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THE FRUITS OF THEIR LABOR
NITROGEN MANAGEMENT IN STONE FRUIT AND ALMOND PRODUCTION

VIDEO HANDBOOK

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Sponsored by

California Department of Food and Agriculture
Fertilizer Research and Education Program

1996

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This handbook and videotape was funded by a grant from the Fertilizer Research and Education Program, California Department of Food and Agriculture. The Fertilizer Research and Education Program provides funding to advance the environmentally safe and agronomically sound use and handling of fertilizing materials.

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INTRODUCTION

A. STONE FRUIT AND ALMOND PRODUCTION IN CALIFORNIA

California has been the leading agricultural producing state for nearly 50 consecutive years. Gross receipts in 1994 for all crops totaled $14.72 billion. California is also the leading state in the production of almonds and nearly all of the stone fruits: almonds (99.9% of the U.S. total), dried prunes (100%), apricots (94.8%), nectarines (93%), plums (86.8%), peaches (70.3%), and sweet cherries (25.1%). In 1994 these crops were produced on 643,100 acres of California cropland and produced gross receipts of $1.5 billion.

It is estimated that 1/3 of agricultural production nationwide can be attributed to the use of nitrogen fertilizers with at least that level of contribution in California. Stone fruit and almond trees are moderately to highly responsive to the applications of nitrogen fertilizers. Under irrigated conditions and long growing seasons, nitrogen fertilizers are an especially important input for the production of stone fruit and almond. Production of nearly all fresh stone fruits and almonds in California is concentrated in the central and southern portions of the San Joaquin Valley including Kern, Tulare, Kings, Fresno, Madera, Merced, Stanislaus, and Santa Clara Counties. Dried prune production is primarily in the Sacramento Valley counties of Sutter, Butte, Yuba, Tehama and Glenn.

B. ADVERSE AGRONOMIC AND ENVIRONMENTAL EFFECTS OF EXCESSIVE NITROGEN FERTILIZER USE

The soils in California's arid Central Valley that are typically used for stone fruit and almond production are light-textured with a high potential for leaching due to a low water holding capacity. Development of irrigation greatly increased the potential yields of the crops grown on these soils and greatly increased the need for nitrogen fertilizers. Dramatic early responses of stone fruits and almonds to nitrogen fertilizers has led to the widespread use, and in some cases overuse of these fertilizers. Over-fertilization was once seen as insurance against nitrogen deficiencies, which reduce both yields and profits. But as research by the University of California has shown, this practice has many agronomic and economic disadvantages.

Adverse agronomic effects of over-fertilization include excessive shoot growth and the consequent shading of fruiting wood, which negatively affects flower bud development, fruit set, fruit quality, and shoot survival. Specific adverse effects include delayed maturity of many stone fruits, smaller peaches, loss of color in peaches and nectarines, more split pits in peaches, increased susceptibility of nectarines to infection by brown rot and peach twig borers feeding on nectarines, extra costs of summer pruning, and of losses from split or wind-damaged trees.

Over-fertilization also wastes nitrogen fertilizer and reduces profits. In many cases, over-fertilization is necessitated by over-application of irrigation water which leaches soil nitrate below the root zone where it is unavailable to the crop and contributes to losses of nitrogen gases back into the atmosphere via the process of denitrification. Along with the agronomic and economic losses associated with over-fertilization, the main driving force behind the current

interest in using more "optimum" nitrogen rates is the desire to protect groundwater resources from contamination by nitrates that leach below the crop root zone with excess irrigation or rainfall. Although nitrate is found in all living systems, too much nitrate can adversely affect human health and the environment. High nitrate levels in drinking water can cause the infant disease methemoglobinemia, or "blue-baby syndrome". Excess nitrogen can lead to other environmental problems as well, such as the growth of oxygen-depleting algae in rivers and lakes (eutrophication) and the destruction of many forms of aquatic life. Groundwater aquifers that become contaminated with nitrate are difficult and costly to remediate. Additional costs of nitrate in groundwater can include increased costs for drinking water treatment, land use restrictions, and a reduced tax base.

C. IMPORTANCE OF BMP'S IN OPTIMUM NITROGEN USE

Nitrogen fertilizer is an essential input in high-yielding agriculture such as that found in California. Research has shown that a coordinated effort to apply both nitrogen and irrigation water at levels that just optimize crop production can minimize growers' input costs, maximize profits, and prevent contamination of ground and surface water by nitrate. These are the goals of implementing agricultural Best Management Practices (BMP's).

In this video, we give growers the tools they need to manage nitrogen efficiently and profitably. This begins with an assessment of the nitrogen-supplying capacity of your particular orchard, including contributions from the native soil, nitrogen contained in the irrigation water, and nitrogen supplies from cover crops, composts and manures. Estimations of crop removal of nitrogen in harvested fruit and implementation of annual leaf tissue analysis will also be discussed.

We will then discuss optimum timing and placement of nitrogen fertilizer materials. For irrigated crops, this includes a careful look at fertigation practices and proper irrigation scheduling. Finally, we offer guidance on selecting the correct type of nitrogen fertilizer and its rate of use that will be most appropriate for a particular orchard.

SECTION 1: ORCHARD NITROGEN ASSESSMENT

A. NITROGEN REMOVAL BY THE CROP

The development of a sound nitrogen program involves several steps. First, a rough estimate of the orchard's nitrogen needs and its nitrogen removal rate is made. Second, nitrogen supplied by other sources such as soil organic matter, irrigation water, and cover crops is estimated. This information is used to develop an approximate fertilization rate. The final step is to fine-tune the rate from year to year using leaf tissue analysis, yield records, vigor estimates, and general observations of the trees.

