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Final Report

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Development of Irrigation and Nitrogen Fertilization Programs on Tall Fescue to Facilitate Irrigation-Water Savings and Fertilizer-Use Efficiency

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TABLE OF CONTENTS

List of Tables

List of Tables *(continued)*

List of Tables *(continued)*

List of Tables *(continued)*

List of Figures

FINAL REPORT
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Development of Irrigation and Nitrogen Fertilization Programs on Tall Fescue to Facilitate Irrigation-Water Savings and Fertilizer-Use Efficiency

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Statement of Objective

This project involves the study and development of best management practices (BMPs) for landscape water conservation and nitrogen- (N-) fertility efficiency on tall fescue, currently the most widely-planted turfgrass species in California. We believe this subject is worthy of investigation because water use is the most important environmental issue in California and it is consistent with CDFA/FREP goals of improving crop-water management and fertilizer-use efficiency. The objectives of this 3-year project are listed below.

1. Test irrigating tall fescue at a defined annual amount (80% historical ET_o plus rain) with increased irrigation during the warm season to improve turfgrass performance, and then proportionally adjusting the cool-season irrigation amount downward to make up for the addition of warm-season irrigation. These treatments will be compared to irrigating tall fescue at a constant rate of 1) 80% historical ET_o plus rain and 2) 80% ET_o plus rain (80% real-time ET_o plus rain).

2. In conjunction with irrigation treatments, test the influence of the annual N-fertility rate on the performance of tall fescue.

3. Quantify the effects of irrigation and N-fertility treatments on tall fescue visual appearance and drought stress tolerance, growth (clipping yield), and N uptake, along with treatment effects on soil-water content and soil N status.

4. Develop BMPs for tall fescue relating to turfgrass water conservation and N fertilizer use efficiency, which provide optimal performance in terms of visual quality and drought stress tolerance, growth (clipping yields), and N uptake.

5. Conduct outreach activities, including trade journal publications and oral presentations, emphasizing the importance of turfgrass BMPs, and how to properly carry out these practices for turfgrass irrigation and N fertilization.

Executive Summary

This project involved the study and development of best management practices (BMPs) for landscape water conservation and nitrogen- (N-) fertility efficiency on tall fescue, currently the most widely-planted turfgrass species in California. We believe this subject was worthy of investigation because water use is the most important environmental issue in California and it was consistent with CDFA/FREP goals of improving crop-water management and fertilizer-use efficiency. The objectives of this 3-year project were to: 1) test irrigating tall fescue at a defined annual amount (80% historical ET_o plus rain) with increased irrigation during the warm season to improve turfgrass performance, and then proportionally adjusting the cool-season irrigation amount downward to make up for the addition of warm-season irrigation (water banking treatments) as compared to irrigating tall fescue at a constant rate of 80% historical ET_o plus rain and 80% ET_o plus rain (80% real-time ET_o plus rain); 2) in conjunction with irrigation treatments, test the influence of the annual N-fertility rate on the performance of tall fescue; 3) quantify the effects of irrigation and N-fertility treatments on tall fescue visual appearance and drought stress tolerance, growth (clipping yield) and N uptake, along with treatment effects on soil-water content and soil N status; 4) develop BMPs for tall fescue relating to turfgrass water conservation and N-fertilizer use efficiency, which provide optimal performance in terms of visual quality and drought stress tolerance, growth (clipping yields), and N uptake; 5) conduct outreach activities, including trade journal publications and oral presentations, emphasizing the importance of turfgrass BMPs, and how to properly carry out these practices for turfgrass irrigation and N fertilization.

Field Study Protocol and Weather Information

Treatment, measurement, and research plot management protocols proceeded well during the 3-year study. It should be noted that the 80% historical ET_o plus rain and the 80% ET_o plus rain irrigation treatments were basically equivalent to 100% historical ET_o plus rain and 100% ET_o plus rain, respectively, for typical landscape irrigation systems. As might be expected, the irrigation system distribution uniformity (DU) for the research plot (average DU for the 12 irrigation main plots = 83%) was basically 20% higher than for typical landscapes. Thus, the amount of irrigation applied according to our irrigation-level treatments was representative of current landscape irrigation water budgets which allocate 80% to 100% ET_o per unit surface area of landscape. However, unlike our turfgrass experimental plots, most landscape surface area is not covered with 100% turfgrass. Many landscapes are covered with a combination of trees, shrubs, groundcovers, turfgrasses, and non-plant materials.

In 1998, annual ET_o was 5% below historical ET_o, with an abundance of rainfall during the January to March quarter and a lack of rainfall during the October to December quarter. Both 1999 and 2000 were close to normal for ET_o, although annual rainfall totals were considerably lower than historical totals. As might be expected, such fluctuations in rainfall affected our data and interpretations concerning irrigation-level and N-fertility treatments.

Field Study Results

From 3 Apr. 1998 to 15 Dec. 2000, there were 66 rating dates for visual turfgrass quality and color. The N treatments affected these ratings more than the irrigation treatments. The irrigation x N treatment interaction basically was not significant. The majority of the ratings were between 5.0 and 5.5, which would be considered relatively low on a 1 to 9 scale. These ratings were relatively low due to a lack of irrigation versus a lack of N fertilizer. This is surprising because our irrigation treatments were equivalent to 100% historical ET_o plus rain and 100% ET_o plus rain (typical irrigation budgets are between 80% and 100% ET_o). These data show that when developing BMPs for tall fescue, the first priority is allocating sufficient irrigation (not too little nor too much). To achieve this may involve matching the area of tall fescue maintained to the area the water budget can support.

Greater amounts of slow-release N fertilizer improved visual turfgrass quality and color. These data suggest that under water-limiting conditions, additional amounts of slow-release N may help maintain growth activity which results in higher visual turfgrass quality and color.

Clipping yield and N uptake measurements are a direct measurement of growth activity which can be affected by irrigation and N treatments, temperatures, and other factors. Cooler temperatures during November and December dramatically reduced growth activity during all 3 years of the study. The influence of N treatments was significant and straightforward during all 3 years of the study: more N fertilizer resulted in more growth activity. The influence of irrigation treatments on clipping yield and N uptake (growth activity) was significant and caused by drought conditions of selected irrigation treatments and growth periods. The irrigation x N interaction basically was not significant.

Leaves rolling and wilting and turning brown, which were due to drought stress, were rather common during the study, especially from June through January. These data show that drought stress was an important factor during this study. However, there were very few significant differences among irrigation or N treatments. There basically were no significant irrigation x N treatment interactions.

Irrigation and N treatments generally did not affect soil concentration of TKN, NH_4-N, and NO_3-N when soil was sampled in October of each year of the study. It is possible that soil N concentrations would have been significantly different among N treatments during different periods of the year.

Another fairly consistent trend during the 3-year study for soil water levels was that the water banking irrigation treatments had a higher volumetric soil water content (wetter) and lower soil water tension (wetter) than the 80% historical ET_o and 80% ET_o irrigation treatments during the July to September quarter. These data would be expected since more irrigation water was applied for the former irrigation treatments.

Conclusions of the Field Research

These data show that when tall fescue is maintained in Riverside, Calif. (inland area between marine and desert climates), under an irrigation water budget that is similar to 100% historical ET_o plus rain or 100% ET_o plus rain, per unit landscape area, drought stress occurs which results in relatively low visual turfgrass quality and color. Also, growth activity (clipping yield and N uptake) are reduced. Basically, this condition was due to a lack of water versus the lack of N fertilizer and illustrates the need for the maintenance of shoot growth and plant vigor by providing a good plan for an irrigation water budget and a good N-fertility program. A good plan for an irrigation water budget for tall fescue includes not planting 100% of the landscape area in tall fescue, maintaining the best possible irrigation system, and irrigation water banking. A good N-fertility program for tall fescue includes enough N to promote growth to endure and recover from drought stress and the use of fertilizers with a higher percentage of slow-release nutrients.

Best Management Practices for Tall Fescue Irrigation and Nitrogen Fertilization

1. Provide adequate irrigation for the maintenance of growth activity (shoot growth and N uptake) and visual appearance. This is the first priority in the maintenance of tall fescue.
   - 1.1 Match the area of tall fescue maintained to the area the water budget can support for all 12 months of the year.
   - 1.2 As often as possible, adjust irrigation amount to actual tall fescue water needs.
   - 1.3 Maintain the most efficient irrigation system as possible.
   - 1.4 Practice water banking.
   - 1.5 Promote good growth activity, especially N uptake, for a good defense against NO_3-N leaching below the rootzone and contributing to groundwater contamination.
   - 1.6 Comments 1.1 to 1.4 are important practices leading to water conservation.
2. Provide adequate N for the maintenance of growth activity (shoot growth and N uptake) and visual appearance.
   - 2.1 Nitrogen has a dramatic affect on growth activity (shoot growth and N uptake) and visual appearance, especially when adequate water is provided.
   - 2.2 Growth activity is helpful during times of plant stress and recovery. However, this growth activity should not be minimal nor excessive.
   - 2.3 Use larger amounts of slow-release N fertilizers to improve visual appearance and growth activity of tall fescue subjected to drought stress.
   - 2.4 In California, it is optimal to fertilize in the fall, followed by the spring, and then in the summer. Fertilization during the winter is not recommended. These comments are based on the air and soil temperatures required to support growth activity. As the season becomes less desirable for N fertilization, use smaller amounts of N and/or use N fertilizers with a higher percentage of slow-release N.

Outreach Activities

In terms of our outreach activities, we identified professional turfgrass managers, personnel involved in the fertilizer industries, educators, and consultants as the primary audience for the outreach activities, and home-lawn owners as the secondary audience. These are the people who would either be directly implementing BMPs or would be recommending appropriate BMPs to others. In order to reach both our primary and secondary audiences, we submitted articles to trade journals that summarized the background and objectives of the research project, including special emphasis on irrigation and fertility-related BMPs for managing tall fescue and we identified appropriate venues in which to present oral presentations. We had two articles published and presented eight talks at six venues over the course of the research project.

In order to both obtain audience feedback regarding the oral presentation, and also in order to assess what the audience considered to be generally accepted BMPs for turfgrass management, we submitted a survey and evaluation form immediately following the presentations in 1998 and 1999. The respondents included our primary target audience of decision-makers, with the vast majority (88%) indicating they were always or usually responsible for making turfgrass management decisions or recommendations at their sites. The survey results showed that turfgrass managers (as opposed to advisors), in particular sports turfgrass managers, were the most committed to implementing the BMPs listed in the survey. Overall, the respondents considered BMPs to be both important and not highly difficult to implement. The limitations to the adoption of BMPs were indicated to be a lack of financial backing, employee training, and necessary time – all of which could be remedied with a sufficient commitment of resources by the turfgrass industry.

Work Description: YEAR 1 (Jan. to Dec. 1998)

Task 1: Implement treatments according to protocol described in Fig. 1 and Table 1.

Irrigation treatments were designed to test irrigating tall fescue at a defined annual amount (80% historical ET_o plus rain), with increased irrigation during the warm season to improve grass performance, and then proportionally adjusting the cool-season irrigation amount downward to make up for the additional warm-season irrigation. These treatments were compared to irrigating tall fescue at a constant rate of 1) 80% historical ET_o plus rain and 2) 80% ET_o plus rain (80% real-time ET_o plus rain). With the exception of the 80% ET_o plus rain irrigation treatment (treatment D), each irrigation treatment was defined by an irrigation allotment for four, 3-month quarters. The N-fertility treatments were designed to test the influence of the annual N-fertility rate on the performance of tall fescue when irrigated at a defined annual amount. To facilitate this objective it was necessary to hold N-fertilizer sources and dates of application constant across fertility treatments. The treatment design and data collection resulted in a greater understanding of the influence of irrigation-conservation and N-fertility practices on the performance of tall fescue, especially during the warm season.

Please note that the 80% ET_o plus rain irrigation treatment was added to the protocol and implemented 1 Apr. 1998, following approval (Table 6). The assignment of irrigation treatments to the 12, 6.1- x 6.1-m (20.0- x 20.0-ft) main plots consisted of a new randomization to accommodate three replications of four irrigation treatments. From 1 Jan. to 31 Mar. 1998, there were four replications of three irrigation treatments (A, B, and C as shown in Table 1). Fortunately, during this quarter there was 366 mm (14.4 inches) rain (Table 7), which resulted in uniform soil water content over the three irrigation treatments.

Task 2: Implement data collection according to protocol described in Table 4.

The purpose of this task was to quantify adequately, via sound methodology, the treatment effects on the visual appearance and drought stress tolerance, growth (clipping yield), and N uptake of tall fescue, along with treatment effects on soil-water content and soil-N status. Since weather conditions also influence plant and soil measurements, detailed weather data was collected, and aided in data interpretation. Proper plant and soil measurements were collected in order to adequately test the significance of treatment effects. Please note that due to the change in the irrigation treatment protocol, all data collected prior to 1 Apr. 1998 are not included in this report.

Task 3: Implement research plot management according to protocol described in Table 5.

The primary purpose of this task was to ensure representative tall fescue that is to be maintained under consistent conditions for the duration of the 3-year study. This practice helped to discern treatment effects. A second purpose of this task was to ensure consistent irrigation treatments by frequent irrigation-system monitoring.

Task 4: Implement outreach activities.

The purpose of this task was to present three oral presentations concerning the background and objectives of the research project, and to create and utilize an audience evaluation form to both provide feedback on the presentations and allow for an assessment of the current turfgrass management practices of the target audience in relation to generally accepted BMPs. The presentations were given at general grower meetings, at the UCR Turfgrass Research Conference and Field Day, and at specially planned meetings and/or tours. The task products were three oral presentations, three corresponding audience evaluations of the presentations, and an overall assessment of the current turfgrass management practices of the target audience.

Subtask 4.1: Identified the target audience, planned and prepared a presentation, identified potential meetings and dates where the presentations were to be delivered, and planned and prepared an audience evaluation form to both evaluate each presentation and assess the current turfgrass management practices used by the target audience. The meetings where the presentations and evaluation forms were scheduled to be given included the 1998 UCR Turfgrass Research Conference and Field Day (15 Sept. 1998), SCTC Turfgrass and Landscape Expo Workshops (7 Oct. 1998) and the SCTC Turfgrass and Landscape Institute (9 Dec. 1998).

Subtask 4.2: Presented three oral presentations with corresponding audience evaluation forms. Summarized evaluation forms for both presentation feedback and an assessment of current turfgrass management practices in relation to generally accepted BMPs. Presentations were modified to reflect salient audience feedback from evaluations.

Task 5: Prepared an Interim Report and Annual Report detailing the progress of Tasks 1 to 4. These reports provided the tools for evaluating the activity for the first 12 months of the project.

Work Description: YEAR 2 (Jan. to Dec. 1999)

Task 1: Implement treatments according to protocol described in Fig. 1 and Table 2.

Irrigation treatments were designed to test irrigating tall fescue at a defined annual amount (80% historical ET_o plus rain), with increased irrigation during the warm season to improve turfgrass performance, and then proportionally adjusting the cool-season irrigation amount downward to make up for the additional warm-season irrigation. These treatments were compared to irrigating tall fescue at a constant rate of 1) 80% historical ET_o plus rain and 2) 80% ET_o plus rain (80% real-time ET_o plus rain). With the exception of the 80% ET_o plus rain irrigation treatment, each irrigation treatment was defined by an irrigation allotment for four, 3-month quarters. The N-fertility treatments were designed to test the influence of the annual N-fertility rate on the performance of tall fescue when irrigated at a defined annual amount. To facilitate this objective it was necessary to hold N-fertilizer sources and dates of application constant across fertility treatments.

Task 2: Implement data collection according to protocol described in Table 4.

We quantified, via sound methodology, the treatment effects on the visual appearance and drought stress tolerance, growth (clipping yield), and N uptake of tall fescue, along with treatment effects on soil-water content and soil-N status. Since weather conditions also influence plant and soil measurements, detailed weather data were collected.

Task 3: Implement research plot management according to protocol as described in Table 5.

We ensured representative tall fescue by maintaining the research plot under conditions consistent with the previous year of the study. This practice helps to discern treatment effects by reducing external error. Also, irrigation treatment consistency was ensured by frequent irrigation-system monitoring.

Task 4: Implement outreach activities.

We identified two industry meetings and one publication for two oral presentations and one popular article concerning the background, objectives, methodology, and preliminary findings of the research project and general information concerning turfgrass BMPs. The presentations were to include the distribution of audience evaluation forms to provide both feedback on the presentations, and allow for an assessment of the current turfgrass management practices of the target audience in relation to generally accepted BMPs. Information from the first years' assessment of the target audience's turfgrass management practices was presented, with suggestions on how such practices should be modified in order to meet the requirements of the generally accepted BMPs for turfgrass irrigation and N fertilization. The task products were scheduled to include two oral presentations, two corresponding audience evaluations of the presentations, an overall assessment of the current turfgrass management practices of the target audience, and one popular article.

Subtask 4.1: Planned and prepared a presentation, identified potential meetings and dates where the presentations were to be delivered, planned and prepared an audience evaluation form to both evaluate each presentation and assess the current turfgrass management practices used by the target audience. Evaluation forms were modified to reflect salient audience feedback from the 1998 evaluations. The meetings where the presentations and evaluation forms were scheduled to be given included the 1999 UCR Turfgrass Research Conference and Field Day (14 Sept. 1999) and the 41st Annual SCTC Turfgrass and Landscape Institute (15 Dec. 1999).

Subtask 4.2: Presented one oral presentation with corresponding audience evaluation forms. Due to circumstances beyond our control, the presentation and evaluation at the SCTC Institute was unexpectedly canceled. The short notice and the late date of the event did not enable us to reschedule the presentation for later in 1999. Also, summarized the evaluation forms for both presentation feedback and an assessment of the respondent's current turfgrass management practices in relation to generally accepted BMPs.

Subtask 4.3: Prepared and published one popular article in a trade journal [Turf Tales Mag. 6(2):6–7].

Task 5: Prepared an Interim Report and Annual Report detailing the progress of Tasks 1 to 4. These reports provided the tools for evaluating the second-year activity of this project.

Work Description: YEAR 3 (Jan. to Dec. 2000)

Task 1: Implement treatments according to protocol described in Fig. 1 and Table 2.

Irrigation treatments were designed to test irrigating tall fescue at a defined annual amount (80% historical ET_o plus rain), with increased irrigation during the warm season to improve turfgrass performance, and then proportionally adjusting the cool-season irrigation amount downward to make up for the additional warm-season irrigation. These treatments were compared to irrigating tall fescue at a constant rate of 1) 80% historical ET_o plus rain and 2) 80% ET_o plus rain (80% real-time ET_o plus rain). With the exception of the 80% ET_o plus rain irrigation treatment, each irrigation treatment was defined by an irrigation allotment for four, 3-month quarters. The N-fertility treatments were designed to test the influence of the annual N-fertility rate on the performance of tall fescue when irrigated at a defined annual amount. To facilitate this objective it was necessary to hold N-fertilizer sources and dates of application constant across fertility treatments.

Task 2: Implement data collection according to protocol described in Table 4.

We quantified, via sound methodology, the treatment effects on the visual appearance and drought stress tolerance, growth (clipping yield), and N uptake of tall fescue, along with treatment effects on soil-water content and soil-N status. Since weather conditions also influence plant and soil measurements, detailed weather data were collected.

Task 3: Implement research plot management according to protocol as described in Table 5.

We ensured representative tall fescue by maintaining the research plot under conditions consistent with the previous year of the study. This practice helps to discern treatment effects by reducing external error. Also, irrigation treatment consistency was ensured by frequent irrigation-system monitoring.

Task 4: Implement outreach activities.

We identified two industry meetings and one publication for two oral presentations and one popular article concerning the background, objectives, methodology, and preliminary findings of the research project, general information concerning turfgrass BMPs, and the target audience's turfgrass management practices as determined by the surveys conducted in 1998 and 1999. The task products included two oral presentations and one popular article.

Subtask 4.1: Planned and prepared a presentation, identified potential meetings and dates where the presentations were to be delivered, including the 2000 UCR Turfgrass Research Conference and Field Day (14 Sept. 2000) and the CDFA-FREP Conference (14 Nov. 2000).

Subtask 4.2: Presented two oral presentations at the meetings and dates noted in Subtask 4.1.

Subtask 4.3: Prepared and published one popular article in a trade journal [Turf Tales Mag. 8(3&4):8–11].

Task 5: Prepared an Interim Report detailing the progress of Tasks 1 to 4 in 2000 and a Final Report evaluating the entire 3-year project.

Results, Discussion, and Conclusions for Field Research

Field Study Protocol and Weather Information

Treatment, measurement, and research plot management protocols proceeded well throughout the 3-year study (Fig. 1; Tables 1, 2, 4, and 5). A calendar of major activities associated with the study is shown in Table 6.

It should be noted that the 80% ET_o plus rain irrigation treatment was added to the protocol and implemented on 1 Apr. 1998, following approval. When the treatment was implemented, the assignment of irrigation treatments to the 12, 6.1 x 6.1-m (20.0- x 20.0-ft) main plots consisted of a new randomization to accommodate three replications of four irrigation treatments. From 1 Jan. to 31 Mar. 1998 there were four replications of three irrigation treatments (A, B, and C as shown in Table 1). Fortunately, during this quarter there was 366 mm rainfall (Table 7) which resulted in uniform soil water content over the irrigation treatments. However, all plant and soil data collected prior to 1 Apr. 1998 were not included in this report.

The 80% historical ET_o plus rain and the 80% ET_o plus rain irrigation treatments are basically equivalent to 100% historical ET_o plus rain and 100% ET_o plus rain, respectively, for typical landscape irrigation systems. As might be expected, the irrigation system distribution uniformity (DU) for the research plot (average DU for the 12 irrigation main plots = 83%) is basically 20% higher than for typical landscapes. Thus, the amount of irrigation applied according to our irrigation-level treatments is representative of current landscape irrigation water budgets which allocate 80% to 100% ET_o per unit surface area of landscape. However, unlike our turfgrass experimental plots, most landscape surface area is not covered with 100% turfgrass. Many landscapes are covered with a combination of trees, shrubs, groundcovers, turfgrasses, and non-plant materials.

Tables 7, 8, and 9 provide a summary of ET_o, historical ET_o, rainfall, and applied irrigation water in 1998, 1999, and 2000, respectively. In 1998, annual ET_o was 5% below historical ET_o, with an abundance of rainfall during the January to March quarter and a lack of rainfall during the October to December quarter. Both 1999 and 2000 were close to normal for annual ET_o, although annual rainfall totals were significantly lower than historical totals (45% and 51% below normal, respectively). In fact, only the April to June 1999 quarter had higher than historical rainfall for this 2-year period. The October to December quarter was consistently low in all 3 years; rainfall totals were only 29%, 46%, and 17% of historical rainfall in 1998, 1999, and 2000, respectively. The abundance of rainfall in the first quarter of 1998 and the lack of it in the last quarter of 1998 was reflected in the modifications to the water-banking irrigation treatments (B and C) which were put into effect beginning January 1999 (Tables 1 and 2). Basically, more irrigation was applied during the October to December quarter while less irrigation was applied during the January to March quarter.

When no irrigation events were cancelled due to rainfall, the actual amount of irrigation water applied was close to the amount specified by the irrigation-level treatment protocol in all 3 years (see underlined numbers in Tables 7, 8 and 9). Other weather information, including soil and air temperatures, can be seen in Fig. A-1 and Table A-2 (see Appendix A).

Irrigation and Nitrogen Treatment Effects

Visual turfgrass quality and color

From 3 Apr. 1998 to 15 Dec. 2000, there were 66 rating dates for visual turfgrass quality and color. The number of dates that irrigation treatments significantly affected visual turfgrass quality and color was 14 and 12, respectively (Tables 18 to 23). The number of dates that N treatments significantly affected visual turfgrass quality and color was 33 and 47, respectively. The irrigation x N treatment interaction basically was not significant. In terms of the annual overall analysis, the overall N treatments effect was significant in 1998, 1999, and 2000 for both visual turfgrass quality and color (Tables 18 to 23). No overall irrigation treatment effect was significant. These data show that N treatments affected these ratings more than irrigation treatments.

The majority of the ratings were between 5.0 and 5.5 on a 1 to 9 scale (for visual turfgrass quality: 1=worst, 5=minimally acceptable, and 9=best tall fescue; for visual turfgrass color: 1=brown, 5=minimally acceptable, and 9=darkest green tall fescue) (Tables 10 to 17). These ratings were generally higher in 1998 than in 1999 and 2000, which may be due to the relatively high rainfall in 1998 as compared to 1999 or 2000. Considering the 66 rating dates, visual quality ratings (Table 13) and visual color ratings (Table 17) would be considered relatively low, which was primarily due to the lack of irrigation and rainfall versus the lack of N fertilization. Irrigation level was limiting and this is surprising because, as previously noted, the 80% historical ET_o plus rain and the 80% ET_o plus rain irrigation treatments were basically equivalent to 100% to 100% historical ET_o plus rain and 100% ET_o plus rain, respectively, for typical landscapes. This level is representative of current landscape irrigation budgets which allocated 80% to 100% ET_o per unit surface area of landscape.

As stated earlier, N treatments significantly affected visual turfgrass quality and color ratings more than irrigation treatments and this was partially because all irrigation treatments lacked enough irrigation and rainfall which resulted in relatively low visual ratings and relatively small differences among irrigation treatments. These data show that when developing BMPs for tall fescue, the first priority is allocating sufficient irrigation (not too little nor too much) and the second priority is allocating sufficient N fertilization.

In terms of the percentage of 66 rating dates with average visual ratings $\geq$5.5, higher annual N rates increased the percentage for visual quality (Table 13) and visual color (Table 17). These data suggest that under water-limiting conditions, the application of more N may help maintain turfgrass vigor, resulting in higher visual turfgrass quality and color. In this situation, a fertilizer with a relatively high percentage of a slow-release N source should be used.

Clipping yield and N uptake

Clipping yield and N uptake measurements are a direct measurement of growth activity which can be affected by irrigation and N treatments, temperature, and other factors. Cooler temperatures during the November/December 4-week growth period dramatically reduced growth activity and resulted in lower clipping yield (Tables 24 to 26) and N uptake (Tables 27 to 29) during all 3 years of the study. This is an example of how temperatures can reduce growth activity in spite of irrigation and N fertilizer levels. An understanding of the differences in seasonal temperatures and its impact on growth activity is important when developing BMPs for tall fescue.

The influence of N treatments on clipping yield and N uptake was straightforward during all 3 years of the study: more N fertilizer resulted in more growth activity (clipping yield and N uptake).

The influence of irrigation treatments on clipping yield and N uptake basically occurred during the last 2 years of the study. The irrigation x N interaction basically was not significant. Droughty conditions, due to selected irrigation treatments and selected 4-week growth periods, caused less growth activity (clipping yield and N uptake). Examples of this reduced clipping yield (Tables 25 and 26) and N uptake (Tables 28 and 29) were the water banking treatments during the first (March/April) 4-week growth period and the 80% ET_o treatment during the third (September/October) 4-week growth period. The reduced clipping yield and N uptake of the water banking treatments during the March/April growth period was probably due to plant water stress during the January to March quarter and the 40% historical ET_o irrigation level and lack of rainfall. It is interesting to note that visual turfgrass quality (Tables 11 and 12) and color (Tables 15 and 16) ratings of these irrigation treatments during these 4-week growth periods were not consistently lower than the other irrigation treatments. These data suggest that direct measurements of growth activity (clipping yield, N uptake, etc.) are more sensitive to plant drought conditions than visual turfgrass ratings of quality and color.

Percent leaves rolled and/or wilted and percent brown leaves

Leaves rolling and wilting, which were due to drought stress, were rather common during this study, especially during June through January (Tables 30 to 32). This shows that drought stress was an important factor during this study. There were significant differences among irrigation treatments on relatively few dates. The significantly higher percent leaves rolled and/or wilted of the 80 ET_o irrigation treatment during July to Sept. 1999 (Table 31) was consistent with the significantly lower visual turfgrass quality (Table 19) and color (Table 22), and significantly lower clipping yield (Table 25) and N uptake (Table 28) during the approximate same time period. There basically was no significant N treatment effect nor irrigation x N treatment interaction for percent leaves rolled and/or wilted.

Leaves turning brown, which was primarily due to drought stress, were rather common during the study, especially during June through January (Tables 33 to 35). Similar to leaves rolling and/or wilting, these data show that drought stress was an important factor during this study. However, there were very few significant differences among irrigation or N treatments. There basically was no significant irrigation x N treatment interaction.

