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Farmers are Adopting Changes in Irrigation Methods and Fertilizer Management Practices in California

Joe Dillon, Susan Edinger-Marshall and John Letey

ABSTRACT

We conducted a direct survey of farmers in 42 California counties with over 800 respondents. A set of questions concerning irrigation and nutrient management techniques for individual crops were asked for the 1986 and 1996 growing years. Answers were used to identify changing trends in these areas of management and to relate the rates of change to one another.

We found that the percent acreage irrigated with gravity systems has decreased by 11% over this 10 year period while the use of micro irrigation systems in California has increased by 12%. Our assessment of the rate of change agrees with an analysis of previous irrigation surveys. We also found that the percentage of growers utilizing nitrogen management techniques such as fertigation, foliar applications, soil analysis and plant tissue testing have increased in the last decade throughout much of California and on most crop types. We also found that farms which changed their irrigation system adopted new nutrient management techniques at a more rapid rate than farms which did not change their irrigation system, thus showing that these two management spheres are intertwined.

Despite the adoption of "more efficient" nitrogen management techniques, in most cases farmers are applying the same amount of nitrogen fertilizer (57% of the respondents) to their fields or even more nitrogen fertilizer (24% of the respondents) than a decade ago.

INTRODUCTION

Californians desire efficient agricultural use of natural resources for producing high crop yields with minimal environmental impact. Agricultural water use is scrutinized because it represents a large fraction of the water used in California. Water quality degradation through nonpoint source pollution from agricultural chemicals is also a concern.

Several fertilizer management practices such as split applications, soil and plant analyses and fertigation are available to promote high crop yields with little water quality degradation. However, the overall effectiveness of these practices is strongly linked to irrigation technology and management practices employed by the growers. Advancements in irrigation technology such as micro irrigation systems provide the opportunity for combined water and fertilizer management to achieve the dual goal of high yield and low water quality degradation.

A survey was undertaken to determine transitions in irrigation and nitrogen fertilizer management techniques in California over the last ten years. Quantitative, current, and geographically extensive data are not available. This survey differs from others conducted in the past because it directly asks growers about irrigation and nitrogen management techniques from two distinct points in time to characterize real changes in management and to allow us to relate the changes to each other.

The target audience for this survey was growers of irrigated field, vegetable, tree and vine crops. Nurseries, confined animal production facilities, rice growers and some other forms of

fertilize, can not change their techniques (i.e. rice and flood irrigation) or do not occupy a large amount of acreage in the state-wide picture.

We asked these farmers to identify, by crop, the acreage in 1986 and 1996 under four classes of irrigation methods and then to answer a short series of questions about their nitrogen fertilization techniques for the same crops (Table 1- Irrigation Questions, Table 2 - Nitrogen Fertilizer Questions)

With the generous cooperation of numerous individuals in the University of California Cooperative Extension (UCCE) system, 42 of California's 58 counties were chosen to be surveyed. Due to Cooperative Extension's method of cross-listing farm advisors in counties or delegating responsibility for two counties to one office, the participating counties were eventually examined as 34 separate units and subsequently categorized by region. (Table 3).

Our total mailing consisted of 7635 surveys. The surveys were randomly mailed to growers from the UCCE County office mailing lists we obtained. In most cases, a cover letter from the appropriate UCCE county director or farm advisor accompanied the survey. If such a letter could not be obtained, a cover letter generated by our office was sent. The cover letter described the purpose and potential use of the survey as a guidance tool for the UCCE County offices as well as noting the support of UCCE and the California Farm Bureau Federation for the project. 833 useable surveys were returned to us for a response rate of 11%. This response rate was disappointingly low, but was in line with the predictions of most of the farm advisors we collaborated with on the project.

The data was organized by crop and by region for analysis. Crop categories were taken from the 1996 California Agricultural Resource Directory produced by the California Department of Food and Agriculture's Office of External Affairs. The following categories were used in the analysis: nut crops, citrus fruits, non-citrus fruits, grapes, vegetables and field crops. The category of orchards was compiled by us so that we could examine the data for tree crops as one unit. Grapes were examined as a separate unit because of the large number of responses we received from vineyards throughout the state.

Regional categories were created from DWR Bulletin 113-4 of April 1996 "Crop Water Use in California" using Appendix F (Index to Agroclimate Stations pg. 66-67) and Appendix G (Evaporation Pan Data pg. 69-73). Counties are placed into one of the categories based upon their classification in the agroclimate station map and then a comparison of their evaporation pan data during the summer months (Table 3).

Acreage was summed by region and by crop for the analyses. Answers to the nitrogen management questions were also summed with the question "Times that commercial N fertilizer was surface applied ?" being calculated as a Likert scale with 0 = 0 applications and 6 = more than 5 applications. Percentages were calculated for each question both by crop type and region as well as the overall state numbers. The differences in the percentages for 1986 and 1996 were examined for statistical significance by using a standard Z test.

RESULTS

Irrigation methods have changed in nearly all categories of analysis both by crop and by region (Graphs 1 and 2). There was a significant decrease in reported percent acreage irrigated by surface methods (-11% statewide) and an increase in percent acreage irrigated with micro systems (+12% statewide) for all regions and crops except for the Mountain areas during this ten year

period. Additionally, the acreage reported for field crops managed with a micro irrigation system was low (0 acres in 1986 and 180 acres in 1996) and these results should be interpreted with caution.

There was a decrease in the percent acreage irrigated by sprinklers in all regions except the San Joaquin Valley and Mountain regions. The San Joaquin Valley reported large acreage in field crops and the Mountain areas reported large amounts of irrigated pasture and alfalfa. At the statewide level there was a significant, although not large (2%), decrease in the percent of acreage irrigated with sprinklers. This is due to the large decrease in percent sprinkler acreage reported in the North and Central Coast Interior Valley region and the Desert areas where micro irrigation systems have been adopted at a more rapid pace than the San Joaquin and Mountain regions. This change is particularly interesting since the San Joaquin Valley region accounted for 54% of the reported acreage in 1986 and 50% in 1996 and thus had a large influence on the statewide numbers.

The trends from the nutrient management portion of the survey are more complicated. At the statewide level, a strong trend away from only one surface application was found. Significant increases in the acreage managed without a surface application or with multiple (and presumably smaller) applications were found (Graph 3). This corresponds to the observed trends towards adopting other methods of supplying nitrogen to the crops. A significant increase in the percentage of farmers who managed their crops with foliar N applications, fertigation, soil and plant tissue testing or using cover crops and organic amendments was found (Graph 4).

We separately examined these nitrogen management questions for farms which reported a change in their irrigation method and they are identified as "CF" in Graph 4. All of the differences (for all farms which replied and only those which changed their irrigation technique) at the statewide level tested to be statistically significant at the 99% confidence level. However the percentage of change between these two categories of farms is quite different. For all questions, farms which changed their irrigation system showed a greater percentage of adoption of the nitrogen management techniques than farms which did not have an irrigation management change (Table 4).

The adoption of these methods is most prominent in the North and Central Coast Interior Valleys, the San Joaquin Valley and for nut, grape and vegetable crops. (Individual graphs for each category are not presented here.)

In the final nitrogen fertilizer management question, we asked the grower to identify the total lbs of commercial actual N/acre they applied to the crop. We then took the usable responses and classified them as either 1.) increased the amount, 2.) decreased the amount, or 3.) no change in the amount. The results of this analysis are presented by crop in Graph 5 and by region in Graph 6. In the majority of cases (Statewide - 57%) the total amount of nitrogen being applied remained the same. The percentage of growers who increased the total amount applied (Statewide - 24%) was higher in all categories except for the Southern Desert region and for citrus and non-citrus fruit crops. These categories reported a decrease in the total amount of nitrogen applied (Statewide - 19%). The Mountain regions and the grape growers reported an equal number of farmers who increased and decreased their total applications.

The relatively low percentage of replies caused us to analyze the data in a manner to identify a potential bias in the responses. First we checked our responses to ensure that the percentage of return was not influenced by region. We found that five of the six regions had a 10-12% response rate (The Southern California Desert region was the exception at 7%.) and yet the regions had

different reported rates of irrigation and nutrient management technique change. Thus there was no bias in the number of returns by region and there was no correlation between percent return and percent reporting change in management.

We also checked the size (by acreage) of the farms in 1996 which responded to our survey against the CDFA Agricultural Production and Export Statistics for 1995. We found that the percentage of smallest farms (1 to 49 acres) which responded to our survey to be below the CDFA estimates by 14.2%. The percentages in the remainder of the categories set forth by CDFA were close however (Graph 7) with our responses in each category being 0.9% to 5.2% higher. Thus the responses were not greatly biased by farm size.

Finally, we compared our data with data from other irrigation surveys which were compiled and examined in an article published in May-June 1997 issue of California Agriculture (Susan Edinger-Marshall and John Letey 1997. "Irrigation shifts toward sprinklers, drip and micro sprinklers." California Agriculture 51(3):38-40). Examining the data for the two surveys closest to ours, the 1988 Bureau of Census (BOC) survey and the 1995 Natural Resources Conservation Service (NRCS) survey, we find that the percent change per year for our surveys to be in close agreement. Our survey shows a 1% per year decrease in acreage irrigated with gravity systems while comparing the other two surveys yields a 1.4% per year decrease in acreage under these systems. The micro irrigation systems show a 1.2% per year increase in acreage both in our survey and in comparing the NRCS and BOC survey data. This shows that the trend captured in our survey is the same as that found by other surveys.

CONCLUSIONS

The trends in shifting irrigation away from surface systems to pressurized micro irrigation or sprinklers is consistent with the results of other surveys (Marshall and Letey 1997.). Pressurized irrigation systems provide the farmer with greater control on the amount applied water and, for properly designed and managed systems, better uniformity of irrigation than surface systems. The irrigation results must be considered to be positive.

The trend toward adoption of nitrogen fertilization management practices such as soil testing, plant tissue testing, multiple fertilizer applications, etc. that are considered to be good management practices is also a positive finding. However, adoption of better irrigation systems and improved nitrogen management practices have not translated into overall reduced nitrogen application amounts.

We can only speculate on the reason(s) that overall nitrogen application amounts have balanced out to be about the same for 1986 and 1996. Possible explanation includes the following considerations. Improved irrigation can lead to increased yield which would require higher nitrogen inputs to meet crop needs. One farmer growing a nut crop specified that the increase in N application between 1986 and 1996 was because the trees had grown and required more N.

Research and Extension activities which address shifts in fertilizer application which should accompany a shift in irrigation technique may be lacking. In other words, the farmer in the absence of new information relies on previous fertilizer application guidelines even though there has been a shift in irrigation systems.

The survey instrument allowed the farmers to provide a message they would like the nonfarming community to understand. The most common message was that they were well aware of and concerned about environmental quality. They pointed out that water and fertilizer are

of and concerned about environmental quality. They pointed out that water and fertilizer are costly and that it would be economically unsound for them to apply more than necessary to get a good yield. The results of this survey suggests that they are voluntarily taking a number of steps to improve management, however, the apparent stability in nitrogen application amounts requires further investigation before it can be properly interpreted.

Personal Information

Joe Dillon is a Staff Research Associate, Water Quality Program, Centers for Water and Wildland Resources; Susan Edinger-Marshall was formerly a Staff Research Associate, Water Quality Program, Centers for Water and Wildland Resources, and is presently an Assistant Professor in Natural Resources at Humboldt State University, Arcata, CA; and John Letey is Professor of Soil Physics, Department of Soil and Environmental Sciences, UC Riverside, Associate Director of the Centers for Water and Wildland Resources, State Water Quality Coordinator for UCCE , and coordinator of the UC Salinity and Drainage Program/Prosser Trust.

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Acknowledgement

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Table 1

For each major crop listed above, please provide information about irrigation practices. (You may group crops into management types if necessary.)

CROP:_____

Irrigation Method	ACRES in 1986	ACRES in 1996
Micro (i.e., surface or buried drip, microsprinklers, etc.)		
Surface (i.e., border, basin, furrow, flood, etc.)		
Sprinkler (i.e., solid set, hand move, pivot, etc.)		
Combination (i.e., sprinkler for germination, surface for remainder of season, etc.)		

Comments: If your method didn't change, identify other management adjustments you may have adopted (i.e. changes in furrow lengths, set times, amount of water applied, etc.)

Table 2

Nitrogen Fertilizer Management - For each crop that you grew in 1986 and 1996, how have your nitrogen fertilization methods changed? Please circle answers and add comments as necessary.

Crop: _____

	1986	1996
Times that commercial N fertilizer was *surface* applied?	None 1 2 3 4 5 More	None 1 2 3 4 5 More
Number of foliar N applications?	None 1 2 3 4 5 More	None 1 2 3 4 5 More
Fertilize through a water system?	Yes No	Yes No
Cover crops during off season?	Yes No N/A	Yes No N/A
Soil test for nitrogen?	Yes No	Yes No
Plant tissue analysis for nitrogen?	Yes No	Yes No
Organic amendments (i.e., manures, compost, manure water, biosolids)?	Yes No	Yes No
Total lbs. **commercial actual** N/ac?		

Comments: Are there other ways in which your fertilization methods have changed that are not covered in the questions listed above?

Table 3

Listing of Participating Counties and their Regional Classification

North and Central Coast Interior Valleys	***San Joaquin Valley***	***Sacramento Valley***	***Nonparticipating Counties***
Contra Costa and Alameda Counties	Fresno County	Butte County	Alpine County
Lake County	Kern County	Colusa County	Amador County
Napa County	Kings County	Glenn and Tehama Counties	Calaveras County
Monterey County	Madera County	Sacramento County	Del Norte County
San Benito County	Merced County	Solano and Yolo Counties	Humboldt County
San Luis Obispo County	San Joaquin County	Sutter and Yuba Counties	Los Angeles County
Santa Clara County	Stanislaus County		Marin County
Santa Cruz County	Tulare County		Mariposa County
Shasta and Trinity Counties			Mendocino County
Siskiyou County			Modoc County
Sonoma County			Orange County
	South Coast		Plumas County
Southern California Desert	***Interior Valleys***	***Mountain Counties***	San Francisco County
Imperial County	San Diego County	El Dorado County	San Mateo County
Inyo and Mono Counties	Santa Barbara County	Lassen County	Sierra County
San Bernardino and Riverside Counties	Ventura County	Placer and Nevada Counties	Tuolumne County

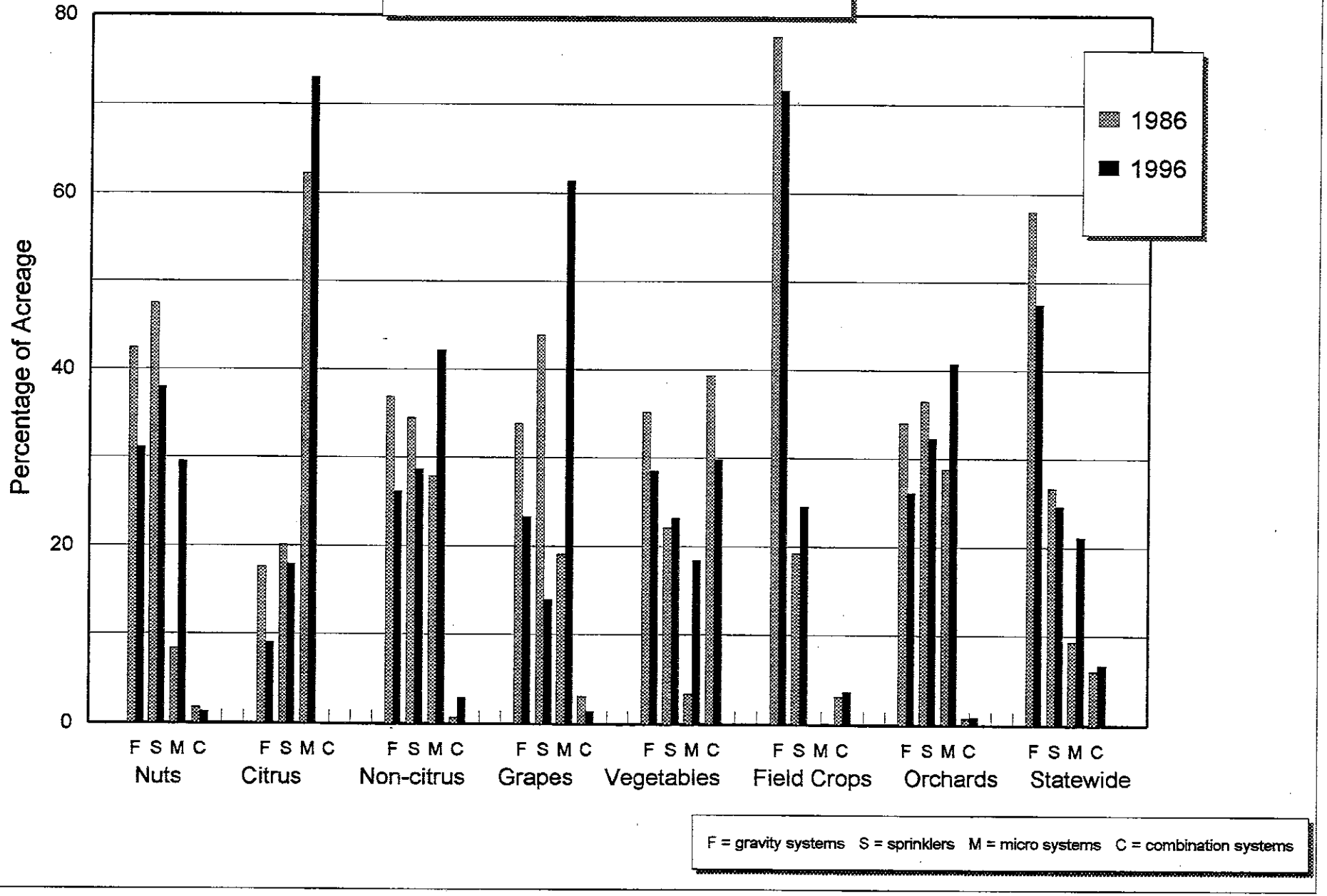
Table 4

Percentage Difference for Nitrogen Management Techniques

	All Farms	Changed Farms
Use Foliar Applications?	7.5%	12.1%
Fertigate your crops?	10.9%	26.8%
Use Cover Crops ?	6.9%	14.5%
Soil Test your Fields?	9.2%	15.2%
Tissue Test your Crops?	8.8%	15.2%
Use Organic Amendments?	6.1%	9.4%
Zero Surface Applications?	5.5%	15.7%
One Surface Application?	-9.2%	-13.7%
Two Surface Applications?	-2.0%	-10.7%
Three or More Surface Applications?	5.7%	8.8%