A certain amount of nitrogen is removed from the orchard in the harvested crop. Table 1 shows the amounts of nitrogen removed in harvested fruits and nuts grown under conditions similar to those in California.

Nitrogen fertilizer rates that exceed the crop removal of nitrogen must be applied for optimum productivity, because growers realize that there are inherent inefficiencies in cropping systems. However, growers have traditionally applied fertilizer nitrogen at rates of 3 to 5 times the amount removed by the crop. Although these rates would be appropriate for flood-irrigated orchards with fair to poor fertilizer use efficiency, it should not be necessary to apply more than 1.5 to 2 times the nitrogen removal rate where more efficient fertilizer management is practiced. The efficiency of fertilizer management can be influenced by fertilizer materials, timing, and placement; fertigation techniques; and irrigation application efficiency.

Table 1

Nitrogen removal in the harvested crop of selected stone fruits, almonds, and walnuts.

Tree crop	Yield ranges[a] (tons/acre)	Pounds of Nitrogen removed (per ton of yield)	Nitrogen removed in crop (lbs/acre)
Almond	0.8 - 1.2[b]	100	80 - 120
Walnut	2 - 3[c]	36	72 - 108
Peach	17 - 28	3.0	51 - 84
Apricot	10 - 15	5.1	51 - 76
Prune	12 - 18	3.7	44 - 67
Nectarine	15 - 25	1.9	28 - 48
Plum	10 - 15	2.8	28 - 42
Cherry, sweet	5 - 7	2.8	14 - 20

Adapted from S.A. Weinbaum, R.S. Johnson, and T.M. DeJong. 1992. Causes and consequences of over fertilization in orchards. HortTechnology 2(1):112-121.
Note: Values do not include pruning which can total 5-20 lbs N/acre depending on the vigor and size of the trees.
[a]Range of yields, considered very good to excellent under California conditions. All values are for fresh weight, except for nut crops.
[b]Kernal weight with standard 5% moisture content.
[c]In-shell weight with standard 8% moisture content.

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As a tree grows, a certain amount of nitrogen is incorporated into its permanent structures. In most cases, this probably amounts to only 5 to 20 lbs of nitrogen per acre per year depending on the size and vigor of the particular trees. The remainder of the nitrogen in leaves, prunings, weeds, and so on, is eventually recycled within the orchard or lost to the environment.

Growers can use Table 1 to make calculations based on the yields their orchards produce. For example, the nitrogen removed from an almond orchard with a yield of 1.2 tons per acre can be calculated as follows:

$$1.2 \frac{\text{tons nut yield}}{\text{acre}} \times 100 \frac{\text{lbs N removed}}{\text{ton of yield}} = 120 \frac{\text{lbs N removed}}{\text{per season per acre}}$$

Similarly, the calculation for a peach orchard producing 28 tons per acre would be:

$$28 \frac{\text{tons fresh yield}}{\text{acre}} \times 3.0 \frac{\text{lbs N removed}}{\text{ton of yield}} = 84 \frac{\text{lbs N removed}}{\text{per season per acre}}$$

B. NATIVE SOIL NITROGEN FERTILITY AND NITROGEN IN IRRIGATION WATER

Most soils contain 2,000 to 4,000 pounds of nitrogen per acre. Most of this nitrogen however, is tied up in the soil organic matter and thus is not readily available to plants. A fertile soil may supply stone and almond trees as much as 50 lbs. of nitrogen per acre per year, whereas a sandy soil may supply very little. The average soil will mineralize about 10 to 20 lbs of nitrogen per acre per year. Previous cropping and fertilization practices may also influence the amount of stored nitrogen in the soil. Following heavy fertilization or incorporation of leguminous cover crops, some soils may be able to maintain vigorous tree growth and fruit production for several years without additional fertilization. Table 2 provides an estimate of the nitrogen-supplying capacity of various types of soil.

The nitrate concentration of some well waters in California has been increasing. In the San Joaquin Valley, for example, the nitrate concentration in wells used to irrigate orchards has been increasing over the past 20 years and commonly exceeds the drinking water standard of 45 parts per million (ppm) of nitrate, which is equivalent to 10 mg of nitrate-N per liter (10 ppm); the amount considered unsafe for infants. According to data collected by the California Department of Water Resources, none of the wells tested in a Tulare County study from 1945 to 1948 exceeded the EPA drinking water standard. By 1987, 38% of these wells exceeded the limit.

Table 2.

Estimated annual nitrogen mineralization rates of various California soils.

Soil type	Nitrogen released (lbs/acre/year)
Previous heavy fertilization or legume crop	60
Fertile loam	40
Sandy loam	20
Sand	10

When water high in nitrate is used for irrigation, the nitrogen it contains should be taken into account in the overall nitrogen budget. Nitrogen applied in irrigation water can be used very efficiently since it is applied evenly, in small amounts, and almost exclusively while trees are actively growing and assimilating nitrogen.

The nitrate concentration of well water used for irrigation should be tested at least annually. This sample can also be used to evaluate other important water quality factors, such as pH, salinity, and sodium, and the levels of boron, sulfate, chloride or other nutrients of interest. Irrigation water contains 2.7 lbs of plant-available nitrogen per acre-foot for every ppm or milligram per liter (mg/l) of nitrate-N. For example, an orchard that receives each year 2.5 acre-feet of water containing 10 ppm nitrate-N will receive 68 lbs of "free" nitrogen per acre. Most surface water from lakes, rivers, and reservoirs contains very low levels of nitrate-N; usually below 1 to 2 ppm.