Soil nitrogen and water levels

Irrigation and N treatments generally did not affect soil concentrations of TKN, NH_4-N, and NO_3-N when sampled in October of each year of the study (Table 36). These data show that differences in N fertilizer application rates did not result in differences in soil N when measured only once during the year. It is possible that soil N concentrations would have been significantly different among N treatments during different periods of the year.

Volumetric soil-water content and soil-water tension data were collected from the Jaguar III subplot (Fig. 1 and Table 4). These plots were fertilized with one N fertilizer rate versus the three N fertilizer rates (Tables 1 and 2) applied to the Shortstop subplots. Thus, N treatments did not confound soil water data.

Neutron probe volumetric soil water content data for 1998 to 2000 are shown in Tables 37 to 54. There were significant differences among the irrigation treatments on selected dates and soil depths. One fairly consistent trend during the 3 years of the study was that the water banking irrigation treatments had a higher volumetric soil water content (wetter) than the 80% historical ET_o and 80% ET_o irrigation treatments during the July to September quarter. This was most evident at the 23- to 61-cm

(9- to 24-inch) depths. These data would be expected since more irrigation water was applied for the former irrigation treatments (Tables 7 to 9). As stated earlier, the 80% ET_o irrigation treatment showed significant symptoms of drought stress during the July to September 1999 quarter which was most likely associated with lower volumetric soil water content (drier) conditions.

Soil water tension for 1998 to 2000 are shown in Tables 55 to 60. There were significant differences among the irrigation treatments on selected dates and depths. There was the same trend for soil water tension data as for volumetric soil water content data. That is, during the 3 years of the study, there was a trend for the water banking irrigation treatments to have lower soil water tension (wetter) than the 80% historical ET_o and 80% ET_o irrigation treatments during the July to September quarter.

Conclusions

These data show that when tall fescue is maintained in Riverside, Calif. (inland area between marine and desert climates), under an irrigation water budget that is similar to 100% historical ET_o plus rain or 100% ET_o plus rain, per unit surface area of landscape, drought stress occurs which results in relatively low visual turfgrass quality and color. Also, growth activity (clipping yield and N uptake) are reduced. Basically, this condition was due to a lack of water versus the lack of N fertilizer and illustrates the need for the maintenance of shoot growth and plant vigor by providing a good plan for an irrigation water budget and a good N-fertility program. A good plan for an irrigation water budget for tall fescue includes not planting 100% of the landscape area in tall fescue, maintaining the best possible irrigation system, and irrigation water banking. A good N-fertility program for tall fescue includes enough N to promote growth to endure and recover from drought stress and the use of fertilizers with a higher percentage of slow-release nutrients.

Best Management Practices for Tall Fescue Irrigation and Nitrogen Fertilization

1. Provide adequate irrigation for the maintenance of growth activity (shoot growth and N uptake) and visual appearance. This is the first priority in the maintenance of tall fescue.
   - 1.1 Match the area of tall fescue maintained to the area the water budget can support for all 12 months of the year.
   - 1.2 As often as possible, adjust irrigation amount to actual tall fescue water needs.
   - 1.3 Maintain the most efficient irrigation system as possible.
   - 1.4 Practice water banking.
   - 1.5 Promote good growth activity, especially N uptake, for a good defense against NO_3-N leaching below the rootzone and contributing to groundwater contamination.
   - 1.6 Comments 1.1 to 1.4 are important practices leading to water conservation.
2. Provide adequate N for the maintenance of growth activity (shoot growth and N uptake) and visual appearance.
   - 2.1 Nitrogen has a dramatic affect on growth activity (shoot growth and N uptake) and visual appearance, especially when adequate water is provided.
   - 2.2 Growth activity is helpful during times of plant stress and recovery. However, this growth activity should not be minimal nor excessive.
   - 2.3 Use larger amounts of slow-release N fertilizers to improve visual appearance and growth activity of tall fescue subjected to drought stress.
   - 2.4 In California, it is optimal to fertilize in the fall, followed by the spring, and then in the summer. Fertilization during the winter is not recommended. These comments are based on the air and soil temperatures required to support growth activity. As the season becomes less desirable for N fertilization, use smaller amounts of N and/or use N fertilizers with a higher percentage of slow-release N.

Project Evaluation

The BMP recommendations for tall fescue which resulted from this study include both irrigation and N-fertility components. A good plan for an irrigation water budget for tall fescue includes not planting 100% of the landscape area in tall fescue, maintaining the best possible irrigation system, and irrigation water banking. A good N-fertility program for tall fescue includes enough N to promote growth to endure and recover from drought stress and the use of fertilizers with a higher percentage of slow-release nutrients.

The limitations to adopting turfgrass BMPs, as indicated by the surveys we conducted as part of our outreach program, were a lack of financial backing, employee training, and necessary time, all of which would need to be rectified in order to properly implement the BMPs from this study. The greater use of slow-release N-fertilizers will require larger fertilizer budgets, although this could perhaps be partially off-set by the less-frequent applications required by these slow-release fertilizers, and the concomitant reduction in labor costs. The need for an intensive and effective irrigation maintenance schedule would require additional employee training, time, and increased budgets. However, this, too, may be partially off-set by lower costs associated with the use of less water, especially in the event that exceeding impending water budgets may incur costly penalties. The remaining elements of the BMPs are less impacted by these limitations. Instead, they require additional planning in fertilizer scheduling, irrigation scheduling, or in the planning of site renovation or construction of landscapes to adjust the area of tall fescue maintained to the area a water budget can support.

Outreach Activities

We identified professional turfgrass managers, personnel involved in the fertilizer industries, educators, and consultants as the primary audience for the outreach activities, and home-lawn owners as the secondary audience. These are the people who would either be directly implementing BMPs or would be recommending appropriate BMPs to others. In order to reach both our primary and secondary audiences, we submitted articles to trade journals that summarized the background and objectives of the research project, including special emphasis on irrigation and fertility-related BMPs for managing tall fescue and we identified appropriate venues in which to present oral presentations. We had two articles published (one in 1999 and one in 2001) and presented eight talks at six venues over the course of the research project, as per the workplan (please note that one scheduled talk in 1999 was cancelled due to circumstances beyond our control). Additional information about the articles and the talks can be found in Appendix B. Now that the Final Report has been prepared, it is likely that more articles will be published and more presentations given.

Trade Journal Articles

Green, R., G. Klein, J. Hartin, W. Richie, V. Gibeault. 1999. Best management practices for tall fescue irrigation and nutrition in southern California. Turf Tales Mag. 6(2):6–7.

Klein, G. and R. Green. 2001. A survey of professional turfgrass managers in southern California concerning their use of turfgrass best management practices. Turf Tales Mag. 8(3&4):8–11

Oral Presentations

1.1. Best management practices for tall fescue irrigation and nutrition in southern California. 1998 Univ. of Calif., Riverside, Turfgrass Res. Conf. and Field Day, Riverside, Calif., 15 Sept. 1998. 250 estimated participants, including professional turfgrass managers, personnel involved in the fertilizer industries, educators, and consultants.

1.2. Tall fescue irrigation and nutrition field study. 1998 Univ. of Calif., Riverside, Turfgrass Res. Conf. and Field Day, Riverside, Calif., 15 Sept. 1998. 250 estimated participants, including professional turfgrass managers, personnel involved in the fertilizer industries, educators, and consultants.

2. Selection and use of slow release nitrogen products. Calif. Fert. Assn. Seminar at the 1998 Southern Calif. Turfgrass Council Expo and Wkshp., Costa Mesa, Calif., 7 Oct. 1998. 20 estimated participants, including professional turfgrass managers, personnel involved in the fertilizer industries, educators, and consultants.

3. Irrigation and nutritional best management practices of tall fescue in southern California. Turfgrass Mgt. session at the 40th Annu. Turfgrass and Landscape Conf. Inst., Buena Park, Calif., 8 Dec. 1998. 50 estimated participants, including professional turfgrass managers, personnel involved in the fertilizer industries, educators, and consultants.

4. Results from a survey of professional turfgrass managers in southern California concerning their use of turfgrass best management practices. Univ. of Calif., Riverside, Turfgrass Res. Conf. and Field Day, Riverside, Calif., 12 Sept. 2000. 350 estimated participants, including professional turfgrass managers, personnel involved in the fertilizer industries, educators, and consultants.

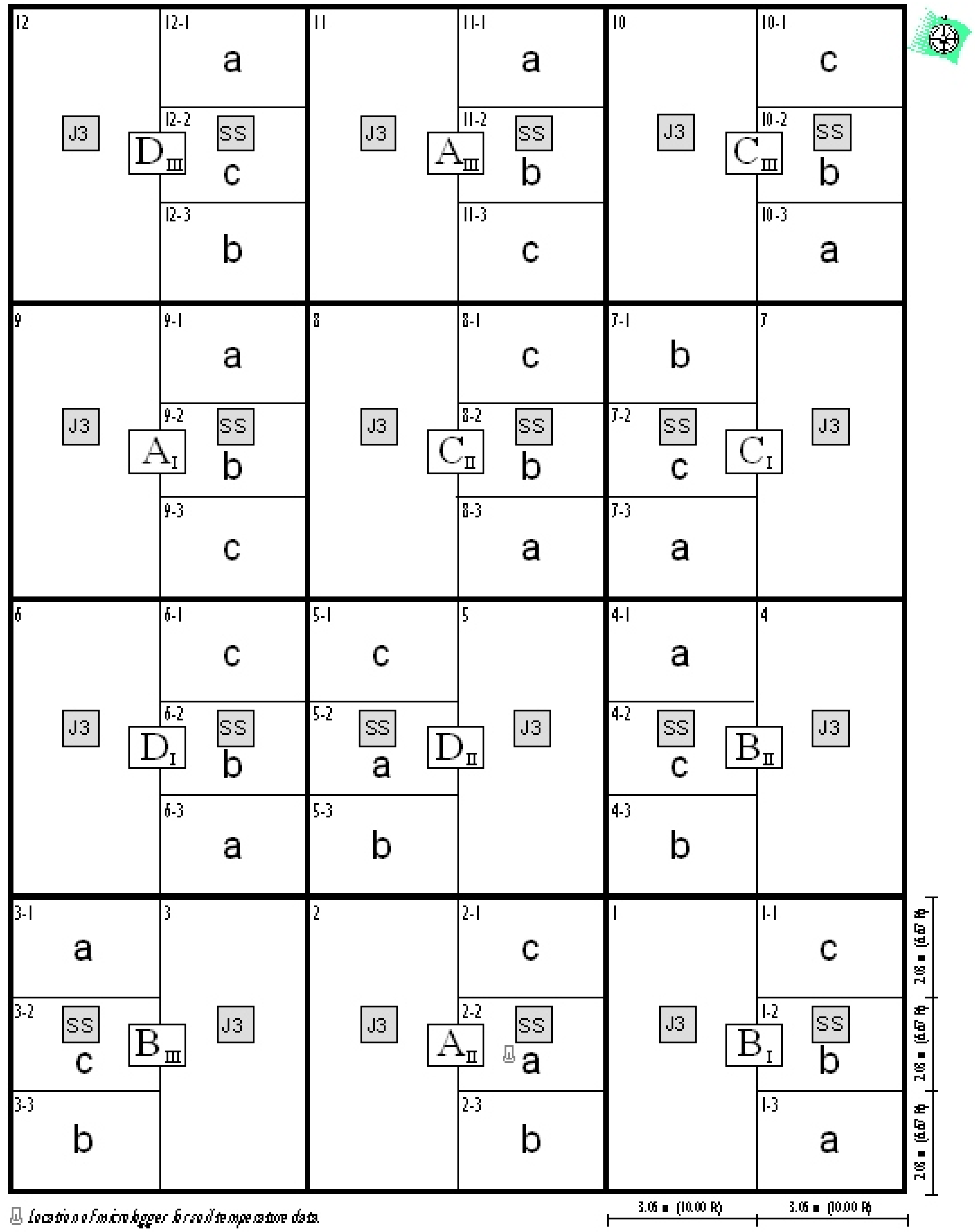
5.1. Best management practices for tall fescue irrigation and nitrogen fertility. 1999 Univ. of Calif., Riverside, Turfgrass Res. Conf. and Field Day, Riverside, Calif., 14 Sept. 1999. 350 estimated participants, including professional turfgrass managers, personnel involved in the fertilizer industries, educators, and consultants.

5.2. Tall fescue best management practices field study. 1999 Univ. of Calif., Riverside, Turfgrass Res. Conf. and Field Day, Riverside, Calif., 14 Sept. 1999. 350 estimated participants, including professional turfgrass managers, personnel involved in the fertilizer industries, educators, and consultants.

6. Development of irrigation and nitrogen fertilization programs for turfgrass. 8th Annu. Fert. and Educ. Program (FREP) Conf., Tulare, Calif., 14 Nov. 2000.

In order to both obtain audience feedback regarding the oral presentation, and also in order to assess what the audience considered to be generally accepted BMPs for turfgrass management, we submitted a survey and evaluation form immediately following the presentations in 1998 and 1999 (see Appendix B). The audience was given approximately 10 min to complete the form. In this manner, a total of 381 forms were returned to us (305 of which were used in the final analysis). The respondents included our primary target audience of decision-makers, with the vast majority (88%) indicating they were always or usually responsible for making turfgrass management decisions or recommendations at their sites. The survey results showed that turfgrass managers (as opposed to advisors), in particular sports turfgrass managers, were the most committed to implementing the BMPs listed in the survey. Overall, the respondents considered BMPs to be both important and not highly difficult to implement. The limitations to the adoption of BMPs were indicated to be a lack of financial backing, employee training, and necessary time – all of which could be remedied with a sufficient commitment of resources by the turfgrass industry. For a complete assessment of the survey data, please see Appendix C.

Figure 1. Plot plan for the tall fescue irrigation and N-fertility study.



Key:

Genotype: SS = Shortstop tall fescue, J3 = Jaguar III tall fescue

Irrigation treatments – main plots [6.10 x 6.10 m (20.00 x 20.00 ft)]:

A = 80%, 80%, 80%, 80% hist. ET_o
B = 58%, 90%, 90%, 58% hist. ET_o (1998) or 40%, 92%, 91%, 70% hist. ET_o (1999 and 2000)
C = 58%, 96%, 85%, 58% hist. ET_o (1998) or 40%, 85%, 97%, 70% hist. ET_o (1999 and 2000)
D = 80%, 80%, 80%, 80% ET_o
I, II, III = replications (blocked according to irrigation distribution uniformity of each plot)

Fertility treatments – subplots [2.03 x 3.05 m (6.67 x 10.00 ft)]:

a = 3.0 lb N/1000 ft^2 per year (1998) or 4.0 lb N/1000 ft^2 per year (1999 and 2000)
b = 4.5 lb N/1000 ft^2 per year (1998) or 6.0 lb N/1000 ft^2 per year (1999 and 2000)
c = 6.0 lb N/1000 ft^2 per year (1998) or 7.7 lb N/1000 ft^2 per year (1999 and 2000)

Table 1. Protocol for irrigation treatments based on a percentage of historical (hist.) ET_o (three treatments) and for ET_o (one treatment) for four, 3-month quarters and three N-fertility treatments based on the annual N-fertility rate for 1998.

Month (Quarter)	Monthly historical ET_o (inch)[z]	Monthly historical rainfall (inch)[y]	Quarterly historical ET_o (inch)[z]	Irrigation treatment[x] A	B	C	D	N-fertility treatment[w] Date of application	Source of N	Rate (lb N/1000 ft^2) a	b	c
Jan. (1)	2.07	1.85										
Feb. (1)	2.87	2.05	8.97	80% hist. ET_o (7.18 inch)	58% hist. ET_o (5.20 inch)	58% hist. ET_o (5.20 inch)	80% ET_o	1 Mar.	$CaNO_3$	0.75	1.125	1.5
Mar. (1)	4.03	1.65										
Apr. (2)	4.13	1.02										
May (2)	6.10	0.28	17.32	80% hist. ET_o (13.86 inch)	90% hist. ET_o (15.59 inch)	96% hist. ET_o (16.63 inch)	80% ET_o	15 May	NH_4NO_3	0.75	1.125	1.5
June (2)	7.09	0.04										
July (3)	7.93	0.00										
Aug. (3)	7.57	0.12	21.64	80% hist. ET_o (17.31 inch)	90% hist. ET_o (19.48 inch)	85% hist. ET_o (18.39 inch)	80% ET_o	15 Aug.	NH_4NO_3	0.75	1.125	1.5
Sept. (3)	6.14	0.20										
Oct. (4)	4.15	0.39										
Nov. (4)	2.60	1.02	8.70	80% hist. ET_o (6.96 inch)	58% hist. ET_o (5.05 inch)	58% hist. ET_o (5.05 inch)	80% ET_o	15 Oct.	$CaNO_3$	0.75	1.125	1.5
Dec. (4)	1.95	1.81										
Total	56.63	10.43	56.63	45.31 inch	45.32 inch	45.27 inch	TBD[v]			3.0	4.5	6.0

[z] Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of California, Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y] Anonymous. 1981. California rainfall summary, monthly total precipitation, 1949-1980. SDWR. 54 pp. plus microfiche.

[x] The CDFA study is a split-plot design, with irrigation treatments assigned to 20.0 x 20.0-ft main plots that are arranged in three randomized complete blocks. Treatments A, B, and C reflect reported monthly turfgrass crop coefficients (Table 3) and are applied in two irrigation events per week–Saturday and Wednesday morning before sunrise. These treatments are based on the 3-month irrigation treatment quantity and scheduled utilizing the application rates of each main plot and the total number of irrigation events per quarter (irrigation run times are set the first day of each 3-month quarter). Treatment D is based on the previous 7 d accumulative ET_o [from an on-site CIMIS station 51 m (169 ft) from the center of the research plot] and are applied in two irrigation events per week–Saturday and Wednesday morning before sunrise. This treatment is scheduled utilizing the application rates of each main plot and the two irrigation events per week (irrigation run times are set on Tuesdays). Irrigation events for all treatments are cycled to prevent runoff. Rain is not subtracted from either the 3-month or weekly irrigation treatment quantity but may result in cancellation of an irrigation event.

[w] N-fertility treatments applied uniformly to subplots by hand application. Note that N-fertility of the Jaguar III tall fescue (Fig. 1) follows the "b" N-fertility treatment and is applied using a calibrated drop spreader. P_2O_5 applied as needed, according to annual soil test in December. K_2O applied in April, May, June, November and December at the rate of 1.2 lb K_2O/1000 ft^2 per application (for a total of 6.0 lb K_2O applied during the year). Note: irrigation used to water in fertilizer is subtracted from irrigation treatments.

[v] TBD = to be determined.

Table 2. Protocol for irrigation treatments based on a percentage of historical (hist.) ET_o (three treatments) and for ET_o (one treatment) for four, 3-month quarters and three N-fertility treatments based on the annual N-fertility rate for 1999 to 2000.

Month (Quarter)	Monthly historical ET_o (inch)[z]	Monthly historical rainfall (inch)[y]	Quarterly historical ET_o (inch)[z]	Irrigation treatment[x] A	Irrigation treatment[x] B	Irrigation treatment[x] C	Irrigation treatment[x] D	N-fertility treatment[w] Date of application	N-fertility treatment[w] Source of N $N-P_2O_5-K_2O$	Rate (lb N/1000 ft^2) a	Rate (lb N/1000 ft^2) b	Rate (lb N/1000 ft^2) c
Jan. (1)	2.07	1.85										
Feb. (1)	2.87	2.05	8.97	80% hist. ET_o (7.18 inch)	40% hist. ET_o (3.59 inch)	40% hist. ET_o (3.59 inch)	80% ET_o	1 Mar.	Polyon 43-0-0	1.0	1.5	2.00
Mar. (1)	4.03	1.65										
Apr. (2)	4.13	1.02										
May (2)	6.10	0.28	17.32	80% hist. ET_o (13.86 inch)	92% hist. ET_o (15.93 inch)	85% hist. ET_o (14.72 inch)	80% ET_o	15 May	Polyon 42-0-0	1.0	1.5	1.85
June (2)	7.09	0.04										
July (3)	7.93	0.00										
Aug. (3)	7.57	0.12	21.64	80% hist. ET_o (17.31 inch)	91% hist. ET_o (19.69 inch)	97% hist. ET_o (20.99 inch)	80% ET_o	15 Aug.	Polyon 42-0-0	1.0	1.5	1.85
Sept. (3)	6.14	0.20										
Oct. (4)	4.15	0.39										
Nov. (4)	2.60	1.02	8.70	80% hist. ET_o (6.96 inch)	70% hist. ET_o (6.09 inch)	70% hist. ET_o (6.09 inch)	80% ET_o	15 Oct.	Polyon 43-0-0	1.0	1.5	2.00
Dec. (4)	1.95	1.81										
Total	56.63	10.43	56.63	45.31 inch	45.30 inch	45.39 inch	TBD[v]			4.0	6.0	7.7

[z] Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of California, Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y] Anonymous. 1981. California rainfall summary, monthly total precipitation, 1949-1980. SDWR. 54 pp. plus microfiche.

[x] The CDFA study is a split-plot design, with irrigation treatments assigned to 20.0 x 20.0-ft main plots that are arranged in three randomized complete blocks. Treatments A, B, and C reflect reported monthly turfgrass crop coefficients (Table 3) and are applied in two irrigation events per week–Saturday and Wednesday morning before sunrise. These treatments are based on the 3-month irrigation treatment quantity and scheduled utilizing the application rates of each main plot and the total number of irrigation events per quarter (irrigation run times are set the first day of each 3-month quarter). Treatment D is based on the previous 7 d accumulative ET_o [from an on-site CIMIS station 51 m (169 ft) from the center of the research plot] and are applied in two irrigation events per week–Saturday and Wednesday morning before sunrise. This treatment is scheduled utilizing the application rates of each main plot and the two irrigation events per week (irrigation run times are set on Tuesdays). Irrigation events for all treatments are cycled to prevent runoff. Rain is not subtracted from either the 3-month or weekly irrigation treatment quantity but may result in cancellation of an irrigation event.

[w] N-fertility treatments applied uniformly to subplots by hand application. Note that N-fertility of the Jaguar III tall fescue (Fig. 1) follows the "b" N-fertility treatment and is applied using a calibrated drop spreader. P_2O_5 applied as needed, according to annual soil test in December. K_2O applied in April, May, June, November and December at the rate of 1.2 lb K_2O/1000 ft^2 per application (for a total of 6.0 lb K_2O applied during the year). Note: irrigation used to water in fertilizer is subtracted from irrigation treatments.

[v] TBD = to be determined.

Table 3. Cool- and warm-season turfgrass crop coefficients for use in the arid southwest with monthly, quarterly, semi-annual, and annual irrigation programming.

	Cool-season crop coefficients[z]				Warm-season crop coefficients[z]			
Month	Monthly	Quarterly	Semi-annually	Annually	Monthly	Quarterly	Semi-annually	Annually
April	1.04				0.72			
May	0.95	0.96			0.79	0.73		
June	0.88				0.68			
July	0.94		0.9		0.71		0.71	
August	0.86	0.85			0.71	0.68		
September	0.74				0.62			
October	0.75			0.8	0.54			0.6
November	0.69	0.68			0.58	0.56		
December	0.6		0.67		0.55			
January	0.61				0.55		0.59	
February	0.64	0.67			0.54	0.62		
March	0.75				0.76			

[z]Meyer, J.L., V.A. Gibeault, and V.B. Youngner. 1985. Irrigation of turfgrass below replacement of evapotranspiration as a means of water conservation: determining crop coefficient of turfgrasses, p. 357-364. In: F. Lemaire (ed.). Proc. 5th Intl. Turfgrass Res. Conf., Avignon, France, July 1985. INRA Publications, Versailles, France.

Table 4. Protocol for measurements collected during the tall fescue irrigation and N-fertility study.

	Measurement	Frequency	Method and other comments
1.	Visual turfgrass quality	Once every 2 weeks on Friday, which is the day of mowing. Ratings follow mowing.	1 to 9 scale, with 1 = worst quality and 9 = best quality for tall fescue
2.	Visual turfgrass color	Same time as visual turfgrass quality	1 to 9 scale, with 1 = worst color (brown) and 9 = best color (dark green) for tall fescue
3.	Visual estimate of percent leaves that are wilted and rolled	As needed	1 to 100 percent of entire canopy of each subplot
4.	Visual estimate of percent leaves that are fired and yellow to brown	As needed	1 to 100 percent of entire canopy of each subplot
5.	Clipping yield, TKN, and N uptake	Four growth periods, with each period spanning four consecutive weekly clipping yields. All periods start 5 weeks following each of the four N-fertility treatment application dates (Tables 1 and 2). Generally, periods are from 1-30 Apr., 15 June-15 July, 15 Sept.- 15 Oct., and 15 Nov.-15 Dec.	Weekly clipping yield, representing growth of 7 d, collected with the same mower used for the routine, Friday mowing, except a specially constructed collection box is attached to the mower. A subsample, 2.7 m^2 (28.9 ft^2), was harvested from each subplot. Weekly clipping yields were dried and weighed via standard procedures. The four weekly yields within each growth period were pooled by the 36 subplots and prepared for TKN analysis via standard procedures. TKN analysis was conducted at the DANR laboratory located at UC Davis. With appropriate calculations, N uptake during four, 4-week growth periods was determined along with the statistical effect of N-fertility and irrigation treatments.
6.	Volumetric soil-water content; soil-water tension	Once every month (volumetric soil-water content) and once every week (soil-water tension) on Tuesdays. Note that soil-water measurements were collected from Jaguar III tall fescue (Fig. 1).	Volumetric soil-water content at 22.9-, 30.5-, 45.7-, 61.0-, 91.4-, and 121.9-cm (9-, 12-, 18-, 24-, 36-, and 48-inch) depths via the neutron-scattering method (Campbell Pacific Nuclear, Model 503 Hydroprobe). Two neutron probe access tubes per irrigation cell, at the same center locations of each Jaguar III plot (Fig. 1). Soil-water tension at the 15.2- and 22.9-cm (6- and 12-inch) depths using Watermark granular matrix sensors connected to a Watermark soil-moisture meter. Two locations per irrigation cell, at the same center locations of each Jaguar III plot (Fig. 1).
7.	Soil NO_3-N, NH_4-N and TKN	1 Oct.	Soil samples collected from each subplot and prepared according to standard procedures. Analyses conducted at the DANR laboratory, located at UC Davis.
8.	Weather data	Continuous	Data obtained from a CIMIS station located 51 m (169 ft) from the center of the research plot. Soil-temperature data logger installed on the research plot at a depth of 10.2 cm (4 inch).

Note: All measured variables, except weather data and soil-water data, were statistically analyzed according to a split-plot design, with main-plots arranged in a RCB design. Soil-water data were analyzed for the irrigation treatments as a RCB design. A repeated-measures design was used within and between years when appropriate. Weather data were summarized by week.

Table 5. Protocol for research plot management and associated information for the tall fescue irrigation and N-fertility study.

Activity	Comment
1. Mowing	Each Friday, using a walk-behind, rotary mower set at a 3.8-cm (1.5-inch) mowing height. Clippings collected. Note that the Jaguar III tall fescue was mowed the same as the Shortstop tall fescue (Fig. 1).
2. Irrigation	Two irrigation events per week, according to irrigation treatment protocol (Tables 1 and 2). Irrigations events were on Wednesday and Saturday mornings, before sunrise. Irrigation water quality was excellent because it was from the potable water supply of Riverside, Calif.
3. Irrigation-system check	The vertical of all heads, checked with a level and adjusted once every 2 weeks. Clock operation, irrigation run times via hour meters hooked parallel with solenoid values, and pressure of the irrigation system routinely monitored to ensure accurate irrigation treatments. Catch-can tests conducted on each irrigation cell in January and June. Most recent application rates of each irrigation cell were then used in calculating irrigation run times.
4. Fertility	P_2O_5 and K_2O applied as needed based on annual soil tests. Native soil = Hanford fine sand loam. The following information is from a soil test[z] taken 18 Dec. 1998: pH = 7.0; EC_e = 2.37 mmhos/cm; soluble Ca, Mg, and Na = 357, 49, and 182 ppm, respectively; SAR = 2.39; ESP = 2.22%; HCO_3 = 1159 ppm; Fe = 40 ppm; CEC = 10.2 meq/100 g; OM = 1.21%; P-bicarbonate = 29.4 ppm; extractable K, Ca, Mg, and Na = 117, 1804, 195, and 138 ppm, respectively; 15 % clay; 51% sand; and 34% silt.
5. Pesticide application	Pesticides were applied as needed to ensure representative tall fescue.

