapotranspiration within a deciduous orchard

show that cover crops can increase by 32% the demand for water as compared to a clean cultivated orchard (Dept. of Water Resources, 1983). However, the use of ground cover has beneficial aspects, both in terms of reducing ground water contamination and citrus production. Ground covers in row middles reduce the area treated with herbicides, control the rapid run off of herbicide tainted water from the orchard floor, and enhance the degradation of herbicides by increasing soil organic matter and its microbial activity (Rao and Davidson, 1980; Elliott, 1990). Cover crops also improve soil structure, prevent soil erosion, and enrich the fertility of the soil (Reuther, 1973). A growing body of evidence indicates that cover crops decrease pest damage to crops (DeBach, 1964; Jordon, 1972; Altieri and Letourneau, 1982; Settle et al., 1986; Lanini et al., 1988). Cover crops enhance the activity of natural enemies which in turn aid in the suppression of crop pests. The benefits of using cover crops in citrus production requires careful evaluation of crop plant characteristics to determine if they could surpass their disadvantages by taking into account both the overall cost of producing citrus and the environmental consequences of using conventional weed management practices.

Farming Practices and Well Residues

There was a positive linear regression between proportion of wells containing herbicide residues and number of citrus growers per township (Fig. 9A). However, when areas with deepest ground water were excluded to reduce problems associated with confounding (cells J-L), the data show a positive though non-significant trend (Fig. 9B). Results differed because the lowest numbers of growers per township and the least contamination occurred where ground water was deepest, thus eliminating extreme values from the regression analysis. These results suggest that citrus production practices as a whole may be

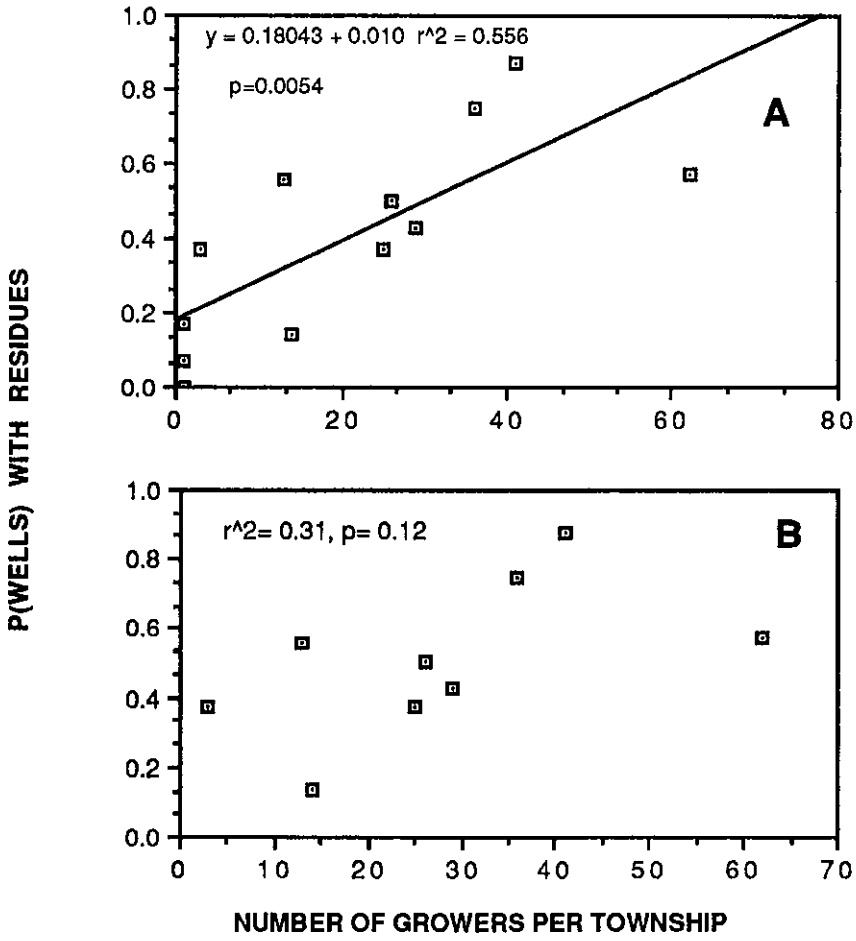


Fig. 9. Proportion contaminated wells versus number of growers per township. Regression using all data , cells A-L (A); regression using only data from cells A-I (B).

associated with ground water contamination but additional information on hydrogeology is needed to explain the incidence of detections.

The relationship between contamination of well water and irrigation practices used by citrus producers was examined further by regressing proportion of wells with residues against the use of each of the three most frequently used frost protection methods: (1) irrigation water alone, 19.4% of respondents, (2) the combination irrigation water and wind machines, 45% of respondents, and (3) wind machines alone, 13% of respondents. There was a significant linear regression between the proportion of wells with residues and number of growers in an area using irrigation for frost protection (Fig. 10A-B). A significant linear relationship between proportion of wells with residues and use of the combination irrigation water and wind machines for frost protection was detected at $p = 0.0028$ using all data (Fig. 11A). However, when areas with deepest ground water were excluded (cells J-L), the relationship was significant at only $p = 0.06$ (Fig. 11B). There was no significant relationship between well water contamination and number of respondents using wind machines only for frost protection (Fig. 12A-B).

The frequency of ground water contamination was also regressed against numbers of growers using each of three major categories of irrigation systems. For growers reporting use of low volume (57.7% of respondents) and furrow irrigation (24.9% of respondents), the frequency of well water contamination in a cell increased as the number of users in the respective townships increased. However, when areas with the deepest ground water were excluded (cells J-L) no significant relationship was measured (Figs. 13-14). There was no significant relationship between dragline (16.3% of respondents) and well water residues (Fig. 15A-B).