C. NITROGEN SUPPLIED BY COMPOSTS, MANURES AND COVER CROPS

The nitrogen contributions of composts and manures added to improve soil structure or water penetration cannot be ignored. Although it is not easy to determine the amount of nitrogen that these materials supply, some rough estimations can be helpful. Manures generally provide nitrogen over a period of several years according to an exponential decay- type function; that is, they release 50 to 90% of the nitrogen they contain in the first year and decreasing amounts in subsequent years. The rate of release of nitrogen depends on many factors, including the type of manure, nitrogen concentration, the carbon to nitrogen (C:N) ratio of the manure, the soil type, and climatic conditions. Nitrogen release from several types of manure applications is shown in Table 3.

The values shown in Table 3 should be used only as general guidelines, because they can be changed dramatically by a number of factors. For example, the C:N ratio of plant residues can significantly affect nitrogen release from manures. If manure with a high C:N ratio-such as straw, dried weeds, and shredded prunings is applied, much of the nitrogen in the manure will be tied up by soil microorganisms and will not be immediately available for tree uptake.

Table 3

Nitrogen release from selected types of animal manure.

Type of Manure	Year 1	2	3	4
	- lbs N released/ton of manure -			
Chicken manure, 1.6% N	29	0.3	0.2	0.1
Fresh bovine waste, 3.5% N	52	2.6	1.5	1.0
Dry corral manure, 2.5% N	20	7.5	1.4	0.6
Dry corral manure, 1.5% N	10	3.0	1.7	1.2
Dry corral manure, 1.0% N	4	1.6	1.1	0.7
Liquid sludge, 2.5% N	18	3.2	1.7	1.4

Source: Adapted from the Western Fertilizer Handbook, 7th Edition,1985. Table 8-2 p 143.

Composting is the aerobic, high-temperature decomposition of organic residues. Nitrogen contained in thoroughly composted materials is in a more stable form than that in manures and is therefore released into the soil much more slowly. Instead of trying to predict the contribution of nitrogen from compost, these materials should probably be viewed as an aid to recycling nitrogen within the orchard system. Compost additions often stimulate soil microbial activity, which in turn, helps recycle nitrogen. In essence, the bodies of soil organisms serve as a reservoir for nitrogen and other nutrients that can slow the movement of those nutrients through the soil profile.

Cover crops can remove, recycle, or supply nitrogen in an orchard system. When properly managed, leguminous cover crops can contribute 50 to 150 lbs of nitrogen per acre, much of which can eventually be taken up by tree roots. Common legume cover crops include vetches, medics, and clovers. Non-legumes such as grasses and broadleaf plants can effectively capture and recycle residual nitrogen in orchard soils, especially in the winter.

Both organic soil amendments and cover crops should be viewed as a source of organic matter, essentially a slow-release fertilizer. By building up the level of organic matter over time, the application of commercial fertilizers can be reduced, sometimes quite significantly. The addition of organic amendments and the use of cover crops in orchards should be viewed as just one part of an "integrated" crop production system.

D. CALCULATING THE NITROGEN FERTILIZER RATE

Let's look at an example of how to calculate the nitrogen fertilizer requirement for a peach orchard with an expected yield of 28 tons of fruit per acre. The orchard is located on a sandy loam soil with no cover crop. The irrigation water has a nitrate-N concentration of 5 milligrams per liter (5 ppm) and three acre feet of irrigation water are to be applied using a micro-sprinkler system with "good" irrigation efficiency. No manure or compost will be applied.

Nitrogen removal is 28 tons/acre x 3.0 lbs of N/ton = 84 lbs nitrogen removed in the crop (see Table 1). The use of nitrogen in the annual growth of the tree structures is estimated at 20 lbs/acre. The fertilizer use efficiency is estimated to be "Moderate", or one lb of nitrogen taken up by the trees for every 2 lbs of nitrogen applied. The total nitrogen need is therefore (84 + 20) x 2 = 208 lbs N/acre. Other contributions of nitrogen include 20 lbs/acre from the mineralization of soil organic matter (see Table 2); 40 lbs/acre from the irrigation water (3 acre-ft x 5 mg nitrate-N/liter x 2.7 lb/acre-ft/mg/L); and 0 from manures, composts and cover crops, for a subtotal of 60 lbs N/acre. Subtracting the total nitrogen contribution (60 lbs/acre) from the total nitrogen need (208 lbs/acres) gives the approximate nitrogen fertilizer rate of 148 lbs N/acre.

This fertilizer rate would then be adjusted during the growing season based on observations of tree vigor, crop productivity and leaf tissue analysis, if these results are available in time.

E. SAMPLING AND INTERPRETATION OF LEAF TISSUE

A regular program of leaf sampling and analysis for nitrogen concentration can be a valuable tool in fine-tuning a nitrogen fertilizer program. The procedure has been developed over many years and is similar for all stone fruit crops, almonds, and walnuts.

Samples are generally taken in July, when nitrogen and other nutrient levels in tree leaves are relatively stable. Sampling of peaches and nectarines can also be done in June. In almonds, walnuts, plums, prunes, and apricots, mature non-fruiting spur leaves are sampled. In peaches, nectarines and sweet cherries leaves from the middle of moderately vigorous fruiting shoots are sampled. The numbers of leaves to collect are summarized in Table 4.