[z] For information regarding analytical methodologies, see Table A-3.

Table 6. Calendar of major activities associated with the field research study, 1 Jan. 1998 to 2 Feb. 2001.

Date	Activity
19 Dec. 1997	Soil sample collected for analysis of soil salinity/alkalinity/toxicity, fertility, and characteristics.
1 Jan. 1998	Mowing regime set for duration of study to once per week at a 3.8-cm (1.5-inch) mowing height with a walk-behind Toro rotary mower.
28 Jan. 1998	Irrigation program set for 80% historical ET_o and water-banking treatments for Jan. to Mar. 1998 [establishment of four replications of three irrigation treatments (A, B, and C)].
5-12 Feb. 1998	Irrigation catch-can tests.
10 Feb. 1998	Initial Watermark readings for 1998.
18 Feb. 1998	Datalogger installed; beginning of hourly soil temperature readings [at 10.2-cm (4-inch) depth] for duration of study.
27 Feb. 1998	Initial neutron probe readings for 1998. Subsequently once per month on the day prior to irrigation.
3 Mar. 1998	Watermark readings.
6 Mar. 1998	Pre-fertility-treatment visual ratings (quality, color, and drought-related).
10 Mar. 1998	First application of N-fertility treatments for 1998 (calcium nitrate).
17 Mar. 1998	Watermark readings.
20 Mar. 1998	Initial visual turfgrass quality and color ratings for 1998. Subsequently taken every 2 weeks. Initial visual turfgrass drought-related ratings for 1998. Subsequently once per month.
24 Mar. 1998	Watermark readings. Subsequently taken twice per week; one before and another after irrigation.
31 Mar. 1998	Irrigation program set for 80% historical ET_o and water-banking treatments for April to June 1998. Initial programming of 80% ET_o treatment for 1998. Subsequently programmed weekly prior to Wednesday irrigation [establishment of three replications of four irrigation treatments (A, B, C, and D)].
3 Apr. 1998	Applied 1.2 lb K_2O/1000 ft^2.
10 Apr.-1 May 1998	First collection of clipping yield (taken once per week from 7 d of growth during this period) for 1998.
8 May 1998	Applied 1.2 lb K_2O/1000 ft^2.
18 May 1998	Second application of N-fertility treatments for 1998 (ammonium nitrate).
9 June 1998	Applied 1.2 lb K_2O/1000 ft^2.
19 June-10 July 1998	Second collection of clipping yield (taken once per week from 7 d of growth during this period) for 1998.
30 June 1998	Irrigation program set for 80% historical ET_o and water-banking treatments for July to Sept. 1998.
14 Aug. 1998	Third application of N-fertility treatments for 1998 (ammonium nitrate).
18 Sept.-9 Oct. 1998	Third collection of clipping yield (taken once per week from 7 d of growth during this period) for 1998.
6 Oct. 1998	Irrigation program set for 80% historical ET_o and water-banking treatments for Oct. to Dec. 1998.
14 Oct. 1998	Soil cores taken for TKN, NO_3-N, and NH_4-N analyses.
16-17 Oct. 1998	Fourth application of N-fertility treatments for 1998 (calcium nitrate).
6 Nov. 1998	Applied 1.2 lb K_2O/1000 ft^2.
20 Nov.-15 Dec. 1998	Fourth collection of clipping yield (taken once per week from 7 d of growth during this period) for 1998.
15 Dec. 1998	Final visual turfgrass drought-related ratings for 1998.
18 Dec. 1998	Final visual turfgrass quality and color ratings for 1998. Soil sample collected for analysis of soil salinity/alkalinity/toxicity, fertility, and characteristics.
22 Dec. 1998	Final neutron probe readings for 1998.

Table 6 *(continued)*. Calendar of major activities associated with the field research study, 1 Jan. 1998 to 2 Feb. 2001.

29 Dec. 1998	Initial programming of 80% ET_o treatment for 1999. Subsequently programmed weekly prior to Wednesday irrigation.
30 Dec. 1998	Final Watermark readings for 1998. Irrigation program set for 80% historical ET_o and water-banking treatments for Jan. to Mar. 1999.
5 Jan. 1999	Initial Watermark readings for 1999. Subsequently taken twice per week; one before and another after irrigation.
8 Jan. 1999	Initial visual turfgrass quality and color ratings for 1999. Subsequently taken every two weeks.
19 Jan. 1999	Initial neutron probe readings for 1999. Subsequently taken once per month on the day prior to irrigation.
22 Jan. 1999	Initial visual turfgrass drought-related ratings for 1999. Subsequently taken once per month.
3 Feb. 1999	Irrigation catch-can tests.
5 Mar. 1999	First application of N-fertility treatments for 1999 (Polyon 43-0-0).
24-26 Mar. 1999	Installation of tall fescue fetch around research plots.
31 Mar. 1999	Irrigation program set for 80% historical ET_o and water-banking treatments for Apr. to June 1999.
2 Apr. 1999	Applied 1.2 lb K_2O/1000 ft^2.
9 Apr.-7 May 1999	First collection of clipping yield (taken once per week from 7 d of growth during this period) for 1999.
21 Apr.-5 May 1999	Irrigation catch-can tests.
14 May 1999	Second application of N-fertility treatments for 1999 (Polyon 42-0-0). Applied 1.2 lb K_2O/1000 ft^2.
4 June 1999	Applied 1.2 lb K_2O/1000 ft^2.
18 June-9 July 1999	Second collection of clipping yield (taken once per week from 7 d of growth during this period) for 1999.
29 June 1999	Irrigation program set for 80% historical ET_o and water-banking treatments for July to Sept. 1999.
4-11 Aug. 1999	Irrigation catch-can tests.
13 Aug. 1999	Third application of N-fertility treatments for 1999 (Polyon 42-0-0).
4-8 Sept. 1999	Irrigation catch-can tests.
17 Sept.-15 Oct. 1999	Third collection of clipping yield (taken once per week from 7 d of growth during this period) for 1999.
28 Sept. 1999	Irrigation program set for 80% historical ET_o and water-banking treatments for Oct. to Dec. 1999.
13 Oct. 1999	Soil cores taken for TKN, NO_3-N, and NH_4-N analyses.
15 Oct. 1999	Fourth application of N-fertility treatments for 1999 (Polyon 43-0-0).
5 Nov. 1999	Applied 1.2 lb K_2O/1000 ft^2.
19 Nov.-10 Dec. 1999	Fourth collection of clipping yield (taken once per week from 7 d of growth during this period) for 1999.
7 Dec. 1999	Applied 1.2 lb K_2O/1000 ft^2.
17 Dec. 1999	Final visual turfgrass quality, color and drought-related ratings for 1999. Soil sample collected for analysis of soil salinity/alkalinity/toxicity, fertility, and characteristics.
21 Dec. 1999	Final neutron probe readings for 1999.
28 Dec. 1999	Initial programming of 80% ET_o treatment for 2000. Subsequently programmed weekly prior to Wednesday irrigation. Irrigation program set for 80% historical ET_o and water-banking treatments for Jan. to Mar. 2000.
29 Dec. 1999	Final Watermark readings for 1999.

Table 6 *(continued)*. Calendar of major activities associated with the field research study, 1 Jan. 1998 to 2 Feb. 2001.

4 Jan. 2000	Initial Watermark readings for 2000. Subsequently taken twice per week; one before and another after irrigation.
7 Jan. 2000	Initial visual turfgrass quality and color ratings for 2000. Subsequently taken every 2 weeks.
12 Jan. 2000	Irrigation catch-can tests.
18 Jan. 2000	Initial neutron probe readings for 2000. Subsequently taken once per month on the day prior to irrigation.
19 Jan. 2000	Irrigation catch-can tests.
21 Jan. 2000	Initial visual turfgrass drought-related ratings for 2000. Subsequently taken once per month.
3 Mar. 2000	First application of N-fertility treatments for 2000 (Polyon 43-0-0).
29 Mar. 2000	Irrigation program set for 80% historical ET_o and water-banking treatments for Apr. to June 2000.
7-28 Apr. 2000	First collection of clipping yield (taken once per week from 7 d of growth during this period) for 2000.
14 Apr. 2000	Applied 1.2 lb K_2O/1000 ft^2.
5 May 2000	Applied 1.2 lb K_2O/1000 ft^2.
10 May 2000	Irrigation catch-can tests.
12 May 2000	Second application of N-fertility treatments for 2000 (Polyon 42-0-0).
17 May 2000	Irrigation catch-can tests.
14 June 2000	Applied 1.2 lb K_2O/1000 ft^2.
16 June-7 July 2000	Second collection of clipping yield (taken once per week from 7 d of growth during this period) for 2000.
28 June 2000	Irrigation program set for 80% historical ET_o and water-banking treatments for July to Sept. 2000.
11 Aug. 2000	Third application of N-fertility treatments for 2000 (Polyon 42-0-0).
6 Sept. 2000	Irrigation catch-can tests.
13 Sept. 2000	Irrigation catch-can tests.
15 Sept.-6 Oct. 2000	Third collection of clipping yield (taken once per week from 7 d of growth during this period) for 2000.
3 Oct. 2000	Irrigation program set for 80% historical ET_o and water-banking treatments for Oct. to Dec. 2000.
11 Oct. 2000	Soil cores taken for TKN, NO_3-N, and NH_4-N analyses.
13 Oct. 2000	Fourth application of N-fertility treatments for 2000 (Polyon 43-0-0).
10 Nov. 2000	Applied 1.2 lb K_2O/1000 ft^2.
17 Nov.-8 Dec. 2000	Fourth collection of clipping yield (taken once per week from 7 d of growth during this period) for 2000.
8 Dec. 2000	Applied 1.2 lb K_2O/1000 ft^2.
15 Dec. 2000	Final visual turfgrass quality and color ratings for 2000.
18 Dec. 2000	Soil sample collected for analysis of soil salinity/alkalinity/toxicity, fertility, and characteristics.
19 Dec. 2000	Final neutron probe readings for 2000.
22 Dec. 2000	Final visual turfgrass drought-related ratings for 2000.
27 Dec. 2000	Final Watermark readings for 2000.
2 Feb. 2001	Soil temperature data collection terminated.

Table 7. Summary of ET_o and historical ET_o, rainfall, and applied irrigation water in 1998.

	1998 quarter																1998			
	January to March				April to June				July to September				October to December				January to December			
	Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)			
Variable	A (80% hist. ET_o)[z]	B (58% hist. ET_o)	C (58% hist. ET_o)	D (80% ET_o)[y]	A (80% hist. ET_o)[z]	B (90% hist. ET_o)	C (96% hist. ET_o)	D (80% ET_o)[y]	A (80% hist. ET_o)[z]	B (90% hist. ET_o)	C (85% hist. ET_o)	D (80% ET_o)[y]	A (80% hist. ET_o)[z]	B (58% hist. ET_o)	C (58% hist. ET_o)	D (80% ET_o)[y]	A (80%,80%, 80%, 80% hist. ET_o)[z]	B (58%,90%, 90%,58% hist. ET_o)	C (58%,96%, 85%,58% hist. ET_o)	D (80%,80%, 80%, 80% ET_o)[y]
Real-time ET_o (mm)	195	195	195	195	418	418	418	418	513	513	513	513	245	245	245	245	1371	1371	1371	1371
Historical ET_o (mm)	228	228	228	228	440	440	440	440	550	550	550	550	221	221	221	221	1439	1439	1439	1439
ET_{crop} (ET_o x K_c month) (mm)	134	134	134	134	399	399	399	399	441	441	441	441	169	169	169	169	1143	1143	1143	1143
Rainfall (mm)	366	366	366	366	43	43	43	43	14	14	14	14	24	24	24	24	447	447	447	447
Historical rainfall (mm)[x]	141	141	141	141	34	34	34	34	8	8	8	8	82	82	82	82	265	265	265	265
Applied water (mm)[w]	53	60	60	66	296	336	358	219	444	497	466	433	178	128	131	201	971	1021	1015	919
Total water (rainfall plus applied) (mm)	419	426	426	432	339	379	401	262	458	511	480	447	202	152	155	225	1418	1468	1462	1366
(Applied water/ET_{crop}) x 100	40	45	45	49	74	84	90	55	101	113	106	98	105	76	78	119	85	89	89	80
(Total water/ET_{crop}) x 100	313	318	318	322	85	95	101	66	104	116	109	101	120	90	92	133	124	128	128	120
(Applied water/real-time ET_o) x 100	27	31	31	34	71	80	86	52	87	97	91	84	73	52	53	82	71	74	74	67
(Applied water/historical ET_o) x 100	23	26	26	29	67	76	81	50	81	90	85	79	81	58	59	91	67	71	71	64
No. irrigation events	10	10	10	10	22	22	22	19	27	27	27	27	26	26	26	26	85	85	85	82
No. irrigation events canceled	16	16	16	16	4	4	4	7	0	0	0	0	0	0	0	0	20	20	20	23

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p. 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Anonymous. 1981. California summary, monthly total precipitation, 1949-1980. SDWR. 54 pp. plus microfiche.

[w]Applied water is calculated as (actual water time per day / system precipitation rate) x no. irrigation events. Numbers for each irrigation treatment are calculated as the average of three replicate plots.

Note: Within each column, underlined percentages can be compared to the percentages that are listed directly below the letters (A, B, C, D) that designate irrigation treatments.

Table 8. Summary of ET_o and historical ET_o, rainfall, and applied irrigation water in 1999.

	1999 quarter																1999			
	January to March				April to June				July to September				October to December				January to December			
	Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)			
Variable	A (80% hist. ET_o)[z]	B (40% hist. ET_o)	C (40% hist. ET_o)	D (80% ET_o)[y]	A (80% hist. ET_o)[z]	B (92% hist. ET_o)	C (85% hist. ET_o)	D (80% ET_o)[y]	A (80% hist. ET_o)[z]	B (91% hist. ET_o)	C (97% hist. ET_o)	D (80% ET_o)[y]	A (80% hist. ET_o)[z]	B (70% hist. ET_o)	C (70% hist. ET_o)	D (80% ET_o)[y]	A (80%,80%, 80%, 80% hist. ET_o)[z]	B (40%,92%, 91%,70% hist. ET_o)	C (40%,85%, 97%,70% hist. ET_o)	D (80%,80%, 80%, 80% ET_o)[y]
Real-time ET_o (mm)	245	245	245	245	411	411	411	411	518	518	518	518	291	291	291	291	1465	1465	1465	1465
Historical ET_o (mm)	228	228	228	228	440	440	440	440	550	550	550	550	221	221	221	221	1439	1439	1439	1439
ET_{crop} (ET_o x K_c month) (mm)	166	166	166	166	389	389	389	389	436	436	436	436	201	201	201	201	1192	1192	1192	1192
Rainfall (mm)	48	48	48	48	58	58	58	58	3	3	3	3	38	38	38	38	147	147	147	147
Historical rainfall (mm)[x]	141	141	141	141	34	34	34	34	8	8	8	8	82	82	82	82	265	265	265	265
Applied water (mm)[w]	184	90	94	202	357	423	367	319	438	498	525	418	173	154	162	232	1152	1165	1148	1171
Total water (rainfall plus applied) (mm)	232	138	142	250	415	481	425	377	441	501	528	421	211	192	200	270	1299	1312	1295	1318
(Applied water/ET_{crop}) x 100	111	54	57	122	92	109	94	82	100	114	120	96	86	77	81	115	97	98	96	98
(Total water/ET_{crop}) x 100	140	83	86	151	107	124	109	97	101	115	121	97	105	96	100	134	109	110	109	111
(Applied water/real-time ET_o) x 100	75	37	38	82	87	103	89	78	85	96	101	81	59	53	56	80	79	80	78	80
(Applied water/historical ET_o) x 100	81	39	41	89	81	96	83	73	80	91	95	76	78	70	73	105	80	81	80	81
No. irrigation events	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	104	104	104	104
No. irrigation events canceled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p. 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Anonymous. 1981. California summary, monthly total precipitation, 1949-1980. SDWR. 54 pp. plus microfiche.

[w]Applied water is calculated as (actual water time per day / system precipitation rate) x no. irrigation events. Numbers for each irrigation treatment are calculated as the average of three replicate plots.

Note: Within each column, underlined percentages can be compared to the percentages that are listed directly below the letters (A, B, C, D) that designate irrigation treatments.

Table 9. Summary of ET_o and historical ET_o, rainfall, and applied irrigation water in 2000.

	2000 quarter																2000			
	January to March				April to June				July to September				October to December				January to December			
	Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)				Irrigation treatment (% quarterly ET_o)			
Variable	A (80% hist. ET_o)[z]	B (40% hist. ET_o)	C (40% hist. ET_o)	D (80% ET_o)[y]	A (80% hist. ET_o)[z]	B (92% hist. ET_o)	C (85% hist. ET_o)	D (80% ET_o)[y]	A (80% hist. ET_o)[z]	B (91% hist. ET_o)	C (97% hist. ET_o)	D (80% ET_o)[y]	A (80% hist. ET_o)[z]	B (70% hist. ET_o)	C (70% hist. ET_o)	D (80% ET_o)[y]	A (80%,80%, 80%, 80% hist. ET_o)[z]	B (40%,92%, 91%,70% hist. ET_o)	C (40%,85%, 97%,70% hist. ET_o)	D (80%,80%, 80%, 80% ET_o)[y]
Real-time ET_o (mm)	226	226	226	226	505	505	505	505	521	521	521	521	219	219	219	219	1471	1471	1471	1471
Historical ET_o (mm)	228	228	228	228	440	440	440	440	550	550	550	550	221	221	221	221	1439	1439	1439	1439
ET_{crop} (ET_o x K_c month) (mm)	155	155	155	155	480	480	480	480	448	448	448	448	150	150	150	150	1233	1233	1233	1233
Rainfall (mm)	96	96	96	96	16	16	16	16	4	4	4	4	14	14	14	14	130	130	130	130
Historical rainfall (mm)[x]	141	141	141	141	34	34	34	34	8	8	8	8	82	82	82	82	265	265	265	265
Applied water (mm)[w]	191	92	99	160	358	413	367	381	447	503	544	447	177	154	162	159	1173	1162	1172	1147
Total water (rainfall plus applied) (mm)	287	188	195	256	374	429	383	397	451	507	548	451	191	168	176	173	1303	1292	1302	1277
(Applied water/ET_{crop}) x 100	123	59	64	103	75	86	76	79	100	112	121	100	118	103	108	106	95	94	95	93
(Total water/ET_{crop}) x 100	185	121	126	165	78	89	80	83	101	113	122	101	127	112	117	115	106	105	106	104
(Applied water/real-time ET_o) x 100	85	41	44	<u>71</u>	71	82	73	<u>75</u>	86	97	104	<u>86</u>	81	70	74	<u>73</u>	80	79	80	78
(Applied water/historical ET_o) x 100	<u>84</u>	<u>40</u>	<u>43</u>	70	<u>81</u>	<u>94</u>	<u>83</u>	87	<u>81</u>	<u>91</u>	<u>99</u>	81	<u>80</u>	<u>70</u>	<u>73</u>	72	82	81	81	80
No. irrigation events	26	26	26	26	26	26	26	26	27	27	27	27	26	26	26	26	105	105	105	105
No. irrigation events canceled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p. 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Anonymous. 1981. California summary, monthly total precipitation, 1949-1980. SDWR. 54 pp. plus microfiche.

[w]Applied water is calculated as (actual water time per day / system precipitation rate) x no. irrigation events. Numbers for each irrigation treatment are calculated as the average of three replicate plots.

Note: Within each column, underlined percentages can be compared to the percentages that are listed directly below the letters (A, B, C, D) that designate irrigation treatments.

Table 10. The effect of irrigation-level treatment and N-fertility rate treatment on the percent of rating dates that tall fescue visual turfgrass quality was ≥5.0, ≥5.5, and ≥6.0 for four, 3-month quarters and annually in 1998.

	1998 quarter												1998		
	January to March[z]			April to June			July to September			October to December			April to December		
	Visual quality rating			Visual quality rating			Visual quality rating			Visual quality rating			Visual quality rating		
Treatments	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0
				------ % of 7 rating dates -------			*------ % of 6 rating dates -------*			*------ % of 6 rating dates -------*			*------ % of 19 rating dates ------*		
Irrigation-level treatments															
80%, 80%, 80%, 80% hist. ET_o[y]	–	–	–	100	86	43	83	33	0	83	33	0	89	53	16
58%, 90%, 90%, 58% hist. ET_o	–	–	–	100	86	43	100	83	0	83	33	0	95	68	16
58%, 96%, 85%, 58% hist. ET_o	–	–	–	100	86	43	100	67	0	50	17	0	84	58	16
80%, 80%, 80%, 80% ET_o[y]	–	–	–	100	86	57	100	83	0	100	50	17	100	74	26
N-fertility rate treatments[w]															
3.0 lb N/1000 ft^2/year	–	–	–	100	86	29	100	33	0	50	17	0	84	47	11
4.5 lb N/1000 ft^2/year	–	–	–	100	86	43	100	33	0	83	50	0	95	58	16
6.0 lb N/1000 ft^2/year	–	–	–	100	86	57	100	83	17	100	83	33	100	84	37

[z]Due to changes in the initial research protocol, all data taken from January to March 1998 are not included in the study results.

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Applied 10 Mar., 18 May, 14 Aug., and 16-17 Oct 1998.

Table 11. The effect of irrigation-level treatment and N-fertility rate treatment on the percent of rating dates that tall fescue visual turfgrass quality was ≥5.0, ≥5.5, and ≥6.0 for four, 3-month quarters and annually in 1999.

	1999 quarter												1999		
	January to March[z]			April to June			July to September			October to December			January to December		
	Visual quality rating			Visual quality rating			Visual quality rating			Visual quality rating			Visual quality rating		
Treatments	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0
	------ *% of 6 rating dates* -------			------ *% of 6 rating dates* -------			------ *% of 5 rating dates* -------			------ *% of 5 rating dates* -------			------ *% of 22 rating dates* ------		
Irrigation-level treatments															
80%, 80%, 80%, 80% hist. ET_o[y]	33	0	0	100	83	0	40	0	0	0	0	0	45	23	0
40%, 92%, 91%, 70% hist. ET_o	33	0	0	83	67	0	100	0	0	20	0	0	59	18	0
40%, 85%, 97%, 70% hist. ET_o	0	0	0	100	67	0	100	0	0	20	0	0	55	18	0
80%, 80%, 80%, 80% ET_o[x]	17	0	0	100	67	0	0	0	0	40	0	0	41	18	0
N-fertility rate treatments[w]															
4.0 lb N/1000 ft^2/year	0	0	0	83	33	0	20	0	0	0	0	0	27	9	0
6.0 lb N/1000 ft^2/year	17	0	0	100	67	0	80	0	0	0	0	0	50	18	0
7.7 lb N/1000 ft^2/year	67	17	0	100	100	50	100	0	0	60	0	0	82	32	14

[z]Please note that fertility treatments for 1999 were first applied on 5 Mar. 1999; subsequently, ratings taken on or before 5 Mar. 1999 are still influenced by the 1998 fertility treatments (3.0, 4.5, and 6.0 lb N/1000 ft^2 per year instead of 4.0, 6.0, and 7.7 lb N/1000 ft^2 per year, respectively).

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Applied 5 Mar., 14 May, 13 Aug., and 15 Oct. 1999.

Table 12. The effect of irrigation-level treatment and N-fertility rate treatment on the percent of rating dates that tall fescue visual turfgrass quality was ≥5.0, ≥5.5, and ≥6.0 for four, 3-month quarters and annually in 2000.

	2000 quarter												2000		
	January to March			April to June			July to September			October to December			January to December		
	Visual quality rating			Visual quality rating			Visual quality rating			Visual quality rating			Visual quality rating		
Treatments	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0
	------ % of 7 rating dates -------			*------ % of 6 rating dates -------*			*------ % of 7 rating dates -------*			*------ % of 5 rating dates -------*			*------ % of 25 rating dates ------*		
Irrigation-level treatments															
80%, 80%, 80%, 80% hist. ET_o[z]	86	57	14	83	33	0	29	0	0	100	60	0	72	36	4
40%, 92%, 91%, 70% hist. ET_o	71	43	0	100	100	0	71	14	0	100	100	0	84	60	0
40%, 85%, 97%, 70% hist. ET_o	57	29	0	100	33	0	100	14	0	100	40	0	88	28	0
80%, 80%, 80%, 80% ET_o[y]	100	43	14	100	17	0	57	0	0	100	0	0	88	16	4
N-fertility rate treatments[x]															
4.0 lb N/1000 ft^2/year	43	14	0	100	0	0	57	0	0	100	20	0	72	8	0
6.0 lb N/1000 ft^2/year	71	43	0	100	33	0	57	0	0	100	0	0	80	20	0
7.7 lb N/1000 ft^2/year	100	57	43	100	83	17	71	14	0	100	100	0	92	60	16

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).
[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.
[x]Applied 3 Mar., 12 May, 11 Aug., and 13 Oct. 2000.

Table 13. The effect of irrigation-level treatment and N-fertility rate treatment on the percent of rating dates that tall fescue visual turfgrass quality was ≥5.0, ≥5.5, and ≥6.0 for four, 3-month quarters over 3 years and the 3-year total for 1998, 1999, and 2000.

	1998-2000 quarter												1998-2000		
	January to March[z]			April to June			July to September			October to December			January to December		
	Visual quality rating			Visual quality rating			Visual quality rating			Visual quality rating			Visual quality rating		
Treatments	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0
	----- *% of 13 rating dates* -------			----- *% of 19 rating dates* -------			----- *% of 18 rating dates* -------			----- *% of 16 rating dates* -------			------ *% of 66 rating dates* ------		
Irrigation-level treatments															
80%, 80%, 80%, 80% hist. ET_o[y]	62	31	8	95	68	16	50	11	0	63	31	0	68	36	6
58%, 90%, 90%, 58% hist. ET_o (1998) 40%, 92%, 91%, 70% hist. ET_o (1999-2000)	54	23	0	95	84	16	89	33	0	69	44	0	79	48	5
58%, 96%, 85%, 58% hist. ET_o (1998) 40%, 85%, 97%, 70% hist. ET_o (1999-2000)	31	15	0	100	63	16	100	28	0	56	19	0	76	33	5
80%, 80%, 80%, 80% ET_o[x]	62	23	8	100	58	21	56	28	0	81	19	6	76	33	9
N-fertility rate treatments[w]															
3.0 lb N/1000 ft^2/year (1998) 4.0 lb N/1000 ft^2/year (1999-2000)	23	8	0	95	42	11	61	11	0	50	13	0	61	20	3
4.5 lb N/1000 ft^2/year (1998) 6.0 lb N/1000 ft^2/year (1999-2000)	46	23	0	100	63	16	78	11	0	63	19	0	74	30	5
6.0 lb N/1000 ft^2/year (1998) 7.7 lb N/1000 ft^2/year (1999-2000)	85	38	23	100	89	42	89	33	6	88	63	13	91	58	21

[z]Percentages include data for 1999 and 2000 only; there are no rating dates for this quarter in 1998.

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Applied 10 Mar., 18 May, 14 Aug., and 16-17 Oct 1998; 5 Mar., 14 May, 13 Aug., and 15 Oct. 1999; 3 Mar., 12 May, 11 Aug., and 13 Oct. 2000.

Table 14. The effect of irrigation-level treatment and N-fertility rate treatment on the percent of rating dates that tall fescue visual turfgrass color was ≥5.0, ≥5.5, and ≥6.0 for four, 3-month quarters and annually in 1998.

	1998 quarter												1998		
	January to March[z]			April to June			July to September			October to December			April to December		
	Visual color rating			Visual color rating			Visual color rating			Visual color rating			Visual color rating		
Treatments	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0
				------ *% of 7 rating dates* -------			------ *% of 6 rating dates* -------			------ *% of 6 rating dates* -------			------ *% of 19 rating dates* ------		
Irrigation-level treatments															
80%, 80%, 80%, 80% hist. ET_o[y]	–	–	–	100	57	43	83	17	0	83	50	0	89	42	16
58%, 90%, 90%, 58% hist. ET_o	–	–	–	100	57	43	100	100	0	83	17	0	95	58	16
58%, 96%, 85%, 58% hist. ET_o	–	–	–	100	71	43	100	83	0	67	17	0	89	58	16
80%, 80%, 80%, 80% ET_o[x]	–	–	–	100	71	57	100	83	17	100	67	17	100	74	32
N-fertility rate treatments[w]															
3.0 lb N/1000 ft^2/year	–	–	–	100	57	29	100	33	0	50	17	0	84	37	11
4.5 lb N/1000 ft^2/year	–	–	–	100	57	57	100	83	0	83	50	0	95	63	21
6.0 lb N/1000 ft^2/year	–	–	–	100	86	57	100	83	17	100	83	33	100	84	37

[z]Due to changes in the initial research protocol, all data taken from January to March 1998 are not included in the study results.