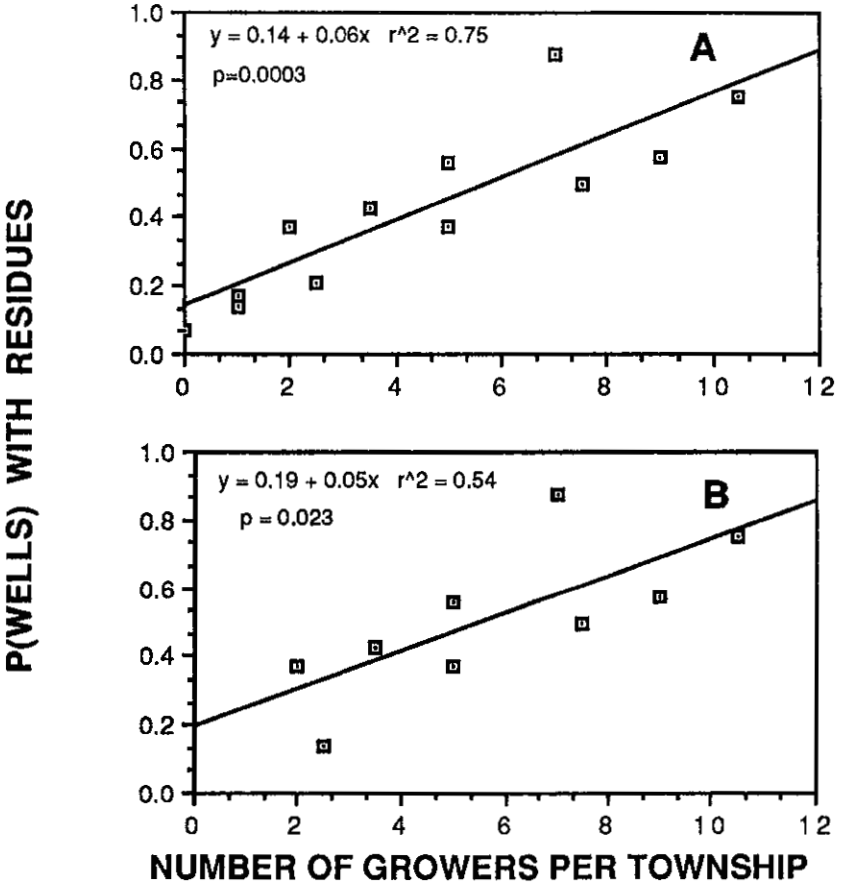


Fig. 10. Proportion contaminated wells versus number of growers using irrigation water for frost protection. Regression using all data, cells A-L, (A); regression using only data from cells A-I (B).

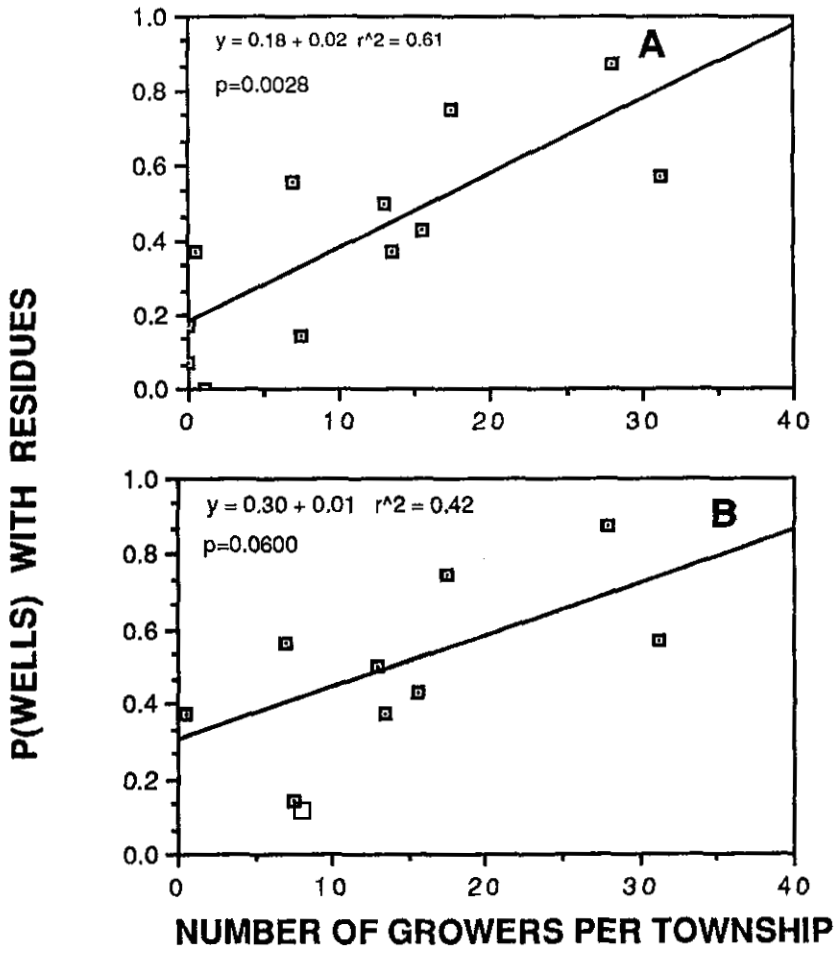


Fig. 11. Proportion contaminated wells versus number of growers using the combination irrigation water and wind for frost protection. Regression using all data, cells A-L, (A); regression using only data from cells A-I (B).

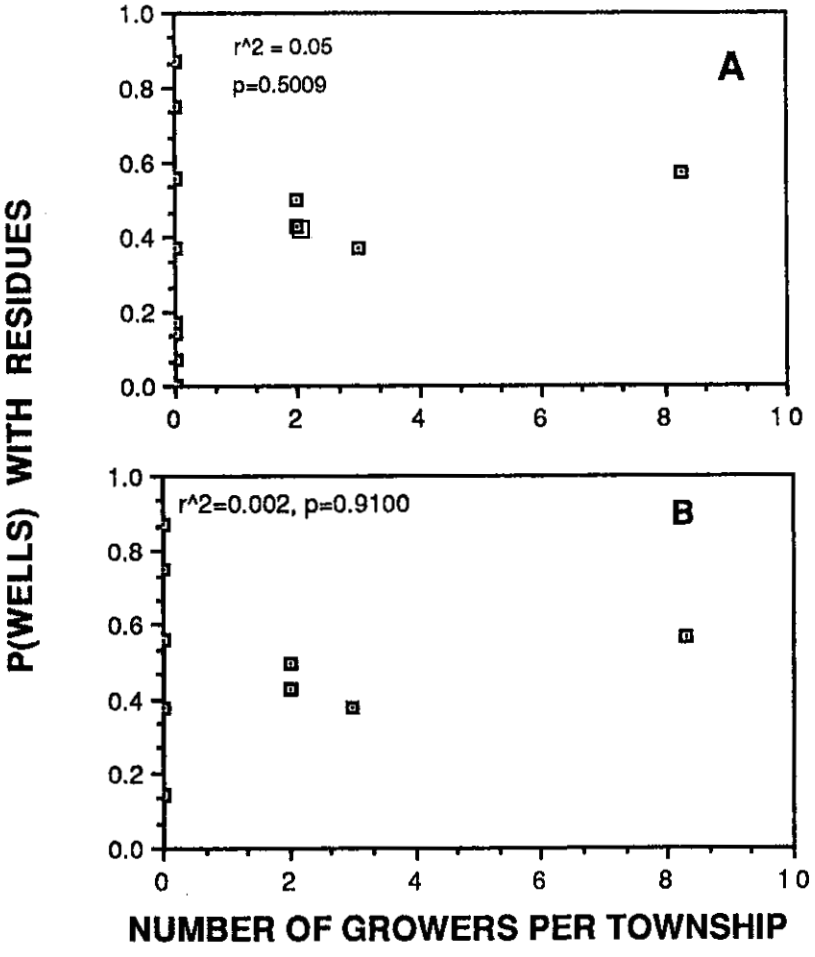


Fig. 12. Proportion contaminated wells versus number of growers using wind for frost protection. Regression using all data, cells A-L, (A); regression using only data from cells A-I (B).