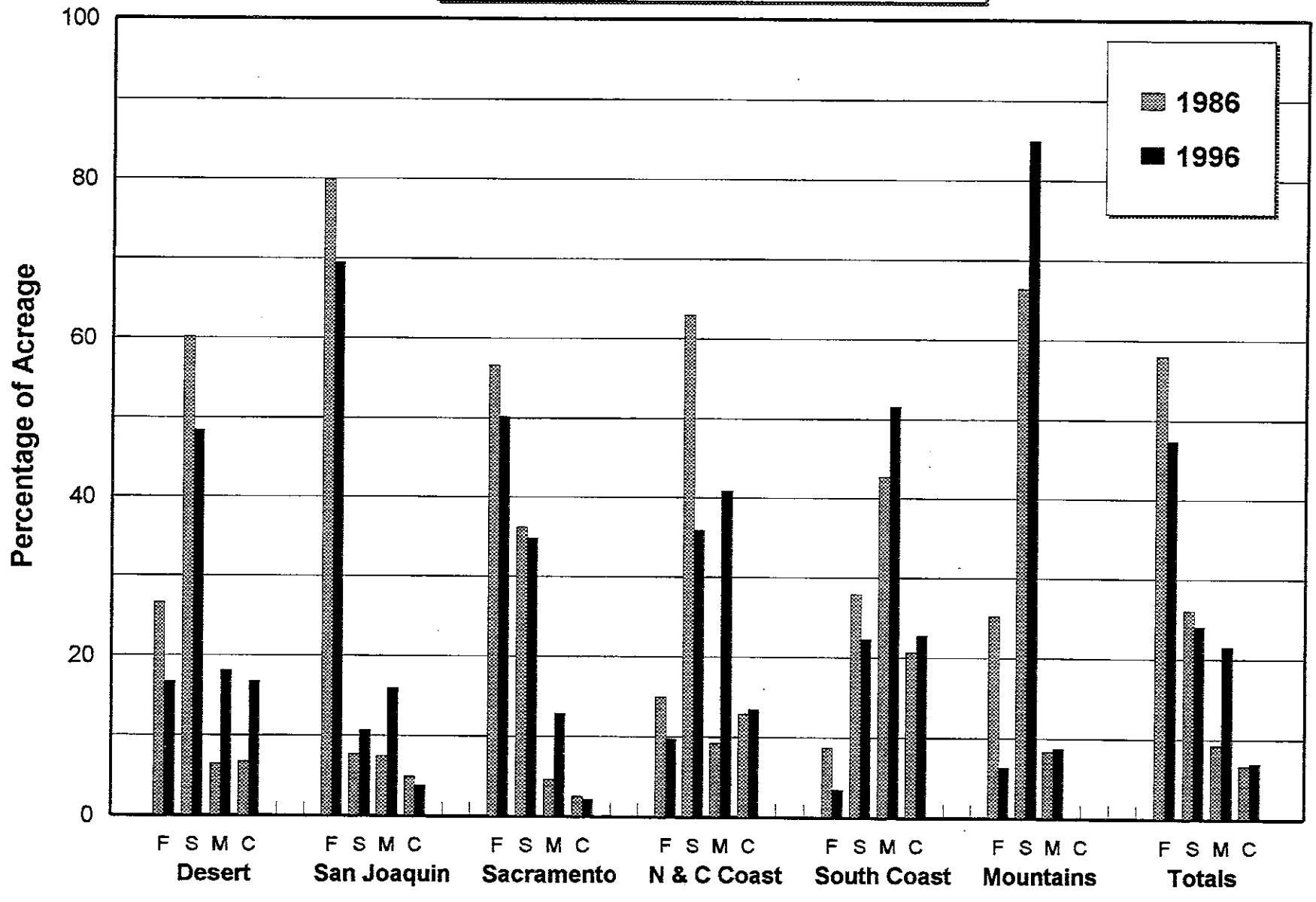
Graph 1

Irrigation Method Changes by Crop



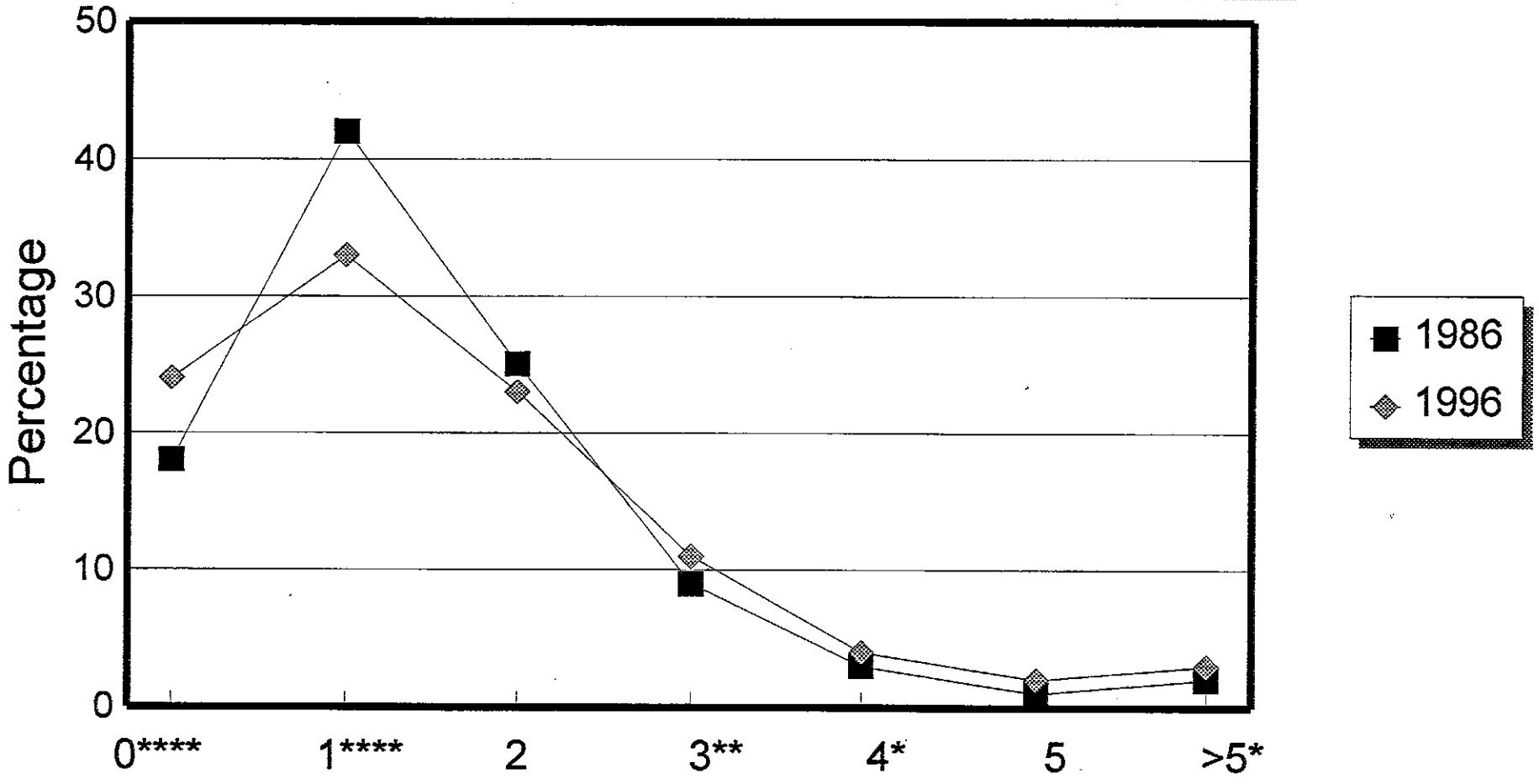
Graph 2

Irrigation Method Changes by Region



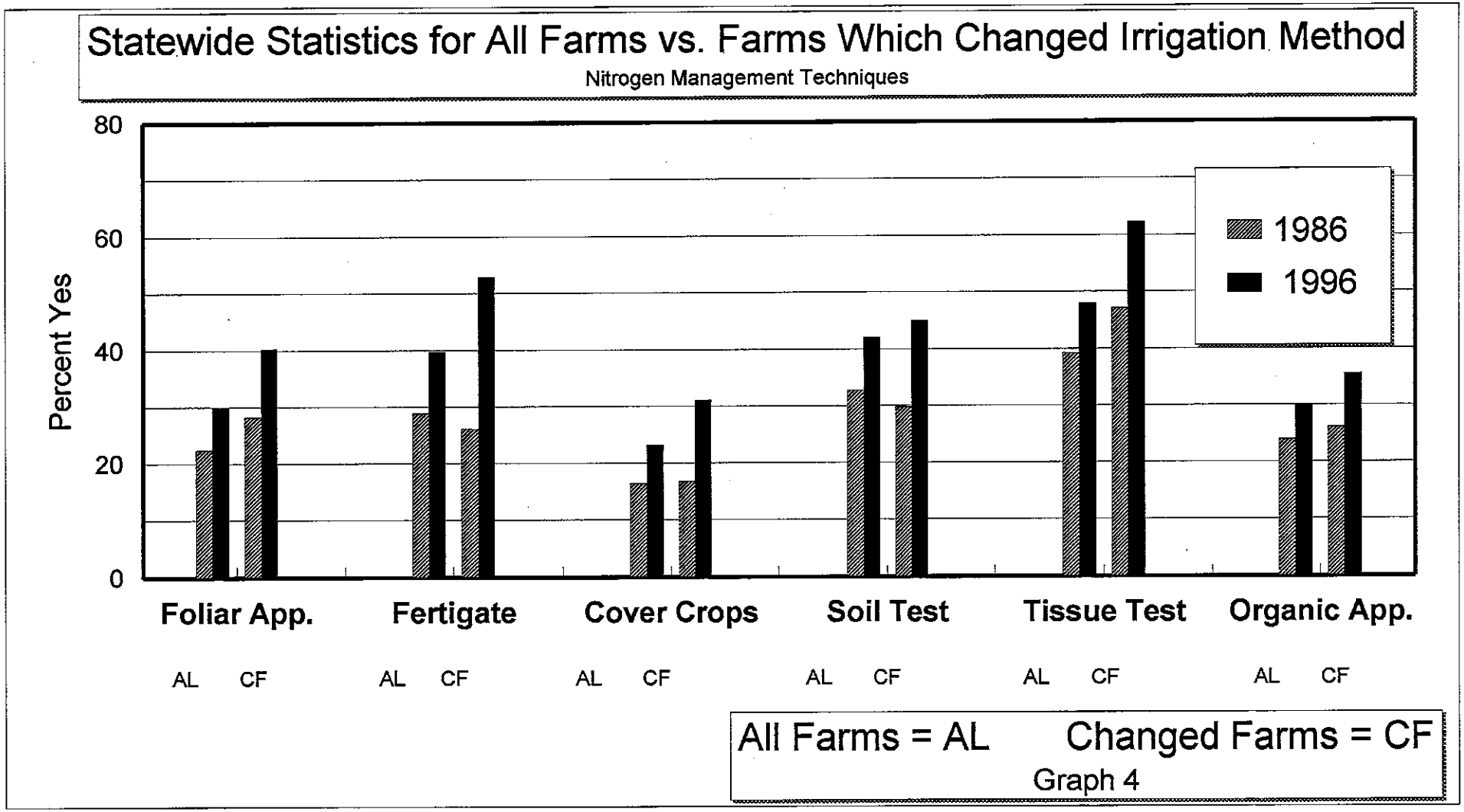
Graph 3

Surface Applications of N - Statewide

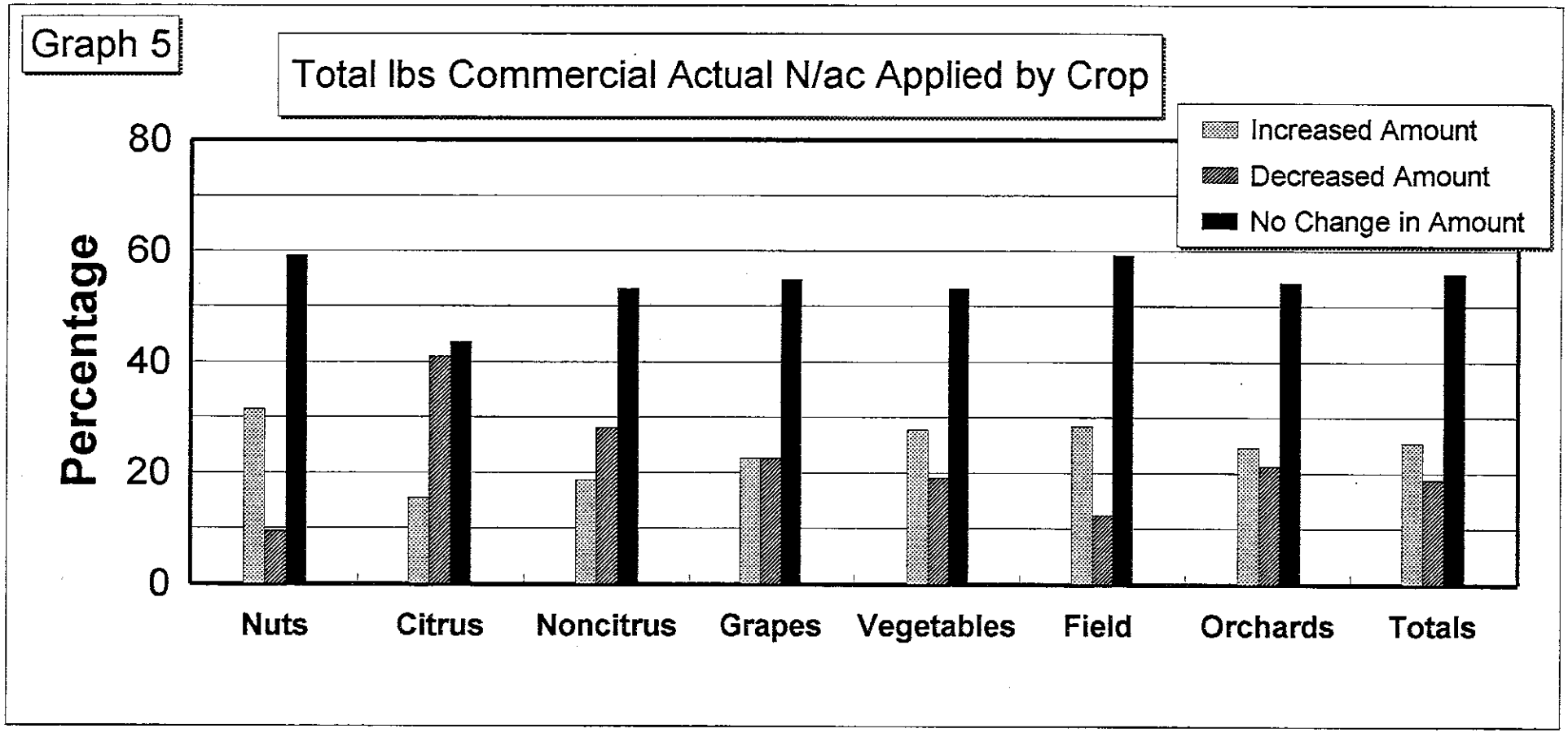


Significance Level

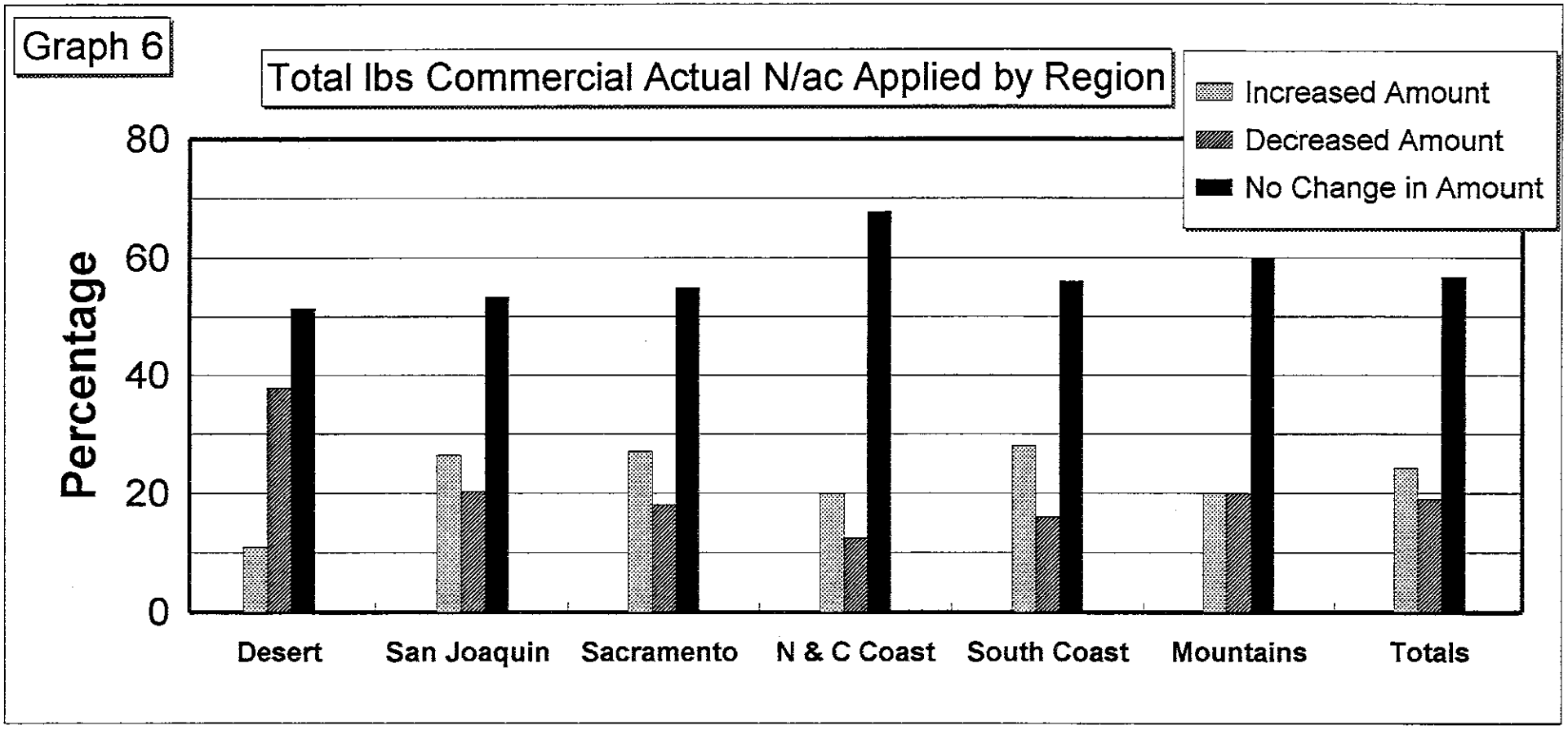
* 90% ** 95% *** 98% **** 99%


Statewide Statistics for All Farms vs. Farms Which Changed Irrigation Method
Nitrogen Management Techniques
Percent Yes
80
60
40
20
0
1986
1996
Foliar App.
Fertigate
Cover Crops
Soil Test
Tissue Test
Organic App.
AL CF AL CF AL CF AL CF AL CF AL CF