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Applied 10 Mar., 18 May, 14 Aug., and 16-17 Oct 1998.

Table 15. The effect of irrigation-level treatment and N-fertility rate treatment on the percent of rating dates that tall fescue visual turfgrass color was ≥5.0, ≥5.5, and ≥6.0 for four, 3-month quarters and annually in 1999.

	1999 quarter												1999		
	January to March[z]			April to June			July to September			October to December			January to December		
	Visual color rating			Visual color rating			Visual color rating			Visual color rating			Visual color rating		
Treatments	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0
	------ % of 6 rating dates -------			*------ % of 6 rating dates -------*			*------ % of 5 rating dates -------*			*------ % of 5 rating dates -------*			*------ % of 22 rating dates ------*		
Irrigation-level treatments															
80%, 80%, 80%, 80% hist. ET_o[y]	50	0	0	100	100	0	60	0	0	0	0	0	55	27	0
40%, 92%, 91%, 70% hist. ET_o	33	0	0	100	67	0	100	0	0	20	0	0	64	18	0
40%, 85%, 97%, 70% hist. ET_o	0	0	0	100	83	0	100	40	0	40	0	0	59	32	0
80%, 80%, 80%, 80% ET_o[x]	33	0	0	100	83	0	0	0	0	60	0	0	50	23	0
N-fertility rate treatments[w]															
4.0 lb N/1000 ft^2/year	0	0	0	83	0	0	20	0	0	0	0	0	6	0	0
6.0 lb N/1000 ft^2/year	33	0	0	100	83	0	80	0	0	20	0	0	13	5	0
7.7 lb N/1000 ft^2/year	100	17	0	100	100	50	100	20	0	60	0	0	20	8	3

[z]Please note that fertility treatments for 1999 were first applied on 5 Mar. 1999; subsequently, ratings taken on or before 5 Mar. 1999 are still influenced by the 1998 fertility treatments (3.0, 4.5, and 6.0 lb N/1000 ft^2 per year instead of 4.0, 6.0, and 7.7 lb N/1000 ft^2 per year, respectively).

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Applied 5 Mar., 14 May, 13 Aug., and 15 Oct. 1999.

Table 16. The effect of irrigation-level treatment and N-fertility rate treatment on the percent of rating dates that tall fescue visual turfgrass color was ≥5.0, ≥5.5, and ≥6.0 for four, 3-month quarters and annually in 2000.

	2000 quarter												2000		
	January to March			April to June			July to September			October to December			January to December		
	Visual color rating			Visual color rating			Visual color rating			Visual color rating			Visual color rating		
Treatments	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0
	------ % of 7 rating dates -------			*------ % of 6 rating dates -------*			*------ % of 7 rating dates -------*			*------ % of 5 rating dates -------*			*------ % of 25 rating dates ------*		
Irrigation-level treatments															
80%, 80%, 80%, 80% hist. ET_o[z]	86	57	43	83	33	0	29	14	0	100	100	0	72	48	12
40%, 92%, 91%, 70% hist. ET_o	71	43	14	100	100	17	100	29	0	100	100	0	92	64	8
40%, 85%, 97%, 70% hist. ET_o	71	29	0	100	67	0	100	29	0	100	100	0	92	52	0
80%, 80%, 80%, 80% ET_o[y]	100	43	29	100	33	0	71	0	0	100	80	0	92	36	8
N-fertility rate treatments[x]															
4.0 lb N/1000 ft^2/year	43	29	0	100	0	0	71	14	0	100	80	0	76	28	0
6.0 lb N/1000 ft^2/year	86	43	29	100	67	0	71	0	0	100	100	0	88	48	8
7.7 lb N/1000 ft^2/year	100	71	43	100	100	50	86	29	0	100	100	0	96	72	24

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).
[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.
[x]Applied 3 Mar., 12 May, 11 Aug., and 13 Oct. 2000.

Table 17. The effect of irrigation-level treatment and N-fertility rate treatment on the percent of rating dates that tall fescue visual turfgrass color was ≥5.0, ≥5.5, and ≥6.0 for four, 3-month quarters over 3 years and the 3-year total for 1998, 1999, and 2000.

	1998-2000 quarter												1998-2000		
	January to March[z]			April to June			July to September			October to December			January to December		
	Visual color rating			Visual color rating			Visual color rating			Visual color rating			Visual color rating		
Treatments	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0	≥5.0	≥5.5	≥6.0
	----- % of 13 rating dates -------			*----- % of 19 rating dates -------*			*----- % of 18 rating dates -------*			*----- % of 16 rating dates -------*			*------ % of 66 rating dates ------*		
Irrigation-level treatments															
80%, 80%, 80%, 80% hist. ET_o[y]	69	31	23	95	63	16	56	11	0	63	50	0	71	39	9
58%, 90%, 90%, 58% hist. ET_o (1998) 40%, 92%, 91%, 70% hist. ET_o (1999-2000)	54	23	8	100	74	21	100	44	0	69	38	0	83	47	8
58%, 96%, 85%, 58% hist. ET_o (1998) 40%, 85%, 97%, 70% hist. ET_o (1999-2000)	38	15	0	100	74	16	100	50	0	69	38	0	80	47	5
80%, 80%, 80%, 80% ET_o[x]	69	23	15	100	63	21	61	28	6	88	50	6	80	42	12
N-fertility rate treatments[w]															
3.0 lb N/1000 ft^2/year (1998) 4.0 lb N/1000 ft^2/year (1999-2000)	23	15	0	95	21	11	67	17	0	50	31	0	62	21	3
4.5 lb N/1000 ft^2/year (1998) 6.0 lb N/1000 ft^2/year (1999-2000)	62	23	15	100	68	21	83	28	0	69	50	0	80	44	9
6.0 lb N/1000 ft^2/year (1998) 7.7 lb N/1000 ft^2/year (1999-2000)	100	46	23	100	95	53	94	44	6	88	63	13	95	64	24

[z]Percentages include data for 1999 and 2000 only; there are no rating dates for this quarter in 1998.

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Applied 10 Mar., 18 May, 14 Aug., and 16-17 Oct 1998; 5 Mar., 14 May, 13 Aug., and 15 Oct. 1999; 3 Mar., 12 May, 11 Aug., and 13 Oct. 2000.

Table 18. The effect of irrigation-level treatment and N-fertility rate on visual turfgrass quality of tall fescue in 1998 (1 to 9 scale, with 1=worst, 5=minimally acceptable, and 9=best tall fescue).

Treatments	Date																			
	3 Apr.	17 Apr.	1 May	15 May	29 May	12 June	26 June	10 July	24 July	7 Aug.	21 Aug.	4 Sept.	18 Sept.	2 Oct.	16 Oct.	30 Oct.	13 Nov.	11 Dec.	18 Dec.	Overall
Irrigation-level treatments																				
80%, 80%, 80%, 80% hist. ET_o[z]	6.6	6.3	5.3	5.5	5.5	6.0	5.8	5.7	5.5	4.8	5.2	5.2	5.2	5.7	4.9	5.4	5.7	5.1	5.0	5.5
58%, 90%, 90%, 58% hist. ET_o	6.6	6.3	5.3	5.6	5.6	6.1	5.7	5.7	5.6	5.4	5.7	5.7	5.7	5.7	4.6	5.4	5.6	5.0	5.1	5.6
58%, 96%, 85%, 58% hist. ET_o	6.6	6.3	5.3	5.6	5.6	6.0	5.9	5.8	5.7	5.1	5.6	5.6	5.4	5.7	4.6	5.2	5.1	4.9	4.7	5.5
80%, 80%, 80%, 80% ET_o[y]	6.6	6.2	5.2	5.5	5.6	6.2	6.1	5.9	5.8	5.3	5.7	5.6	5.7	5.7	5.3	6.5	5.9	5.4	5.3	5.8
LSD, P=0.05	NS	NS	NS	NS	NS	NS	0.2	NS	NS	0.4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[x]																				
3.0 lb N/1000 ft^2/year	6.5	6.2	5.3	5.6	5.6	5.9	5.6	5.5	5.5	5.1	5.4	5.3	5.3	5.6	4.7	5.1	5.1	4.6	4.5	5.4
4.5 lb N/1000 ft^2/year	6.7	6.3	5.2	5.5	5.5	6.0	5.9	5.8	5.7	5.1	5.4	5.4	5.3	5.7	4.7	5.8	5.6	5.1	5.0	5.6
6.0 lb N/1000 ft^2/year	6.6	6.3	5.3	5.6	5.6	6.2	6.0	6.0	5.8	5.3	5.8	5.9	5.9	5.8	5.0	6.0	6.0	5.6	5.5	5.8
LSD, P=0.05	NS	NS	NS	NS	NS	NS	0.2	0.2	NS	NS	0.3	0.4	0.3	0.2	NS	NS	0.4	0.2	0.2	0.1
Summary of ANOVA effects[w]																				
Irrigation (I)	NS	NS	NS	NS	NS	NS	*	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertility (F)	NS	NS	NS	NS	NS	NS	**	**	NS	NS	*	*	**	*	NS	NS	**	***	***	***
I x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
Date (D)																				***
D x I																				***
D x F																				***
D x I x F																				NS

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Applied 10 Mar., 18 May, 14 Aug., and 16-17 Oct 1998.

[w]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 19. The effect of irrigation-level treatment and N-fertility rate on visual turfgrass quality of tall fescue in 1999 (1 to 9 scale, with 1=worst, 5=minimally acceptable, and 9=best tall fescue).

Treatments	Date																						
	8 Jan.[z]	22 Jan.[z]	5 Feb.[z]	19 Feb.[z]	5 Mar.[z]	19 Mar.	2 Apr.	16 Apr.	14 May	28 May	11 June	25 June	23 July	6 Aug.	20 Aug.	3 Sept.	17 Sept.	15 Oct.	29 Oct.	12 Nov.	3 Dec.	17 Dec.	Overall
Irrigation-level treatments																							
80%, 80%, 80%, 80% hist. ET_o[y]	4.8	4.9	4.7	4.8	5.0	5.3	5.3	5.7	5.6	5.9	5.9	5.8	4.9	4.9	5.0	4.9	5.0	4.7	4.4	4.8	4.8	4.8	5.1
40%, 92%, 91%, 70% hist. ET_o	4.4	4.4	4.7	4.7	5.0	5.3	4.9	5.3	5.6	5.8	5.8	5.6	5.3	5.2	5.1	5.1	5.4	4.9	4.4	4.8	5.1	4.8	5.1
40%, 85%, 97%, 70% hist. ET_o	4.2	4.2	4.4	4.6	4.7	4.9	5.0	5.3	5.5	5.8	5.7	5.6	5.4	5.3	5.3	5.3	5.4	5.0	4.8	4.8	4.9	4.8	5.0
80%, 80%, 80%, 80% ET_o[x]	4.8	4.8	4.4	4.7	4.9	5.4	5.2	5.4	5.5	5.5	5.6	5.6	4.9	4.9	4.7	4.7	4.9	4.9	4.9	5.0	5.1	4.9	5.0
LSD, P=0.05	NS	NS	NS	NS	NS	0.3	NS	NS	NS	NS	NS	NS	0.3	NS	0.2	NS	0.4	NS	0.3	NS	NS	NS	NS
N-fertility rate treatments[w]																							
4.0 lb N/1000 ft^2/year	4.1	4.1	4.0	4.3	4.5	4.8	4.7	5.1	5.3	5.5	5.5	5.3	4.9	4.9	4.9	4.9	5.0	4.9	4.7	4.9	4.9	4.8	4.8
6.0 lb N/1000 ft^2/year	4.7	4.6	4.6	4.7	4.9	5.1	5.1	5.3	5.5	5.7	5.7	5.6	5.1	5.1	5.0	4.9	5.2	4.7	4.5	4.8	4.9	4.8	5.0
7.7 lb N/1000 ft^2/year	4.8	4.9	5.0	5.1	5.3	5.6	5.5	5.8	5.8	6.0	6.1	6.0	5.3	5.2	5.2	5.2	5.3	4.9	4.7	5.0	5.1	5.0	5.3
LSD, P=0.05	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.2
Summary of ANOVA effects[v]																							
Irrigation (I)	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	*	NS	**	NS	*	NS	**	NS	NS	NS	NS
Fertility (F)	***	***	***	***	***	***	***	***	***	***	***	***	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	***
I x F	NS	NS	NS	NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date (D)																							***
D x I																							***
D x F																							***
D x I x F																							NS

[z]Please note that fertility treatments for 1999 were first applied on 5 Mar. 1999; subsequently, ratings taken on or before 5 Mar. 1999 are still influenced by the 1998 fertility treatments (3.0, 4.5, and 6.0 lb N/1000 ft^2 per year instead of 4.0, 6.0, and 7.7 lb N/1000 ft^2 per year, respectively).

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Applied 5 Mar., 14 May, 13 Aug., and 15 Oct. 1999.

[v]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 20. The effect of irrigation-level treatment and N-fertility rate on visual turfgrass quality of tall fescue in 2000 (1 to 9 scale, with 1=worst, 5=minimally acceptable, and 9=best tall fescue).

	Date																									
Treatments	7 Jan.	21 Jan.	4 Feb.	18 Feb.	3 Mar.	17 Mar.	31 Mar.	14 Apr.	28 Apr.	12 May	26 May	9 June	23 June	7 July	21 July	4 Aug.	18 Aug.	1 Sept.	22 Sept.	29 Sept.	13 Oct.	27 Oct.	17 Nov.	1 Dec.	15 Dec.	Overall
Irrigation-level treatments																										
80%, 80%, 80%, 80% hist. ET_o[z]	4.9	5.0	5.2	5.5	5.8	6.0	5.9	5.8	5.5	5.4	5.2	5.0	4.7	4.6	4.7	4.4	4.3	4.6	5.0	5.3	5.4	5.5	5.4	5.5	5.5	5.2
40%, 92%, 91%, 70% hist. ET_o	4.7	4.8	5.1	5.1	5.9	5.9	5.8	5.6	5.6	5.6	5.9	5.8	5.5	5.4	5.3	4.9	4.9	5.2	5.4	5.5	5.6	5.6	5.6	5.5	5.6	5.4
40%, 85%, 97%, 70% hist. ET_o	4.8	4.9	4.9	5.0	5.4	5.6	5.5	5.4	5.4	5.4	5.8	5.6	5.1	5.1	5.2	5.0	5.0	5.0	5.4	5.5	5.6	5.6	5.4	5.4	5.4	5.3
80%, 80%, 80%, 80% ET_o[y]	5.0	5.0	5.1	5.2	5.7	5.9	6.1	5.9	5.3	5.3	5.3	5.1	5.1	5.1	5.0	4.7	4.7	5.0	4.8	5.0	5.1	5.3	5.3	5.4	5.3	5.2
LSD, P=0.05	NS	NS	NS	0.1	0.3	NS	NS	0.3	0.2	0.2	0.4	0.6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[x]																										
4.0 lb N/1000 ft^2/year	4.8	4.8	4.8	4.8	5.3	5.4	5.5	5.3	5.2	5.3	5.2	5.1	5.0	4.9	5.0	4.7	4.6	5.0	5.2	5.3	5.4	5.5	5.4	5.4	5.3	5.1
6.0 lb N/1000 ft^2/year	4.8	4.9	5.0	5.2	5.8	5.8	5.8	5.6	5.4	5.3	5.6	5.3	5.0	5.0	5.1	4.7	4.7	4.9	5.1	5.2	5.3	5.3	5.3	5.3	5.3	5.2
7.7 lb N/1000 ft^2/year	5.0	5.2	5.4	5.6	6.1	6.2	6.2	6.1	5.8	5.6	5.9	5.7	5.3	5.2	5.2	4.8	4.8	5.1	5.2	5.5	5.6	5.7	5.6	5.6	5.7	5.5
LSD, P=0.05	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.3	0.4	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.3	NS	0.3	0.3	0.2
Summary of ANOVA effects[w]																										
Irrigation (I)	NS	NS	NS	***	*	NS	NS	*	*	*	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertility (F)	**	***	***	***	***	***	***	***	***	***	**	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	*	**	***
I x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date (D)																										***
D x I																										***
D x F																										***
D x I x F																										NS

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Applied 3 Mar., 12 May, 11 Aug., and 13 Oct. 2000.

[w]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 21. The effect of irrigation-level treatment and N-fertility rate on visual turfgrass color of tall fescue in 1998 (1 to 9 scale, with 1=brown, 5=minimally acceptable, and 9=darkest green tall fescue).

	Date																			
Treatments	3 Apr.	17 Apr.	1 May	15 May	29 May	12 June	26 June	10 July	24 July	7 Aug.	21 Aug.	4 Sept.	18 Sept.	2 Oct.	16 Oct.	30 Oct.	13 Nov.	11 Dec.	18 Dec.	Overall
Irrigation-level treatments																				
80%, 80%, 80%, 80% hist. ET_o[z]	6.5	6.2	5.2	5.4	5.4	6.0	5.9	5.8	5.4	4.9	5.3	5.1	5.2	5.7	4.9	5.6	5.7	5.2	5.2	5.5
58%, 90%, 90%, 58% hist. ET_o	6.5	6.2	5.2	5.4	5.4	6.0	5.7	5.7	5.7	5.5	5.7	5.6	5.7	5.6	4.6	5.4	5.4	5.1	5.0	5.5
58%, 96%, 85%, 58% hist. ET_o	6.5	6.2	5.1	5.4	5.5	6.0	5.9	5.9	5.6	5.2	5.7	5.6	5.6	5.8	4.6	5.3	5.3	5.0	4.7	5.5
80%, 80%, 80%, 80% ET_o[y]	6.6	6.2	5.0	5.5	5.4	6.2	6.1	6.0	5.8	5.3	5.9	5.8	5.8	5.6	5.2	6.5	5.9	5.5	5.3	5.8
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[x]																				
3.0 lb N/1000 ft^2/year	6.4	6.2	5.1	5.4	5.3	5.8	5.6	5.5	5.5	5.2	5.4	5.3	5.4	5.5	4.7	5.1	5.1	4.7	4.5	5.4
4.5 lb N/1000 ft^2/year	6.6	6.2	5.1	5.4	5.4	6.1	6.0	5.9	5.6	5.1	5.6	5.5	5.5	5.7	4.7	5.9	5.6	5.2	5.0	5.6
6.0 lb N/1000 ft^2/year	6.6	6.3	5.1	5.5	5.5	6.2	6.1	6.1	5.8	5.3	5.9	5.9	5.9	5.8	5.0	6.2	6.0	5.6	5.5	5.8
LSD, P=0.05	NS	NS	NS	NS	0.2	0.2	0.3	0.3	0.2	NS	NS	0.3	0.2	0.1	NS	0.5	0.3	0.3	0.2	0.1
Summary of ANOVA effects[w]																				
Irrigation (I)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertility (F)	NS	NS	NS	NS	*	**	**	**	*	NS	**	**	***	***	NS	**	**	***	***	***
I x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
Date (D)																				***
D x I																				***
D x F																				***
D x I x F																				NS

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Applied 10 Mar., 18 May, 14 Aug., and 16-17 Oct 1998.

[w]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 22. The effect of irrigation-level treatment and N-fertility rate on visual turfgrass color of tall fescue in 1999 (1 to 9 scale, with 1=brown, 5=minimally acceptable, and 9=darkest green tall fescue).

Treatments	Date																						
	8 Jan.[z]	22 Jan.[z]	5 Feb.[z]	19 Feb.[z]	5 Mar.[z]	19 Mar.	2 Apr.	16 Apr.	14 May	28 May	11 June	25 June	23 July	6 Aug.	20 Aug.	3 Sept.	17 Sept.	15 Oct.	29 Oct.	12 Nov.	3 Dec.	17 Dec.	Overall
Irrigation-level treatments																							
80%, 80%, 80%, 80% hist. ET_o[y]	4.9	4.8	4.9	5.0	5.1	5.3	5.5	5.7	5.7	5.9	5.8	5.7	5.0	4.9	5.0	4.9	5.1	4.6	4.4	4.6	4.7	4.7	5.1
40%, 92%, 91%, 70% hist. ET_o	4.4	4.3	4.7	4.8	5.0	5.3	5.0	5.3	5.6	5.8	5.8	5.7	5.4	5.3	5.1	5.2	5.4	4.9	4.4	4.8	5.1	4.8	5.1
40%, 85%, 97%, 70% hist. ET_o	4.4	4.2	4.7	4.8	4.8	4.9	5.2	5.5	5.5	5.9	5.9	5.7	5.4	5.4	5.3	5.5	5.6	5.1	4.9	4.9	5.0	4.8	5.2
80%, 80%, 80%, 80% ET_o[x]	4.9	4.9	4.5	4.9	5.0	5.3	5.1	5.5	5.5	5.6	5.6	5.6	4.9	4.9	4.7	4.6	4.9	4.9	4.9	5.1	5.2	5.1	5.1
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	0.3	NS	NS	NS	NS	0.4	0.3	0.2	0.5	0.4	NS	0.3	NS	NS	NS	NS
N-fertility rate treatments[w]																							
4.0 lb N/1000 ft^2/year	4.1	4.0	4.1	4.4	4.6	4.8	4.7	5.1	5.2	5.4	5.3	5.2	4.9	4.9	4.8	4.9	5.0	4.9	4.8	4.8	4.8	4.7	4.8
6.0 lb N/1000 ft^2/year	4.9	4.6	4.8	4.9	5.0	5.2	5.2	5.5	5.6	5.8	5.8	5.7	5.3	5.1	5.0	4.9	5.2	4.8	4.5	4.8	5.0	4.8	5.1
7.7 lb N/1000 ft^2/year	5.0	5.0	5.2	5.3	5.4	5.6	5.7	5.9	5.9	6.2	6.2	6.2	5.4	5.3	5.3	5.3	5.5	4.9	4.7	5.0	5.2	5.0	5.4
LSD, P=0.05	0.4	0.3	0.4	0.3	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.2	NS	NS	0.4	0.4	0.2	NS	NS	NS	0.2	0.1	0.1
Summary of ANOVA effects[v]																							
Irrigation (I)	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	*	**	**	*	*	NS	**	NS	NS	NS	NS
Fertility (F)	***	***	***	***	***	***	***	***	***	***	***	***	NS	NS	*	*	**	NS	NS	NS	**	***	***
I x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date (D)																							***
D x I																							***
D x F																							***
D x I x F																							NS

[z]Please note that fertility treatments for 1999 were first applied on 5 Mar. 1999; subsequently, ratings taken on or before 5 Mar. 1999 are still influenced by the 1998 fertility treatments (3.0, 4.5, and 6.0 lb N/1000 ft^2 per year instead of 4.0, 6.0, and 7.7 lb N/1000 ft^2 per year, respectively).

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Applied 5 Mar., 14 May, 13 Aug., and 15 Oct. 1999.

[v]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 23. The effect of irrigation-level treatment and N-fertility rate on visual turfgrass color of tall fescue in 2000 (1 to 9 scale, with 1=brown, 5=minimally acceptable, and 9=darkest green tall fescue).

	Date																									
Treatments	7 Jan.	21 Jan.	4 Feb.	18 Feb.	3 Mar.	17 Mar.	31 Mar.	14 Apr.	28 Apr.	12 May	26 May	9 June	23 June	7 July	21 July	4 Aug.	18 Aug.	1 Sept.	22 Sept.	29 Sept.	13 Oct.	27 Oct.	17 Nov.	1 Dec.	15 Dec.	Overall
Irrigation-level treatments																										
80%, 80%, 80%, 80% hist. ET_o[z]	4.9	5.1	5.3	5.6	6.0	6.1	6.1	5.9	5.6	5.4	5.4	5.1	4.8	4.7	4.8	4.5	4.4	4.8	5.3	5.5	5.7	5.7	5.6	5.7	5.6	5.3
40%, 92%, 91%, 70% hist. ET_o	4.8	4.9	5.1	5.2	5.9	6.0	5.9	5.8	5.9	5.6	6.0	5.9	5.6	5.4	5.4	5.1	5.0	5.3	5.6	5.7	5.6	5.7	5.6	5.6	5.6	5.5
40%, 85%, 97%, 70% hist. ET_o	4.8	4.9	5.0	5.1	5.4	5.7	5.7	5.4	5.6	5.5	5.9	5.7	5.2	5.2	5.4	5.2	5.1	5.2	5.7	5.7	5.8	5.8	5.6	5.6	5.5	5.4
80%, 80%, 80%, 80% ET_o[y]	5.1	5.2	5.3	5.3	5.9	6.1	6.2	5.9	5.5	5.3	5.4	5.3	5.2	5.2	5.1	4.7	4.7	5.2	5.1	5.2	5.4	5.6	5.6	5.6	5.6	5.4
LSD, P=0.05	NS	NS	NS	0.2	0.1	0.2	NS	NS	NS	NS	0.5	0.6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[x]																										
4.0 lb N/1000 ft^2/year	4.7	4.8	4.8	4.8	5.4	5.5	5.6	5.4	5.3	5.3	5.3	5.2	5.0	5.0	5.0	4.7	4.7	5.1	5.4	5.5	5.6	5.7	5.5	5.5	5.3	5.2
6.0 lb N/1000 ft^2/year	4.9	5.1	5.2	5.3	5.9	6.1	6.0	5.8	5.7	5.4	5.7	5.5	5.2	5.1	5.2	4.9	4.8	5.1	5.3	5.4	5.5	5.6	5.5	5.5	5.5	5.4
7.7 lb N/1000 ft^2/year	5.1	5.3	5.6	5.7	6.1	6.3	6.3	6.1	6.0	5.6	6.1	5.9	5.5	5.4	5.4	5.0	4.8	5.2	5.5	5.6	5.8	5.9	5.8	5.8	5.9	5.7
LSD, P=0.05	0.1	0.2	0.3	0.3	0.2	0.3	0.4	0.3	0.2	0.1	0.4	0.4	NS	NS	NS	NS	NS	NS	NS	NS	0.2	0.2	0.2	0.2	0.2	0.1
Summary of ANOVA effects[w]																										
Irrigation (I)	NS	NS	NS	**	***	*	NS	NS	NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertility (F)	***	***	***	***	***	***	***	***	***	***	**	**	NS	NS	NS	NS	NS	NS	NS	NS	**	**	**	**	**	***
I x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date (D)																										***
D x I																										***
D x F																										***
D x I x F																										NS

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Applied 3 Mar., 12 May, 11 Aug., and 13 Oct. 2000.

[w]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 24. The effect of irrigation-level treatment and N-fertility rate treatment on clipping yield [g dry clippings/2.7 m^2 (28.9 ft^2) per 7 d growth] in 1998.

	4-week growth period[z]																			
	3 Apr. to 1 May					12 June to 10 July					11 Sept. to 9 Oct.					13 Nov. to 11 Dec.				
	Sample date				4-week total yield	Sample date				4-week total yield[y]	Sample date				4-week total yield	Sample date				4-week total yield
Treatments	10 Apr.	17 Apr.	24 Apr.	1 May		19 June	26 June	3 July	10 July		18 Sept.	25 Sept.	2 Oct.	9 Oct.		20 Nov.	27 Nov.	4 Dec.	11 Dec.	
Irrigation-level treatments																				
80%, 80%, 80%, 80% hist. ET_o[x]	69.31	44.18	46.19	33.86	193.54	48.92	29.86	21.51	22.56	122.85	37.67	28.76	29.96	20.38	116.77	15.42	9.68	6.54	3.17	34.81
58%, 90%, 90%, 58% hist. ET_o	73.21	46.08	46.91	36.33	202.53	53.67	42.18	25.05	28.99	148.89	48.22	38.53	32.86	21.79	141.39	16.29	10.74	8.79	3.91	39.72
58%, 96%, 85%, 58% hist. ET_o	73.11	44.13	51.44	37.98	206.67	42.62	33.05	20.47	23.63	119.77	46.95	34.90	28.06	18.65	128.56	15.50	8.59	7.82	4.37	36.28
80%, 80%, 80%, 80% ET_o[w]	69.07	44.75	36.66	31.09	181.57	45.61	27.92	19.79	21.24	114.56	45.64	36.23	30.67	23.44	135.98	15.90	10.79	9.06	3.17	38.92
LSD, P=0.05	NS	NS	NS	NS	NS	NS	9.16	NS	NS	NS	NS	5.67	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[v]																				
3.0 lb N/1000 ft^2/year	64.30	41.25	44.40	31.54	181.49	40.68	27.76	20.43	20.74	109.61	37.17	29.64	25.08	17.22	109.12	10.27	7.03	5.41	2.72	25.43
4.5 lb N/1000 ft^2/year	69.76	45.50	43.05	33.76	192.07	45.59	32.07	20.15	24.45	122.27	44.10	34.04	29.73	21.06	128.93	16.58	9.63	7.33	3.40	36.94
6.0 lb N/1000 ft^2/year	79.84	47.73	48.27	39.34	215.17	57.82	42.48	25.14	28.49	153.92	53.98	41.31	36.42	25.04	156.75	20.56	13.23	11.72	4.94	50.45
LSD, P=0.05	NS	NS	NS	3.97	12.27	4.02	6.00	NS	4.81	9.31	6.19	3.92	4.81	3.28	14.18	4.25	2.38	1.82	1.19	6.42
Summary of ANOVA effects[u]																				
Irrigation (I)	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Fertility (F)	NS	NS	NS	**	***	***	**	NS	*	***	***	**	**	**	***	***	***	***	**	***
I x F	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS

[z]Clipping yields taken 5 weeks after fertilizer application.