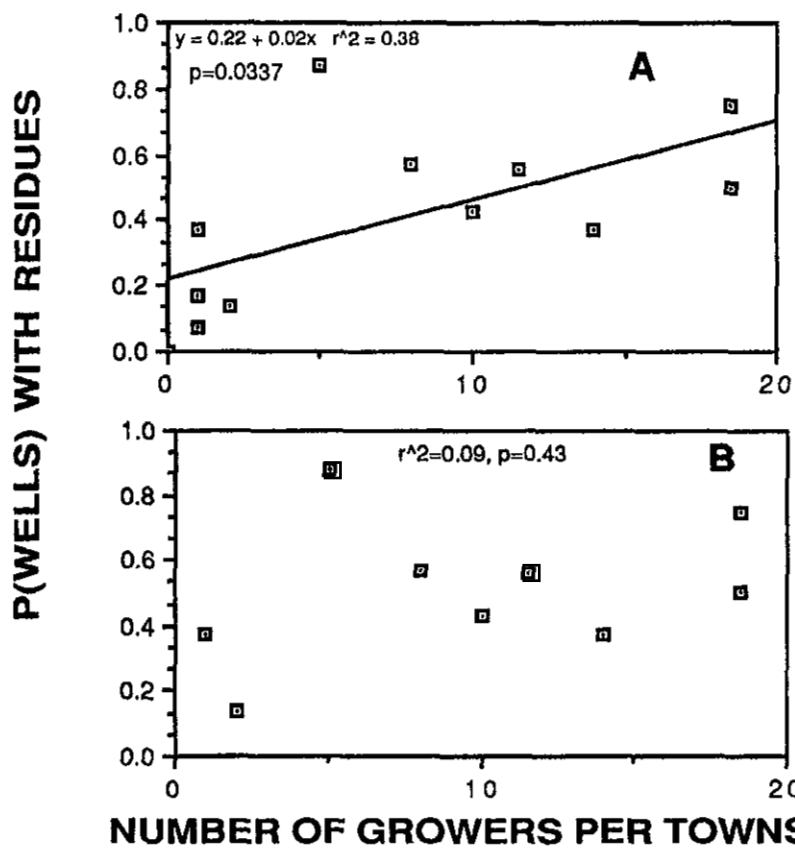


Fig. 13. Proportion contaminated wells versus number of growers using furrow irrigation. Regression using all data, cells A-L, (A); regression using only data from cells A-I (B).

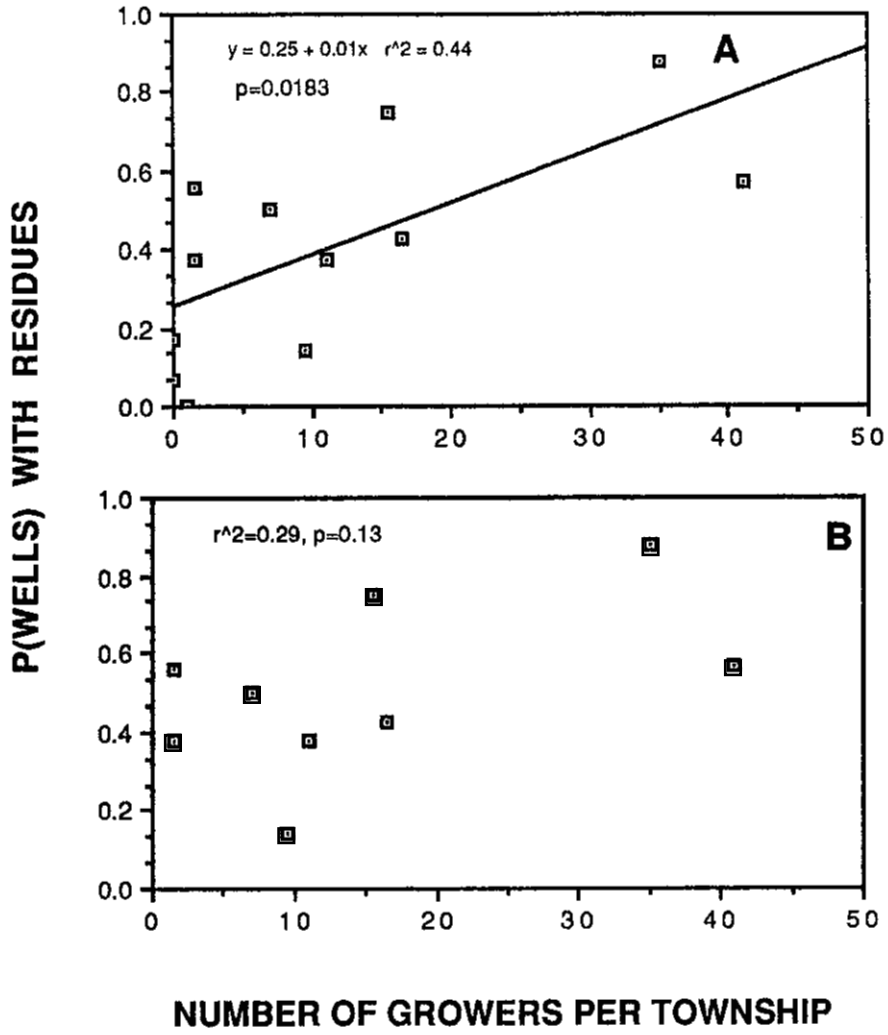


Fig. 14. Proportion contaminated wells versus number of growers using low volume irrigation. Regression using all data, cells A-L, (A); regression using only data from cells A-I (B).