All Farms = AL Changed Farms = CF

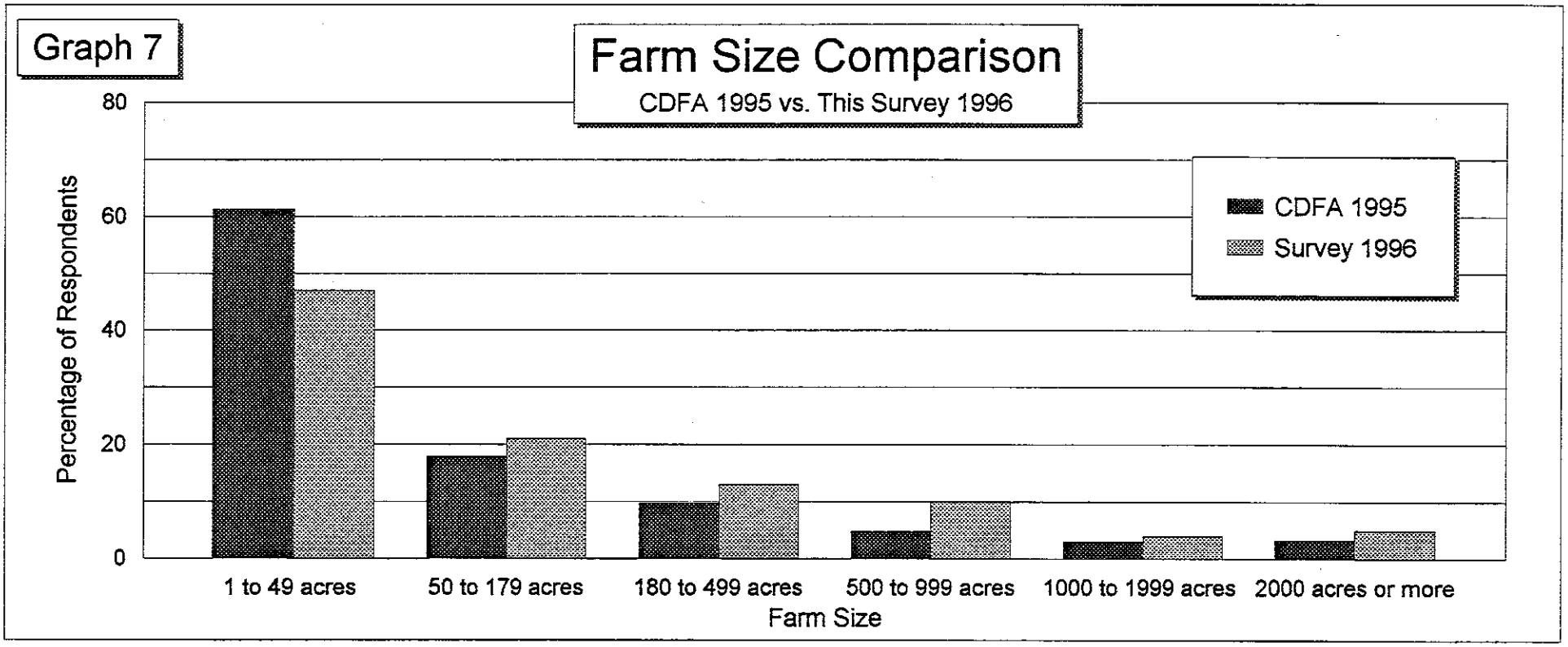
Graph 4

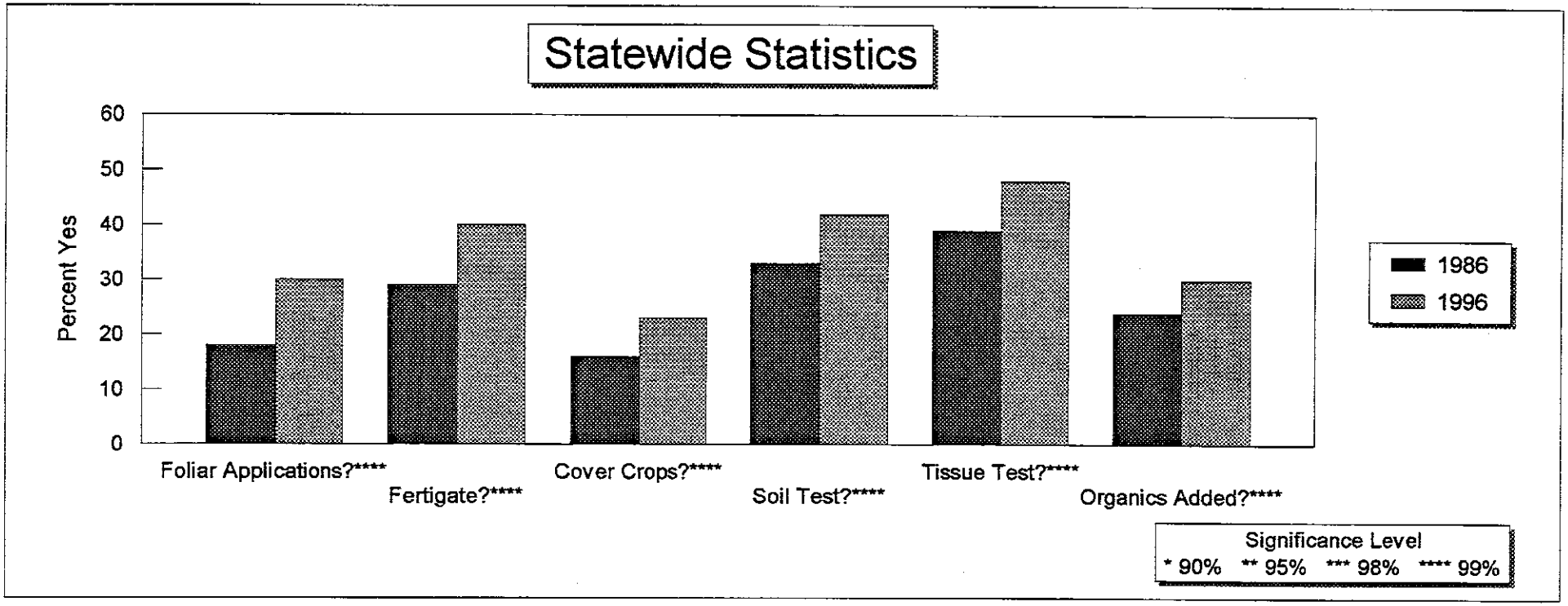

Graph 5
Total lbs Commercial Actual N/ac Applied by Crop
Increased Amount
Decreased Amount
No Change in Amount
Percentage
80
60
40
20
0
Nuts
Citrus
Noncitrus
Grapes
Vegetables
Field
Orchards
Totals

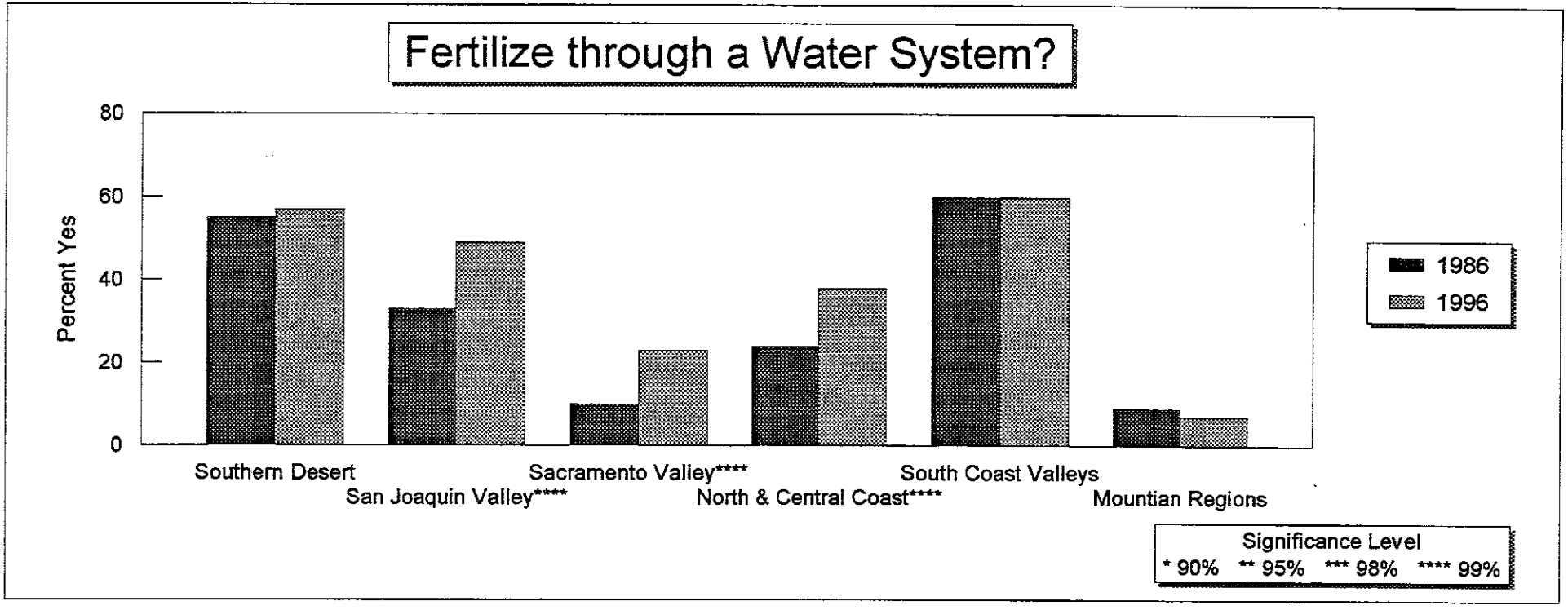
Graph 6

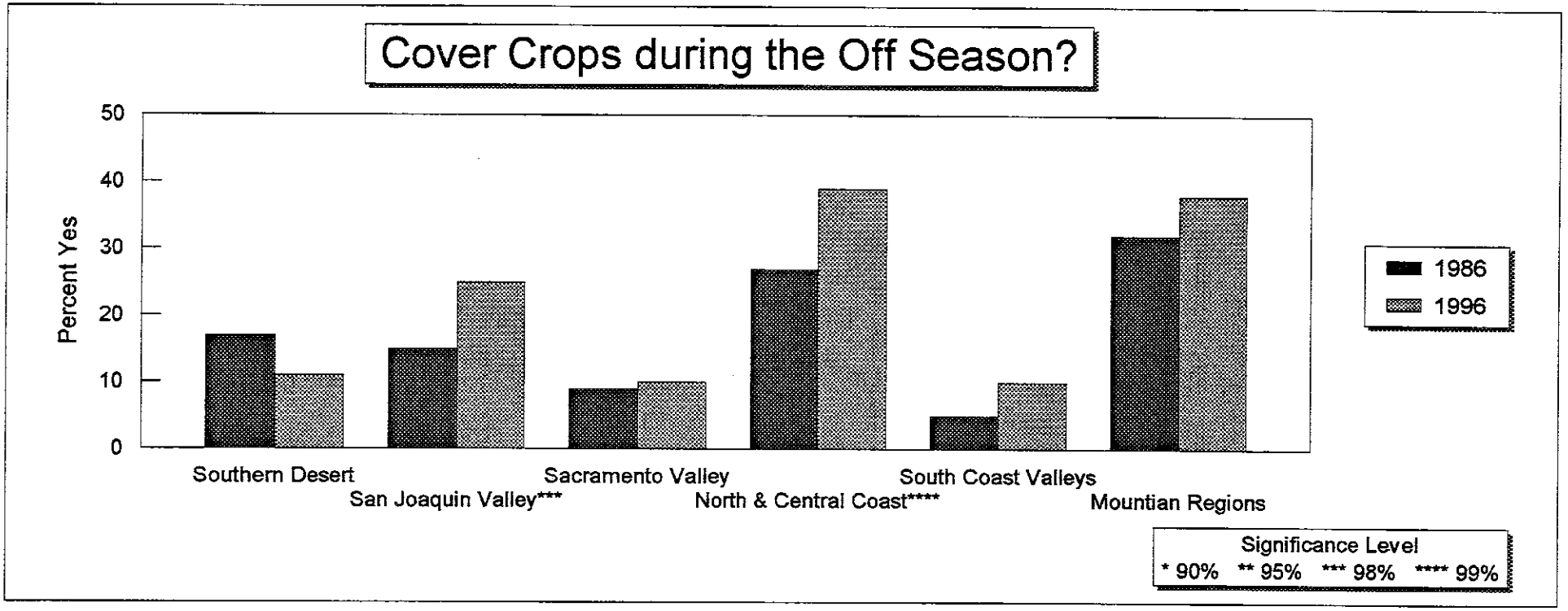

Total lbs Commercial Actual N/ac Applied by Region
Increased Amount
Decreased Amount
No Change in Amount
Percentage
80
60
40
20
0
Desert
San Joaquin
Sacramento
N & C Coast
South Coast
Mountains
Totals