[y]Due to missing data, 4-week total yields may not equal total of weekly yields. Any plot which has missing data in any week has been eliminated from the cumulative yield calculations for that growth period.

[x]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[w]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[v]Applied 10 Mar., 18 May, 14 Aug., and 16-17 Oct 1998.

[u]Split-plot statistical design effects.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 25. The effect of irrigation-level treatment and N-fertility rate treatment on clipping yield [g dry clippings/2.7 m^2 (28.9 ft^2) per 7 d growth] in 1999.

	4-week growth period[z]																			
	9 Apr. to 7 May					11 June to 9 July					10 Sept. to 8 Oct.					12 Nov. to 10 Dec.				
	Sample date				4-week total yield	Sample date				4-week total yield[y]	Sample date				4-week total yield	Sample date				4-week total yield
Treatments	16 Apr.	23 Apr.	30 Apr.	7 May		18 June	25 June	2 July	9 July		17 Sept.	24 Sept.	1 Oct.	8 Oct.		19 Nov.	26 Nov.	3 Dec.	10 Dec.	
Irrigation-level treatments																				
80%, 80%, 80%, 80% hist. ET_o[x]	13.75	31.63	30.44	33.02	108.84	35.63	24.39	19.49	17.30	96.47	27.40	38.84	37.46	30.76	134.46	13.01	7.78	11.43	3.67	35.88
40%, 92%, 91%, 70% hist. ET_o	6.51	20.18	21.42	27.32	75.43	33.07	22.46	22.26	19.95	97.74	31.82	44.99	42.60	35.72	155.12	13.09	9.45	10.46	4.00	37.00
40%, 85%, 97%, 70% hist. ET_o	5.71	17.36	18.35	21.69	63.11	25.58	16.66	16.59	15.10	73.94	36.45	41.58	40.57	33.97	152.57	12.90	8.73	13.80	3.80	39.23
80%, 80%, 80%, 80% ET_o[w]	14.55	33.04	30.76	34.19	112.54	29.79	16.86	17.31	13.80	77.75	23.75	31.76	26.51	22.29	104.30	13.16	8.11	14.62	3.49	39.38
LSD, P=0.05	1.70	8.84	3.04	4.06	14.22	NS	5.71	3.40	NS	16.57	6.11	NS	7.49	7.76	29.23	NS	NS	NS	NS	NS
N-fertility rate treatments[v]																				
4.0 lb N/1000 ft^2/year	6.11	15.30	15.04	17.48	53.94	20.06	13.33	13.19	11.44	58.02	21.42	28.16	28.57	23.73	101.89	8.28	5.44	7.54	2.48	23.74
6.0 lb N/1000 ft^2/year	9.22	23.93	25.16	27.79	86.10	31.15	18.40	17.47	15.16	81.16	30.16	39.53	36.98	31.12	137.79	13.37	8.77	13.05	3.81	39.00
7.7 lb N/1000 ft^2/year	15.06	37.43	35.52	41.90	129.91	41.84	28.05	26.08	23.01	118.98	37.98	50.18	44.81	37.21	170.17	17.47	11.34	17.14	4.93	50.88
LSD, P=0.05	2.61	4.91	4.99	4.36	14.82	4.70	2.66	3.77	3.93	12.04	4.31	5.13	6.24	5.21	16.03	1.70	2.01	2.41	0.86	5.13
Summary of ANOVA effects[u]																				
Irrigation (I)	***	**	***	***	***	NS	*	*	NS	*	**	NS	**	*	*	NS	NS	NS	NS	NS
Fertility (F)	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
I x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Clipping yields taken 5 weeks after fertilizer application except for the 9 Apr. to 17 May period, which was taken 6 weeks after fertilizer application.

[y]Due to missing data, 4-week total yields may not equal total of weekly yields. Any plot which has missing data in any week has been eliminated from the cumulative yield calculations for that growth period.

[x]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[w]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[v]Applied 5 Mar., 14 May, 13 Aug., and 15 Oct. 1999.

[u]Split-plot statistical design effects.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 26. The effect of irrigation-level treatment and N-fertility rate treatment on clipping yield [g dry clippings/2.7 m^2 (28.9 ft^2) per 7 d growth] in 2000.

	4-week growth period[z]																				
	31 Mar. to 28 Apr.					9 June to 7 July					8 Sept. to 6 Oct.					10 Nov. to 8 Dec.				
	Sample date				4-week total yield	Sample date				4-week total yield	Sample date				4-week total yield	Sample date				4-week total yield
Treatments	7 Apr.	14 Apr.	21 Apr.	28 Apr.		16 June	23 June	30 June	7 July		15 Sept.	22 Sept.	29 Sept.	6 Oct.		17 Nov.	24 Nov.	1 Dec.	8 Dec.	
Irrigation-level treatments																				
80%, 80%, 80%, 80% hist. ET_o[y]	27.42	25.20	25.71	37.46	115.79	11.60	8.77	8.09	5.94	34.40	30.79	27.49	37.28	55.18	150.75	12.59	6.32	6.23	3.84	28.99
40%, 92%, 91%, 70% hist. ET_o	17.00	17.38	24.08	39.21	97.67	17.86	15.18	14.37	12.20	59.61	35.30	30.98	44.60	48.25	159.13	11.95	7.11	7.74	4.47	31.28
40%, 85%, 97%, 70% hist. ET_o	15.49	17.62	20.30	34.75	88.17	13.73	10.71	11.06	10.24	45.74	34.85	30.12	44.07	57.89	166.93	13.40	6.84	6.29	4.61	31.14
80%, 80%, 80%, 80% ET_o[x]	28.58	23.11	25.78	35.67	113.15	11.54	10.16	9.80	7.50	39.00	19.98	20.48	32.44	45.89	118.78	10.95	5.64	5.34	3.06	25.00
LSD, P=0.05	3.93	4.82	4.00	NS	13.20	NS	4.19	NS	NS	NS	6.46	6.29	8.71	NS	28.49	NS	NS	1.24	NS	3.61
N-fertility rate treatments[w]																				
4.0 lb N/1000 ft^2/year	14.75	12.65	14.30	21.52	63.23	9.71	8.44	7.69	6.49	32.34	22.66	21.90	27.89	41.81	114.27	8.28	5.13	4.77	2.62	20.80
6.0 lb N/1000 ft^2/year	22.59	20.70	25.92	39.08	108.29	13.09	11.40	10.09	8.30	42.88	31.37	28.01	42.41	50.84	152.62	13.17	6.54	6.35	4.34	30.40
7.7 lb N/1000 ft^2/year	29.03	29.13	31.68	49.72	139.56	18.24	13.78	14.71	12.11	58.84	36.66	31.89	48.50	62.74	179.79	15.23	7.76	8.09	5.04	36.11
LSD, P=0.05	2.24	4.02	3.51	5.60	12.79	4.33	3.73	3.72	3.73	13.37	4.83	5.43	5.99	6.50	19.68	2.59	1.55	1.42	0.90	5.36
Summary of ANOVA effects[v]																				
Irrigation (I)	***	*	*	NS	**	NS	*	NS	NS	NS	**	*	*	NS	*	NS	NS	*	NS	*
Fertility (F)	***	***	***	***	***	**	*	**	*	**	***	**	***	***	***	***	**	***	***	***
I x F	***	NS	NS	NS	NS	NS	*	*	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Clipping yields taken 5 weeks after fertilizer application.

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Applied 3 Mar., 12 May, 11 Aug., and 13 Oct. 2000.

[v]Split-plot statistical design effects.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 27. The effect of irrigation-level treatment and N-fertility rate treatment on 4-week total clipping yield [g dry clippings/2.7 m^2 (28.9 ft^2) per 7 d growth for consecutive 4-week periods] and N uptake [g N/2.7 m^2 (28.9 ft^2) per 7 d of growth for consecutive 4-week periods] in 1998.

	4-week growth period[z]							
	3 Apr. to 1 May		12 June to 10 July		11 Sept. to 9 Oct.		13 Nov. to 11 Dec.	
Treatments	4-week total yield	N uptake[y]	4-week total yield	N uptake[y]	4-week total yield	N uptake[y]	4-week total yield	N uptake[y]
Irrigation-level treatments								
80%, 80%, 80%, 80% hist. ET_o[x]	193.54	5.08	122.85	2.00	116.77	2.69	34.81	1.05
58%, 90%, 90%, 58% hist. ET_o	202.53	4.91	149.89	2.82	141.39	3.35	39.72	1.20
58%, 96%, 85%, 58% hist. ET_o	206.67	4.32	119.77	2.19	128.56	3.12	36.28	1.03
80% 80%, 80%, 80% ET_o[w]	181.57	4.86	114.56	1.97	135.98	3.12	38.92	1.18
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments								
3.0 lb N/1000 ft^2/year	181.49	4.74	109.61	1.99	109.12	2.63	25.43	0.66
4.5 lb N/1000 ft^2/year	192.07	4.43	122.27	1.98	128.93	3.09	36.94	1.07
6.0 lb N/1000 ft^2/year	215.17	5.16	153.92	2.91	156.75	3.56	50.45	1.62
LSD, P=0.05	12.27	NS	9.31	0.36	14.18	NS	6.42	0.26
Summary of ANOVA effects[v]								
Irrigation (I)	NS	NS	NS	NS	NS	NS	NS	NS
Fertility (F)	***	NS	***	**	***	NS	***	***
I x F	NS	NS	NS	NS	NS	NS	NS	NS

[z]Clipping yields taken 5 weeks after fertilizer application.

[y]Calculated as 4-week total yield mass x TKN concentration of pooled 4-week total yield mass.

[x]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[w]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[v]Split-plot statistical design effects.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 28. The effect of irrigation-level treatment and N-fertility rate treatment on 4-week total clipping yield [g dry clippings/2.7 m^2 (28.9 ft^2) per 7 d growth for consecutive 4-week periods] and N uptake [g N/2.7 m^2 (28.9 ft^2) per 7 d of growth for consecutive 4-week periods] in 1999.

	4-week growth period[z]							
	9 Apr. to 7 May		11 June to 9 July		10 Sept. to 8 Oct.		12 Nov. to 10 Dec.	
Treatments	4-week total yield	N uptake[y]	4-week total yield	N uptake[y]	4-week total yield	N uptake[y]	4-week total yield	N uptake[y]
Irrigation-level treatments								
80%, 80%, 80%, 80% hist. ET_o[x]	108.84	2.52	96.47	1.78	134.46	3.94	35.88	0.70
40%, 92%, 91%, 70% hist. ET_o	75.43	1.94	97.74	1.50	155.12	4.12	37.00	0.66
40%, 85%, 97%, 70% hist. ET_o	63.11	1.53	73.94	1.09	152.57	4.35	39.23	0.80
80% 80%, 80%, 80% ET_o[w]	112.54	2.80	77.75	1.72	104.30	2.70	39.38	0.85
LSD, P=0.05	14.22	0.46	16.57	0.21	29.23	0.90	NS	NS
N-fertility rate treatments								
4.0 lb N/1000 ft^2/year	53.94	1.19	58.02	0.89	101.89	2.77	23.74	0.43
6.0 lb N/1000 ft^2/year	86.10	2.23	81.16	1.37	137.79	3.58	39.00	0.81
7.7 lb N/1000 ft^2/year	129.91	3.16	118.98	2.31	170.17	4.97	50.88	1.00
LSD, P=0.05	14.82	0.51	12.04	0.29	16.03	0.84	5.13	0.19
Summary of ANOVA effects[v]								
Irrigation (I)	***	**	*	***	*	*	NS	NS
Fertility (F)	***	***	***	***	***	***	***	***
I x F	NS	NS	NS	NS	NS	NS	NS	NS

[z]Clipping yields taken 5 weeks after fertilizer application except for the 9 Apr. to 17 May period, which was taken 6 weeks after fertilizer application.

[y]Calculated as 4-week total yield mass x TKN concentration of pooled 4-week total yield mass.

[x]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[w]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[v]Split-plot statistical design effects.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 29. The effect of irrigation-level treatment and N-fertility rate treatment on 4-week total clipping yield [g dry clippings/2.7 m^2 (28.9 ft^2) per 7 d growth for consecutive 4-week periods] and N uptake [g N/2.7 m^2 (28.9 ft^2) per 7 d of growth for consecutive 4-week periods] in 2000.

	4-week growth period[z]							
	31 Mar. To 28 Apr.		9 June to 7 July		8 Sept. to 6 Oct.		10 Nov. to 8 Dec.	
Treatments	4-week total yield	N uptake[y]	4-week total yield	N uptake[y]	4-week total yield	N uptake[y]	4-week total yield	N uptake[y]
Irrigation-level treatments								
80%, 80%, 80%, 80% hist. ET_o[x]	115.79	3.73	34.40	0.74	150.75	5.04	28.99	0.77
40%, 92%, 91%, 70% hist. ET_o	97.67	3.13	59.61	1.34	159.13	5.32	31.28	0.87
40%, 85%, 97%, 70% hist. ET_o	88.17	2.92	45.74	1.05	166.93	4.85	31.14	0.89
80%, 80%, 80%, 80% ET_o[w]	113.15	3.98	39.00	0.94	118.78	3.84	25.00	0.66
LSD, P=0.05	13.20	0.76	NS	NS	28.49	NS	3.61	NS
N-fertility rate treatments								
4.0 lb N/1000 ft^2/year	63.23	1.87	32.34	0.64	114.27	3.50	20.80	0.50
6.0 lb N/1000 ft^2/year	108.29	3.62	42.88	0.92	152.62	4.87	30.40	0.84
7.7 lb N/1000 ft^2/year	139.56	4.83	58.84	1.48	179.79	5.93	36.11	1.05
LSD, P=0.05	12.79	0.64	13.37	0.45	19.68	0.73	5.36	0.18
Summary of ANOVA effects[v]								
Irrigation (I)	**	*	NS	NS	*	NS	*	NS
Fertility (F)	***	***	**	**	***	***	***	***
I x F	NS	NS	*	NS	NS	NS	NS	NS

[z]Clipping yields taken 5 weeks after fertilizer application.

[y]Calculated as 4-week total yield mass x TKN concentration of pooled 4-week total yield mass.

[x]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[w]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[v]Split-plot statistical design effects.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 30. The effect of irrigation-level treatment and N-fertility rate treatment on percent leaves rolled and/or wilted in 1998.

	Date								
Treatments	17 Apr.	12 June	24 July	28 Aug.	18 Sept.	6 Nov.	24 Nov.	15 Dec.	Overall
Irrigation-level treatments									
80%, 80%, 80%, 80% hist. ET_o[z]	0	0	7	39	12	23	15	17	14
58%, 90%, 90%, 58% hist. ET_o	0	0	1	5	6	9	15	42	10
58%, 96%, 85%, 58% hist. ET_o	0	0	11	30	4	29	31	69	22
80%, 80%, 80%, 80% ET_o[y]	0	0	4	16	4	1	1	11	5
LSD, P=0.05	.	.	NS	NS	NS	NS	NS	18	NS
N-fertility rate treatments[x]									
3.0 lb N/1000 ft^2/year	0	0	6	16	4	14	17	43	13
4.5 lb N/1000 ft^2/year	0	0	5	29	6	13	12	32	12
6.0 lb N/1000 ft^2/year	0	0	4	18	7	17	16	33	12
LSD, P=0.05	.	.	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[w]									
Irrigation (I)	.	.	NS	NS	NS	NS	NS	***	NS
Fertility (F)	.	.	NS	NS	NS	NS	NS	NS	NS
I x F	.	.	NS	NS	NS	NS	NS	NS	NS
Date (D)									**
D x I									***
D x F									NS
D x I x F									NS

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Applied 10 Mar., 18 May, 14 Aug., and 16-17 Oct 1998.

[w]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 31. The effect of irrigation-level treatment and N-fertility rate treatment on percent leaves rolled and/or wilted in 1999.

Treatments	Date										Overall
	22 Jan.[z]	19 Feb.[z]	19 Mar.	28 May	25 June	30 July	20 Aug.	24 Sept.	12 Nov.	17 Dec.	
Irrigation-level treatments											
80%, 80%, 80%, 80% hist. ET_o[y]	29	0	0	0	4	34	31	4	41	39	18
40%, 92%, 91%, 70% hist. ET_o	34	0	0	0	3	17	25	1	41	40	16
40%, 85%, 97%, 70% hist. ET_o	46	0	6	0	11	18	18	2	22	37	16
80%, 80%, 80%, 80% ET_o[x]	14	0	0	0	15	44	62	24	18	32	21
LSD, P=0.05	12	.	NS	.	NS	20	30	14	NS	NS	NS
N-fertility rate treatments[w]											
4.0 lb N/1000 ft^2/year	38	0	3	0	10	28	35	9	29	32	18
6.0 lb N/1000 ft^2/year	31	0	1	0	10	25	35	6	35	42	19
7.7 lb N/1000 ft^2/year	23	0	0	0	5	32	31	8	27	37	16
LSD, P=0.05	6	.	NS	.	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]											
Irrigation (I)	**	.	NS	.	NS	*	*	*	NS	NS	NS
Fertility (F)	***	.	NS	.	NS	NS	NS	NS	NS	NS	NS
I x F	*	.	NS	.	NS	NS	NS	NS	NS	NS	NS
Date (D)											***
D x I											***
D x F											NS
D x I x F											NS

[z]Please note that fertility treatments for 1999 were first applied on 5 Mar. 1999; subsequently, ratings taken on or before 5 Mar. 1999 are still influenced by the 1998 fertility treatments (3.0, 4.5, and 6.0 lb N/1000 ft^2 per year instead of 4.0, 6.0, and 7.7 lb N/1000 ft^2 per year, respectively).

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Applied 5 Mar., 14 May, 13 Aug., and 15 Oct. 1999.

[x]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 32. The effect of irrigation-level treatment and N-fertility rate treatment on percent leaves rolled and/or wilted in 2000.

	Date											
Treatments	21 Jan.	25 Feb.	17 Mar.	12 May	2 June	23 June	21 July	1 Sept.	29 Sept.	27 Oct.	22 Dec.	Overall
Irrigation-level treatments												
80%, 80%, 80%, 80% hist. ET_o[z]	4	0	0	13	38	72	63	0.4	0	0	1	17
40%, 92%, 91%, 70% hist. ET_o	16	0	0	4	27	40	41	2	0	0	3	12
40%, 85%, 97%, 70% hist. ET_o	11	0	0	10	27	58	28	2	0	0	1	12
80%, 80%, 80%, 80% ET_o[y]	7	0	0	16	33	58	57	2	0	0	7	16
LSD, P=0.05	6	0	0	NS	NS	NS	NS	NS	0	0	NS	NS
N-fertility rate treatments[x]												
4.0 lb N/1000 ft^2/year	10	0	0	14	35	59	49	1	0	0	3	16
6.0 lb N/1000 ft^2/year	11	0	0	10	33	61	47	2	0	0	4	15
7.7 lb N/1000 ft^2/year	7	0	0	8	25	50	45	2	0	0	2	13
LSD, P=0.05	4	0	0	NS	NS	NS	NS	NS	0	0	NS	NS
Summary of ANOVA effects[w]												
Irrigation (I)	*	.	.	NS	NS	NS	NS	NS	.	.	NS	NS
Fertility (F)	*	.	.	NS	NS	NS	NS	NS	.	.	NS	NS
I x F	NS	.	.	NS	NS	NS	NS	NS	.	.	NS	NS
Date (D)												***
D x I												***
D x F												NS
D x I x F												NS

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Applied 3 Mar., 12 May, 11 Aug., and 13 Oct. 2000.

[w]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

NS, *, **, ***Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 33. The effect of irrigation-level treatment and N-fertility rate treatment on percent brown leaves in 1998.

Treatments	Date 17 Apr.	12 June	24 July	28 Aug.	18 Sept.	6 Nov.	24 Nov.	15 Dec.	Overall
Irrigation-level treatments									
80%, 80%, 80%, 80% hist. ET_o[z]	0	0	7	27	6	11	5	2	7
58%, 90%, 90%, 58% hist. ET_o	0	0	1	2	1	3	6	2	2
58%, 96%, 85%, 58% hist. ET_o	0	0	11	20	2	21	21	19	12
80%, 80%, 80%, 80% ET_o[y]	0	0	4	6	1	0	0	0	1
LSD, P=0.05	.	.	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[x]									
3.0 lb N/1000 ft^2/year	0	0	6	9	2	10	11	10	6
4.5 lb N/1000 ft^2/year	0	0	5	18	3	9	7	6	6
6.0 lb N/1000 ft^2/year	0	0	5	10	2	7	6	1	4
LSD, P=0.05	.	.	NS	NS	NS	NS	NS	3	NS
Summary of ANOVA effects[w]									
Irrigation (I)	.	.	NS	NS	NS	NS	NS	NS	NS
Fertility (F)	.	.	NS	NS	NS	NS	NS	*	NS
I x F	.	.	NS	NS	NS	NS	NS	*	NS
Date (D)									NS
D x I									***
D x F									NS
D x I x F									NS

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Applied 10 Mar., 18 May, 14 Aug., and 16-17 Oct 1998.

[w]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

NS, *, **, ***Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 34. The effect of irrigation-level treatment and N-fertility rate treatment on percent brown leaves in 1999.

Treatments	Date										Overall
	22 Jan.[z]	19 Feb.[z]	19 Mar.	28 May	25 June	30 July	20 Aug.	24 Sept.	12 Nov.	17 Dec.	
Irrigation-level treatments											
80%, 80%, 80%, 80% hist. ET_o[y]	31	0	0	0	1	21	16	0	16	14	10
40%, 92%, 91%, 70% hist. ET_o	34	0	0	0	1	7	10	0	18	17	9
40%, 85%, 97%, 70% hist. ET_o	49	0	1	0	2	10	7	1	7	14	9
80%, 80%, 80%, 80% ET_o[x]	30	0	0	0	3	20	27	8	4	13	10
LSD, P=0.05	11	.	NS	.	NS	NS	NS	6	NS	NS	NS
N-fertility rate treatments[w]											
4.0 lb N/1000 ft²/year	43	0	0.4	0	3	15	15	2	10	15	10
6.0 lb N/1000 ft²/year	37	0	0	0	2	11	15	2	15	16	10
7.7 lb N/1000 ft²/year	27	0	0	0	1	18	15	3	10	12	9
LSD, P=0.05	5	.	NS	.	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[v]											
Irrigation (I)	*	.	NS	.	NS	NS	NS	*	NS	NS	NS
Fertility (F)	***	.	NS	.	NS	NS	NS	NS	NS	NS	NS
I x F	NS	.	NS	.	NS	NS	NS	NS	NS	NS	NS
Date (D)											***
D x I											***
D x F											NS
D x I x F											NS

[z]Please note that fertility treatments for 1999 were first applied on 5 Mar. 1999; subsequently, ratings taken on or before 5 Mar. 1999 are still influenced by the 1998 fertility treatments (3.0, 4.5, and 6.0 lb N/1000 ft² per year instead of 4.0, 6.0, and 7.7 lb N/1000 ft² per year, respectively).

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Applied 5 Mar., 14 May, 13 Aug., and 15 Oct. 1999.

[x]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 35. The effect of irrigation-level treatment and N-fertility rate treatment on percent brown leaves in 2000.

	Date											
Treatments	21 Jan.	25 Feb.	17 Mar.	12 May	2 June	23 June	21 July	1 Sept.	29 Sept.	27 Oct.	22 Dec.	Overall
Irrigation-level treatments												
80%, 80%, 80%, 80% hist. ET_o[z]	1	0	0	3	16	47	33	15	7	3	1	11
40%, 92%, 91%, 70% hist. ET_o	4	0	0	0.3	9	24	24	9	5	3	1	7
40%, 85%, 97%, 70% hist. ET_o	3	0	0	4	10	37	11	7	5	2	1	7
80%, 80%, 80%, 80% ET_o[y]	1	0	0	2	12	24	30	9	13	8	2	9
LSD, P=0.05	NS	.	.	NS	NS	NS	NS	NS	NS	NS	NS	NS
N-fertility rate treatments[x]												
4.0 lb N/1000 ft^2/year	3	0	0	3	14	35	25	10	8	5	1	9
6.0 lb N/1000 ft^2/year	2	0	0	1	12	34	27	10	8	4	2	9
7.7 lb N/1000 ft^2/year	1	0	0	2	9	30	22	9	6	2	1	7
LSD, P=0.05	NS	.	.	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[w]												
Irrigation (I)	NS	.	.	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertility (F)	NS	.	.	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x F	NS	.	.	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date (D)												***
D x I												***
D x F												NS
D x I x F												NS

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Applied 3 Mar., 12 May, 11 Aug., and 13 Oct. 2000.

[w]Split-plot statistical design effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 36. The effect of irrigation level treatment and N-fertility rate treatment on TKN, NH_4-N, and NO_3-N, of soil at the 0- to 10-cm (0- to 4-inch) depth root zone sampled Oct. 1998, 1999, and 2000.

	Year								
	1998			1999			2000		
Treatments	TKN[z]	NH_4-N[z]	NO_3-N[z]	TKN	NH_4-N	NO_3-N	TKN	NH_4-N	NO_3-N
	ppm								
Irrigation-level treatments									
80%, 80%, 80%, 80% hist. ET_o[y]	1000	6.4	1.3	740	7.5	1.6	690	7.0	1.4
58%, 90%, 90%, 58% hist. ET_o (1998) 40%, 92%, 91%, 70% hist. ET_o (1999-2000)	950	6.4	1.3	910	17.3	3.0	720	13.5	1.8
58%, 96%, 85%, 58% hist. ET_o (1998) 40%, 85%, 97%, 70% hist. ET_o (1999-2000)	990	6.5	1.4	680	6.4	1.1	650	5.5	1.1
80%, 80%, 80%, 80% ET_o[x]	1000	7.0	1.5	650	12.4	2.1	670	10.9	1.8
LSD, P=0.05	NS	NS	NS	NS	5.5	1.0	NS	NS	NS
N-fertility rate treatments									
3.0 lb N/1000 ft^2/year (1998) 4.0 lb N/1000 ft^2/year (1999-2000)	980	6.6	1.4	760	11.1	1.9	620	10.4	1.2
4.5 lb N/1000 ft^2/year (1998) 6.0 lb N/1000 ft^2/year (1999-2000)	1000	6.5	1.5	750	12.2	2.1	660	8.5	1.4
6.0 lb N/1000 ft^2/year (1998) 7.7 lb N/1000 ft^2/year (1999-2000)	980	6.7	1.3	720	9.5	1.9	760	8.7	2.0
LSD, P=0.05	NS	NS	NS	NS	NS	NS	110	NS	0.6
Summary of ANOVA effects[w]									
Irrigation (I)	NS	NS	NS	NS	**	*	NS	NS	NS
Fertility (F)	NS	NS	NS	NS	NS	NS	*	NS	*
I x F	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]TKN, NH_4-N and NO_3-N determined according to relevant DANR analytical methodologies (Table A-3 in Appendix A).

[y]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of California, Division of Agricultural and Natural Resources. Publ. 21454 (see p.62).

[x]Real-time ET_o based on 7-day cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[w]Split-plot statistical design effects.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 37. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 23-cm (9-inch) depth in 1998.