Samples should be limited to leaves that are free from insects, mites, and diseases and that are from shoulder-height branches that are well exposed to sunlight. Follow a random pattern through the orchard when sampling leaves. The samples should be placed in a paper bag (plastic bags should **never** be used) and sent to a reputable laboratory for chemical analysis including a test for "total nitrogen". (A list of commercial laboratories that conduct leaf tissue testing for total nitrogen, as well as providing many other services, is in Appendix 1).

Table 4

Guidelines for proper leaf tissue sampling of stone fruit, almond and walnut orchards.

Tree crop	Leaf type	Time of collection	Recommended sample size[a]
Almond	Non-fruiting spur leaf	July	100
Walnut	Terminal leaflets	July	60 - 100
Apricot	Non-fruiting spur leaf	July	50
Plum	Non-fruiting spur leaf	July	75
Prune	Non-fruiting spur leaf	July	75
Nectarine	Mid-shoot leaf	June - July	60 - 100
Peach	Mid-shoot leaf	June - July	60 - 100
Cherry, sweet	Mid-shoot leaf	July	50

[a]Based in part on University of California Prune and Peach/Nectarine Production manuals.

The mid-summer leaf nitrogen concentration ranges that are considered desirable for stone fruit, almond, and walnut crops are shown in Table 5.

In interpreting the results of leaf nitrogen analysis, several factors should be remembered. First, both the numerical level and the trends over time are useful information. It may take two or three years for a change in fertilization to show up in the leaf nitrogen levels, especially if the change involves composts or cover crops. In this case, the trend is more important than the absolute level. Second, when evaluating trends, it should be kept in mind that there is a large reservoir of nitrogen in the soil and in the tree itself. The nitrogen content of mature fruit and nut trees appears to be two to three times greater than the annual uptake of nitrogen from the soil. A large change in leaf nitrogen therefore, is not likely unless a large application of fertilizer has been made. In many cases, little or no increase in leaf nitrogen concentration is observed even when excessively high rates of nitrogen fertilizer are applied. This apparent insensitivity of leaf nitrogen levels to rates of applied nitrogen may result from growth-induced dilution (a dilution of leaf nitrogen within a larger tree canopy volume) or from a lack of any additional uptake of soil nitrogen.

Third, a sudden decrease in leaf nitrogen concentration is probably due to the sampling or laboratory procedure. If the lab analysis of leaf nitrogen is low, the trees should be checked for indications of nitrogen deficiency. These symptoms include pale yellow-green foliage, low tree vigor, and small fruit size in stone fruit crops. Care should be taken not to confuse symptoms of nitrogen deficiency with problems stemming from disease, insect damage, improper irrigation, and excessive fruit load. Increased applications of fertilizer will not solve these problems.

Table 5

Suggested mid-summer leaf nitrogen concentrations for stone fruit, almond, and walnut crops.

Tree crop	Desired leaf N levels % N
Almond	2.3 - 2.5
Walnut	2.3 - 2.8
Apricot, canning	2.5 - 3.0
Apricot, fresh	2.0 - 2.5
Plum	2.3 - 2.8
Prune	2.3 - 2.8
Nectarine	2.6 - 3.0
Peach	2.6 - 3.0
Cherry, sweet	2.0 - 3.0

Source: Adapted from "Soil and Plant Tissue Testing in California", H.M. Reisenauer (Ed.). Div. Of Agric. Sci. Univ. of Calif. Bulletin No. 1879. 1978, and from "Peaches, Plums and Nectarines - Growing and Handling for Fresh Market", Div. Agric. & Natural Res. Publication No. 3331. In many cases, there is only anecdotal evidence for these suggested ranges in leaf N concentration.

SECTION 2: MAXIMIZING ORCHARD NITROGEN USE EFFICIENCY

A. TIMING OF NITROGEN APPLICATIONS

Nitrogen fertilizer should be applied only when there are leaves on the tree. Dormant applications are very inefficient since tree roots do not take up water and nitrogen during this time. Also, fertilizer nitrogen can be lost from the root zone during the winter via denitrification, leaching, and runoff from rains.

Nitrogen fertilizers (if needed) can be efficiently applied to stone fruit and almond crops during two periods in the growing season. The first period is in the late spring when the new flush of shoot and leaf growth is actively occurring (late March to May). The second period is during the mid- to late-summer months prior to harvest. Nitrogen applied at this time will be efficiently taken up by the roots and stored in the tree over the winter months. This stored nitrogen will then be efficiently re-mobilized, early in the following spring during cell division phases of fruit, shoot, and leaf growth. Nitrogen applied too early in the spring will remain unutilized in the soil for an extended period of time and is thus subject to losses. Nitrogen applied from late spring through the summer can often promote excessive shoot growth, and is too late to enhance fruit development. This time is also inconvenient due to conflict with the grower's busy harvest schedule.

The optimal distribution of nitrogen applications during the spring growth flush and the summer periods varies depending on the crop, soil conditions, the efficiency of the irrigation system, and the level of tree vigor that is desired. More frequent, split applications of nitrogen are recommended on sandier soils and where nitrogen can be injected into the irrigation water. Table 6 shows the generally recommended distribution of nitrogen fertilizer applications for stone fruit and almond crops.

Table 6

Recommended distribution of nitrogen fertilizer applications for stone fruit and almond crops.