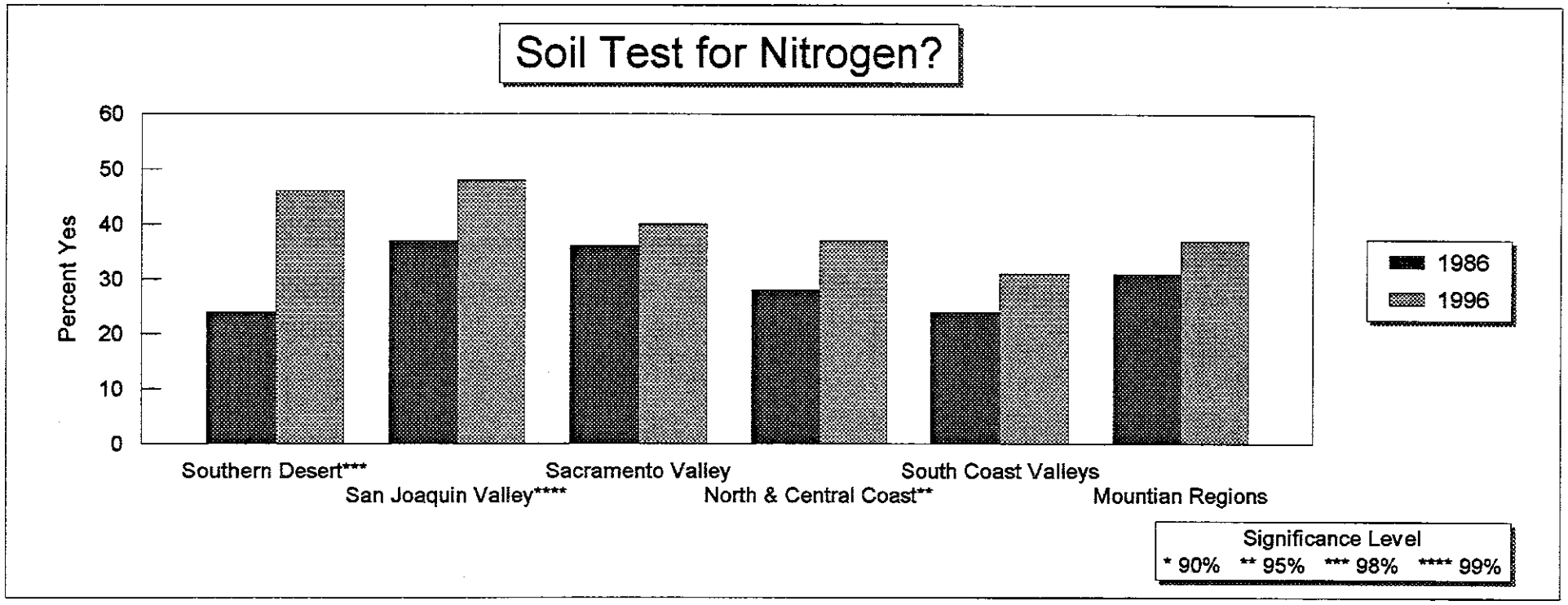
Graph 7

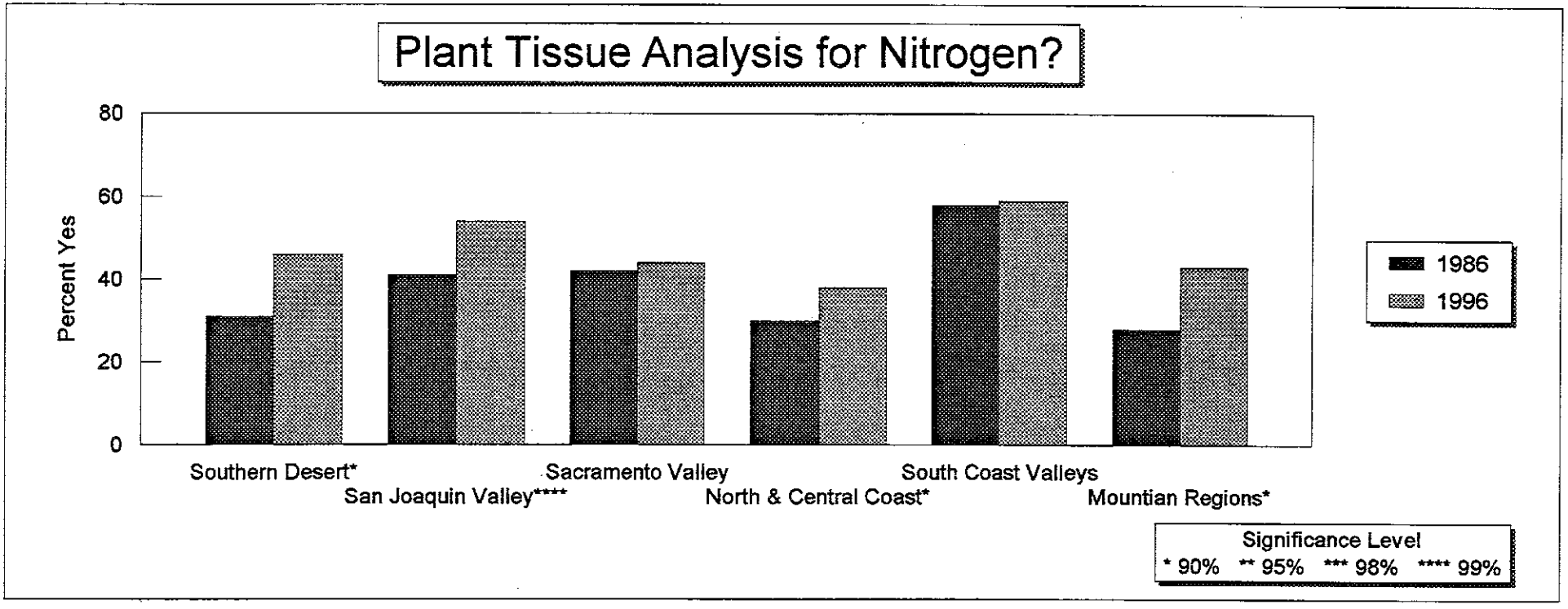

Farm Size Comparison
CDFA 1995 vs. This Survey 1996
Percentage of Respondents
80
60
40
20
0
CDFA 1995
Survey 1996
1 to 49 acres
50 to 179 acres
180 to 499 acres
500 to 999 acres
1000 to 1999 acres
2000 acres or more
Farm Size

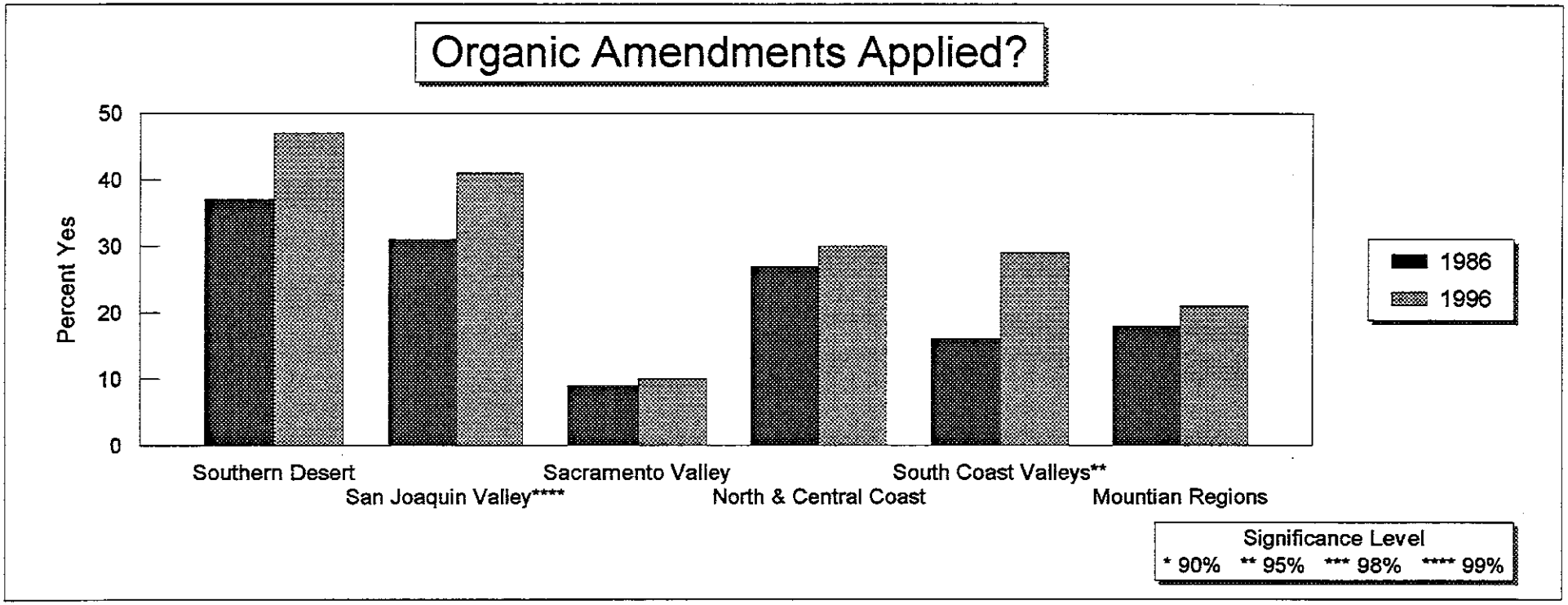

Statewide Statistics
Percent Yes
60
50
40
30
20
10
0
Foliar Applications?****
Fertigate?****
Cover Crops?****
Soil Test?****
Tissue Test?****
Organics Added?****
1986
1996
Significance Level
* 90% ** 95% *** 98% **** 99%


Fertilize through a Water System?
80
60
40
20
0
Percent Yes
Southern Desert
San Joaquin Valley****
Sacramento Valley****
North & Central Coast****
South Coast Valleys
Mountian Regions
1986
1996
Significance Level
* 90% ** 95% *** 98% **** 99%

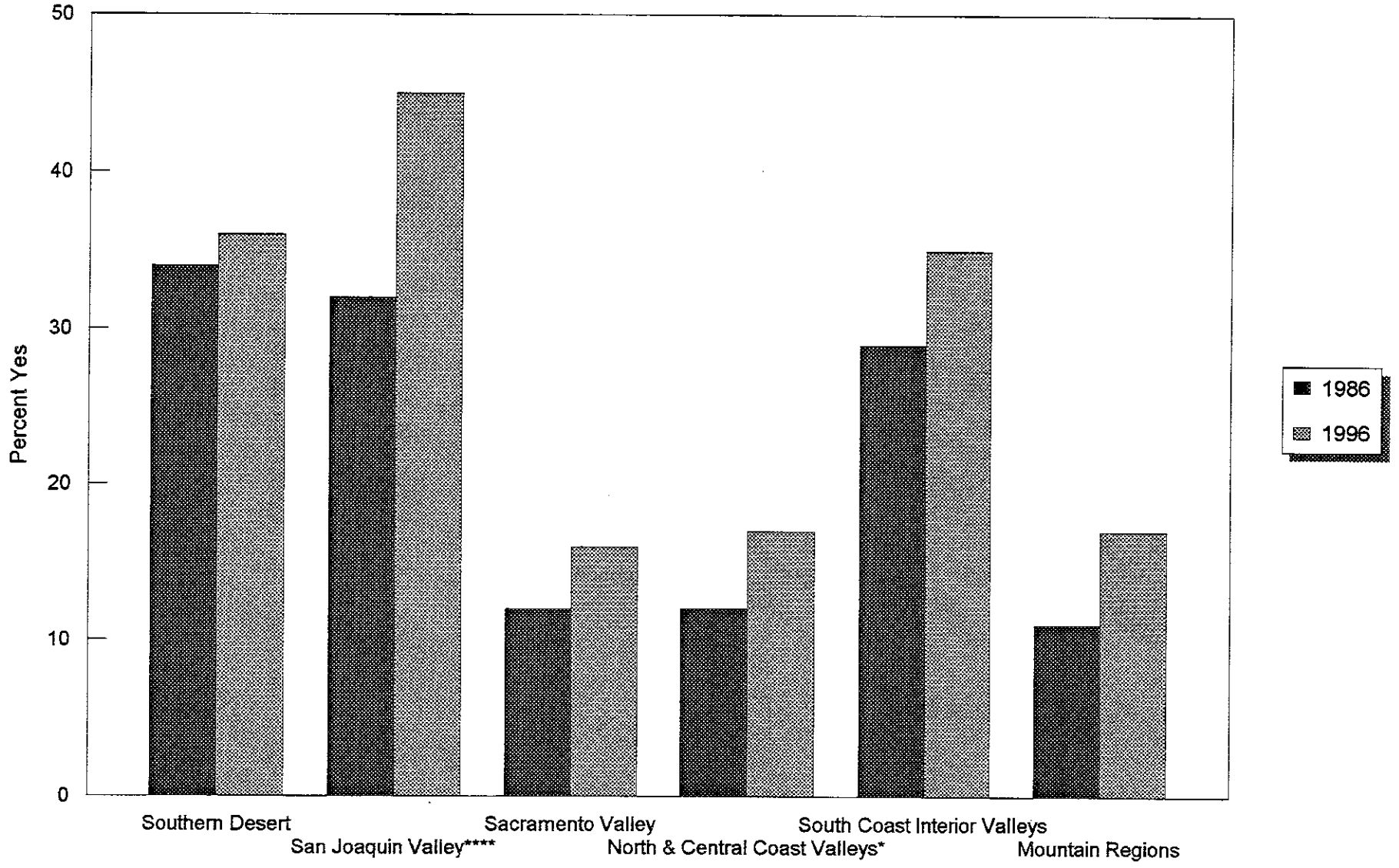

Cover Crops during the Off Season?
Percent Yes
50
40
30
20
10
0
Southern Desert
San Joaquin Valley***
Sacramento Valley
North & Central Coast****
South Coast Valleys
Mountian Regions
1986
1996
Significance Level
* 90% ** 95% *** 98% **** 99%


Soil Test for Nitrogen?
Percent Yes
60
50
40
30
20
10
0
Southern Desert***
San Joaquin Valley****
Sacramento Valley
North & Central Coast**
South Coast Valleys
Mountian Regions
1986
1996
Significance Level
* 90% ** 95% *** 98% **** 99%