Treatments	Date								Overall
	21 Apr.	21 May	23 June	24 July	18 Aug.	22 Sept.	20 Oct.	25 Nov.	
Irrigation-level treatments	-------	-------	-------	-------	*cm³ H₂O/cm³ soil x 100*	-------	-------	-------	-------
80%, 80%, 80%, 80% hist. ET_o[z]	18.8	18.1	15.0	10.3	10.1	10.8	9.7	8.2	12.6
58%, 90%, 90%, 58% hist. ET_o	17.8	18.0	16.9	17.5	17.9	18.5	9.2	8.8	15.5
58%, 96%, 85%, 58% hist. ET_o	20.2	20.3	16.3	17.1	17.4	18.3	12.0	9.5	16.4
80%, 80%, 80%, 80% ET_o[y]	13.9	16.7	14.8	12.0	15.1	15.1	15.4	15.6	14.8
LSD, P=0.05	2.1	1.6	NS	5.3	5.2	5.5	NS	4.1	2.5
Summary of ANOVA effects[x]									
Irrigation (I)	**	**	NS	*	*	*	NS	**	*
Date (D)									***
D x I									***

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 38. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 30-cm (12-inch) depth in 1998.

Treatments	Date								Overall
	21 Apr.	21 May	23 June	24 July	18 Aug.	22 Sept.	20 Oct.	25 Nov.	
Irrigation-level treatments	-------	-------	-------	-------	*cm³ H₂O/cm³ soil x 100*	-------	-------	-------	-------
80%, 80%, 80%, 80% hist. ET_o[z]	19.3	19.1	14.9	10.6	9.9	10.4	10.5	9.0	13.0
58%, 90%, 90%, 58% hist. ET_o	18.7	18.8	17.4	17.7	18.7	18.0	12.8	10.7	16.6
58%, 96%, 85%, 58% hist. ET_o	21.1	21.5	17.1	17.3	17.2	18.3	14.2	11.4	17.3
80%, 80%, 80%, 80% ET_o[y]	14.5	18.2	15.4	12.9	15.6	15.7	16.1	15.8	15.5
LSD, P=0.05	2.1	1.8	NS	5.0	5.6	NS	NS	NS	NS
Summary of ANOVA effects[x]									
Irrigation (I)	***	*	NS	*	*	NS	NS	NS	NS
Date (D)									***
D x I									*

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 39. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 46-cm (18-inch) depth in 1998.

Treatments	Date								Overall
	21 Apr.	21 May	23 June	24 July	18 Aug.	22 Sept.	20 Oct.	25 Nov.	
Irrigation-level treatments	---------- *cm^3 H_2O/cm^3 soil x 100* ----------								
80%, 80%, 80%, 80% hist. ET_o[z]	20.7	21.5	17.1	13.1	11.9	11.5	13.1	11.5	15.1
58%, 90%, 90%, 58% hist. ET_o	20.2	20.3	18.2	17.8	19.8	20.3	17.9	14.9	18.7
58%, 96%, 85%, 58% hist. ET_o	22.1	22.6	18.7	18.6	17.4	18.5	15.6	14.5	18.5
80%, 80%, 80%, 80% ET_o[y]	18.0	20.4	16.8	13.9	16.5	16.8	17.1	17.1	17.1
LSD, P=0.05	2.3	NS	NS	NS	4.7	4.7	NS	NS	NS
Summary of ANOVA effects[x]									
Irrigation (I)	*	NS	NS	NS	*	*	NS	NS	NS
Date (D)									***
D x I									**

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 40. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 61-cm (24-inch) depth in 1998.

Treatments	Date								Overall
	21 Apr.	21 May	23 June	24 July	18 Aug.	22 Sept.	20 Oct.	25 Nov.	
Irrigation-level treatments	---------- *cm^3 H_2O/cm^3 soil x 100* ----------								
80%, 80%, 80%, 80% hist. ET_o[z]	20.5	21.1	16.9	14.4	12.6	11.7	12.8	11.8	15.2
58%, 90%, 90%, 58% hist. ET_o	19.6	20.7	18.3	17.3	19.0	19.7	18.6	16.4	18.7
58%, 96%, 85%, 58% hist. ET_o	21.4	22.2	18.1	18.7	17.7	17.2	16.2	15.4	18.4
80%, 80%, 80%, 80% ET_o[y]	18.9	19.6	17.3	13.9	15.1	15.0	15.8	15.6	16.4
LSD, P=0.05	NS	NS	NS	NS	NS	4.4	NS	NS	NS
Summary of ANOVA effects[x]									
Irrigation (I)	NS	NS	NS	NS	NS	*	NS	NS	NS
Date (D)									***
D x I									**

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 41. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 91-cm (36-inch) depth in 1998.

	Date								
Treatments	21 Apr.	21 May	23 June	24 July	18 Aug.	22 Sept.	20 Oct.	25 Nov.	Overall
Irrigation-level treatments	---	---	---	---	*cm^3 H_2O/cm^3 soil x 100*	---	---	---	---
80%, 80%, 80%, 80% hist. ET_o [z]	15.1	15.6	12.9	12.7	11.2	10.5	11.9	10.2	12.5
58%, 90%, 90%, 58% hist. ET_o	14.1	14.5	12.1	11.8	12.2	13.0	12.5	11.1	12.6
58%, 96%, 85%, 58% hist. ET_o	17.9	18.5	14.6	15.8	15.3	14.8	15.0	14.0	15.8
80%, 80%, 80%, 80% ET_o [y]	14.3	14.0	13.6	11.1	10.9	10.6	11.1	10.5	12.0
LSD, P=0.05	1.7	2.2	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[x]									
Irrigation (I)	**	**	NS	NS	NS	NS	NS	NS	NS
Date (D)									***
D x I									NS

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).
[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.
[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.
[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 42. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 122-cm (48-inch) depth in 1998.

	Date								
Treatments	21 Apr.	21 May	23 June	24 July	18 Aug.	22 Sept.	20 Oct.	25 Nov.	Overall
Irrigation-level treatments	---	---	---	---	*cm^3 H_2O/cm^3 soil x 100*	---	---	---	---
80%, 80%, 80%, 80% hist. ET_o [z]	14.2	15.1	13.1	12.6	11.9	11.9	12.7	11.3	12.8
58%, 90%, 90%, 58% hist. ET_o	13.1	14.1	11.2	10.9	11.0	11.8	11.8	10.9	11.8
58%, 96%, 85%, 58% hist. ET_o	17.7	17.1	13.1	14.5	13.9	13.3	12.7	13.1	14.4
80%, 80%, 80%, 80% ET_o [y]	14.8	14.8	15.0	12.7	13.0	12.7	13.4	12.7	13.6
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[x]									
Irrigation (I)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date (D)									**
D x I									NS

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).
[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.
[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.
[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 43. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 23-cm (9-inch) depth in 1999.

Treatments	Date												Overall
	19 Jan.	23 Feb.	30 Mar.	20 Apr.	18 May	22 June	27 July	24 Aug.	21 Sept.	19 Oct.	23 Nov.	14 Dec.	
Irrigation-level treatments	*cm^3 H_2O/cm^3 soil x 100*												
80%, 80%, 80%, 80% hist. ET_o[z]	9.1	17.6	17.6	16.8	16.3	14.6	9.3	9.7	14.7	6.3	8.6	7.3	12.3
40%, 92%, 91%, 70% hist. ET_o	7.2	15.7	12.9	16.0	16.7	15.3	11.6	11.3	16.8	8.2	7.4	6.4	12.1
40%, 85%, 97%, 70% hist. ET_o	7.6	16.4	12.5	17.3	17.6	16.0	14.7	15.5	18.2	9.3	10.1	9.3	13.7
80%, 80%, 80%, 80% ET_o[y]	13.2	18.8	12.7	17.3	13.1	11.6	7.9	7.3	9.9	8.1	11.5	7.9	11.6
LSD, P=0.05	NS	1.8	NS	NS	1.1	2.4	4.7	4.8	3.7	NS	NS	NS	NS
Summary of ANOVA effects[x]													
Irrigation (I)	NS	*	NS	NS	***	*	*	*	**	NS	NS	NS	NS
Date (D)													***
D x I													***

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 44. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 30-cm (12-inch) depth in 1999.

Treatments	Date												Overall
	19 Jan.	23 Feb.	30 Mar.	20 Apr.	18 May	22 June	27 July	24 Aug.	21 Sept.	19 Oct.	23 Nov.	14 Dec.	
Irrigation-level treatments	*cm^3 H_2O/cm^3 soil x 100*												
80%, 80%, 80%, 80% hist. ET_o[z]	9.4	18.6	21.3	18.8	17.3	15.8	10.5	10.4	14.6	8.1	9.0	8.6	13.5
40%, 92%, 91%, 70% hist. ET_o	9.3	15.8	14.2	17.7	18.4	17.1	13.1	12.7	17.4	10.7	8.8	8.4	13.6
40%, 85%, 97%, 70% hist. ET_o	9.5	16.5	9.6	18.7	19.1	17.7	16.3	16.8	19.3	12.0	11.5	10.8	14.8
80%, 80%, 80%, 80% ET_o[y]	9.4	19.8	9.6	19.0	15.3	13.2	9.5	9.0	10.9	10.1	11.5	9.7	12.6
LSD, P=0.05	NS	2.4	8.7	NS	1.9	2.1	NS	5.5	4.2	NS	NS	NS	NS
Summary of ANOVA effects[x]													
Irrigation (I)	NS	*	*	NS	**	**	NS	*	**	NS	NS	NS	NS
Date (D)													***
D x I													***

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 45. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 46-cm (18-inch) depth in 1999.

Treatments	Date												Overall
	19 Jan.	23 Feb.	30 Mar.	20 Apr.	18 May	22 June	27 July	24 Aug.	21 Sept.	19 Oct.	23 Nov.	14 Dec.	
Irrigation-level treatments	*cm^3 H_2O/cm^3 soil x 100*												
80%, 80%, 80%, 80% hist. ET_o[z]	12.0	21.2	20.6	21.0	19.9	18.4	12.8	12.3	14.5	11.6	11.0	10.9	15.5
40%, 92%, 91%, 70% hist. ET_o	12.7	15.8	17.7	19.5	19.9	19.5	15.4	14.9	17.3	14.8	11.9	11.3	15.9
40%, 85%, 97%, 70% hist. ET_o	11.9	14.1	16.6	19.9	20.5	19.9	17.5	18.5	20.2	16.0	14.1	13.4	16.9
80%, 80%, 80%, 80% ET_o[y]	16.0	21.2	15.5	21.0	17.9	15.7	12.2	11.5	12.3	12.4	12.6	11.9	15.0
LSD, P=0.05	NS	2.4	NS	NS	NS	NS	NS	NS	5.3	NS	NS	NS	NS
Summary of ANOVA effects[x]													
Irrigation (I)	NS	***	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
Date (D)													***
D x I													***

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 46. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 61-cm (24-inch) depth in 1999.

Treatments	Date												Overall
	19 Jan.	23 Feb.	30 Mar.	20 Apr.	18 May	22 June	27 July	24 Aug.	21 Sept.	19 Oct.	23 Nov.	14 Dec.	
Irrigation-level treatments	*cm^3 H_2O/cm^3 soil x 100*												
80%, 80%, 80%, 80% hist. ET_o[z]	11.9	20.1	19.7	20.4	19.2	18.5	13.8	12.4	13.2	11.7	10.8	10.6	15.2
40%, 92%, 91%, 70% hist. ET_o	14.0	15.2	17.7	18.8	19.4	19.4	15.8	14.6	15.5	15.0	12.7	12.0	15.9
40%, 85%, 97%, 70% hist. ET_o	12.5	13.3	15.8	18.5	19.5	19.6	17.5	17.9	19.7	17.2	15.4	14.5	16.8
80%, 80%, 80%, 80% ET_o[y]	15.4	18.9	15.6	20.1	13.5	16.3	12.1	11.0	11.4	11.7	11.9	11.2	14.1
LSD, P=0.05	NS	3.0	NS	NS	NS	NS	3.8	NS	4.6	NS	NS	NS	NS
Summary of ANOVA effects[x]													
Irrigation (I)	NS	**	NS	NS	NS	NS	*	NS	*	NS	NS	NS	NS
Date (D)													***
D x I													***

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 47. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 91-cm (36-inch) depth in 1999.

Treatments	Date												Overall
	19 Jan.	23 Feb.	30 Mar.	20 Apr.	18 May	22 June	27 July	24 Aug.	21 Sept.	19 Oct.	23 Nov.	14 Dec.	
Irrigation-level treatments	*cm^3 H_2O/cm^3 soil x 100*												
80%, 80%, 80%, 80% hist. ET_o[z]	10.0	13.9	14.0	15.3	14.3	13.7	12.1	10.5	10.4	10.2	10.0	9.6	12.0
40%, 92%, 91%, 70% hist. ET_o	10.2	10.3	12.0	12.5	12.7	13.4	11.4	10.6	11.4	10.8	9.9	9.5	11.2
40%, 85%, 97%, 70% hist. ET_o	12.9	12.8	12.9	13.5	15.1	15.8	15.2	14.9	16.1	15.2	9.5	13.6	13.9
80%, 80%, 80%, 80% ET_o[y]	10.5	12.7	12.3	14.7	13.5	12.4	10.4	9.0	8.6	8.8	8.6	8.1	10.8
LSD, P=0.05	NS	NS	NS	NS	NS	NS	2.6	3.5	3.9	3.4	NS	3.2	2.0
Summary of ANOVA effects[x]													
Irrigation (I)	NS	NS	NS	NS	NS	NS	*	*	*	*	NS	*	*
Date (D)													***
D x I													**

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 48. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 122-cm (48-inch) depth in 1999.

Treatments	Date												Overall
	19 Jan.	23 Feb.	30 Mar.	20 Apr.	18 May	22 June	27 July	24 Aug.	21 Sept.	19 Oct.	23 Nov.	14 Dec.	
Irrigation-level treatments	*cm^3 H_2O/cm^3 soil x 100*												
80%, 80%, 80%, 80% hist. ET_o[z]	11.3	12.2	15.6	15.3	14.4	13.8	13.0	12.1	11.9	11.7	11.7	11.3	12.8
40%, 92%, 91%, 70% hist. ET_o	10.0	10.2	13.5	12.0	12.6	12.9	11.6	10.8	11.1	11.2	10.5	10.1	11.4
40%, 85%, 97%, 70% hist. ET_o	12.5	12.2	12.5	12.5	14.1	14.7	14.1	13.9	15.6	14.6	13.7	12.8	13.6
80%, 80%, 80%, 80% ET_o[y]	12.3	13.7	11.6	15.5	14.8	14.2	13.5	12.2	11.9	11.8	11.6	11.5	12.9
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[x]													
Irrigation (I)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date (D)													***
D x I													**

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 49. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 23-cm (9-inch) depth in 2000.

	Date													
Treatments	18 Jan.	22 Feb.	10 Mar.	21 Mar.	25 Apr.	16 May	13 June	18 July	29 Aug.	19 Sept.	17 Oct.	21 Nov.	19 Dec.	Overall
Irrigation-level treatments	*cm³ H_2O/cm³ soil x 100*													
80%, 80%, 80%, 80% hist. ET_o[z]	14.4	18.6	22.7	18.6	20.3	12.1	7.5	6.4	7.6	9.0	13.3	11.6	14.9	13.6
40%, 92%, 91%, 70% hist. ET_o	6.9	18.3	22.4	15.6	19.4	13.6	10.1	9.2	10.7	13.7	15.2	11.5	12.9	13.8
40%, 85%, 97%, 70% hist. ET_o	10.8	19.6	23.4	17.9	20.7	13.1	9.2	10.4	12.8	15.7	16.8	14.1	15.7	15.4
80%, 80%, 80%, 80% ET_o[y]	10.2	18.8	22.7	18.9	18.2	10.2	7.2	7.8	11.6	9.0	11.7	12.5	13.0	13.2
LSD, P=0.05	3.8	NS	NS	2.3	NS	NS	NS	NS	3.7	3.0	1.9	NS	NS	NS
Summary of ANOVA effects[x]														
Irrigation (I)	*	NS	NS	*	NS	NS	NS	NS	*	**	**	NS	NS	NS
Date (D)														***
D x I														***

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 50. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 30-cm (12-inch) depth in 2000.

	Date													
Treatments	18 Jan.	22 Feb.	10 Mar.	21 Mar.	25 Apr.	16 May	13 June	18 July	29 Aug.	19 Sept.	17 Oct.	21 Nov.	19 Dec.	Overall
Irrigation-level treatments	*cm³ H_2O/cm³ soil x 100*													
80%, 80%, 80%, 80% hist. ET_o[z]	13.6	19.0	23.1	20.5	20.3	12.8	8.9	8.0	8.3	9.8	12.6	12.0	14.1	14.1
40%, 92%, 91%, 70% hist. ET_o	8.6	18.5	23.2	19.5	20.0	14.8	11.9	10.8	11.4	14.4	16.4	13.6	13.7	15.1
40%, 85%, 97%, 70% hist. ET_o	11.7	19.9	24.2	21.2	21.1	14.7	10.9	12.0	13.0	17.2	18.4	15.9	16.7	16.7
80%, 80%, 80%, 80% ET_o[y]	10.6	19.4	23.7	21.4	18.6	11.6	9.3	9.6	12.5	10.7	12.3	12.8	13.4	14.3
LSD, P=0.05	2.5	NS	NS	NS	NS	NS	NS	NS	NS	2.6	2.3	NS	NS	NS
Summary of ANOVA effects[x]														
Irrigation (I)	**	NS	NS	NS	NS	NS	NS	NS	NS	***	***	NS	NS	NS
Date (D)														***
D x I														***

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 51. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 46-cm (18-inch) depth in 2000.

Treatments	Date													Overall
	18 Jan.	22 Feb.	10 Mar.	21 Mar.	25 Apr.	16 May	13 June	18 July	29 Aug.	19 Sept.	17 Oct.	21 Nov.	19 Dec.	
Irrigation-level treatments	-------------------						*cm^3 H_2O/cm^3 soil x 100*							-------------------
80%, 80%, 80%, 80% hist. ET_o^z	13.2	20.5	24.5	23.2	21.8	16.0	13.0	10.7	9.9	11.0	11.0	11.0	12.0	15.2
40%, 92%, 91%, 70% hist. ET_o	11.3	12.6	24.0	22.6	21.6	17.2	15.5	13.2	12.5	13.7	17.0	16.1	16.2	16.5
40%, 85%, 97%, 70% hist. ET_o	13.2	15.8	25.4	24.1	22.1	17.2	14.4	14.0	14.5	15.8	18.8	18.2	18.1	18.0
80%, 80%, 80%, 80% ET_o^y	11.9	16.4	24.5	23.2	21.0	14.5	12.6	11.4	12.8	12.0	12.0	12.1	12.5	15.1
LSD, P=0.05	NS	4.1	NS	NS	NS	NS	NS	NS	NS	NS	3.0	2.7	3.5	NS
Summary of ANOVA effects^x														
Irrigation (I)	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	**	**	**	NS
Date (D)														***
D x I														***

^{z}Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

^{y}Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

^{x}Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

NS, *, **, ***Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 52. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 61-cm (24-inch) depth in 2000.

Treatments	Date													Overall
	18 Jan.	22 Feb.	10 Mar.	21 Mar.	25 Apr.	16 May	13 June	18 July	29 Aug.	19 Sept.	17 Oct.	21 Nov.	19 Dec.	
Irrigation-level treatments	-------------------						*cm^3 H_2O/cm^3 soil x 100*							-------------------
80%, 80%, 80%, 80% hist. ET_o^z	11.8	20.5	24.5	23.2	21.8	17.1	13.0	10.7	9.9	11.0	11.0	11.0	12.0	15.2
40%, 92%, 91%, 70% hist. ET_o	11.7	12.6	24.0	22.6	21.6	17.5	15.5	13.2	12.5	13.7	17.0	16.1	16.2	16.5
40%, 85%, 97%, 70% hist. ET_o	13.9	15.8	25.4	24.1	22.1	17.8	14.4	14.0	14.5	15.8	18.8	18.2	18.1	18.0
80%, 80%, 80%, 80% ET_o^y	11.2	16.4	24.5	23.2	21.0	14.8	12.6	11.4	12.8	12.0	12.0	12.1	12.5	15.1
LSD, P=0.05	NS	4.1	NS	NS	NS	NS	NS	NS	NS	NS	3.0	2.7	3.5	NS
Summary of ANOVA effects^x														
Irrigation (I)	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	**	**	**	NS
Date (D)														***
D x I														***

^{z}Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

^{y}Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

^{x}Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

NS, *, **, ***Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 53. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 91-cm (36-inch) depth in 2000.

Treatments	Date													Overall
	18 Jan.	22 Feb.	10 Mar.	21 Mar.	25 Apr.	16 May	13 June	18 July	29 Aug.	19 Sept.	17 Oct.	21 Nov.	19 Dec.	
Irrigation-level treatments	-----	-----	-----	-----	-----	-----	cm^3 H_2O/cm^3 soil x 100	-----	-----	-----	-----	-----	-----	-----
80%, 80%, 80%, 80% hist. ET$_o$[z]	9.9	15.0	19.3	18.0	16.9	13.0	11.5	9.5	8.3	8.4	8.6	9.0	9.3	12.0
40%, 92%, 91%, 70% hist. ET$_o$	9.4	9.2	16.2	15.9	14.4	11.2	10.8	10.1	9.4	9.9	10.6	10.1	10.3	11.3
40%, 85%, 97%, 70% hist. ET$_o$	12.9	13.4	20.5	20.2	18.7	15.1	14.0	12.9	12.8	13.2	14.5	14.1	14.5	15.1
80%, 80%, 80%, 80% ET$_o$[y]	8.2	9.5	18.2	17.0	15.8	11.7	10.5	9.2	7.8	8.5	8.4	8.5	8.7	10.9
LSD, P=0.05	2.9	2.3	NS	2.1	1.8	1.5	2.2	1.7	3.6	2.3	2.2	2.0	2.2	1.7
Summary of ANOVA effects[x]														
Irrigation (I)	*	**	NS	**	**	**	*	**	*	**	**	**	**	**
Date (D)														***
D x I														***

[z]Historical ET$_o$. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET$_o$ based on 7 d cumulative ET$_o$ from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 54. The effect of irrigation-level treatment on volumetric soil-water content as measured with a neutron probe at the 122-cm (48-inch) depth in 2000.

Treatments	Date													Overall
	18 Jan.	22 Feb.	10 Mar.	21 Mar.	25 Apr.	16 May	13 June	18 July	29 Aug.	19 Sept.	17 Oct.	21 Nov.	19 Dec.	
Irrigation-level treatments	-----	-----	-----	-----	-----	-----	cm^3 H_2O/cm^3 soil x 100	-----	-----	-----	-----	-----	-----	-----
80%, 80%, 80%, 80% hist. ET$_o$[z]	11.2	13.3	19.5	18.0	17.0	13.1	12.6	11.9	11.2	11.0	11.2	11.2	11.3	13.3
40%, 92%, 91%, 70% hist. ET$_o$	9.9	9.7	14.8	15.6	14.2	11.2	10.7	10.3	9.7	10.1	10.6	10.3	10.4	11.3
40%, 85%, 97%, 70% hist. ET$_o$	12.5	12.8	18.2	18.6	17.3	13.6	13.1	12.7	12.8	13.3	13.7	13.2	13.4	14.3
80%, 80%, 80%, 80% ET$_o$[y]	11.2	11.1	17.1	17.9	16.9	13.3	12.7	12.1	11.8	11.7	11.5	11.4	11.4	13.1
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[x]														
Irrigation (I)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date (D)														***
D x I														***

[z]Historical ET$_o$. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET$_o$ based on 7 d cumulative ET$_o$ from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 55. The effect of irrigation-level treatment on soil-water tension as measured with Watermark granular sensors at the 15-cm (6-inch) depth in 1998.

Treatments	14 Apr.	28 Apr.	12 May	26 May	2 June	16 June	30 June	7 July	21 July	4 Aug.	18 Aug.	1 Sept.	15 Sept.	29 Sept.	13 Oct.	27 Oct.	10 Nov.	24 Nov.	Overall
	Date																		
Irrigation-level treatments	*KPa*																		
80%, 80%, 80%, 80% hist. ET_o[z]	7	14	10	35	25	16	29	22	28	28	17	57	27	20	30	62	62	73	31
58%, 90%, 90%, 58% hist. ET_o	9	12	11	35	25	16	17	13	13	14	12	18	11	17	41	88	92	97	30
58%, 96%, 85%, 58% hist. ET_o	11	12	9	29	17	39	14	15	15	17	12	17	11	9	27	56	73	93	26
80%, 80%, 80%, 80% ET_o[y]	19	20	15	39	17	27	42	25	38	45	13	25	22	27	35	32	22	22	27
LSD, P=0.05	3	NS	4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[x]																			
Irrigation (I)	***	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date (D)																			***
D x I																			***

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 56. The effect of irrigation-level treatment on soil-water tension as measured with Watermark granular sensors at the 30-cm (12-inch) depth in 1998.

Treatments	14 Apr.	28 Apr.	12 May	26 May	2 June	16 June	30 June	7 July	21 July	4 Aug.	18 Aug.	1 Sept.	15 Sept.	29 Sept.	13 Oct.	27 Oct.	10 Nov.	24 Nov.	Overall
	Date																		
Irrigation-level treatments	*KPa*																		
80%, 80%, 80%, 80% hist. ET_o[z]	4	9	8	19	19	24	39	34	46	77	71	100	112	105	43	67	79	89	52
58%, 90%, 90%, 58% hist. ET_o	6	8	6	17	20	16	19	14	18	12	6	13	8	37	15	42	50	59	21
58%, 96%, 85%, 58% hist. ET_o	5	7	4	17	15	47	10	12	25	29	20	28	13	38	17	45	66	83	27
80%, 80%, 80%, 80% ET_o[y]	13	20	26	23	22	44	68	44	57	68	22	30	31	36	43	30	25	31	35
LSD, P=0.05	3	NS	NS	NS	NS	NS	33	NS	NS	NS	24	28	38	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[x]																			
Irrigation (I)	**	NS	NS	NS	NS	NS	*	NS	NS	NS	**	***	**	NS	NS	NS	NS	NS	NS
Date (D)																			***
D x I																			***

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 57. The effect of irrigation-level treatment on soil-water tension as measured with Watermark granular sensors at the 15-cm (6-inch) depth in 1999.

	Date												
Treatments	19 Jan.	23 Feb.	30 Mar.	20 Apr.	18 May	22 June	27 July	24 Aug.	21 Sept.	19 Oct.	23 Nov.	14 Dec.	Overall
Irrigation-level treatments	*KPa*												
80%, 80%, 80%, 80% hist. ET_o^z	44	10	10	13	15	22	41	39	13	56	53	61	31
40%, 92%, 91%, 70% hist. ET_o	144	16	70	16	14	19	31	43	18	64	92	107	53
40%, 85%, 97%, 70% hist. ET_o	133	17	67	15	13	21	21	15	11	40	48	47	37
80%, 80%, 80%, 80% ET_o^y	53	10	11	18	31	54	64	86	63	90	72	86	53
LSD, P=0.05	49	6	11	NS	8	23	NS	NS	15	NS	NS	NS	NS
Summary of ANOVA effects[x]													
Irrigation (I)	**	*	***	NS	**	*	NS	NS	***	NS	NS	NS	NS
Date (D)													***
D x I													***

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 58. The effect of irrigation-level treatment on soil-water tension as measured with Watermark granular sensors at the 30-cm (12-inch) depth in 1999.

	Date												
Treatments	19 Jan.	23 Feb.	30 Mar.	20 Apr.	18 May	22 June	27 July	24 Aug.	21 Sept.	19 Oct.	23 Nov.	14 Dec.	Overall
Irrigation-level treatments	*KPa*												
80%, 80%, 80%, 80% hist. ET_o^z	81	5	6	7	11	21	40	58	44	45	85	85	41
40%, 92%, 91%, 70% hist. ET_o	104	27	46	9	9	17	36	43	8	42	96	90	44
40%, 85%, 97%, 70% hist. ET_o	120	46	66	8	8	13	19	19	6	45	98	108	44
80%, 80%, 80%, 80% ET_o^y	51	6	5	12	24	47	46	89	75	66	81	91	49
LSD, P=0.05	NS	NS	33	NS	8	20	NS	NS	54	NS	NS	NS	NS
Summary of ANOVA effects[x]													
Irrigation (I)	NS	NS	**	NS	**	*	NS	NS	*	NS	NS	NS	NS
Date (D)													***
D x I													**

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 59. The effect of irrigation-level treatment on soil-water tension as measured with Watermark granular sensors at the 15-cm (6-inch) depth in 2000.