Crop	Fraction of total annual amount of nitrogen that should be applied during: Spring growth flush	Summer
Almond	About 50%, Apply higher rates with a heavy nut set, less with a lighter set	Not more than 50%, usually between mid-July to September[a] to September
Apricot, Peach, Nectarine, Plum	30-70%, Apply higher rates with late-season varieties, usually in early April	30-70%, Apply higher rates with early season varieties, usually in August to September
Prune, dried	50-70%	30-50%
Cherry, sweet	0-20%, Avoid pre-harvest N if excessive vigor or poor color are problems	80-100%, Apply nitrogen post harvest, generally August to September

B. PLACEMENT OF NITROGEN APPLICATIONS

Because roots proliferate in moist soil, nitrogen fertilizers should be applied to the zone of highest root activity for maximum uptake efficiency. In flood- or sprinkler-irrigated orchards, this zone corresponds to the 1 to 3 feet of surface soil that is moistened by the irrigation water. In drip-irrigated orchards, the zone of root proliferation is a pear-shaped volume of soil surrounding each emitter with a vertical dimension of about 18 to 24 inches. Application of nitrogen fertilizers to soil not receiving irrigation water is very inefficient.

Broadcast application of fertilizers containing ammonium or urea should be spread evenly on the soil surface above the root zone and incorporated mechanically or with irrigation water as soon as possible. This rapid incorporation is needed to minimize nitrogen losses due to the volatilization of ammonia. Without incorporation as much as 50% of the nitrogen can be lost when fertilizer containing ammonium or urea are broadcast onto warm, moist, alkaline soils without incorporation.

Special care must be taken in applying nitrogen fertilizers to young fruit and nut trees. To avoid damaging the tree trunk and roots while fertilizing, nitrogen should be applied at least 18 inches from the tree trunk. Again, be sure that nitrogen is applied to the active root zone of the young trees. (i.e. to soil that will receive irrigation water).

C. INCREASING NITROGEN USE EFFICIENCY THROUGH FERTIGATION

Fertigation is the practice of injecting nutrients such as nitrogen directly into irrigation water. Ideally, nutrients applied in this manner are delivered equally to the entire area being irrigated and in a location that is readily available to tree roots. Other potential advantages of fertigation include lower costs of energy, labor, and equipment and greater choice in the timing of nutrient applications than with other mechanical methods of applying fertilizers. The uniformity of the applied nutrients will be no better than the uniformity of the applied water. Therefore, fertigation used in conjunction with any reasonably efficient method of irrigation will result in increased nitrogen uptake efficiency.

High-frequency, pressurized irrigation systems such as drip or mini-sprinkler installations can provide very efficient application and uptake of both water and applied nitrogen. With pressurized irrigation systems, fertigation is by far the most efficient method of nitrogen application. As a general rule, half the amount of nitrogen is needed with a well-designed pressurized irrigation system to obtain the same effect as broadcast applications of nitrogen to the soil surface using surface irrigation methods. In one study, a drip-irrigated perennial fruit crop absorbed three times more fertilizer nitrogen than did the same crop grown with furrow irrigation when the same amount of nitrogen was applied to both crops.

D. USE PROPER IRRIGATION SCHEDULING TECHNIQUES

Irrigation practices dramatically affect nitrogen uptake efficiency. This is because all forms of applied nitrogen fertilizers convert fairly rapidly in the soil to the nitrate (NO_3) form. Nitrates are readily soluble in water and are not adsorbed onto soil particles. Thus, nitrates can move readily with percolating soil water

down and below the tree's root zone. In addition to being lost from the root zone, nitrates can continue moving downward and ultimately contaminate underground aquifers. Therefore, sufficient water should be applied to meet crop plant needs, but not so much that water is wasted and leaching losses of nitrate are excessive. Knowing just when, how, and how much water to apply to a growing crop is one of the most challenging aspects of modern crop production.

There are two critical requirements to implementing a successful irrigation scheduling program. First, the grower must be able to accurately estimate crop water use. This may be done *directly* by taking plant or soil measurements, or *indirectly* by estimation from weather data. Second, the grower must then have the ability to precisely apply predetermined (i.e. "optimum") amounts of irrigation water to individual orchards throughout the growing season.

Any approach to irrigation scheduling must recognize the degree of soil water depletion that the crop can tolerate. Most orchard and nut crops can tolerate depletion of about 50% of available soil water in the rooting zone. Soil moisture deficits can be measured *directly* using devices such as neutron probes, tensiometers, resistance blocks, and gravimetric sampling. Even the "hand-feel" method can be helpful in determining how much irrigation water is needed. Regardless of the method used, some on-site calibration is required.

Estimates of crop water use can also be approximated indirectly from historical evapotranspiration data or from near real-time weather data obtained through the California Irrigation Management Information System (CIMIS). Evapotranspiration is the total amount of water lost from a crop-soil system and is influenced by numerous environmental and crop factors. These include solar radiation, air temperature, relative humidity, wind speed, crop type, and crop growth stage. Information on historical evapotranspiration records and directions on how to access CIMIS weather data is found in Appendices 2 - 5. Crop coefficients for deciduous fruit and nut crops, which are needed to convert reference evapotranspiration (ET_o) into irrigation requirements are listed in Appendix 6. Several examples of how to calculate irrigation water amounts are shown in Appendix 8. An excellent, detailed guide to on-farm irrigation scheduling is also mentioned in Appendix 6.

SECTION 3: CHOOSING NITROGEN FERTILIZER MATERIALS

A. FERTILIZER - SOIL INTERACTIONS

Nitrogen can be added as a fluid or dry fertilizer in several chemical forms, including ammonium nitrate, ammonium sulfate, calcium nitrate, urea, and animal manures. Legume cover crops also contribute available nitrogen as plant residues are deposited on the soil and decompose. However, no matter what form is added, nitrogen is rapidly converted to nitrate during the growing season and is taken up by tree roots primarily in that form.