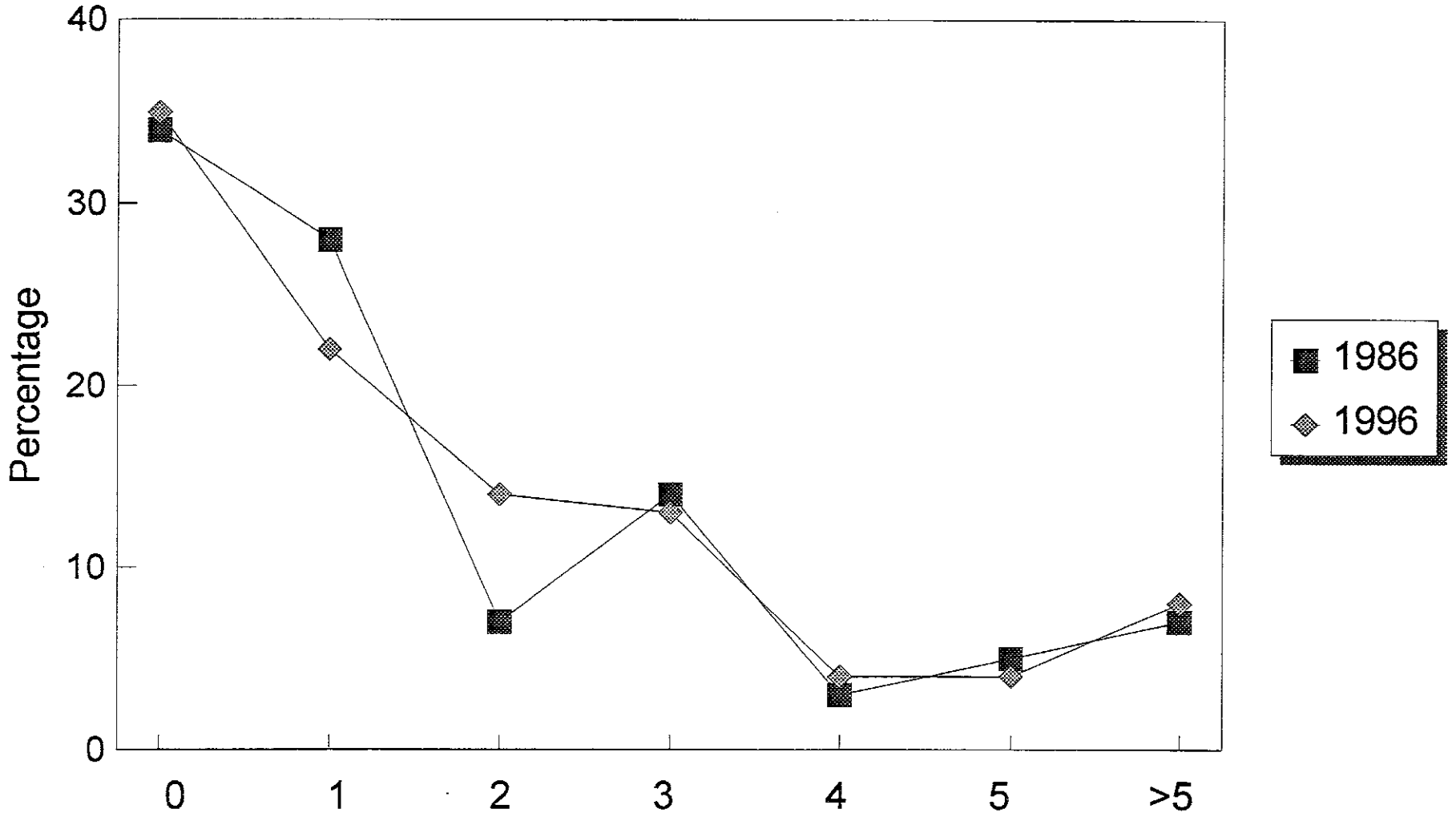

Plant Tissue Analysis for Nitrogen?
Percent Yes
80
60
40
20
0
Southern Desert*
San Joaquin Valley****
Sacramento Valley
North & Central Coast*
South Coast Valleys
Mountian Regions*
1986
1996
Significance Level
* 90% ** 95% *** 98% **** 99%


Organic Amendments Applied?
Percent Yes
50
40
30
20
10
0
Southern Desert
San Joaquin Valley****
Sacramento Valley
North & Central Coast
South Coast Valleys**
Mountian Regions
1986
1996
Significance Level
* 90% ** 95% *** 98% **** 99%

Used Foliar N Application(s)?



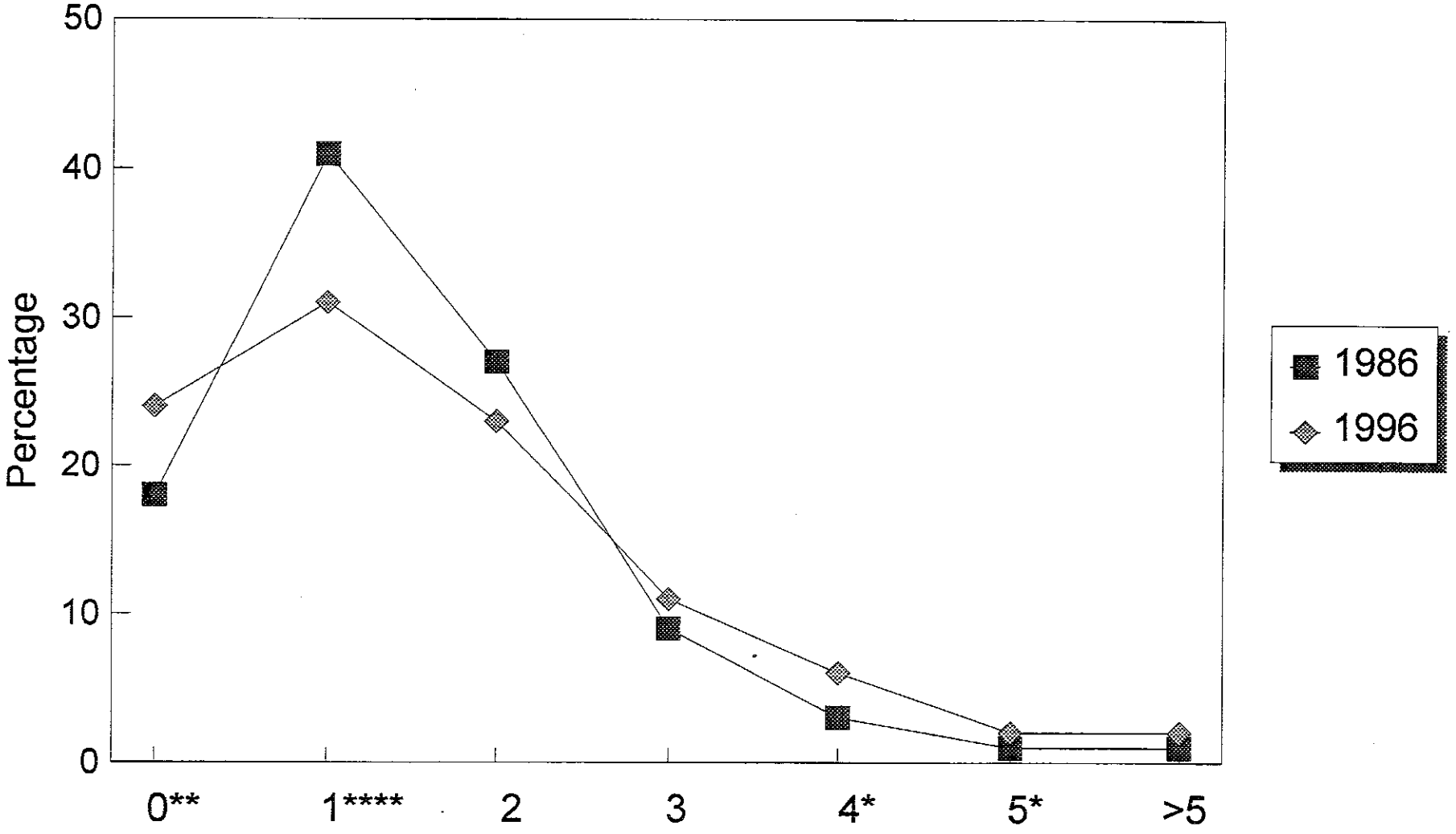
Surface Applications of N - Southern Desert



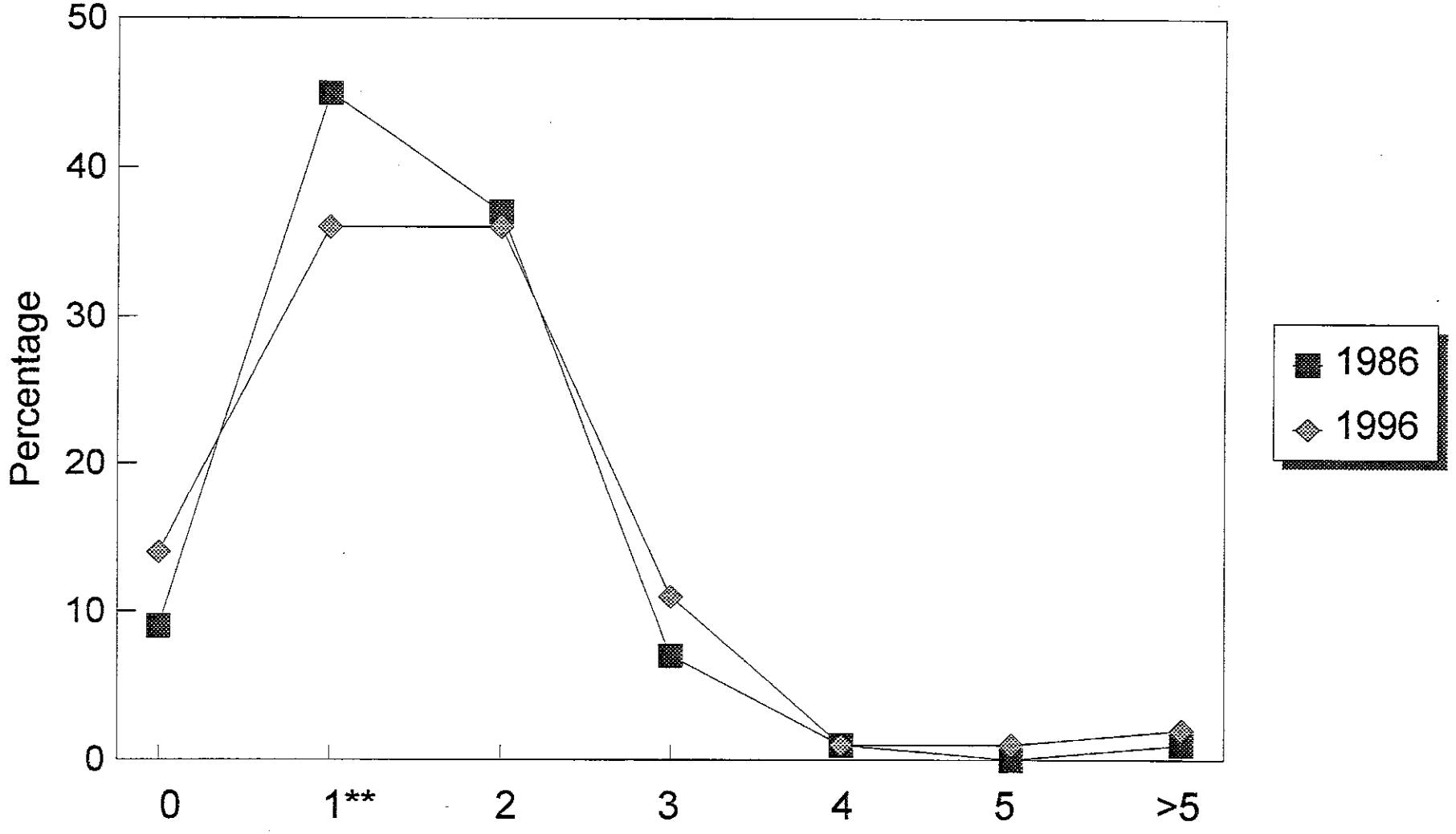
Significance Level

* 90% ** 95% *** 98% **** 99%

Surface Applications of N - San Joaquin Valley



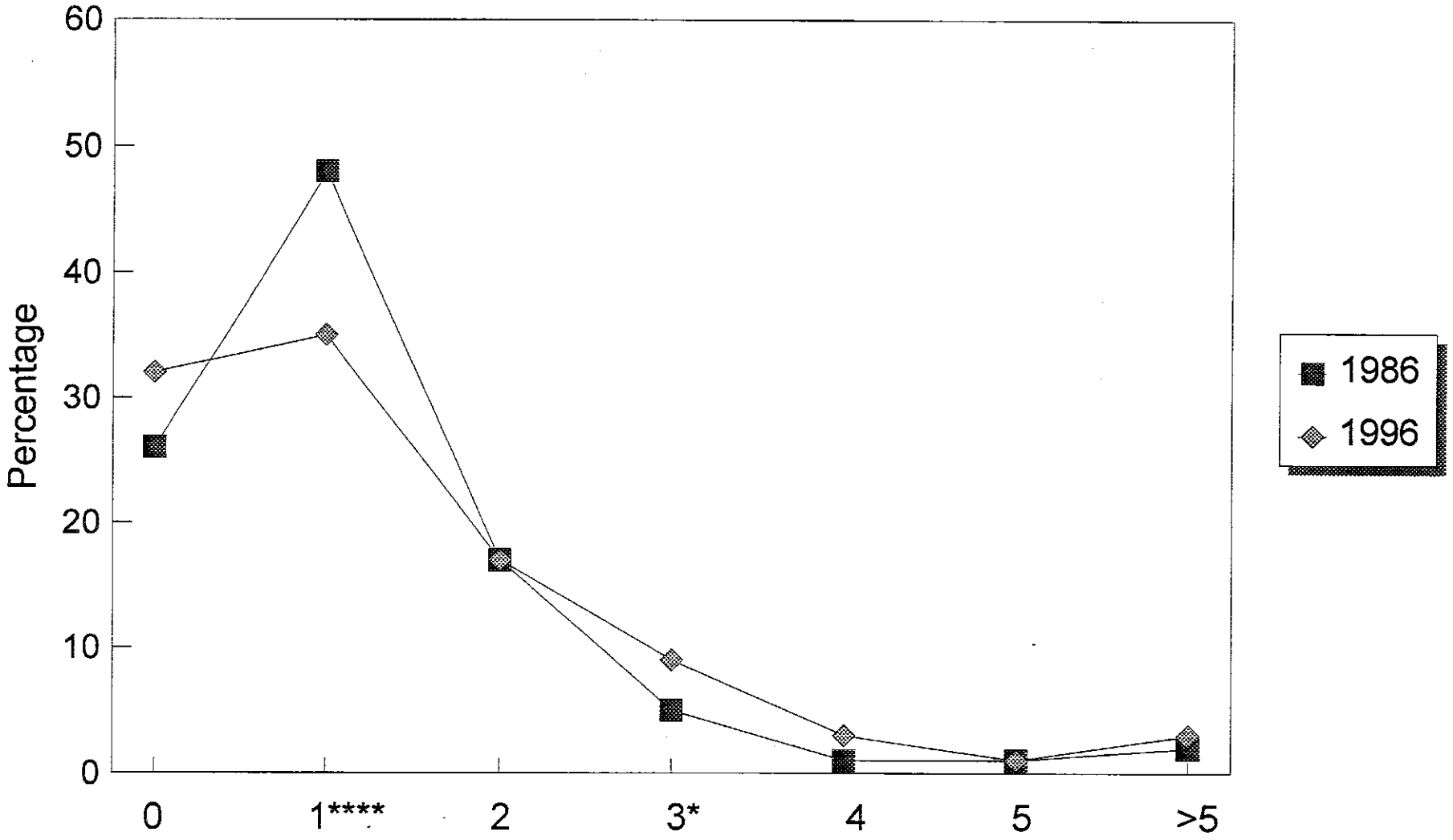
Surface Applications of N - Sacramento Valley