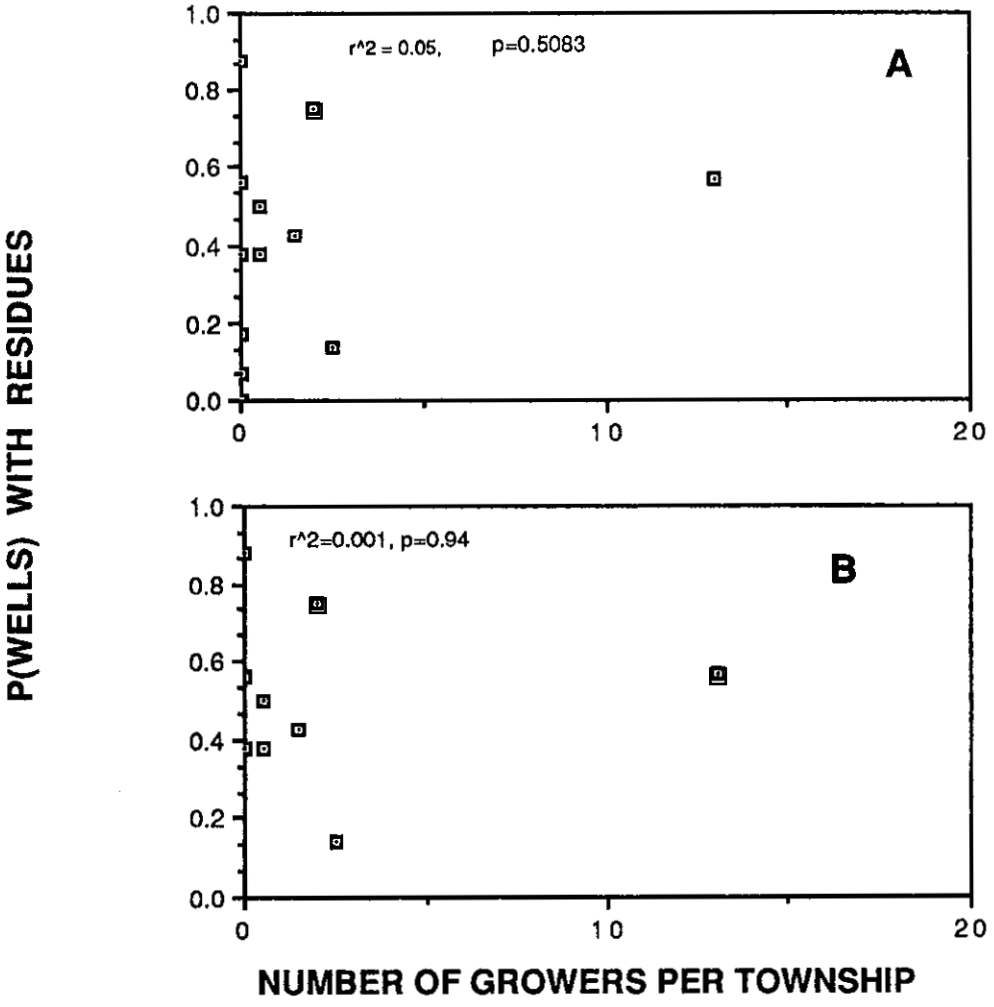


Fig. 15. Proportion contaminated wells versus number of growers using dragline irrigation. Regression using all data, cells A-L, (A); regression using only data from cells A-I (B).

Results from these regression analyses indicate that water use during winter months may influence ground water contamination. Of the six farming practices examined, only one, exclusive use of irrigation water for frost protection, showed a significant linear regression with frequency of well water contamination ($\alpha = 0.05$) when areas with the deepest ground water were excluded. The combined use of irrigation water and wind machines for frost protection was apparently related to contamination, though the significance level changed from $\alpha = 0.03$ to $\alpha = 0.06$ when deep water table areas were excluded from the regression analysis. Low volume and furrow irrigation practices showed no linear relationship to ground water contamination when areas with deepest ground water were excluded. Although citrus growers who practice furrow irrigation generally use relatively large amounts of water, summer irrigations may not represent as much a risk to off-site movement of herbicides as winter frost protection irrigations. This is because a larger percentage of growers apply herbicides in the fall (Appendix I, p. 6) after which cooler temperatures result in slower breakdown of residues than under warmer summer conditions (Ashton, 1982; Madhun and Freed, 1987). Thus more residues are available for deep percolation in the fall and winter. Heavy water applications shortly following applications of herbicides during the coolest time of the year may represent the most likely scenario for promoting off-site movement of herbicide residues.

There was no linear relationship between the use of wind machines for frost protection or the use of dragline irrigation and ground water contamination. Growers using these practices were generally located in the foothill areas of eastern Tulare County where land is not flat ($\underline{r} = 0.72$, $\underline{p} = 0.0001$). In these areas growers may be more conservative with general water use due to its higher cost and the potential for erosion. The zone along the foothill

fringe of Tulare County has meager supplies of ground water and requires substantial pumping energy (Davis et al., 1959, Stetson, 1974). Also, the greater depth to ground water may delay or minimize the leaching of residues downward into ground water.

The present level of ground water contamination may not necessarily reflect current farming practices but those occurring sometime within the last 30 years. Breakdown rates of these materials are slow in ground water because of cool temperatures, reduced oxygen, and low microbial activity (Wilson et al., 1984; Holden, 1986; Jury et al., 1987; Li-Tse Ou et al., 1988). Consequently residues of herbicides may have been accumulating for many years. Research on the off-site movement of these residues will provide better understanding about how current practices can contribute to the movement of contaminants into ground water.

SUMMARY

The 41% response rate to this questionnaire represented a significant portion of the grower population. Much of this success was attributed to careful planning and execution of the survey. The high return rate may also reflect a genuine concern by growers and others in the citrus industry about ground water contamination by herbicides commonly used in citrus cultivation. This concern was shared among growers responding to a recent national survey on farmer's perceptions to environmental problems (Esseks, et al. 1990). It was interesting that thirty percent of respondents were not aware at the time of receiving their survey that a high percentage of Tulare County ground water is contaminated with herbicides.

The low response rate to questions dealing with non-chemical weed control practices (Appendix I, p. 9) suggests that the citrus growers surveyed rely almost exclusively on chemicals for weed control. The primary reasons for maintaining a weed-free orchard are to prevent frost damage, minimize compaction from farm equipment, reduce root competition, and maintain low costs. In light of the ground water contamination issue in Tulare County and the future uncertainty of chemical pesticide availability, the low response rate also emphasizes the need for additional research and demonstration plots concerning alternative practices with soil and weed management. The maintenance of ground cover in citrus orchards has several benefits and should be weighed against their disadvantages. Subsurface irrigation is another practice not currently being used in California citrus production that could open an opportunity for reducing dependency on herbicide treatments.

Results from the survey indicate that specific practices associated with citrus production increase the potential for ground water contamination. The number of growers per township using irrigation water for frost protection shows a linear relationship with frequency of contaminated water. Other practices showed mixed results in terms of their influence on ground water contamination and indicates more knowledge about hydrogeology is needed to interpret residue findings in well water.

The low frequency of well water contamination in foothill areas (where growers use dragline irrigation and wind-frost protection) and areas with deep ground water suggest that areas with deep, minimal ground water supplies have a lower probability of ground water contamination. Additional information on the role of geology and hydrology on valley floor deposits could increase our

understanding of soil structure and its contribution to ground water contamination.

Responses to the questionnaire highlighted several topics that warrant additional research or investigation. Answers to several questions indicate water use can be a key component to frequency of well water contamination. Use of water for frost protection likely increases the potential for leaching. Factors associated with irrigation methods such as excessive water use, runoff, and deep percolation, or timing of herbicide applications, need further examination to determine their influence on leaching. The questionnaire failed to reveal any additional information about use of dry wells and their role in well water contamination. Since dry wells may provide a direct conduit to ground water, additional information is needed to determine their importance in transmitting herbicide residues to ground water.

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A P P E N D I C E S

VERSION 11-9-89

Summary of Tulare County Citrus Grower Survey

Italicized numbers represent the percent of all respondents answering each respective questions. The value zero indicates no response.

I *Description of Orchard.*

1. Are you aware that the herbicides simazine, diuron (e.g., Karmex®, Krovar®), and bromacil (e.g., Hyvar X®) have been found in well water of Tulare County?