In the soil, nitrogen can exist in several chemical forms. For the most part, these include organic nitrogen contained in the soil's organic matter and in plant residues and the inorganic, or mineral forms of nitrogen, nitrate (NO_3) and ammonium (NH_4). In most soils, well over 90% of the nitrogen is in the organic form, tied up in both living organisms and decaying residues. While this amounts to 2,000 - 4,000 pounds of nitrogen per acre, only about 1% of this total, or 20 to 40 lbs per acre is released each year in a plant-available form through the process of mineralization. This is why supplemental sources of nitrogen are needed to support the very productive and high-yielding orchards found in California.

Organic residues decompose or mineralize to ammonium nitrogen in the soil. This is also the form of nitrogen that is found in the majority of commercial fertilizers. However, ammonium nitrogen is then converted into the nitrate form through the process of nitrification. Both nitrification and mineralization occur readily in warm, moist, well-aerated soils. Therefore, the conversion of ammonium nitrogen to nitrate-nitrogen is rapid, and virtually complete within 10 to 14 days.

An understanding of this naturally occurring conversion of soil nitrogen forms is very important in developing effective nitrogen- and water-management practices. The reason is simple: nitrate is soluble and is not held onto the surfaces of silt and clay particles in the soil. Therefore, nitrate is very susceptible to the downward leaching action of excess irrigation water or winter rainfall. To be effective, nitrogen fertilizer- and water-management practices must limit applications of nitrogen and water to those rates just needed to optimize crop yields. These practices will minimize the levels of unutilized nitrate in the soil profile and the volume of drainage water that passes below the crop root zone. Proper irrigation scheduling is particularly important for orchards grown on sandy soils, which are most susceptible to leaching losses because of their high permeability.

Excessive soil water can have other adverse effects as well. Prolonged waterlogging of medium- to fine-textured soils can promote gaseous losses of soil nitrogen back into the atmosphere. This conversion of soil nitrates into nitrous oxide and nitrogen gas is called denitrification. Although not considered a polluting loss, denitrification results in poor nitrogen uptake efficiency and increased input costs for fertilizer nitrogen.

B. SECONDARY FACTORS OF NITROGEN FERTILIZERS

Under most circumstances, all types of commercial nitrogen fertilizers are comparable in their ability to supply plant-available nitrogen. However, in some cases there may be an advantage to selecting a nitrogen source based on a secondary characteristic. The first factor to consider is soil pH. Ammonium fertilizers tend to lower soil pH more than other types and should be avoided in orchards where soil acidity is already a concern. Soil acidity problems increase as the pH of the surface soil in an orchard drops below 5.5. However, at higher pH levels (pH >7.0), an acidifying ammonium nitrogen source could be beneficial in reducing excessive alkalinity in the soil.

Another secondary factor to consider is the companion ion in the nitrogen fertilizer. The sulfur contained in ammonium sulfate, for example, could be beneficial on soils that are perennially irrigated with low-sulfur irrigation water. This includes most surface waters that are very pure and typically originate from snow melt in the Sierra Nevada Mountains. Calcium can also increase water infiltration with snow-melt water. A fertilizer such as calcium nitrate or calcium-ammonium nitrate (CAN-17) may be a good fertilizer to use where water penetration is a problem, although the cost and availability of other calcium sources, such as gypsum may also be considered.

If a serious nitrogen deficiency is observed in an orchard, rapid correction of the deficiency is necessary. In this situation, a fertilizer containing nitrate or urea should be used, because these forms of nitrogen will move readily with irrigation water into the root zone.

Although supplying nitrogen from animal manures has several distinct advantages (slow release, improves nutrient holding capacity), application of animal manures also poses several risks. First, some manures, especially feedlot manures, can contain high levels of unwanted salts, which should be avoided if excessive soil salinity is already a problem. Second, if zinc deficiency is a concern, applications of manure can aggravate the problem.

SECTION 4: DETERMINING ORCHARD SPECIFIC NITROGEN FERTILIZER RATES

A. EVALUATING SITE-SPECIFIC NITROGEN NEEDS FROM FIELD-TO-FIELD AND FROM YEAR-TO-YEAR

Site-specific nitrogen needs should be evaluated from field to field and from year to year on the same field. Table 7 provides a general idea of average nitrogen fertilizer rates applied to stone fruit and almond orchards in California.

For optimum production and profits, the average nitrogen rates shown in Table 7 should be modified on a field-to-field basis. In general, lower rates of nitrogen are needed on medium- to fine-textured soils (silt loams, silty clay loams, and clay loams), for low-vigor and early-maturing varieties, and in seasons with low expected fruit or nut set. Conversely, higher nitrogen rates are needed for orchards grown on sandier soils (sands, loamy sands, and sandy loams), with less efficient irrigation systems, for high-vigor or later-maturing varieties, or during the more productive year in orchards with marked alternate-bearing tendencies.

B. LOOK FOR SIGNS OF HIGH NITROGEN STATUS

Orchardists should always be alert for signs of declining nitrogen status in orchards. However, with current nitrogen usage patterns, it is even more important to watch for signs of high nitrogen status caused by over-fertilization. There are three main warning signs: (1) nitrate levels in irrigation water above 5 milligrams nitrate-N per liter (i.e. 5 ppm); (2) trees showing excessive shoot and leaf growth and very dark green foliage; and (3) trends of increasing leaf nitrogen concentrations over several years. If any one of these conditions is observed, nitrogen rates should be reduced accordingly. Although research has repeatedly demonstrated that fruit or nut yield and quality will not be adversely affected when nitrogen fertilizer applications are skipped for an entire year under these

Table 7

Approximate rates of nitrogen fertilizer being applied to stone fruit and almond orchards in California.