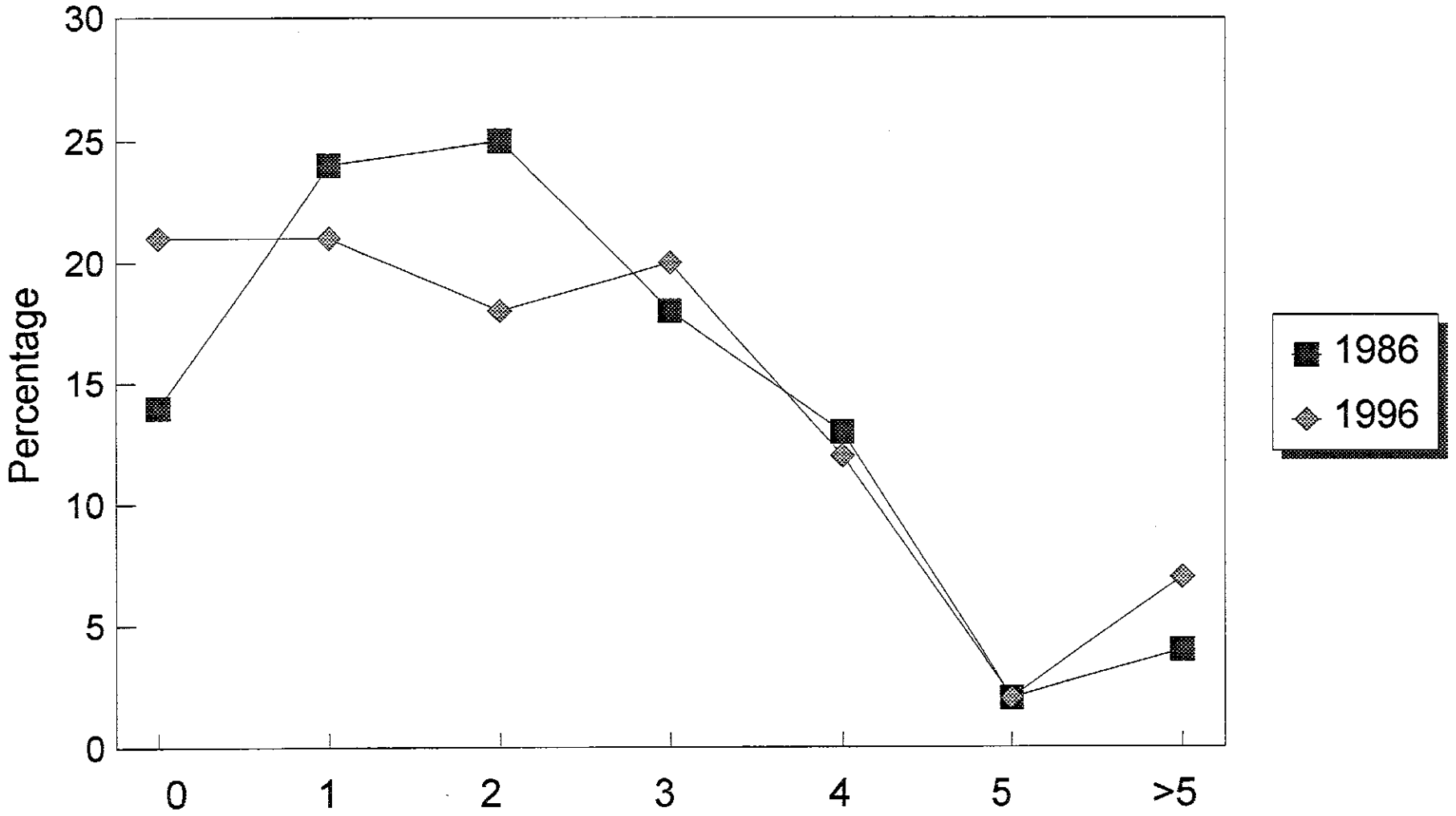
Significance Level

* 90% ** 95% *** 98% **** 99%

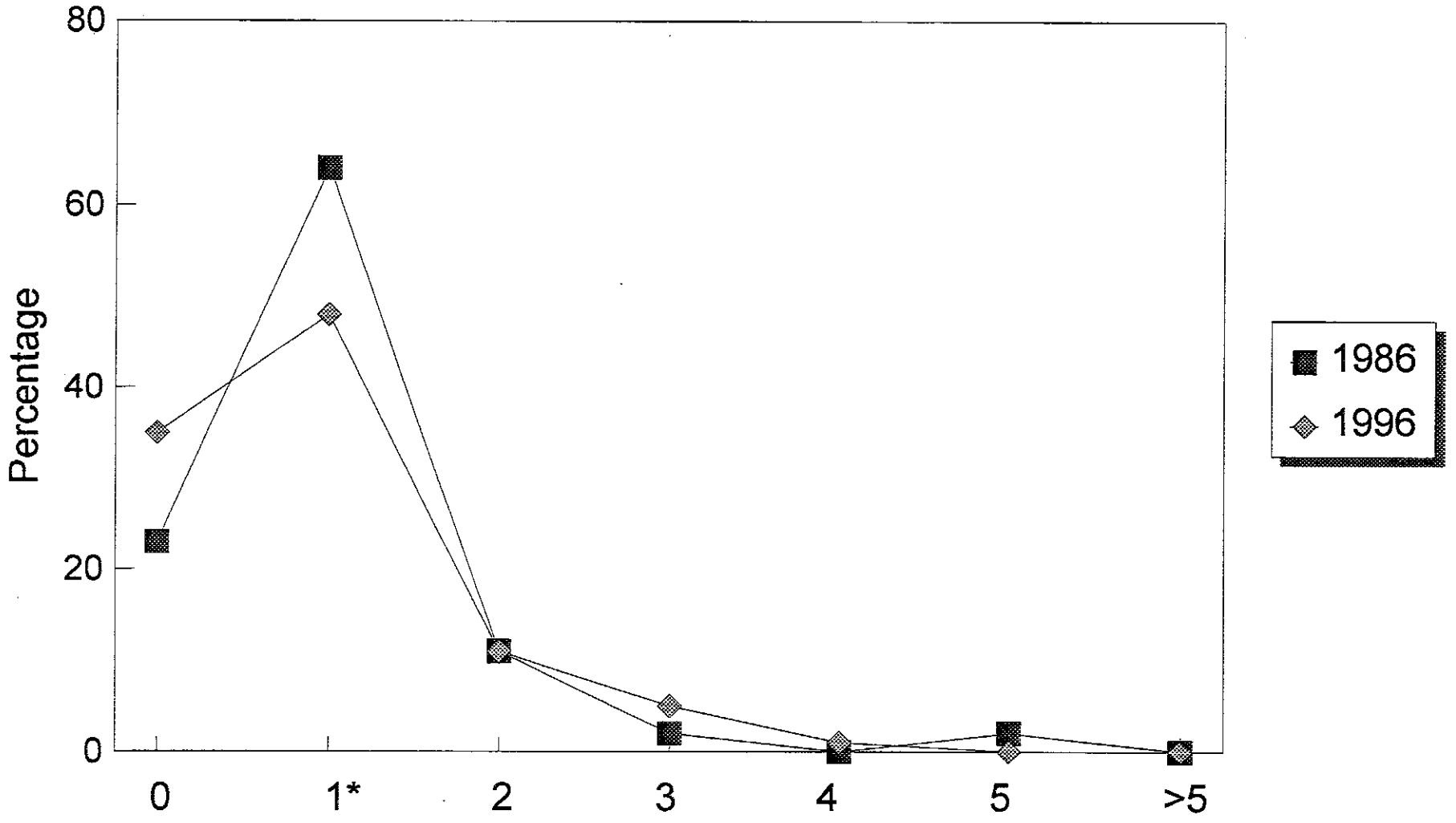
Surface Applications of N - North & Central Coast

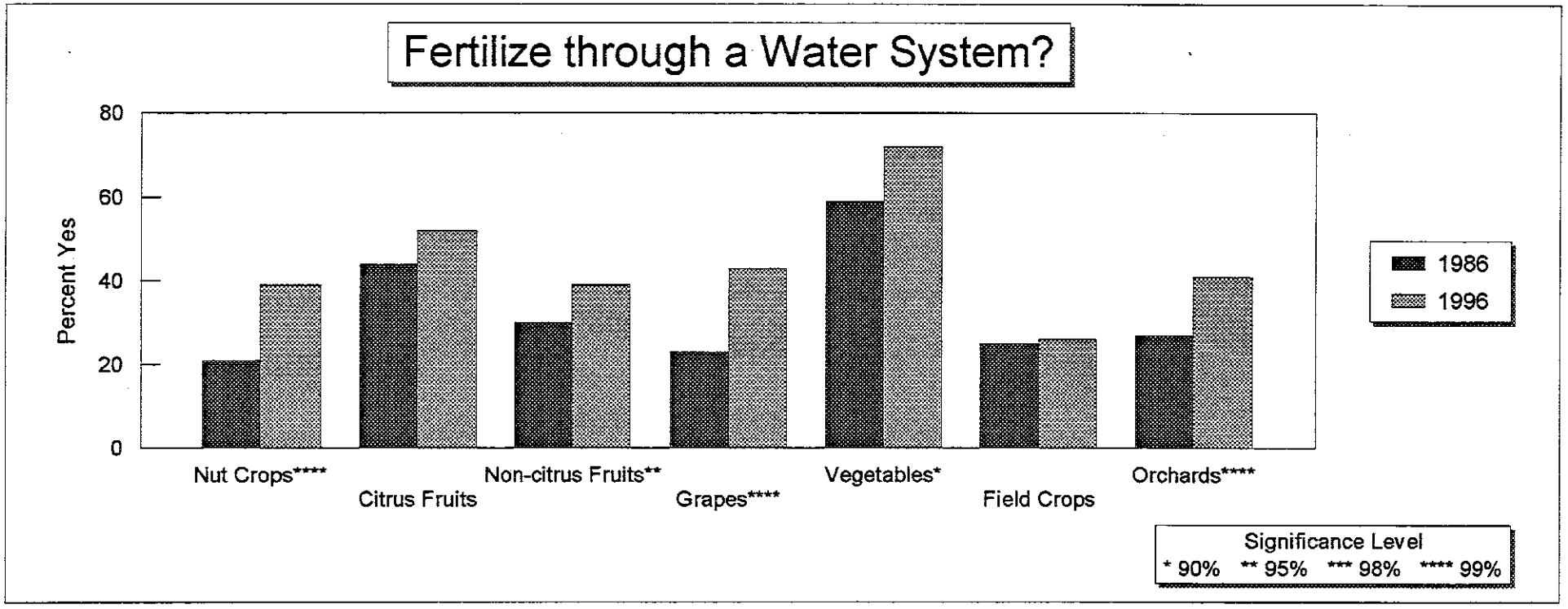


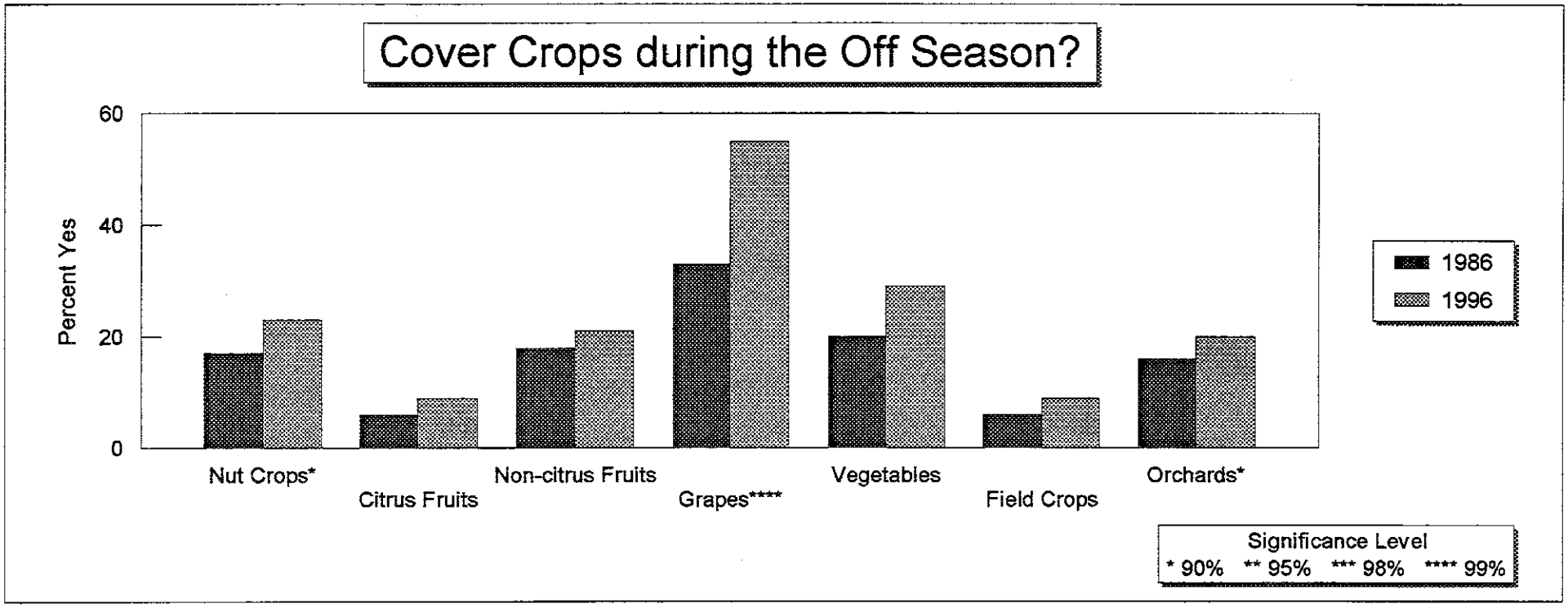
Surface Applications of N - South Coast

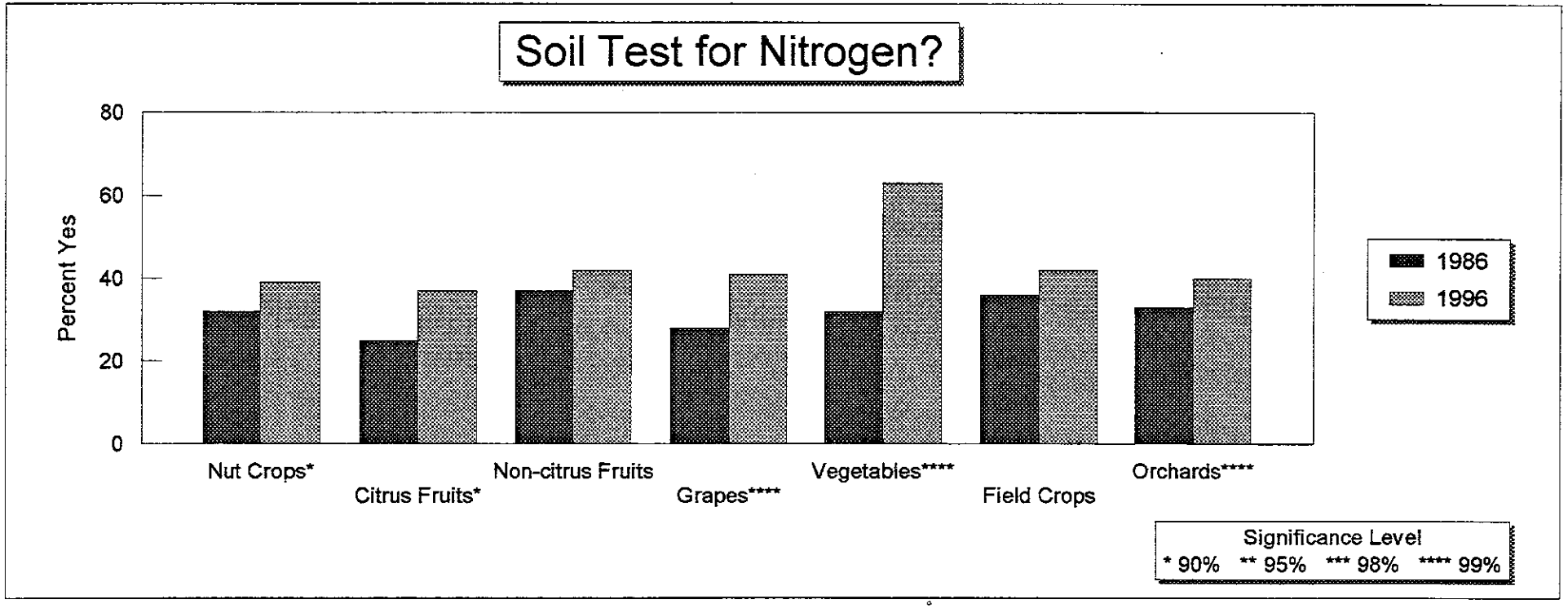


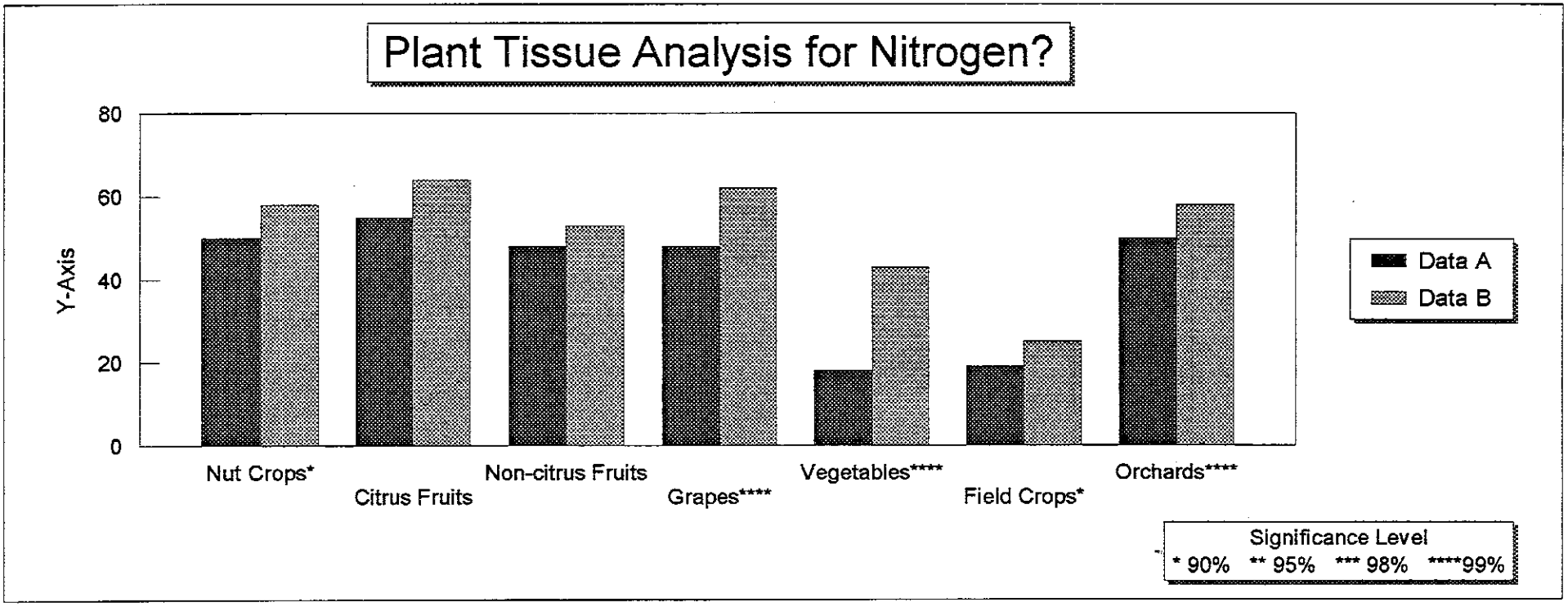
Surface Applications of N - Mountain Regions