(1) YES *65.2*
(2) NO *30.5*

2. Please indicate the importance of each herbicide to the management of your citrus orchard floor. Circle the appropriate rating for each herbicide (1 = very important; 5 = not at all important or insignificant).

0	**1**	**2**	**3**	**4**	**5**	**herbicide**
9.4	*54.1*	*11.8*	*8.5*	*2.6*	*13.5*	SIMAZINE
16.4	*43.2*	*13.7*	*6.8*	*3.5*	*16.6*	KARMEX®(DIURON)
19.5	*29.9*	*10.6*	*12.0*	*7.0*	*21.1*	KROVAR® (DIURON+BROMACIL)
34.8	*8.2*	*6.5*	*5.4*	*7.9*	*37.3*	BROMACIL (HYVAR®)

3. How many separate citrus orchards do you own or manage?

(1) 1	*47.8*	(7) 7	*0.5*
(2) 2	*15.2*	(8) 8	*1.0*
(3) 3	*11.2*	(9) 9	*1.3*
(4) 4	*5.0*	(10) 10	*1.3*
(5) 5	2.4	(11) 11	*9.1*
(6) 6	*2.3*	(12) NO RESPONSE	*2.1*

If you have more than one block of citrus and only one questionnaire, please answer questions for the ***largest block.***

DISCLAIMER: Use of a trade name is for answering questions only. Direct or implied use of a trade name should not in any way be construed as endorsement or implication of any product being found in groundwater.

4. In which water or irrigation district is your citrus orchard located? **Circle only one location.**

(0)	NO RESPONSE	*4.8*			
(1)	ALPAUGH	*0.1*	(17)	LINDSAY-STRATMOR	*16.1*
(2)	ALTA	*6.8*	(18)	LOWER TULE RIVER	*0.1*
(3)	ATWELL ISLAND	*0.0*	(19)	NICKERSON	*0.0*
(4)	ANGIOLA	*0.0*	(20)	ORANGE COV	*5.4*
(5)	CONSOLIDATED	*0.0*	(21)	PIXLEY	*0.0*
(6)	DELANO-EARLIMAR	*0.2*	(22)	PORTERVILLE	*1.5*
(7)	DUCOR	*0.5*	(23)	RAY GULCH	*0.0*
(8)	EXETER	*11.8*	(24)	SAUCELITO	*0.0*
(9)	HILLS VALLEY	*0.0*	(25)	STONE CORRAL	*0.9*
(10)	HOMELAND	*0.0*	(26)	ST. JOHNS	*0.2*
(11)	HOPE	*0.0*	(27)	TEA POT DOME	*2.1*
(12)	IVANHOE	*10.1*	(28)	TERRA BELLA	*9.9*
(13)	KAWEAH DELTA	*0.4*	(29)	TULARE	*0.0*
(14)	KERN-TULARE	*0.1*	(30)	VANDALIA	*1.0*
(15)	LEWIS CREEK	*0.0*	(31)	OTHER, PLEASE SPECIFY	*5.1*
(16)	LINDMORE	*14.8*	(32)	NONE	*7.9*

5. Your orchard is located in which of the listed townships shown on the map, below (each is 36 square miles in size).

_____S _____E

See last page for summary.

6. Your orchard is how many acres in size?

(0)	NO RESPONSE	*1.1*			
(1)	1 to 10	*31.2*	(7)	61 TO 70	*2.6*
(2)	11 TO 20	*22.1*	(8)	71 TO 80	*2.2*
(3)	21 TO 30	*9.8*	(9)	81 TO 90	*2.0*
(4)	31 TO 40	*11.8*	(10)	91 TO 100	*2.9*
(5)	41 TO 50	*4.5*	(11)	MORE THAN 100	*6.5*
(6)	51 TO 60	*3.4*			

7. What is the approximate age in years of the **majority** of trees in this orchard?

(0)	NO RESPONSE	*1.0*			
(1)	LESS THAN 10	*5.0*	(5)	41 to 50	*8.2*
(2)	11 to 20	*15.6*	(6)	51 to 60	*4.6*
(3)	21 to 30	*39.6*	(7)	GREATER THAN 60	*14.6*
(4)	31 to 40	*11.3*			

8. What is the approximate tree spacing (in feet)?

(0)	NO RESPONSE	*2.3*			
(1)	20 x 20	*28.0*	(4)	11 x 22	*5.5*
(2)	22 x 22	*30.9*	(5)	24 x 24	*5.0*
(3)	18 x 20	*14.9*	(6)	OTHER	*13.3*

9. Is there a substantial slope to the floor of your orchard? Circle the appropriate rating (1 = very steep; 5 = insignificant or flat).

NO RESPONSE) *1.1* 1) *2.3* 2) *7.0* 3) *21.7* 4) *26.1* 5) *41.8*

10. Which irrigation system do you use for the majority of your citrus acreage?

(0)	NO RESPONSE	0.9
(1)	FURROW (GO TO **SECTION II, PAGE 3**)	24.9
(2)	DRAG LINE (GO TO **SECTION III, PAGE 3**)	16.3
(3)	LOW VOLUME (GO TO **SECTION IV, PAGE 4**)	57.7

Section II. *Furrow Irrigation system*

1. How many times a year do you irrigate?

(0)	NO RESPONSE	*6.4*
(1)	FEWER THAN 15	*48.0*
(2)	16-20	*35.8*
(3)	MORE THAN 20	*9.8*

2. Please fill in the following blanks regarding your irrigation scheduling.

(Mean acre inches per month)

MONTH	#AC INCHES WATER PER ACRE	MONTH	#AC INCHES WATER PER ACRE
JANUARY	*0.15*	JULY	*3.97*
FEBRUARY	*0.06*	AUGUST	*3.97*
MARCH	*0.69*	SEPTEMBER	*3.45*
APRIL	*1.96*	OCTOBER	*2.26*
MAY	*2.89*	NOVEMBER	*0.53*
JUNE	*3.70*	DECEMBER	*0.10*

3. How much water in inches per acre is used for each irrigation?

(0)	NO RESPONSE	*32.8*			
(1)	LESS THAN 1.0	*5.4*	(5)	2.5	*12.7*
(2)	1.0	*6.4*	(6)	3.0	*10.3*
(3)	1.5	*8.8*	(7)	3.5	*3.9*
(4)	2.0	*14.2*	(8)	MORE THAN 3.5	*5.4*

4. How many furrows are between rows of trees?

(0)	NO RESPONSE	*3.4*
(1)	TWO	*70.1*
(2)	THREE	*23.0*
(3)	OTHER	*2.9*

Go to **Section V,** page 6.