Treatments	Date													Overall
	18 Jan.	22 Feb.	7 Mar.	21 Mar.	25 Apr.	16 May	13 June	18 July	29 Aug.	19 Sept.	17 Oct.	21 Nov.	19 Dec.	
Irrigation-level treatments	*KPa*													
80%, 80%, 80%, 80% hist. ET_o[z]	11	8	7	15	12	23	54	58	65	59	17	37	32	31
40%, 92%, 91%, 70% hist. ET_o	102	22	9	21	16	23	30	34	34	20	15	37	35	29
40%, 85%, 97%, 70% hist. ET_o	55	9	8	19	14	26	51	38	35	17	14	29	19	26
80%, 80%, 80%, 80% ET_o[y]	69	10	10	14	22	44	54	53	57	52	27	26	35	36
LSD, P=0.05	NS	NS	NS	NS	NS	16	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[x]														
Irrigation (I)	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
Date (D)														***
D x I														**

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

Table 60. The effect of irrigation-level treatment on soil-water tension as measured with Watermark granular sensors at the 30-cm (12-inch) depth in 2000.

Treatments	Date													Overall
	18 Jan.	22 Feb.	7 Mar.	21 Mar.	25 Apr.	16 May	13 June	18 July	29 Aug.	19 Sept.	17 Oct.	21 Nov.	19 Dec.	
Irrigation-level treatments	*KPa*													
80%, 80%, 80%, 80% hist. ET_o[z]	48	3	3	10	9	30	53	104	114	94	32	76	79	50
40%, 92%, 91%, 70% hist. ET_o	65	15	4	12	11	19	35	52	70	19	11	18	22	27
40%, 85%, 97%, 70% hist. ET_o	91	24	5	12	16	32	77	70	89	48	13	16	22	40
80%, 80%, 80%, 80% ET_o[y]	66	5	5	10	25	47	57	51	58	87	58	43	42	43
LSD, P=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Summary of ANOVA effects[x]														
Irrigation (I)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Date (D)														***
D x I														***

[z]Historical ET_o. Goldhamer, D. A. and R. L. Snyder. 1989. Irrigation scheduling: A guide for efficient on-farm water management. Univ. of Calif., Division of Agricultural and Natural Resources. Publ. 21454 (see page 62).

[y]Real-time ET_o based on 7 d cumulative ET_o from an on-site CIMIS station 51 m (169 ft) from the center of the research plot.

[x]Randomized complete block design statistical effects by date and overall ANOVA via repeated measures design.

[NS, *, **, ***]Nonsignificant or significant at P 0.05, 0.01, 0.001, respectively.

APPENDIX A

Analyses of soil salinity/alkalinity/toxicity, fertility and characteristics, soil temperatures, weather data, and DANR Analytical Laboratory methods

Table A-1. Analyses of soil salinity/alkalinity/toxicity, fertility and characteristics from samples taken at the 0- to 10-cm (0- to 4-inch) depth root zone each December from 1997 to 2000.

	Year			
	19 Dec. 1997	18 Dec. 1998	17 Dec. 1999	18 Dec. 2000
Soil salinity/alkalinity/toxicity[z]				
pH	7.2	7.0	7.0	7.4
EC (mmhos·cm^{-1})	1.19	2.37	1.67	2.18
Soluble Ca (ppm)	160	357	216	365
Soluble Mg (ppm)	27	49	35	58
Soluble Na (ppm)	69	182	150	200
SAR	1	2	2	3
ESP (%)	<1	2	2	2
HCO_3 (ppm)	244	1159	555	665
CEC (meq/100 g)	12.5	10.2	16.5	19.2
Soil fertility[z]				
Fe (ppm)	23.0	40.0	57.2	32.1
Olsen-P	44.4	29.4	41.4	42.1
Exchangeable K (ppm)	108	117	156	134
Exchangeable Ca (ppm)	1723	1804	1944	1924
Exchangeable Mg (ppm)	207	195	219	182
Exchangeable Na (ppm)	69	138	161	161
Soil characteristics[z]				
OM (%)	1.42	1.21	1.54	1.68
Sand (%)	47	51	54	54
Silt (%)	42	34	31	31
Clay (%)	11	15	15	15

[z]Analyses conducted according to relevant DANR analytical methodologies (Table A-3 in Appendix A).

Figure A-1. Weekly warm mean (12 noon to 4 p.m.) and cool (2 a.m. to 6 a.m.) soil temperatures at the 10-cm (4-inch) depth on the research plot from 22 Feb. 1998 to 6 Jan. 2001.

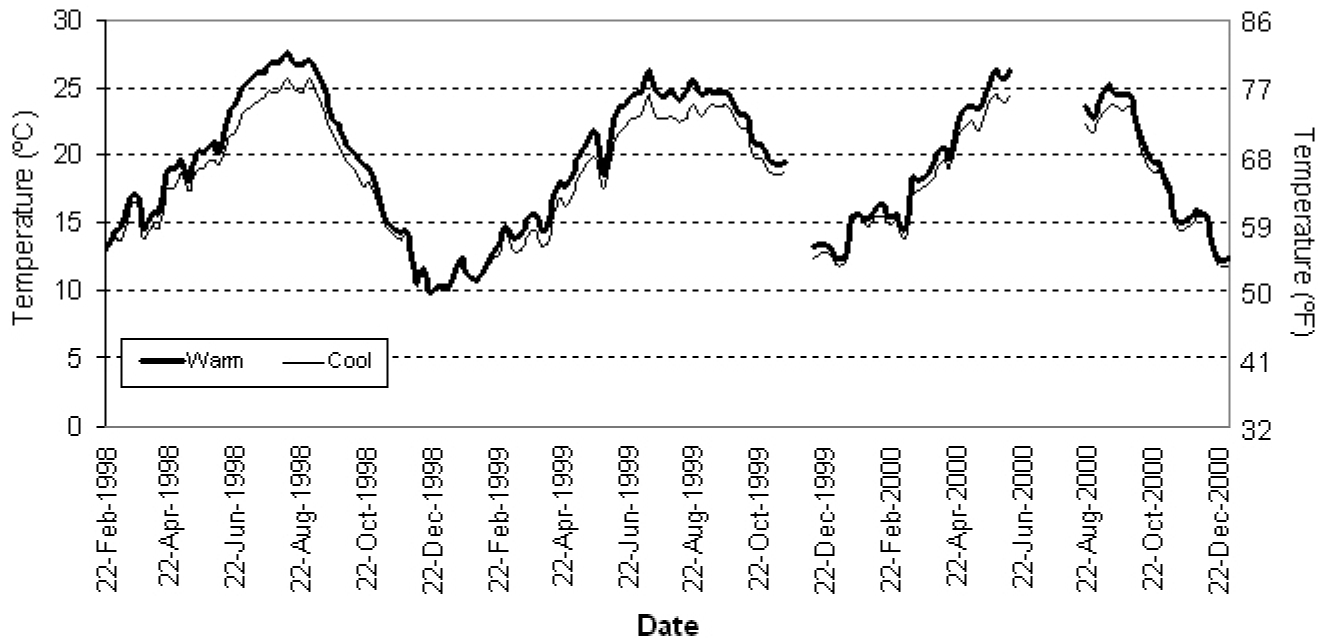


Table A-2. Weekly weather measurements collected from 28 Dec. 1997 to 6 Jan. 2001.

Date	Cumulative ET_o^z (mm/week)	Cumulative precipitation (mm/week)	Average daily solar radiation (W/m^2 per d)	Average air daily temperature		Average daily relative humidity (%)	Average daily soil temperature at 15.2 cm depth	
				ºC	ºF		ºC	ºF
28 Dec. 1997- 3 Jan. 1998	13.50	1	116	16	61	54	11	52
4-10 Jan. 1998	8.82	53	102	10	50	58	11	52
11-17 Jan. 1998	9.16	1	108	12	54	63	13	55
18-24 Jan. 1998	12.75	2	150	12	54	55	13	55
25-31 Jan. 1998	13.49	9	146	12	54	57	13	55
1-7 Feb. 1998	11.15	83	106	11	52	58	13	55
8-14 Feb. 1998	13.62	36	150	11	52	59	14	57
15-21 Feb. 1998	13.30	27	161	10	50	56	13	55
22-28 Feb. 1998	14.66	84	171	11	52	58	13	55
1-7 Mar. 1998	18.78	9	162	13	55	54	15	59
8-14 Mar. 1998	25.09	18	240	15	59	53	15	59
15-21 Mar. 1998	21.46	0	199	15	59	58	17	63
22-28 Mar. 1998	20.37	29	177	14	57	57	17	63
29 Mar.- 4 Apr. 1998	18.19	17	190	9	48	57	14	57
5-11 Apr. 1998	26.55	2	252	13	55	55	15	59
12-18 Apr. 1998	29.61	1	275	13	55	53	16	61
19-25 Apr. 1998	36.29	0	290	18	64	53	19	66
26 Apr.-2 May 1998	40.22	0	319	19	66	53	20	68
3-9 May 1998	23.26	13	202	16	61	56	21	70
10-16 May 1998	23.79	24	218	14	57	56	20	68
17-23 May 1998	42.95	0	362	18	64	53	22	72
24-30 May 1998	31.08	0	n/a	n/a	n/a	n/a	n/a	n/a
31 May-6 June 1998	33.85	0	271	19	66	54	25	77
7-13 June 1998	22.86	0	194	18	64	55	24	75
14-20 June 1998	36.72	0	296	21	70	55	26	79
21-27 June 1998	41.94	0	336	21	70	55	27	81
28 June-4 July 1998	42.05	0	323	24	75	54	29	84

[z]Weather data collected from an on-site California Irrigation Management System weather station located 51 m (169 ft) from the center of the research plot.

Table A-2 *(continued)*. Weekly weather measurements collected from 28 Dec. 1997 to 6 Jan. 2001.

Date	Cumulative ET_o[z] (mm/week)	Cumulative precipitation (mm/week)	Average daily solar radiation (W/m^2 per d)	Average air daily temperature		Average daily relative humidity (%)	Average daily soil temperature at 15.2 cm depth	
				ºC	ºF		ºC	ºF
5-11 July 1998	46.03	0	337	27	81	52	29	84
12-18 July 1998	44.76	0	324	29	84	52	30	86
19-25 July 1998	39.01	0	282	26	79	54	31	88
26 July-1 Aug. 1998	45.01	0	345	29	84	52	32	90
2-8 Aug. 1998	46.24	0	323	29	84	53	31	88
9-15 Aug. 1998	40.51	14	274	29	84	52	32	90
16-22 Aug. 1998	40.80	0	299	26	79	53	31	88
23-29 Aug. 1998	44.57	0	310	33	91	52	31	88
30 Aug.-5 Sept. 1998	38.47	0	234	35	95	54	31	88
6-12 Sept. 1998	34.14	0	270	25	77	56	30	86
13-19 Sept. 1998	33.22	0	262	24	75	56	28	82
20-26 Sept. 1998	21.73	0	170	20	68	56	26	79
27 Sept.-3 Oct. 1998	25.24	0	206	19	66	57	25	77
4-10 Oct. 1998	30.00	0	248	22	72	52	23	73
11-17 Oct. 1998	23.34	0	191	19	66	56	21	70
18-24 Oct. 1998	25.42	0	202	22	72	52	20	68
25-31 Oct. 1998	18.44	3	173	17	63	58	20	68
1-7 Nov. 1998	17.87	0	172	16	61	57	18	64
8-14 Nov. 1998	16.88	7	147	15	59	54	16	61
15-21 Nov. 1998	16.94	0	147	16	61	52	15	59
22-28 Nov. 1998	13.23	3	130	16	61	55	15	59
29 Nov.-5 Dec. 1998	10.31	4	115	12	54	61	15	59
6-12 Dec. 1998	18.24	6	154	13	55	47	11	52
13-19 Dec. 1998	18.75	0	121	18	64	52	12	54
20-26 Dec. 1998	14.25	1	146	10	50	49	10	50
27 Dec. 1998-2 Jan. 1999	16.98	0	153	17	63	51	11	52
3-9 Jan. 1999	19.03	0	174	17	63	51	11	52

[z]Weather data collected from an on-site California Irrigation Management System weather station located 51 m (169 ft) from the center of the research plot.

Table A-2 *(continued)*. Weekly weather measurements collected from 28 Dec. 1997 to 6 Jan. 2001.

Date	Cumulative ET_o^z (mm/week)	Cumulative precipitation (mm/week)	Average daily solar radiation (W/m^2 per d)	Average air daily temperature		Average daily relative humidity (%)	Average daily soil temperature at 15.2 cm depth	
				ºC	ºF		ºC	ºF
10-16 Jan. 1999	16.29	0	154	15	59	53	11	52
17-23 Jan. 1999	11.60	5	115	13	55	60	13	55
24-30 Jan. 1999	13.86	23	132	11	52	55	12	54
31 Jan.-6 Feb. 1999	13.07	10	131	12	54	56	11	52
7-13 Feb. 1999	16.52	6	162	12	54	51	12	54
14-20 Feb. 1999	20.54	0	178	12	54	44	13	55
21-27 Feb. 1999	25.41	0	211	14	57	42	14	57
28 Feb.-6 Mar. 1999	21.85	0	173	14	57	44	16	61
7-13 Mar. 1999	21.73	0	188	10	50	43	14	57
14-20 Mar. 1999	23.57	4	203	11	52	44	15	59
21-27 Mar. 1999	21.57	0	176	12	54	57	16	61
28 Mar.-3 Apr. 1999	21.74	5	192	12	54	66	17	63
4-10 Apr. 1999	22.40	13	212	10	50	61	15	59
11-17 Apr. 1999	34.83	18	234	17	63	47	17	63
18-24 Apr. 1999	25.50	4	186	17	63	60	21	70
25 Apr.-1 May 1999	23.14	5	204	13	55	72	20	68
2-8 May 1999	31.46	0	256	16	61	64	22	72
9-15 May 1999	30.93	0	254	16	61	70	24	75
16-22 May 1999	31.35	2	249	17	63	65	25	77
23-29 May 1999	33.87	0	278	19	66	67	27	81
30 May-5 June 1999	23.20	11	200	15	59	66	26	79
6-12 June 1999	34.87	0	287	18	64	65	27	81
13-19 June 1999	44.58	0	324	23	73	55	30	86
20-26 June 1999	42.41	0	317	21	70	57	32	90
27 June-3 July 1999	42.85	0	299	22	72	61	33	91
4-10 July 1999	39.59	0	285	24	75	54	33	91
11-17 July 1999	47.93	0	325	27	81	49	35	95

^{z}Weather data collected from an on-site California Irrigation Management System weather station located 51 m (169 ft) from the center of the research plot.

Table A-2 *(continued)*. Weekly weather measurements collected from 28 Dec. 1997 to 6 Jan. 2001.

Date	Cumulative ET_o[z] (mm/week)	Cumulative precipitation (mm/week)	Average daily solar radiation (W/m^2 per d)	Average air daily temperature		Average daily relative humidity (%)	Average daily soil temperature at 15.2 cm depth	
				ºC	ºF		ºC	ºF
18-24 July 1999	49.12	1	373	24	75	38	33	91
25-31 July 1999	43.20	0	327	22	72	55	33	91
1-7 Aug. 1999	43.14	2	305	23	73	53	33	91
8-14 Aug. 1999	37.74	0	318	22	72	61	32	90
15-21 Aug. 1999	45.31	0	264	25	77	41	32	90
22-28 Aug. 1999	42.25	0	252	27	81	40	27	81
29 Aug.-4 Sept. 1999	36.44	0	295	20	68	61	24	75
5-11 Sept. 1999	33.36	0	261	21	70	58	23	73
12-18 Sept. 1999	27.75	0	225	20	68	67	23	73
19-25 Sept. 1999	28.63	0	225	22	72	62	23	73
26 Sept.-2 Oct. 1999	35.76	0	244	24	75	40	22	72
3-9 Oct. 1999	32.11	0	233	21	70	44	21	70
10-16 Oct. 1999	31.33	0	220	23	73	39	21	70
17-23 Oct. 1999	32.09	0	219	22	72	20	19	66
24-30 Oct. 1999	24.85	0	191	19	66	42	19	66
31 Oct.-6 Nov. 1999	20.56	22	172	18	64	50	17	63
7-13 Nov. 1999	14.39	8	143	16	61	62	17	63
14-20 Nov. 1999	11.49	0	129	15	59	75	17	63
21-27 Nov. 1999	20.83	0	156	14	57	30	14	57
28 Nov.-4 Dec. 1999	17.34	0	129	14	57	42	13	55
5-11 Dec. 1999	21.24	0	138	12	54	30	11	52
12-18 Dec. 1999	17.76	0	130	14	57	30	10	50
19-25 Dec. 1999	24.12	0	135	16	61	20	11	52
26 Dec. 1999-1 Jan. 2000	13.31	8	109	13	55	46	11	52
2-8 Jan. 2000	18.24	0	144	12	54	32	10	50
9-15 Jan. 2000	14.77	0	131	13	55	47	10	50
16-22 Jan. 2000	10.82	0	102	15	59	68	13	55

[z]Weather data collected from an on-site California Irrigation Management System weather station located 51 m (169 ft) from the center of the research plot.

Table A-2 *(continued)*. Weekly weather measurements collected from 28 Dec. 1997 to 6 Jan. 2001.

Date	Cumulative ET_o^z (mm/week)	Cumulative precipitation (mm/week)	Average daily solar radiation (W/m^2 per d)	Average air daily temperature ºC	Average air daily temperature ºF	Average daily relative humidity (%)	Average daily soil temperature at 15.2 cm depth ºC	Average daily soil temperature at 15.2 cm depth ºF
23-29 Jan. 2000	12.64	6	128	14	57	62	14	57
30 Jan.-5 Feb. 2000	15.36	2	139	14	57	56	13	55
6-12 Feb. 2000	13.53	6	129	14	57	61	14	57
13-19 Feb. 2000	12.71	11	125	13	55	71	14	57
20-26 Feb. 2000	10.56	29	124	11	52	73	13	55
27 Feb.-4 Mar. 2000	14.76	19	156	11	52	73	14	57
5-11 Mar. 2000	15.82	20	166	11	52	69	13	55
12-18 Mar. 2000	28.77	0	241	17	63	56	16	61
19-25 Mar. 2000	34.74	0	264	15	59	44	16	61
26 Mar.-1 Apr. 2000	31.32	1	229	15	59	54	16	61
2-8 Apr. 2000	33.61	0	270	18	64	55	17	63
9-15 Apr. 2000	34.22	0	276	17	63	53	19	66
16-22 Apr. 2000	23.22	15	215	14	57	70	18	64
23-29 Apr. 2000	37.79	0	296	19	66	58	20	68
30 Apr.-6 May 2000	40.45	0	313	20	68	55	21	70
7-13 May 2000	38.13	0	303	18	64	54	21	70
14-20 May 2000	42.65	0	331	19	66	48	21	70
21-27 May 2000	32.69	1	251	21	70	67	22	72
28 May-3 June 2000	45.06	0	332	22	72	54	24	75
4-10 June 2000	43.73	0	338	21	70	50	23	73
11-17 June 2000	43.66	0	327	22	72	58	24	75
18-24 June 2000	41.93	0	326	22	72	63	25	77
25 June-1 July 2000	46.17	0	335	25	77	51	26	79
2-8 July 2000	44.55	0	352	21	70	59	25	77
9-15 July 2000	41.58	0	323	21	70	58	25	77
16-22 July 2000	49.02	0	343	25	77	43	26	79
23-29 July 2000	46.67	0	319	26	79	45	26	79

^{z}Weather data collected from an on-site California Irrigation Management System weather station located 51 m (169 ft) from the center of the research plot.

Table A-2 *(continued)*. Weekly weather measurements collected from 28 Dec. 1997 to 6 Jan. 2001.

Date	Cumulative ET_o[z] (mm/week)	Cumulative precipitation (mm/week)	Average daily solar radiation (W/m^2 per d)	Average air daily temperature		Average daily relative humidity (%)	Average daily soil temperature at 15.2 cm depth	
				ºC	ºF		ºC	ºF
30 July-5 Aug. 2000	44.85	0	297	27	81	48	27	81
6-12 Aug. 2000	47.55	0	334	27	81	45	26	79
13-19 Aug. 2000	47.81	0	310	27	81	39	27	81
20-26 Aug. 2000	40.19	0	292	24	75	55	26	79
27 Aug.-2 Sept. 2000	26.24	0	218	20	68	69	25	77
3-9 Sept. 2000	36.88	0	270	22	72	44	24	75
10-16 Sept. 2000	40.91	0	266	26	79	37	24	75
17-23 Sept. 2000	24.97	4	191	22	72	63	24	75
24-30 Sept. 2000	23.69	0	216	20	68	64	23	73
1-7 Oct. 2000	16.77	0	155	19	66	75	22	72
8-14 Oct. 2000	17.69	3	172	16	61	68	21	70
15-21 Oct. 2000	19.76	0	174	19	66	60	20	68
22-28 Oct. 2000	16.74	1	137	16	61	63	19	66
29 Oct.-4 Nov. 2000	20.52	6	170	15	59	51	17	63
5-11 Nov. 2000	15.80	3	147	12	54	57	16	61
12-18 Nov. 2000	16.91	0	169	10	50	43	14	57
19-25 Nov. 2000	16.18	0	141	14	57	41	13	55
26 Nov.-2 Dec. 2000	14.96	0	139	15	59	46	14	57
3-9 Dec. 2000	13.17	0	104	16	61	48	14	57
10-16 Dec. 2000	9.56	0	109	12	54	68	14	57
17-23 Dec. 2000	17.42	0	137	14	57	27	12	54
24-30 Dec. 2000	20.85	0	144	15	59	22	11	52
31 Dec. 2000-6 Jan. 2001	17.38	1	131	15	59	27	11	52

[z]Weather data collected from an on-site California Irrigation Management System weather station located 51 m (169 ft) from the center of the research plot.

Table A-3. DANR Analytical Laboratory soil, plant and water analyses methods.

Note: The soil and plant analyses information excerpted from the DANR Analytical Laboratory methodology and citation handout dated 5 Mar. 1997. The water analyses information was provided by DANR in May 1998 upon request.

SOIL SALINITY / ALKALINITY / TOXICITY ANALYSES	
pH	Semi-quantifies soil pH using the saturated paste and pH meter. Determination: U.S. Salinity Laboratory Staff, 1954.
EC_e	Semi-quantifies the amount of soluble salts in the saturation paste extract using conductivity meter. Determination: Rhoades, 1982.
HCO_3,CO_3	Quantification of the bicarbonate (HCO_3) and carbonate (CO_3) in the saturated paste extract by titration with 0.05 Normal H_2SO_4 acid. Determination: Nelson, 1982.
Cl	Amount of chloride based on electrometric titration of the saturated paste extract by chloridometer. Determination: Rhoades, 1982.
B	ICP-AES determination of amount of boron in saturated paste extract. Extraction: Rhoades, 1982; determination: Soltanpour, et al, 1982.
Ca, Mg	Amounts of soluble calcium and magnesium in the saturated paste extract by inductively coupled plasmic atomic emission spectrometry. Extraction: Lanyon and Heald, 1982; determination, Soltanpour, et al, 1982.
Na, K(sol)	Amounts of soluble potassium and sodium in the saturated paste extract by emission spectometry. Determination: Knudsen, Peterson and Pratt, 1982.
SAR	Sodium Absorption Ratio estimated calculation from calcium, magnesium and sodium on saturated paste extract. Calculation: U.S. Salinity Laboratory, 1954.
ESP	Estimated value for exchangeable sodium percentage. Calculated from SAR values. Calculation: U.S. Salinity Laboratory, 1954.
SOIL FERTILITY ANALYSES	
X-K, X-Na, X-Ca, X-Mg	Equilibrium extraction of soil for plant available exchangeable potassium, sodium, calcium and magnesium using 1 Normal ammonium acetate (pH 7.0) and subsequent determination by atomic absorption/emission spectrometry. Extraction: Knudsen, Peterson and Pratt, 1982 and Lanyon and Heald, 1982. Measurement of exchangeable minerals residing on the soil colloid exchange sites is by displacement with buffered ammonium acetate solution. Determination: Franson, 1985.
Cu, Zn, Mn, Fe	Equilibrium extraction of soil using DTPA and subsequent determination by atomic absorption spectrometry. Extraction: Lindsay and Norvell, 1978; determination: Franson, 1985.
Olsen-P	Extractable phosphate based on alkaline extraction by 0.5 Normal $NaHCO_3$. Plant available phosphate for soil with pH greater than 6.5 by ascorbic acid reduction of phosphomolybdate complex and measurement by spectrophotometry. Extraction and determination: Olsen, et al, 1954.
SOIL PHYSIO-CHEMICAL ANALYSES	
OM	Organic Matter by potassium dichromate reduction of organic carbon and subsequent spectrophotometric measurement (modified Walkley-Black). Determination: Nelson and Sommers, 1982.
CEC	Cation Exchange Capacity by barium acetate saturation and calcium replacement. Determination: Rible and Quick, 1960 and Janitzky, 1986.
PSA	Particle Size Analysis of sand, silt and clay in soil suspension by hydrometer. Determination: Gee and Bauder, 1979.
PLANT TISSUE ANALYSES	
N	Total Nitrogen by Nitrogen Gas Analyzer utilizing induction furnace and thermal conductivity (LECO FP-428). Sample size 100 mg, results corrected to 100% dry matter basis. Determination: Sweeney, 1989.

Table A-3 *(continued)*. DANR Analytical Laboratory soil, plant and water analyses methods.

K	Total K, extraction by 2% acetic acid extraction. Quantitative determination by atomic emission spectrometry (AES). Extraction: Johnson and Ulrich, 1959; determination: Franson, 1985.
B, Ca, Mg, Mo, P, S	Totals, microwave acid digestion/dissolution of sample. Quantitative determination by atomic emission spectroscopy (ICP-AES). Digestion: Sah and Miller, 1992.
Na	Totals, microwave acid digestion/dissolution of sample. Quantitative determination by atomic emission spectrometry (AES). Digestion: Sah and Miller, 1992; determination, Franson, 1985.
Cu, Fe, Mn, Zn	Totals, microwave acid digestion/dissolution of sample. Quantitative determination by atomic emission spectrometry (AAS). Digestion: Sah and Miller, 1992; determination, Franson, 1985.
WATER SALINITY / ALKALINITY / TOXICITY ANALYSES	
pH	Semi-quantifies H_2O pH using the pH meter. U.S. Salinity Laboratory, 1954.
ECe	Semi-quantifies the amount of soluble salts in H_2O using the conductivity meter. Rhoades, 1982.
HCO_3, CO_3	Quantification of the bicarbonate (HCO_3) and carbonate (CO_3) in H_2O by titration with 0.05 Normal H_2SO_4 acid. Rhoades, 1982.
Cl	Amount of chloride based on electrometric titration of H_2O by chloridometer. Rhoades, 1982.
P	Quantitative determination by ascorbic acid reduction of phosphomolybdate complex and quantitative measurement by flow injection analysis. Franson, 1985.
SO_4-S	Amount of sulfate sulfur present in H_2O, by inductively coupled plasmic emission spectrometry. Soltanpour, et al, 1982.
B	ICP-AES determination of amount of boron in H_2O. Soltanpour, et al, 1982.
Ca, Mg	Amounts of soluble calcium and magnesium in H_2O by inductively coupled plasmic atomic emission spectrometry. Soltanpour, et al, 1982.
Na, K (sol)	Amounts of soluble potassium and sodium in H_2O by emission spectrometry. Knudsen, 1982.
SAR	Sodium Absorption Ratio estimated calculation from calcium, magnesium and sodium in H_2O. Calculation: U.S. Salinity Laboratory Staff, 1954.
ESP	Estimated value for exchangeable sodium percentage. Calculated from SAR values. Calculation: U.S. Salinity Laboratory Staff, 1954.
NO_3-N, NH_4-N	Determination by diffusion-conductivity analyzer. Carlson, 1978.
TKN	Total Kjeldahl Nitrogen in H_2O. Total reduced nitrogen by the wet oxidation of H_2O using standard Kjeldahl procedure with sulfuric acid and digestion catalyst. Carlson, 1978.
Zn, Cu, Mn, Fe	Determination by atomic absorption spectrometry. DeBoer and Reisenauer, 1973.
Se	Total selenium using nitric/perchloric acid digestion/dissolution of sample. Quantitative determination by vapor generation by inductively coupled plasma atomic emission spectroscopy (ICP-AES). Determination: Tracy and Moeller, 1990.