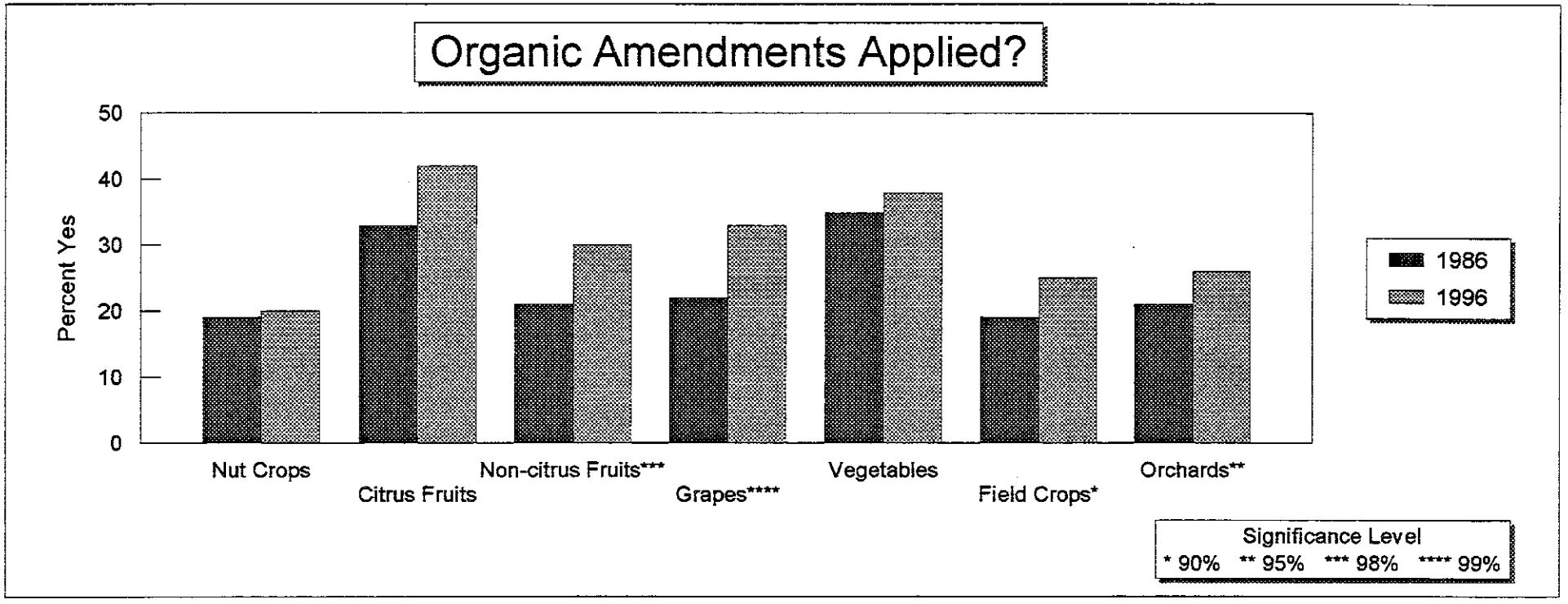


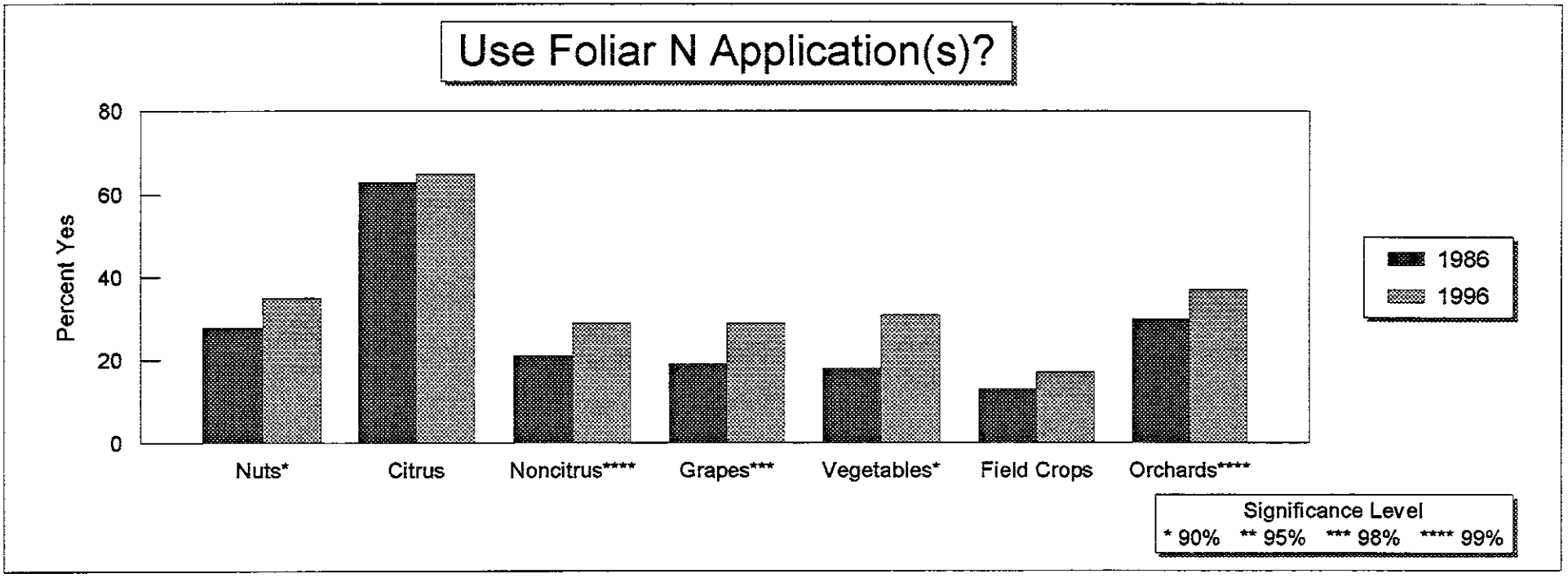

Fertilize through a Water System?
Percent Yes
80
60
40
20
0
Nut Crops****
Citrus Fruits
Non-citrus Fruits**
Grapes****
Vegetables*
Field Crops
Orchards****
1986
1996
Significance Level
* 90% ** 95% *** 98% **** 99%


Cover Crops during the Off Season?
Percent Yes
60
40
20
0
Nut Crops*
Citrus Fruits
Non-citrus Fruits
Grapes****
Vegetables
Field Crops
Orchards*
1986
1996
Significance Level
* 90% ** 95% *** 98% **** 99%

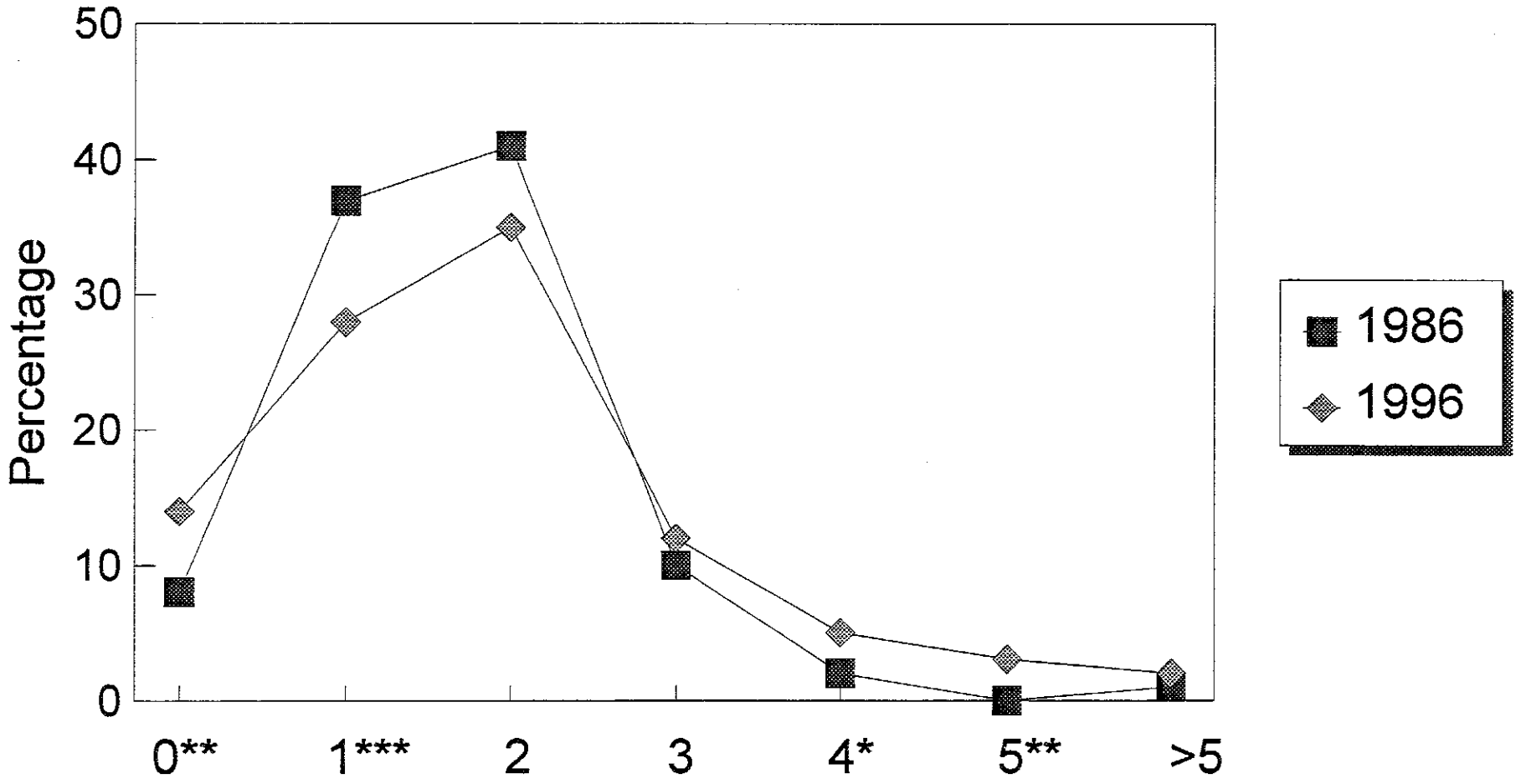

Soil Test for Nitrogen?
Percent Yes
80
60
40
20
0
Nut Crops*
Citrus Fruits*
Non-citrus Fruits
Grapes****
Vegetables****
Field Crops
Orchards****
1986
1996
Significance Level
* 90% ** 95% *** 98% **** 99%


Plant Tissue Analysis for Nitrogen?
80
60
40
20
0
Y-Axis
Nut Crops*
Citrus Fruits
Non-citrus Fruits
Grapes****
Vegetables****
Field Crops*
Orchards****
Data A
Data B
Significance Level
* 90% ** 95% *** 98% ****99%


Organic Amendments Applied?
Percent Yes
50
40
30
20
10
0
Nut Crops
Citrus Fruits
Non-citrus Fruits***
Grapes****
Vegetables
Field Crops*
Orchards**
1986
1996
Significance Level
* 90% ** 95% *** 98% **** 99%


Use Foliar N Application(s)?
Percent Yes
80
60
40
20
0
Nuts*
Citrus
Noncitrus****
Grapes***
Vegetables*
Field Crops
Orchards****
1986
1996
Significance Level
* 90% ** 95% *** 98% **** 99%