Section III. *Drag Line Irrigation.*

1. Please fill in the following blanks regarding your irrigation scheduling.

(Mean acre inches per month)

MONTH	#AC INCHES WATER PER ACRE		#AC INCHES WATER PER ACRE
JANUARY	*0.07*	JULY	*3.15*
FEBRUARY	*0.12*	AUGUST	*3.26*
MARCH	*0.55*	SEPTEMBER	*2.59*
APRIL	*1.33*	OCTOBER	*1.74*
MAY	*2.17*	NOVEMBER	*0.54*
JUNE	*2.88*	DECEMBER	*0.09*

2. What is the number of sprinklers per hose?

(0) 0	2.2	(4) 4	20.9
(1) 1	-.-	(5) 5	5.2
(2) 2	4.5	(6)MORE THAN 5	6.7

Go to **Section V,** page 6.

Section IV. *Low volume irrigation.*

1. Which type of watering system do you use?

(0)	NO RESPONSE	*1.3*
(1)	MISTER (=FOGGER) **(GO TO QUESTION 2)**	*37.0*
(2)	MICROSPRINKLER OR JET TYPES **(GO TO QUESTION 6, PAGE 5)**	*59.2*
(3)	DRIP **(GO TO QUESTION 11 PAGE 5)**	*2.5*

*Questions 2-5 should be answered if you use a **mister type** watering system:*

2. What is the spray direction?

(0)	NO RESPONSE	*0.6*
(1)	UPWARDS	*36.6*
(2)	INTO FURROW	*28.0*
(3)	HORIZONTAL (SIDEWAYS)	*34.9*

3. What is the number of embitters per tree?

(0)	NO RESPONSE	*1.1*
(1)	1	*28.0*
(2)	2	*67.4*
(3)	3	*1.7*
(4)	MORE THAN 3	*1.7*

4. What is the volume of delivery in gallons per hour (per emitter)?

(0)	NO RESPONSE	*4.0*
(1)	LESS THAN 3	*10.9*
(2)	3	*30.9*
(3)	4	*13.1*
(4)	5	*38.9*

5. Please fill in the following blanks regarding your irrigation scheduling.

(*Mean acre inches per month*)

MONTH	#AC INCHES WATER PER ACRE		#AC INCHES WATER PER ACRE
JANUARY	*0.03*	JULY	*2.04*
FEBRUARY	*0.05*	AUGUST	*2.02*
MARCH	*0.35*	SEPTEMBER	*1.65*
APRIL	*0.84*	OCTOBER	*1.09*
MAY	*1.17*	NOVEMBER	*0.24*
JUNE	*1.69*	DECEMBER	*0.02*

Go to **Section V**, page 6.

*Questions 6-10 should be answered if you use a **microsprinkler** or jet type watering system.*

6. What is the position of the delivery system?

(0)	NO RESPONSE	*2.5*
(1)	TREE ROWS	*80.7*
(2)	BETWEEN ROWS	*16.8*

7. What is the surface diameter of the wetted area (in feet)?

(1)	1 FOOT	*1.4*	(4)	5 TO 6 FEET	*15.0*
(2)	1 TO 2 FEET	*0.7*	(5)	7 TO 8 FEET	*21.4*
(3)	3 TO 4 FEET	*3.6*	(6)	9 OR MORE FEET	*57.9*

8. Please fill in the following blanks regarding your irrigation scheduling.

(*Mean acre inches per month*)

MONTH	#AC INCHES WATER PER ACRE		#AC INCHES WATER PER ACRE
JANUARY	*0.10*	JULY	*3.67*
FEBRUARY	*0.10*	AUGUST	*3.63*
MARCH	*0.50*	SEPTEMBER	*3.07*
APRIL	*1.48*	OCTOBER	*2.01*
MAY	*2.40*	NOVEMBER	*0.56*
JUNE	*3.14*	DECEMBER	*0.08*

9. What is your most frequent or common irrigation duration?

(0) NO RESPONSE *4.6*
(1) 24 HR *45.7*
(2) 48 HR *35.7*
(3) 72 TO 96 HR *12.9*
(4) LONGER THAN 96 HR *1.1*

Go to **Section V**, page 7.

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*Questions 11- 13 deal with **drip line** irrigation:*

11. What is the number of emitters per tree?

(0)	NO RESPONSE	*8.3*			
(1)	2 OR LESS	*75.0*	(4)	7 TO 8	*0.0*
(2)	3 to	*8.3*	(5)	9 TO 10	*0.0*
(3)	5 to 6	*8.3*	(6)	MORE THAN 10	*0.0*

12. What is the gallons per hour per emitter?

(0)	NO RESPONSE	*8.3*
(1)	LESS THAN 1 GAL	*8.3*
(2)	1 GAL	*16.7*
(3)	1.5 GAL	*0.0*
(4)	2 GAL	*33.3*
(5)	MORE THAN 2 GAL	*16.7*

13. Please fill in the following blanks regarding your irrigation scheduling.

MONTH	#AC INCHES WATER PER ACRE		#AC INCHES WATER PER ACRE
JANUARY	*0.00*	JULY	*3.43*
FEBRUARY	*0.01*	AUGUST	*3.61*
MARCH	*0.23*	SEPTEMBER	*2.92*
APRIL	*1.33*	OCTOBER	*1.80*
MAY	*2.29*	NOVEMBER	*0.25*
JUNE	*3.14*	DECEMBER	*0.00*

Section V. *Pre-emergent materials.*

1. What pre-emergent material did you use in fall 1987?

(0) NO RESPONSE	*5.1*
(1) NONE	*15.7*
(2) SIMAZINE	*14.8*
(3) BROMACIL (e.g., HYVAR X®)	*0.4*
(4) DIURON (e.g., KARMEX®)	*3.4*
(5) DIURON PLUS BROMACIL	*14.8*
(6) SIMAZINE AND BROMACIL	*1.6*
(7) SIMAZINE AND DIURON	*36.0*
(8) OTHER, PLEASE SPECIFY	*8.3*

2. What pre-emergent material did you use in spring 1988?

(0)	NO RESPONSE	*9.5*
(1)	NONE	*43.2*
(2)	SIMAZINE	*7.2*
(3)	BROMACIL (e.g., HYVAR X®)	*0.4*
(4)	DIURON (e.g., KARMEX®)	*6.3*
(5)	DIURON PLUS BROMACIL (e.g., KROVAR®)	*10.2*
(6)	SIMAZINE AND BROMACIL	*1.3*
(7)	SIMAZINE AND DIURON	*16.8*
(8)	OTHER, PLEASE SPECIFY	*5.0*

Continue with questions in **Section VI.**

Section VI. *Other questions.*

1. What soil texture in the root zone makes up the **majority** of this orchard?

(0)	NO RESPONSE	*2.2*
(1)	FINE (CLAY TO CLAY-LOAM)	*52.8*
(2)	MEDIUM (LOAM TO SANDY-LOAM)	*42.0*
(3)	COURSE (SANDY-LOAM TO SAND)	*3.0*

2. Do you have hardpan under the **majority** of your citrus orchard?

(0)	NO RESPONSE	*3.0*
(1)	YES	*66.1*
(2)	NO	*30.9*

3. If **yes**, what is the depth in feet to the hardpan?

(0)	NO RESPONSE	*35.6*
(1)	LESS THAN 2 FEET	*7.3*
(2)	2-4 FEET	*45.5*
(3)	5-7 FEET	*9.9*
(4)	8-10 FEET	*1.2*
(5)	GREATER THAN 10 FEET	*0.5*