Crop	Non-bearing orchards	Mature, bearing orchards
Almond	Year 1: 5-10 lbs N/acre Years 2-3: 25-50 lbs N/acre	200-250 lbs N/acre or 1 lb N per 10 lbs expected nut yield
Apricot, Peach, & Nectarine	Year 1: 0-5 lbs N/acre Years 2-4: 20-35 lbs N/acre	100-200 lbs N/acre with less N on early varieties, more N on late varieties
Prune & Plum	Year 1: 5-10 lbs. N/acre Years 2-4: 25-40 lbs N/acre	Years 6-8: 75-100 lbs N/acre Years 8+: 150 lbs N/acre
Cherries, sweet	Year 1: 0 on med.-texture soils Years 2-4: 0-40 lbs N/acre	50-100 lbs N/acre, use higher rates for brining cherries.

conditions, some growers may be reluctant to take this drastic step. Here is where the added information derived from a consistent annual leaf tissue analysis program and careful observations of their orchards can give them the information and confidence they need to curtail unnecessary and unprofitable applications of nitrogen from their list of routine practices.

The economic impact of using a consistent leaf tissue testing program can be modest or considerable. Two likely scenarios are illustrated. If an almond grower can confidently eliminate 50 lbs of unneeded nitrogen per acre with no effect on yield or quality, the savings would be about $14 per acre. In the case where leaf analysis indicates the need for an additional 50 lbs. nitrogen per acre that results in an additional nut yield of 250 lbs. per acre, the savings would be about $234 per acre! Both examples assume that a leaf tissue analysis costs $40 per 40 acre block, a pound of nitrogen costs $0.30, and a price of almond meats costs $1.00 per lb.

C. TAILORING FERTILIZER NITROGEN RATE TO CROP RESPONSE AND IRRIGATION EFFICIENCY

Nitrogen fertilizer rates should be adjusted in response to a change in the expected crop yield and if there is a major change in irrigation efficiency. Each ton of yield removes 2 to 5 lbs of nitrogen per tons of fruit and 100 lbs of nitrogen per ton of almonds. More importantly, nitrogen uptake efficiency can increase two to three times when an irrigation systems is upgraded. For example, nitrogen fertigation through a well-managed drip irrigation system on a perennial fruit crop resulted in a fertilizer uptake efficiency of 42% compared with an uptake efficiency of only 14% for a flood irrigation system using a single broadcast nitrogen application per season (L.E. Williams. 1991. Vine nitrogen requirements - Utilization of N sources from soil, fertilizers, and reserves. Intl. Symp. Nitrogen in Grapes and Wine. Amer. Soc. Enol Viticult., Davis, CA.).

D-039680

SUMMARY

Proper management of nitrogen fertilizer and irrigation water is essential to producing stone fruit and almond crops with optimum yield, quality and profits. Adequate but not excessive irrigation combined with timely applications of nitrogen derived from either commercial or organic sources will keep trees vigorous and productive. Excessive applications of nitrogen can create a host of undesirable effects in the orchard, as well as for the environment. A universal axiom in pollution science is, "preventing pollution is almost always far cheaper than cleaning it up after the fact".

Many economists and environmentalists are skeptical that growers will voluntarily adopt optimum nitrogen management practices that will effectively safeguard groundwater resources. Most advocate a solution that involves legislative action and regulatory enforcement. To head off such measures agriculture must become more proactive in developing and implementing environmentally sound and economically viable fertilization management strategies.

This handbook and accompanying video provide stone fruit and almond producers with the information they need to integrate truly the best management practices relative to nitrogen management in their current orchard production systems. Additional references on nitrogen management in orchard crops that are available through the California Department of Food and Agriculture and other sources are listed in Appendix 9.

APPENDIX 1.

COMMERCIAL LABORATORIES CONDUCTING LEAF TISSUE ANALYSIS IN CALIFORNIA.