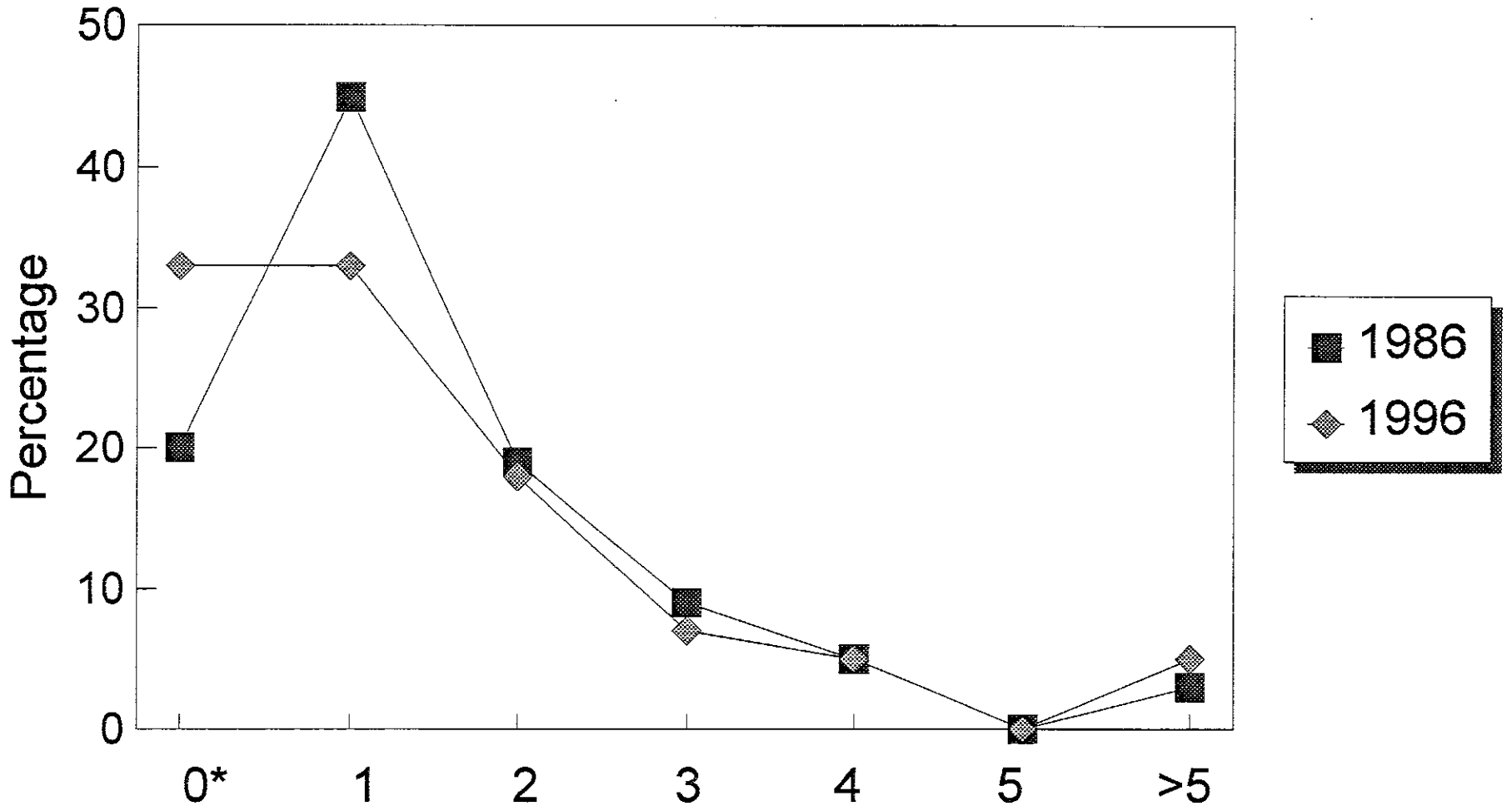
Surface Applications of N - Nut Crops



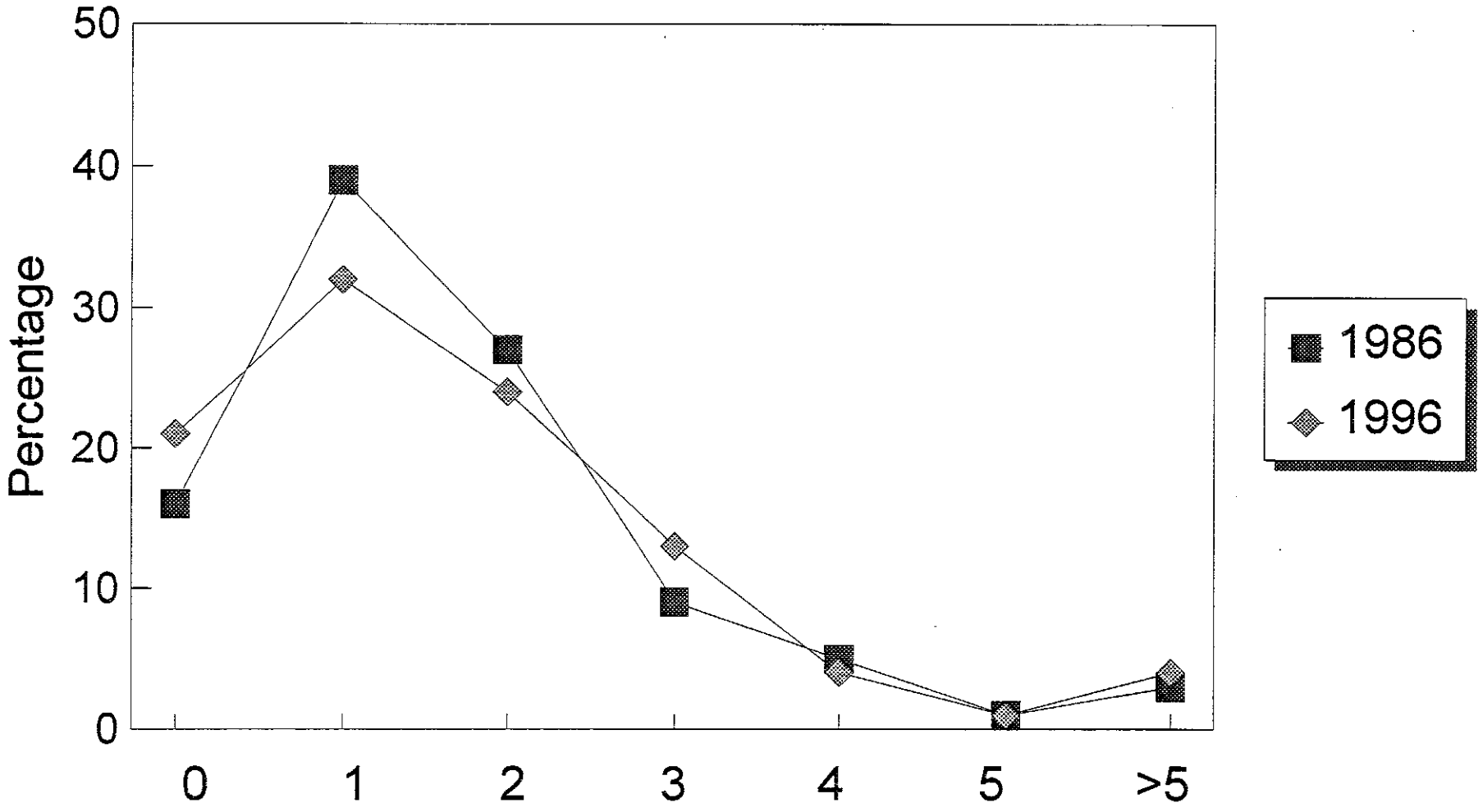
Significance Level

* 90% ** 95% *** 98% **** 99%

Surface Application of N - Citrus Fruit



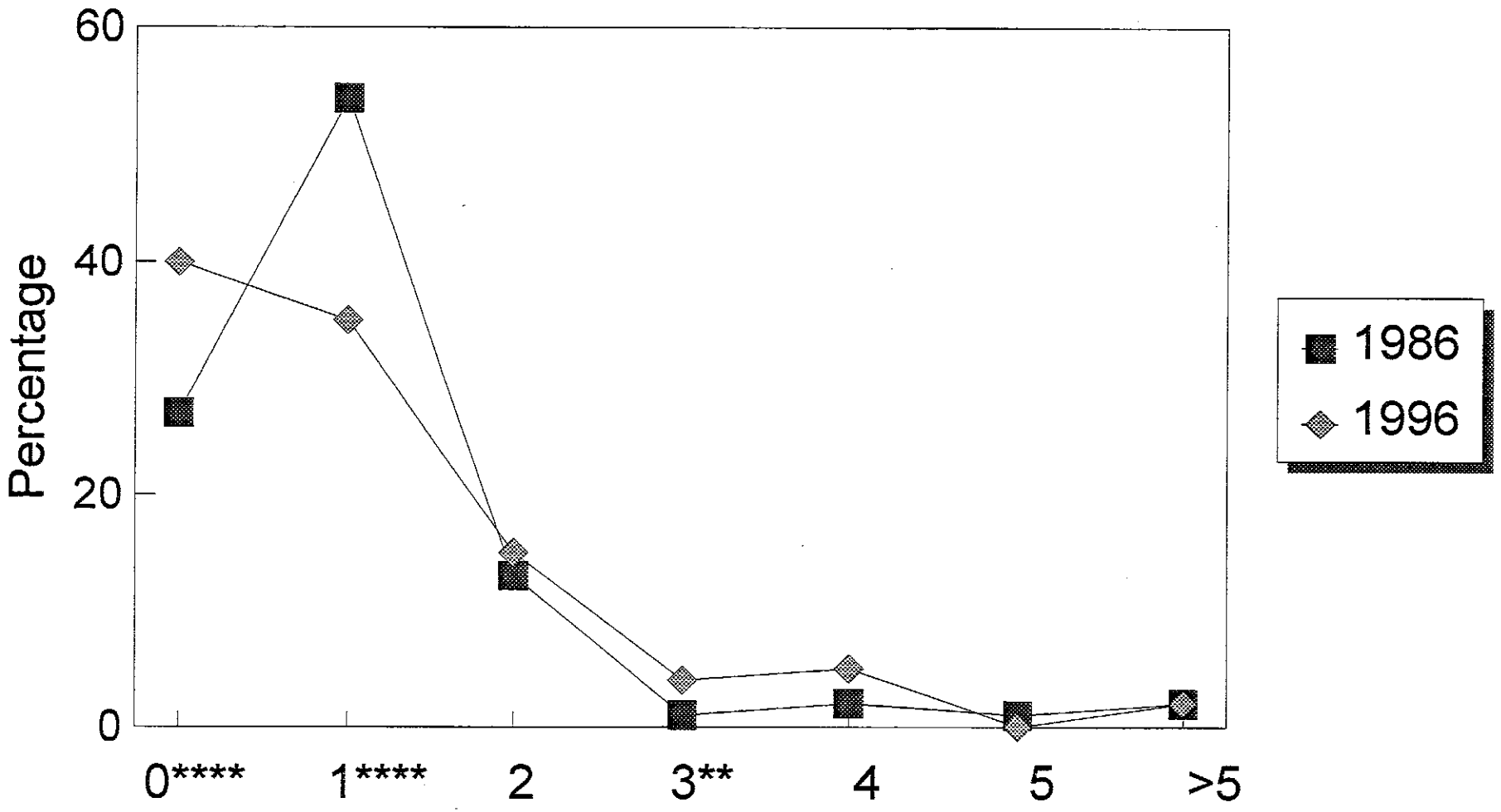
Surface Application of N- Noncitrus Fruit



Significance Level

* 90% ** 95% *** 98% **** 99%

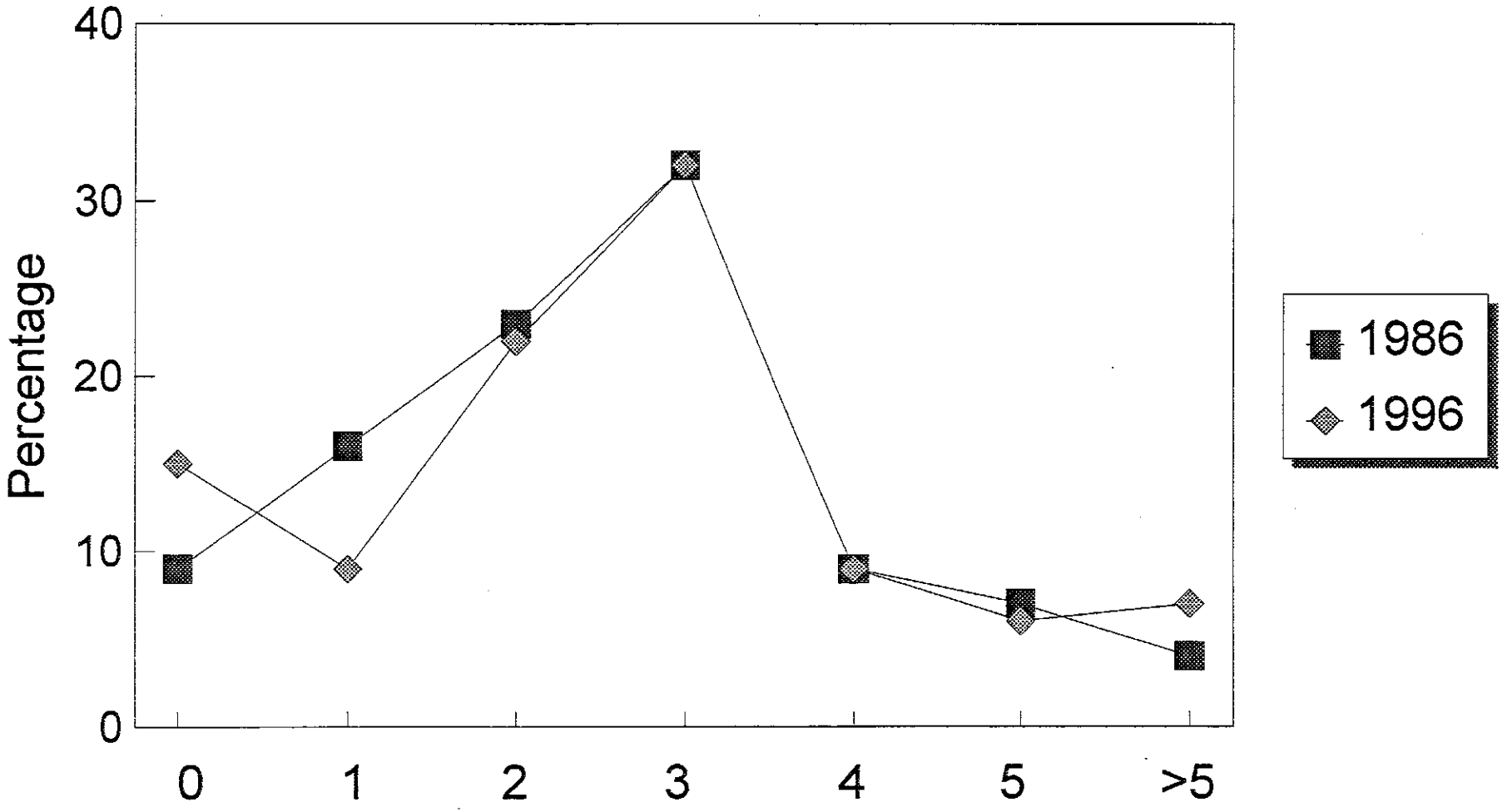
Surface Application of N - Grapes



Significance Level

* 90% ** 95% *** 98% **** 99%

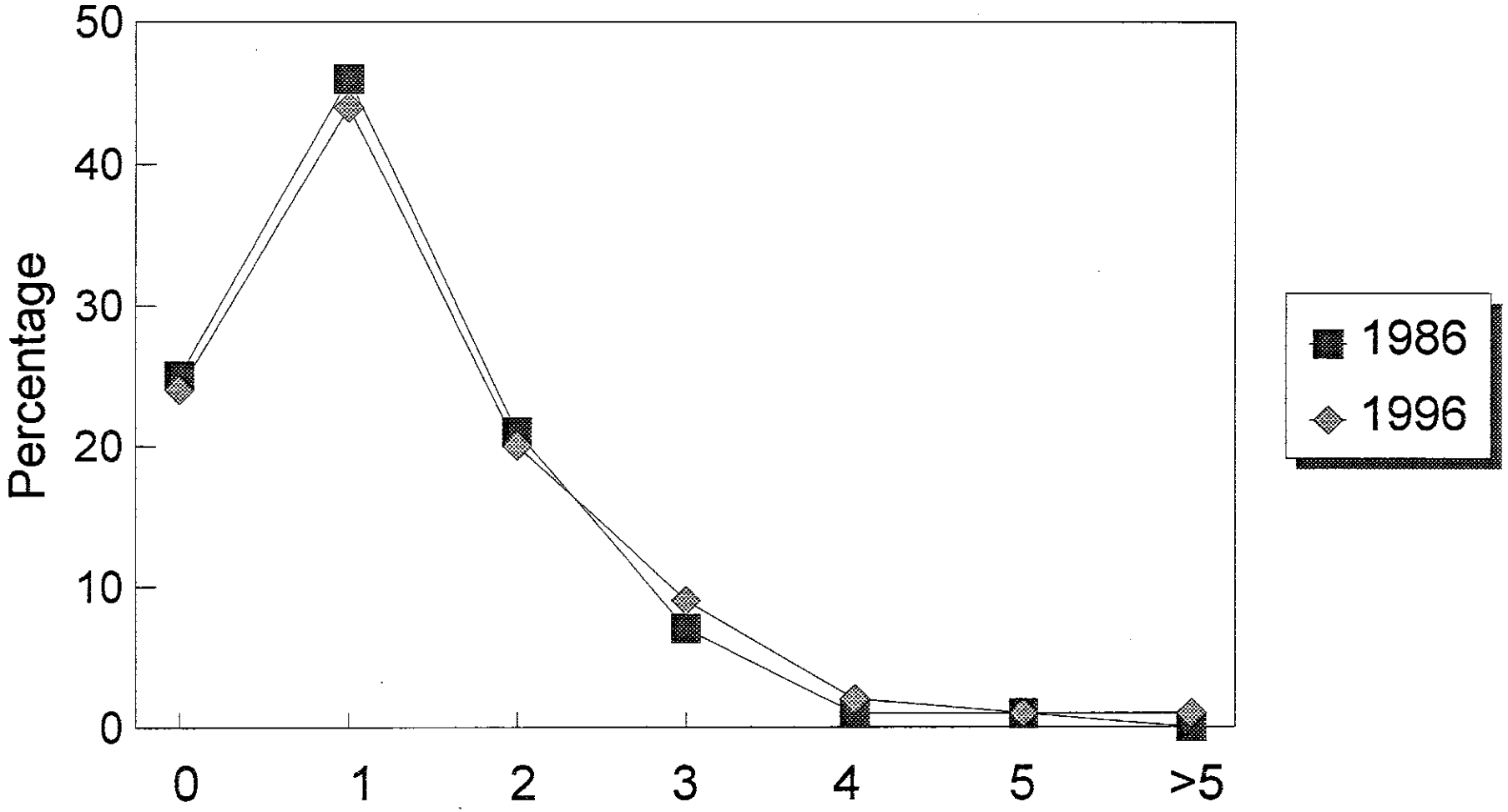
Surface Application of N - Vegetables



Significance Level

* 90% ** 95% *** 98% **** 99%

Surface Application of N - Field Crops



Surface Application of N - Orchards