4. Has your soil been "ripped?"

(0)	NO RESPONSE	*4.8*
(1)	YES	*41.7*
(2)	NO	*35.4*
(3)	DO NOT KNOW	*18.2*

5. What source of information is most frequently used for scheduling your citrus irrigation? Circle all that apply.

(1)	SOIL PROBE	*29.0*
(2)	TENSIOMETER	*15.0*
(3)	CONDITION OF TREES	*67.4*
(4)	CALENDAR (DAYS SINCE LAST IRRIGATION)	*49.4*
(5)	CIMIS OR OTHER ET PUBLISHED DATA	*10.9*
(6)	IRRIGATION CONSULTANT	*3.0*
(7)	NEUTRON PROBE	*0.4*
(8)	OWN WEATHER STATION	*2.7*
(9)	OTHER GROWERS	*2.2*
(10)	PEST CONTROL ADVISER	*1.6*
(11)	SHOVEL	*22.3*
(12)	OTHER, PLEASE SPECIFY_____	*7.3*

6. Do any of the following individuals apply pre-emergent herbicides to rights-of-way (paved roads), private roads, or irrigation ditches that are next to your citrus orchard?

(1)	CAL TRANS	*11.3*
(2)	RAILWAY	*8.5*
(3)	NEIGHBOR	*18.0*
(4)	YOURSELF	*17.1*
(5)	WATER OR IRRIGATION DISTRICT	*9.1*
(6)	NONE ARE APPLIED	*39.1*
(7)	OTHER, PLEASE SPECIFY_____	*4.1*

7. If yes, how many times a year?

(0)	NO RESPONSE	*55.5*
(1)	1	*19.8*
(2)	2	*7.8*
(3)	3	*0.7*
(4)	MORE THAN 3	*0.1*
(5)	DO NOT KNOW	*16.6*

8. Does irrigation or rainfall runoff enter your citrus orchards from sources other than your own property?

(0)	NO RESPONSE	*2.3*
(1)	YES	*50.9*
(2)	NO	*46.8*

9. If yes, please identify this source. Circle all that apply.

(1)	ADJACENT NEIGHBOR	*38.8*
(2)	HIGHWAY	*18.9*
(3)	OVERFLOW FROM DRAINAGE DITCH	*7.4*
(4)	OTHER_____	*4.4*

10. Do you have a return flow system?

(0)	NO RESPONSE	3.9
(1)	YES	19.9
(2)	NO	78.2

11. Are tile drainage systems installed anywhere on your property?

(0)	NO RESPONSE	*3.8*
(1)	YES	*5.4*
(2)	NO	*90.9*

12. What kind of frost protection do you use?

(0)	NO RESPONSE	*1.7*
(1)	IRRIGATION SYSTEM	*19.4*
(2)	ORCHARD HEATERS	*0.1*
(3)	WIND MACHINES	*12.8*
(4)	WIND MACHINES AND HEATERS	*0.5*
(5)	IRRIGATION AND HEATERS	*0.1*
(6)	IRRIGATION AND WIND MACHINES	*41.3*
(7)	ALL THREE SYSTEMS	*5.6*
(8)	NONE	*18.3*

13. Who treats your orchard for weed control in fall and/or spring? Circle all that apply.

(1)	PEST CONTROL ADVISOR	*7.9*
(2)	HIRED EMPLOYEE	*31.7*
(3)	YOURSELF	*59.5*
(4)	FAMILY MEMBER	*10.1*
(5)	NEIGHBOR	*2.1*
(6)	OTHER, PLEASE SPECIFY_____	*6.1*

14. How do you treat weeds in the summer with post-emergent materials ?

(0)	NO RESPONSE	*4.4*
(1)	SPOT TREAT	*85.5*
(2)	TREAT WHOLE FLOOR	*3.8*
(3)	DO NOT TREAT	*6.1*

15. What major weed pests do you have trouble controlling? Check all that apply.

	WEED	WINTER	SPRING	SUMMER
(1)	DALLISGRASS	*3.3*	*12.8*	*23.4*
(2)	FIELD BINDWEED	*0.6*	*4.8*	*9.4*
(3)	NUTSEDGE	*1.6*	*11.7*	*20.2*
(4)	JOHNSON GRASS	*4.3*	*22.7*	*36.6*
(5)	BEARDED SPRANGLETOP	*0.7*	*6.5*	*13.0*
(6)	BARNYARD GRASS	*4.4*	*11.5*	*16.2*
(7)	SPURGE	*3.8*	*27.3*	*58.8*
(8)	COMMON GROUNDSEL	*19.4*	*20.7*	*13.7*
(9)	BERMUDA GRASS	*2.6*	*16.8*	*25.5*
(10)	SPRANGLETOP	*2.1*	*7.0*	*16.8*
(11)	OTHER, PLEASE SPECIFY	*3.8*	*4.8*	*6.6*

16. Do you currently use any of the following agricultural practices?

(0)	NO RESPONSE	*77.6*
(1)	GROUND COVER (STRIP WEED CONTROL)	*5.2*
(2)	MOWING	*3.8*
(3)	TILLAGE	*13.3*
(4)	INTERCROPPING	*0.1*

17. Have you ever had your soil tested for organic matter?

(0) NO RESPONSE	*3.3*
(1) YES	*34.5*
(2) NO	*62.2*

If your answer to question 17 is yes, please answer questions 18 and 19, otherwise go to question 20,

18. At what depth was the soil sampled?

(0)	NO RESPONSE	*66.5*
(1)	DO NOT KNOW	*11.3*
(2)	LESS THAN 3 INCHES	*0.1*
(3)	3 TO 6 INCHES	*5.9*
(4)	GREATER THAN 6 INCHES	*16.2*

19. What is the percent of organic matter in your soil?

(0)	NO RESPONSE	*68.2*
(1)	DO NOT KNOW	*16.8*
(2)	0.5 OR LESS	*6.0*
(3)	0.6-1.0	*6.3*
(4)	1.1-1.5	*1.5*
(5)	GREATER THAN 1.5	*1.2*

The last set of questions deal with the presence of dry wells on your property. These questions are optional.