Table A-3 *(continued)*. DANR Analytical Laboratory soil, plant and water analyses methods.

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APPENDIX B

Survey instruments, trade journal articles, and presentation brochures

APPENDIX C

Analysis of survey data

A Survey of Professional Turfgrass Managers in Southern California Concerning Their Use of Turfgrass Best Management Practices

Summary. The best management practices (BMPs) related to turfgrass management encompass a wide variety of activities, including fertilization, irrigation, mowing, pest control, and soil management. There is a great deal of literature relating proper implementation strategies or evaluating the efficacy of specific BMPs. However, little attention has been given to determining just how effective information regarding BMPs is being assimilated and utilized by professional turfgrass managers. The objectives of this study were to assess the current perception and implementation of several important turfgrass BMPs and to determine whether or not those perceptions and implementations differed between turfgrass advisors and managers and between general and sports turfgrass managers. We surveyed professional managers attending the University of California, Riverside, Turfgrass Research Conference and Field Day in the fall of 1998 and 1999. Turfgrass managers, especially sports turfgrass managers, were found to be the most committed to implementing the BMPs in the survey. Overall, the survey respondents considered BMPs to be important and not highly difficult to implement. The limitations to the adoption of BMPs were indicated to be a lack of financial backing, employee training, and necessary time – all of which could be remedied with a sufficient commitment of resources by the turfgrass industry.

There are numerous definitions of the phrase "best management practice," which vary depending on the specific context involved, as well as the currently accepted standards and goals of agronomic management. In general, however, best management practices (BMPs) are considered to be a set of guidelines or procedures which have been determined, as part of an overall program, to be an effective and practical (technically, socially and economically) method for reducing, preventing, or controlling undesirable effects of management; promoting or maintaining beneficial effects of management; and/or protecting the environment or natural habitat (Campbell, 1996; Hubbard et al., 1998; King County, Wash. Dept. of Transportation, 2000; Lindsey et al., 1998; Logan, 1990; Ohio State Univ. Ext., 1996; The One Plan, 2001; South Carolina Forestry Commission, 2001; U.S. EPA, 2000; Yergert et al., 1993).

Turfgrass-related BMPs encompass a wide variety of activities, including fertilization, irrigation, mowing, pest control, and soil management. There is a great deal of literature relating proper implementation strategies or evaluating the efficacy of specific BMPs. However, little attention has been given to determining just how effective information regarding BMPs is being assimilated and utilized by professional turfgrass managers.

The BMP information, once determined by scientific research, needs to be made readily available to those making turfgrass management decisions. This function is often served by educational outreach programs which disseminate and promote BMPs. A logical starting point for such programs is to determine what BMPs turfgrass managers (and their advisors) are aware of, and which BMPs, if any, are currently being implemented. The objectives of this study were to assess the current perception and implementation of several important turfgrass BMPs and to determine whether or not those perceptions and implementations differed between turfgrass advisors and managers and between general and sports turfgrass managers.

Materials and Methods

We surveyed professional managers attending the University of California, Riverside, Turfgrass Research Conference and Field Day in the fall of 1998 and 1999. The conferences were attended by professional turfgrass managers, personnel working in the turfgrass industries, educators, and consultants from the southern California region. The participants were asked to complete the surveys during a 10-min period following a short presentation regarding BMPs for managing tall fescue (*Festuca arundinacea* Schreb.). There were 191 surveys collected from the 1998 conference and 190 surveys collected from the 1999 conference, for a total of 381 surveys. In 1999, the survey asked the participants if they had answered the survey in the previous year. Responses of "yes" or "not sure" eliminated 76 surveys, leaving a total of 305 surveys as part of the data set. Although this was a sample of convenience (Guilford, 1978; Iversen and Norpoth, 1976; Kish, 1965; Vogt, 1999), which does require caution in terms of generalizability of the data, we believe the survey respondents represented a cross-section of the decision-makers in the turfgrass industry in southern California. A recent survey conducted by Templeton et al. (2000) on the environmental horticulture industry in California included a number of comparable job categories. The distribution they found was similar to our sample.

The survey instrument consisted of three sections (Table C-1): the first section requesting basic information about the conference participants, the second section gauging their activities and perceptions of eight BMPs, and a third section asking about their perceptions regarding the associated tall fescue BMP presentation. This last section was not analyzed statistically and the responses are not discussed herein.

The majority of the survey focused on gauging the respondent's activities and perceptions of eight BMPs, including water conservation; fertility program development; turfgrass selection; mowing program development; integrated pest management (IPM); protecting groundwater and surface water from potential contamination from turfgrass chemicals and fertilizers; protecting nontarget plants, animals and humans from the potential toxic effects of turfgrass chemicals; and protecting native habitats during turfgrass construction and maintenance. The respondents indicated, for each BMP, their perceptions regarding its importance, if it was being currently implemented, if they were likely to continue or to start the practice, and their perceptions regarding its difficulty level. The survey also asked the respondents to identify the factors which have limited their ability to adopt BMPs and which of six fertilization and six irrigation practices they consistently performed.

There were several types of questions in the survey, including: (1) questions which asked for simple, basic information about the respondents themselves, which was then summarized or averaged (questions 1, 2b, and 2c); (2) questions which asked for a single response from a list of possible responses for which the percentages of respondents which indicated each possible answer were determined (questions 2a, 3, 9, and 10); (3) questions which asked survey respondents to "check all that apply" from a list of possible responses for which the percentages of respondents which indicated each choice were determined (questions 4, 6, 7 and 8); and (4) questions which included a series of BMPs which asked respondents to note, for each BMP, on a 1 to 5 scale its importance (1 = not important, 5 = very important), how often it was being currently implemented (1 = never, 5 = always), if they were likely to continue or start the BMP (1 = not likely, 5 = very likely), and its difficulty level (1 = easy, 5 = hard) (questions 5a-h).

In order to facilitate statistical analysis by the chi-square statistic, turfgrass industry job classifications were coded into "advisors" and "managers" and the managers further coded into "general" and "sports" turfgrass managers (Table C-2). Sod and turfgrass seed producers were not included in any of the coding or chi-square analyses because their management practices are substantially different from typical turfgrass managers. Respondents who indicated "other" or who indicated multiple turfgrass industry job classifications were also not included.

The responses to two sets of questions were then analyzed with chi-square tests of independence in a 2 2 frequency table for both "advisors" versus "managers" and "general" versus "sports" turfgrass managers. The first set of questions to be analyzed in this manner were regarding the factors limiting the adoption of BMPs and the implementation of specified fertilization and irrigation practices, with each factor or practice coded as "yes" (if checked) or "no" (not checked). The second set of questions were regarding the series of eight BMPs, with the responses from the original 1 to 5 scales being coded into "low to moderate" (1 to 3) and "high" (4 to 5).

Results and Discussion

The respondents to the surveys were primarily managers of public (government/public property) sites (41%), golf courses (19%), private (commercial/residential) sites (8%), and manufacturers or sales representatives of turfgrass-related products (6%) (Table C-2). The vast majority of the respondents were from southern California (88%) and they had an average of 13 years of experience in the turfgrass industry. The respondents managed a wide variety of turfgrasses, including bermudagrass (*Cynodon* L. C. Rich) (82%), tall fescue (57%), perennial ryegrass (*Lolium perenne* L.) (56%), kikuyugrass (*Pennisetum clandestinum* Hochst. ex Chiov.) (40%), annual bluegrass (*Poa annua* L.) (27%), and creeping bentgrass (*Agrostis palustris* Huds.) (25%). Most notably, the respondents were decision-makers, with a total of 88% indicating they were always or usually responsible for turfgrass management decisions or recommendations at their site.

Factors Limiting Adoption of Best Management Practices (BMPs)

The single most common factor which limited the ability of all survey respondents to adopt BMPs was cost or financial limitations (58%) (Table C-3). About a third of all respondents also chose employee skill level and time (37% and 35%, respectively) as important limitations. Notably only 8% of all respondents indicated that not considering BMPs to be important was a limiting factor for adopting BMPs. However, advisors (18%) were more likely than managers (6%) and general turfgrass managers (9%) more likely than sports turfgrass managers (2%) to indicate this as a limiting factor. Also, lack of organization or planning was more of a limiting factor for general turfgrass managers (26%) than sports turfgrass managers (14%).

Fertilization and Irrigation Practices

Fertilization practices:

The majority of all respondents indicated that they consistently apply appropriate amounts of nitrogen specific for turfgrass species and requirements of turfgrass use (61%), apply nitrogen based on seasonal growth patterns and need (59%), and apply different combinations of slow- and fast-release nitrogen sources according to seasonal growth and expected rainfall (53%) (Table C-4). More than a third (37%) of all respondents also indicated that they conduct soil fertility tests every 1 to 2 years. The least common practices were applying P_2O and K_2O relative to annual nitrogen applied (26%) and avoiding fertilization prior to rain (12%).

There were no statistically significant differences between advisors and managers for any of the fertilization practices. However, 23% to 37% more sports turfgrass managers than general turfgrass managers indicated that they were consistently performing several of the practices.

Irrigation practices:

The vast majority of all respondents (86%) indicated that they consistently check irrigation systems for proper function (Table C-5). Approximately two-thirds of all respondents also indicated that they consistently adjust irrigation clocks at least every 3 months (68%) and size nozzles for balanced precipitation on rotor systems (62%). About half of all respondents consistently cycle irrigation on slopes to prevent runoff (55%) and irrigate according to weather station or soil moisture sensor data (49%). Only 41% of all respondents indicated they consistently check system operating pressures.

There were no statistically significant differences between advisors and managers for any of the irrigation practices. However, significantly more general turfgrass managers (81%) than sports turfgrass managers (49%) indicated they consistently adjusted irrigation clocks at least every 3 months. Also, 20% more sports turfgrass managers than general turfgrass managers noted they irrigated according to weather station or soil moisture sensor data.

Perceptions and Commitment to BMPs in Terms of Different Job Categories

Overall, the majority of respondents considered all eight of the BMPs to be highly important (i.e., rating them 4 or 5 on the 1 to 5 scale, with 5 being highest), ranging from 64% for protecting native habitats during maintenance and construction to 83% for fertility program development (Table C-6). The respondents also considered the BMPs to not be highly difficult – only 22% to 37% rated the BMPs with a 4 or 5 (on the 1 to 5 scale, with 5 being most difficult). Despite the recognition of the importance of the BMPs and the fact that they are generally not highly difficult to implement, only about half to two-thirds of all respondents were conducting the practices with high frequency (ratings of 4 or 5 on the 1 to 5 scale, with 5 being most frequent), or were highly likely to continue or start a practice (ratings of 4 or 5 on the 1 to 5 scale, with 5 being most likely). For all eight of the BMPs in the survey, there were statistically significant differences between the responses of advisors and managers and between general and sports turfgrass managers, as noted below.

Water conservation

More turfgrass managers than advisors considered water conservation to be highly important (83% to 69%, respectively). Managers were also more likely to be implementing water conservation with a high frequency than advisors (60% and 44%, respectively) and to continue or start the practice (73% and 53%, respectively). There were no significant differences between general and sports turfgrass managers in terms of their perceptions and commitment to water conservation.

Fertility program development

There were no significant differences between advisors and managers in terms of their perceptions and commitment to fertility program development. However, more sports turfgrass managers than general turfgrass managers considered this practice to be highly important (90% to 78%, respectively). Sports turfgrass managers, when compared to general turfgrass managers, were also more frequently implementing

(76% to 48%, respectively) and more likely to continue or start the practice (79% to 59%, respectively).

Turfgrass selection

Managers were somewhat more likely than advisors to view turfgrass selection as highly important (75% to 61%, respectively). However, only about half of all respondents were either performing this practice highly frequently (47%) or likely to start or continue this practice (55%). Overall, only 33% of the respondents considered the practice to be highly difficult, although more sports turfgrass managers (43%) than general turfgrass managers (30%) considered it to be highly difficult.

Mowing program development

Only 53% of advisors considered mowing program development to be highly important as compared to 82% of managers. Similarly, managers were conducting this practice more highly frequently and were more likely to continue or start the practice than were advisors (differences of 28% and 29%, respectively). Overall, 79% considered the practice to be highly important, and only 24% considered it to be highly difficult to implement. There were no statistically significant differences between general and sports turfgrass managers in regards to this BMP.

Integrated pest management (IPM)

IPM was viewed by managers to be more highly important than it was by advisors (73% and 58%, respectively), and managers were more highly likely to continue or start the practice than advisors (58% and 42%, respectively). Less than half of both managers and advisors practiced IPM highly frequently (49% and 42%, respectively). Most of the general and sports turfgrass managers considered IPM to be highly important (70% and 78%, respectively), but sports turfgrass managers were more frequently conducting IPM and more highly likely to continue or start IPM than general turfgrass managers (a difference of 24% and 17%, respectively).

Protecting water sources from chemicals and fertilizers

There were no statistical differences between advisors and managers when it came to protecting groundwater and surface water sources from potential contamination from turfgrass chemicals and fertilizers, and only one difference between general and sports turfgrass managers (19% more sports turfgrass managers were more highly likely to be frequently conducting the BMP than general turfgrass managers).

Protecting non-targets from chemicals

Managers were more attentive to protecting non-target plants, animals and humans from the potential toxic effects of turfgrass chemicals than were advisors. There were 15% more managers than advisors who considered the BMP to be highly important, and 16% to 17% were more highly likely to be conducting this practice or likely to continue or start this practice, respectively. There were no statistically significant differences between general and sports turfgrass managers in regards to this BMP.

Protecting native habitats during construction and maintenance

The only statistically significant difference between managers and advisors in regards to protecting native habitats during turfgrass construction and maintenance was that more managers than advisors were highly likely to continue or start the practice (55% and 36%, respectively). However, sports turfgrass managers and general turfgrass managers considered the BMP quite differently. Sports turfgrass managers considered the practice to be more highly important than general turfgrass managers (76% and 61%, respectively) and were more highly likely to be frequently conducting the BMP or highly likely to continue or start the BMP (a difference of 14% and 17%, respectively). Further, 40% of sports turfgrass managers, compared to 26% of general turfgrass managers considered protecting native habitats to be highly difficult to implement.

Conclusions

Overall, the survey respondents considered BMPs to be important, although turfgrass managers, especially sports turfgrass managers, were the most likely to be committed to the BMPs listed in the survey. The survey respondents also did not generally consider the BMPs to be difficult to implement. Together, this suggests that what is needed is a greater commitment on the part of the turfgrass industry as a whole to provide the financial backing, employee training, and necessary time which has previously limited the adoption of important BMPs. Outreach programs will play an important role in this effort, and in order to most effectively create such programs, more in-depth and rigorous surveys of the turfgrass industry are necessary.

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Table C-1. Survey questions.

SECTION 1

1. Did you complete this survey in 1998? *1999 only. Choices: yes; no; or not sure*.

2a. Which of the following indicates how you are primarily involved with turfgrass (choose only one)? *Choices: golf course management; professional consulting/horticulture advising; manufacture/sales of turfgrass-related products; public (government/public property) site management; private (commercial/residential) site management; sports turfgrass management; sod production; turfgrass seed production; turfgrass research; or other.*

2b. Number of years you have been involved with the activity checked above?

2c. What is the county and state where you primarily perform this activity (please specify one county)?

3. How often are you responsible for making decisions or recommendations about turfgrass management practices (turfgrass selection, irrigation practices and system maintenance, fertilization programs, mowing, pesticide applications, etc.)? *Choices: always; usually; rarely; or never.*

4. If you manage turfgrass, please indicate the turfgrass species at your site (check all that apply). *Choices: bermudagrass; tall fescue; creeping bentgrass; perennial ryegrass; kikuyugrass; annual bluegrass; St. Augustinegrass [*Stenotaphrum secundatum *(Walt.) Kuntze]; Kentucky bluegrass (*Poa pratensis *L.); zoysiagrass (*Zoysia *Willd.); and other(s).*

SECTION 2

5. Examine each of the BMPs described below and note whether or not you consider it to be an important management practice, whether or not you are currently performing the practice, whether or not you are likely to either continue or initiate this practice in the future, and whether or not you feel the practice is easy or very difficult to carry out. *Responses on a 1 to 5 scale for the following: importance (1 = not, 5 = very); doing this now? (1 = never, 5 = always); likely to continue/start? (1 = not likely, 5 = very likely); difficulty level (1 = easy, 5 = very hard).*

The BMPs:

a) water conservation (ET_o-based water budgets, seasonal adjustments of irrigation clocks, irrigation system checks, etc.)
b) fertility program development (fertilization based on plant species, type of use, and seasonal and climatic requirements, soil type; use of appropriate fertilizer type, amount, and frequency of application)
c) turfgrass selection [choose species and cultivars that, for example, require less water, possess more tolerance to stress (including pests) or possess other traits that would result in the successful management of turfgrass, etc.]
d) mowing program development (Mowing height/frequency based on species/cultivar requirements, plant growth and/or stress, etc.)
e) integrated pest management (managing the "most healthy" turfgrass as possible via sound agronomic principles as the best prevention to pests, defining threshold pest activity/amount prior to pesticide applications, etc.)
f) protecting ground water and surface water from potential contamination from turfgrass chemicals and fertilizers
g) protecting non-target plants, animals and humans from the potential toxic effects of turfgrass chemicals
h) protecting native habitats during turfgrass construction and maintenance

6. What factor(s) have limited your ability to adopt BMPs in the past (check all that apply)? *Choices: cost/financial limitations; availability of BMP information; lack of organization/planning; government regulations; employee skill level; time; BMPs not considered important; no personal authority to implement BMPs; client/owner/public unaware of or disinterested in BMPs; and other(s)*

7. Which of the following fertilization practice(s) do you consistently perform (check all that apply)? *1999 only. Choices: apply appropriate amount of nitrogen (N) specific for turfgrass species and requirements of turfgrass use; apply different combinations of slow- and fast-release N sources according to seasonal growth and expected rainfall; apply N based on seasonal growth patterns and need; apply* P_2O_5 *and* K_2O *relative to annual N applied; conduct soil fertility tests every 1 to 2 years; and avoid fertilizing prior to rain.*

8. Which of the following irrigation practice(s) do you consistently perform (check all that apply)? *1999 only. Choices: irrigate according to weather station/soil moisture sensor data; check system operating pressures; adjust irrigation clocks at least every 3 months; check irrigation systems for proper function; cycle irrigation on slopes to prevent runoff; and size nozzles for balanced precipitation on rotor systems*.

SECTION 3

9. Was the information presented today and contained in the proceedings/handout on BMPs useful? *Choices: very useful; somewhat useful; not useful; or not sure.*

10. Would you be likely to adopt or change irrigation or fertilization practices based on information presented? *Choices: very likely; somewhat likely; not likely; or not sure.*

11. Comments and suggestions about the presentation or this questionnaire.

Table C-2. Information concerning respondents surveyed over two years at the University of California, Riverside, Turfgrass Research Conference and Field Day.

Turfgrass industry job classification	Respondents		Category		Average number of years of experience	Frequency of decision-making	
	Number	Percent	Advisor/ manager	General/ sports turfgrass		Always /usually	Rarely /never
						--------- % --------	
Public (government/public property) site management	124	41	Manager	General	13	89[z]	11
Golf course management	59	19	Manager	Sports	14	85	15
Private (commercial/residential) site management	24	8	Manager	General	11	96	4
Manufacture/sales of turfgrass-related products	18	6	Advisor	–	14	83	17
Professional consulting/horticultural advising	14	5	Advisor	–	16	93	7
Sports turfgrass management	13	4	Manager	Sports	14	92	8
Sod production	12	4	–	–	8	75	25
Turfgrass research	4	1	Advisor	–	18	100	0
Turfgrass seed production	4	1	–	–	15	75	25
Other	7	2	–	–	10	100	0
Multiple classifications	25	8	–	–	15	84	16
Total[y]	305	100			13	88	12

[z] Percentages under always/usually and rarely/never total 100% of respondents for a given turfgrass industry job classification.
[y] Includes one survey respondent that did not answer the question regarding turfgrass industry job identification.

Table C-3. Influence of job and turfgrass management categories on the perception of factors limiting the adoption of best management practices of survey respondents.

Limiting factor	Job category[z]			Turfgrass management category[y]			All survey respondents[x]
	Advisor	Manager	χ^2	General	Sport	χ^2	
	------- % yes[w] -------			------- % yes[w] ------			% yes[w]
Cost/financial limitations	54	59	0.27^{NS}	60	57	0.13^{NS}	58
Employee skill level	25	39	2.02^{NS}	38	40	0.05^{NS}	37
Time	25	36	1.41^{NS}	38	34	0.27^{NS}	35
Availability of BMP information	32	21	1.81^{NS}	21	22	0.02^{NS}	21
Lack of organization/planning	14	22	0.95^{NS}	26	14	3.94^{*}	21
Government regulations	7	19	2.52^{NS}	21	15	0.99^{NS}	18
No personal authority to implement BMPs	14	20	0.50^{NS}	23	14	2.18^{NS}	19
BMPs not considered important	18	6	4.63^{*}	9	2	3.66^{+}	8
Other	11	5	1.27^{NS}	4	9	2.84^{+}	7

[z] Total number of respondents: 234.

[y] Total number of respondents: 206.

[x] Total number of respondents from all job classifications: 275.

[w] Respondents could check ("yes") for as many of the listed factors limiting the adoption of best management practices as applied to their situation.

^{NS}, $^{+}$, * Nonsignificant or significant at $P \leq 0.10$ or 0.05, respectively, by the chi-square test of independence in a 2x2 frequency table.

Table C-4. Influence of job and turfgrass management categories on the reported frequency of consistently performing selected fertilization best management practices by survey respondents.

Fertilization BMP	Job category[z]			Turfgrass management category[y]			All survey respondents[x]
	Advisor	Manager	χ^2	General	Sport	χ^2	
	------- % yes[w] -------			------- % yes[w] ------			% yes[w]
Apply appropriate amount of nitrogen specific for turfgrass species and requirements of turfgrass use	33	60	0.89^{NS}	46	83	11.95^{***}	61
Apply nitrogen based on seasonal growth patterns and need	33	59	0.81^{NS}	54	69	2.01^{NS}	59
Apply different combinations of slow- and fast-release nitrogen sources according to seasonal growth and expected rainfall	67	52	0.26^{NS}	43	66	4.51^{*}	53
Conduct soil fertility tests every 1 to 2 years	0	36	1.68^{NS}	23	57	10.73^{***}	37
Apply P_2O_5 and K_2O relative to annual nitrogen applied	33	25	0.10^{NS}	20	34	2.44^{NS}	26
Avoid fertilizing prior to rain	0	11	0.37^{NS}	9	14	0.63^{NS}	12

[z] Total number of respondents: 94 (data available for 1999 survey only).

[y] Total number of respondents: 91 (data available for 1999 survey only).

[x] Total number of respondents from all job classifications: 107 (data available for 1999 survey only).

[w] Respondents could check (“yes”) for as many of the listed fertilization best management practices as applied to their situation.

[NS],[*],[***] Nonsignificant or significant at $P \leq 0.05$ or 0.001, respectively, by the chi-square test of independence in a 2x2 frequency table.

C-5. Influence of job and turfgrass management categories on the reported frequency of consistently performing selected irrigation best management practices by survey respondents.

Irrigation BMP	Job category[z]			Turfgrass management category[y]			All survey respondents[x]
	Advisor	Manager	χ^2	General	Sport	χ^2	
	------- % yes[w] -------			------- % yes[w] ------			% yes[w]
Check irrigation systems for proper function	67	88	1.13[NS]	87	89	0.05[NS]	86
Adjust irrigation clocks at least every 3 months	100	69	1.36[NS]	81	49	10.67[***]	68
Size nozzles for balanced precipitation on rotor systems	33	61	0.90[NS]	67	51	2.07[NS]	62
Cycle irrigation on slopes to prevent runoff	67	58	0.08[NS]	61	54	0.41[NS]	55
Irrigate according to weather station/soil moisture sensor data	33	51	0.34[NS]	43	63	3.49[+]	49
Check system operating pressures	33	40	0.06[NS]	39	43	0.14[NS]	41

[z] Total number of respondents: 92 (data available for 1999 survey only).
[y] Total number of respondents: 89 (data available for 1999 survey only).
[x] Total number of respondents from all job classifications: 103 (data available for 1999 survey only).
[w] Respondents could check ("yes") for as many of the listed irrigation best management practices as applied to their situation.
[NS],[+],[***] Nonsignificant or significant at $P \leq 0.10$ or 0.001, respectively, by the chi-square test of independence in a 2x2 frequency table.

Table C-6. Influence of job and turfgrass management categories on the perception and commitment to eight best management practices.

Perception/commitment to best management practices	Job category[z]			Turfgrass management category[y]			All survey respondents[x]
	Advisor	Manager	χ^2	General	Sports	χ^2	
	------- % high[w]------			----- % high[w]----			% high[w]
Importance							
Water conservation	69	83	3.53^{+}	84	81	0.35^{NS}	79
Fertility program development	81	82	0.06^{NS}	78	90	4.70^{*}	83
Turfgrass selection	61	75	3.26^{+}	74	79	0.80^{NS}	75
Mowing program development	53	82	15.07^{***}	81	83	0.16^{NS}	79
Integrated pest management (IPM)	58	73	3.09^{+}	70	78	1.38^{NS}	73
Protecting water sources from chemicals and fertilizers	69	77	1.04^{NS}	77	78	0.01^{NS}	75
Protecting non-target plants, animals and humans from chemicals	69	84	4.16^{*}	84	82	0.22^{NS}	82
Protecting native habitats during	53	66	2.49^{NS}	61	76	4.82^{*}	64
Frequency of current implementation							
Water conservation	44	60	3.26^{+}	57	67	1.73^{NS}	56
Fertility program development	64	57	0.56^{NS}	48	76	15.98^{***}	61
Turfgrass selection	44	45	0.01^{NS}	42	53	2.31^{NS}	47
Mowing program development	39	67	10.73^{***}	64	74	0.16^{NS}	64
Integrated pest management (IPM)	42	49	0.60^{NS}	41	65	11.86^{***}	49
Protecting water sources from chemicals and fertilizers	56	54	0.03^{NS}	48	67	6.82^{**}	52
Protecting non-target plants, animals and humans from chemicals	58	74	3.80^{*}	72	78	0.76^{NS}	71
Protecting native habitats during construction/maintenance	36	48	1.68^{NS}	43	57	3.64^{+}	45
Likelihood to continue/start implementation							
Water conservation	53	73	5.85^{*}	74	69	0.58^{NS}	68
Fertility program development	64	66	0.06^{NS}	59	79	8.37^{**}	69
Turfgrass selection	53	55	0.06^{NS}	54	57	0.16^{NS}	55
Mowing program development	39	68	11.12^{***}	66	71	0.47^{NS}	65
Integrated pest management (IPM)	42	58	3.23^{+}	52	69	6.02^{**}	57
Protecting water sources from chemicals and fertilizers	64	62	0.06^{NS}	61	64	0.19^{NS}	62
Protecting non-target plants, animals and humans from chemicals	58	75	4.06^{*}	74	75	0.01^{NS}	71
Protecting native habitats during construction/maintenance	36	55	4.64^{*}	50	67	5.45^{*}	53
Difficulty level							
Water conservation	33	30	0.12^{NS}	34	24	2.37^{NS}	30
Fertility program development	25	22	0.18^{NS}	22	22	0.01^{NS}	22
Turfgrass selection	39	34	0.31^{NS}	30	43	3.83^{*}	33
Mowing program development	31	23	1.04^{NS}	25	18	1.33^{NS}	24
Integrated pest management (IPM)	39	37	0.06^{NS}	36	38	0.02^{NS}	37
Protecting water sources from chemicals and fertilizers	36	36	0.00^{NS}	39	31	1.33^{NS}	35
Protecting non-target plants, animals and humans from chemicals	28	30	0.10^{NS}	33	25	1.50^{NS}	30
Protecting native habitats during construction/maintenance	28	31	0.14^{NS}	26	40	4.40^{*}	32

[z] Total number of respondents: 256.
[y] Total number of respondents: 220.
[x] Total number of respondents from all job classifications: 305.
[w] Responses originally on a 1 to 5 scale (5 = highest) with 1 to 3 coded as "moderate/low" and 4 to 5 as "high."
^{NS}, $^{+}$, *, **, *** Nonsignificant or significant at $P \leq 0.10$, 0.05, 0.01, or 0.001, respectively, by the chi-square test of independence in a 2x2 frequency table.