20. Do you have any dry wells on your orchard?

(0)	NO RESPONSE	*10.4*
(1)	YES	*6.6*
(2)	NO	*83.0*

21. If yes, do they capture runoff water from any of the following?

(0)	NO RESPONSE	*96.0*
(1)	PAVED ROADS BORDERING ORCHARD	*0.1*
(2)	YOUR CITRUS ORCHARD	*2.1*
(3)	NEIGHBOR'S RANCH	*0.0*
(4)	1 AND 2	*0.5*
(5)	1 AND 3	*0.5*
(6)	2 AND 3	*0.4*
(7)	1, 2, AND 3	*0.5*

22. Are there dry wells adjacent to your property?

(0)	NO RESPONSE	*39.1*
(1)	YES	*4.6*
(2)	NO	*56.2*

23. Does your septic system have dry wells?

(0)	NO RESPONSE	*24.4*
(1)	YES	*12.4*
(2)	NO	*63.2*

LOCATION OF TOWNSHIP

Township/Range	Frequency	Percent
1524	2	0.3
1525	15	2.1
1526	1	0.1
1528	1	0.1
1600	1	0.1
1623	7	1.0
1624	24	3.3
1625	28	3.9
1626	7	1.0
1627	2	0.3
1700	5	0.7
1724	3	0.4
1725	23	3.2
1726	41	5.7
1727	19	2.6
1728	1	0.1
1729	1	0.1
1800	1	0.1
1825	20	2.8
1826	31	4.3
1827	42	5.9
1828	9	1.3
1900	3	0.4
1925	2	0.3
1926	23	3.2
1927	34	4.7
1928	2	0.3
2000	5	0.7
2026	24	3.3
2027	141	19.7
2028	25	3.5
2100	3	0.4
2126	4	0.6
2127	19	2.6
2128	27	3.8
2129	6	0.8
2200	1	0.1
2226	1	0.1
2227	10	1.4
2228	45	6.3
2326	1	0.1
2327	14	2.0
2328	30	4.2
2400	1	0.1
2426	1	0.1
2427	5	0.7
2428	5	0.7
2528	1	0.1

STATE OF CALIFORNIA GEORGE DEUKMEJIAN, Governor

DEPARTMENT OF FOOD AND AGRICULTURE

1220 N Street, P.O. Box 942871
Sacramento, California 94271-0001

October 13, 1988

TO: TULARE COUNTY CITRUS GROWERS

SUBJECT: CITRUS GROWER SURVEY

We need your help in preventing contamination of groundwater. Since 1979, there have been increasing reports nationwide of pesticides found in groundwater and recently the herbicides simazine (Princep®), bromacil (Hyvar X®, Krovar®), and diuron (Karmex®, Krovar®) have been detected in the groundwater of Tulare County. To allow the continued use of these herbicides in areas sensitive to groundwater contamination, the California Department of Food and Agriculture (CDFA) is considering regulations that modify their use.

We know that four basic factors determine whether a pesticide is likely to reach groundwater: properties of the pesticides, soil characteristics, natural site conditions (depth to ground water, climate, etc.), and management practices. Although we don't know the relative importance of these factors, management practices is the one factor that growers have the most control over. In cooperation with John Pehrson and Neil O'Connell (University of California's Cooperative Extension) and those in the industry including California Citrus Mutual's Environmental Affairs Committee, we are initiating a project to survey Tulare County citrus growers to gather information about current management practices.

Only citrus growers of Tulare County are being asked to cooperate on this project. These herbicides have been found in numerous wells throughout the county, and the citrus industry, although not the only user of these herbicides in this region, is one of the largest. Responses from this survey will help us understand the current irrigation and weed control practices and perhaps suggest management strategies that prevent ground water contamination. The survey will also help us evaluate the research needs for citrus orchard floor management.

The questionnaire is not marked in any way and will remain confidential. Please return the enclosed postcard to identify those who have responded to the questionnaire and reduce our costs for second and third mailings. If you desire a summary of the results, check the appropriate box on the enclosed postcard.

Our goal is to determine whether the responsible use of these herbicides can be maintained while protecting California's important groundwater resource. Your participation will help us accomplish this goal. Please join us in this

worthwhile effort. For any questions regarding this survey, please contact Bill Appleby at the Tulare Co. Commissioner's office: (209) 733-6391.

Sincerely,

Lyndon Hawkins
Program Manager
Pest Management Analysis & Planning
Environmental Monitoring and Pest Management, Room A-149
(916) 322-2395

Clyde Churchill
Agricultural Commissioner
Tulare County Dept. of Agriculture
(209) 733-9391

Attachment

STATE OF CALIFORNIA — GEORGE DEUKMEJIAN, Governor

DEPARTMENT OF FOOD AND AGRICULTURE
1220 N Street, P.O. Box 942871
Sacramento, California 94271-0001

November 10, 1988

TO: CITRUS GROWERS

SUBJECT: FOLLOW-UP CITRUS GROWER SURVEY

Recently, we sent you a questionnaire concerning the orchard floor management practices used in your citrus orchard. We have not received your postcard indicating that you completed a questionnaire. If you have lost the questionnaire, please call Bill Appleby at (209) 733-6391, Tulare County Agricultural Commissioner's Office, for another copy. If you have returned your questionnaire, we thank you for your cooperation.

We strongly encourage those of you that have not already done so to complete this questionnaire since your response is critical to the success of this survey and the future use of herbicides in Tulare County.

Thank you for your cooperation.

Sincerely,

Lyndon Hawkins
Program Manager
Pest Management Analysis & Planning
Environmental Monitoring and Pest Management, Room A-149
(916) 322-2395

Clyde Churchill
Agricultural Commissioner
Tulare County Dept of Agriculture
(209) 733-9391

STATE OF CALIFORNIA — GEORGE DEUKMEJIAN, *Governor*

DEPARTMENT OF FOOD AND AGRICULTURE

1220 N Street, P. O. Box 942871
Sacramento, California 94271-0001

November 22, 1988

TO: CITRUS GROWERS

SUBJECT: CITRUS SURVEY

We recently mailed you a questionnaire concerning the floor management practices used in your citrus orchard. We have not received a response to the questionnaire and have enclosed a second copy in the event you lost your original version. If you have already submitted your questionnaire, we thank you for your cooperation. You are now a part of over 700 growers who have responded.

The enclosed questionnaire addresses a serious issue facing Tulare County: the recent finding of the herbicides simazine, (Princep®), bromacil (Hyvar X®), and diuron (Karmex®, Krovar®), in the ground water of this county. To allow the continued use of these herbicides in areas sensitive to ground water contamination, the California Department of Food and Agriculture (CDFA) is considering regulations that modify their use. In cooperation with John Pehrson and Neil O'Connell (University of California's Cooperative Extension) and those in the industry including California Citrus Mutual's Environmental Affairs Committee, we are initiating a project to survey Tulare County citrus growers to gather information about current management practices.

These herbicides have been found in numerous wells throughout Tulare county, and the citrus industry, although not the only user of these herbicides in this region, is one of the largest. Responses from this survey will help us understand the current irrigation and weed control practices and perhaps suggest management strategies that prevent ground water contamination. The survey will also help us evaluate the research needs for citrus orchard floor management.

The questionnaire is not marked in any way and will remain confidential. If you desire a summary of the results, check the appropriate box on the enclosed postcard.

Sincerely,

Lyn Hawkins

Clyde Churchill

Lyn Hawkins, Program Manager
Pest Management Analysis
and Planning Program
Environmental Monitoring and
Pest Management, Room A-149
(916) 322-2395

Clyde Churchill
Agricultural Commissioner
Tulare County Department
of Agriculture
(209) 733-6391

Enclosure