Contact	Lab Name	Address	City, State, Zip	Phone
Robert Butterfield	A&L Western Ag Laboratories, Inc.	1311 Woodland Ave., #1	Modesto, CA 95351	(209) 529-4080
Michael L. Carr	Agricultural Advisory Service	2616 S. Chester	Bakersfield, CA 93304	(805) 831-4868
Leonard Sergi	Agri-Tech, Inc.	8746 N. Fuller	Fresno, CA 93720	(209) 846-8291
Mary Matava	Agri Service	2142 "B" Industrial Ct.	Vista, CA 92083	(619) 727-5451
Leland T. Atkins	Atkins Farmlab	4017 Morehead Ave.	Chico, CA 95928	(916) 343-4947
Tomas Moreno	BOLSA Analytical	8770 Hwy 25	Hollister, CA 95023	(408) 637-9776
Tom Gerecke	California Farm Laboratories	240 E. Kern St., P.O. Box 119	Tulare, CA 93275	(209) 688-1777
Kamal Sakoury	California Growers Laboratory, Inc.	4630 W. Jennifer, Suite 104	Fresno, CA 93722	(209) 275-3377
Nat B. Dellavalle	Dellavalle Laboratory, Inc.	1910 West McKinley, Suite 110	Fresno, CA 93728	(209) 233-6129
Lawrence J. Chrystal	Edward S. Babcock & Sons, Inc.	P.O. Box 432	Riverside, CA 92502	(909) 653-3351
Dr. Greg S. Conrad	Environmental Technical Services	1343 Redwood Way	Petaluma, CA 94954	(707) 795-9505
Terry Rosetti	Farmecology Lab	701 Hwy. 175	Hopland, CA 95449	(707) 744-1191
Dr. Ping H. Lin	Golden State Analytical	9823 Pacific Hghts Blvd., Ste R	San Diego, CA 92121	(619) 554-0622
Diane Joksch	Growers Testing Services	1525-A East Acequia Ave.	Visalia, CA 93292	(209) 732-8378
Dennis M. Serpa Jr.	Harvey Labs	205 D Street	Patterson, CA 95363	—
Dr. Paul J. Eberhardt	IAS Laboratories	2515 E. University Dr.	Phoenix, AZ 85034	(602) 273-7248
Tomas A. Vera	JM Lord, Inc.	267 N. Fulton St.	Fresno, CA 93701-1610	(209) 268-9755
Sam Modesitt	Mid State Laboratory, Inc.	9410 W. Placer Ave.	Visalia, CA 93291	(209) 651-9044
Becky Hanson	Monarch Laboratory, Inc.	563 E. Lindo Ave.	Chico, CA 95926	(916) 343-5818
Clifford Low	Perry Laboratory	471 Airport Blvd.	Watsonville, CA 95076	(408) 722-7606
Amin Abdelmoien	Plant Production Services	420 West Main St.	Brawley, CA 92227	(619) 344-9043
Jon Anderson	Primus Laboratories	3130 Skyway Drive, Suite 308	Santa Maria, CA 93455	(805) 922-0055
Dr. Franz R. Fernandez	Safer Gro Lab	4987 Olivas Parks Drive, Ste 205	Ventura, CA 93003	(805) 650-8933
Dan McLean	Sequoia Analytical Lab	680 Chesapeake Dr.	Redwood City, CA 94063	—
Stan Comer	SMC Laboratory, Inc.	211 Aviation St.	Shafter, CA 93263	(805) 393-3597
Lori Littleford	Soil & Plant Laboratory	352 Mathews St.	Santa Clara, CA 95050	(408) 727-0330
Aron A. Quist	Stanworth Crop Consultants	413 West Hobsonway	Blythe, CA 92225	(619) 922-3106
Gene Oliphant	Sunland Analytical Lab	11353 Pyrites Way, Suite 4	Rancho Cordova, CA 95670	(916) 852-8557
Dr. Kim Anderson	Univ. of Idaho Analytical Sci. Lab	Holm Research Center	Moscow, ID 83844-2203	(208) 885-7081
Garn A. Wallace	Wallace Laboratories	365 Coral Circle	El Segundo, CA 90245	(310) 615-0116

APPENDIX 2.

ACCESSING CIMIS ET_o INFORMATION.

CIMIS (California Irrigation Management Information System) weather data is directly available via computer modem hookup. You must establish an account with the Department of Water Resources (no charge) to obtain an ID and password to call up the system. To obtain information on establishing an account, contact the CIMIS help line at 1-800-922-4647.

OTHER ACCESS POINTS FOR CIMIS ET_o INFORMATION

Agency/Media Outlet	Telephone	Station(s)
Alameda County		
Alameda County Water District Fremont	(510) 659-1970 Ext. 200*	100
East Bay Municipal Utilities District Oakland	(510) 820-7750*	65
Butte County		
Butte County Chico Enterprise Record Chico *Weekly ET for pasture/turf, alfalfa, olives, orchard—three clean tilled leafing dates and one for grass cover crops, beets, corn and grain.*	(916) 891-1234	8
Gridley Herald *Gridley Weekly ET for 11 crops.*	(916) 846-3661	8
Contra Costa County		
Contra Costa Water District Concord	(510) 603-8304*	47,65
Fresno County		
NOAA Weather Radio Station Fresno, 162.400 *CIMIS ET_o information can be heard weekdays, March through October, during the agricultural weather advisory report.*		
Firebaugh-Mendota Journal Firebaugh	(209) 659-3057	7
AgLine UC Cooperative Extension Fresno *The information is on ETo and ETc for trees, vines, field and row crops, and other crops and is prepared by Kings River Conservation District.*	(209) 488-1940*	39

*Each phone number represented is a voice line unless marked with an *, which indicates a recording.

Agency/Media Outlet	Telephone	Station(s)
Imperial County		
KROP 1300 AM El Centro *ET information aired during agricultural forecast*	(619) 344-1300	41,68,87
National Weather Service Forecasting Imperial *ETo for Imperial Valley*	(619) 352-3360*	41,86
Imperial Valley Press El Centro	(619) 337-3400	41,68,87
Imperial Irrigation District Imperial *Provides weekly ETo*	(619) 339-9082	41,68,87
Kern County		
NOAA Weather Radio Station, 162.550 MHZ Bakersfield *CIMIS ETo information can be heard weekdays, March through October, during the agricultural weather advisory report.*		
Kings County		
Hanford Sentinel Hanford	(209) 582-0471	2,15,21
Lassen County		
KSUE 1240 AM, 93.3 FM Susanville *Information aired during agricultural program conducted by local UC Cooperative Extension agent.*	(916) 257-2121	57
Los Angeles County		
KIEV 870 AM Glendale *Garden show on weekends hosted by retired farm advisor (7 a.m. Saturdays; between 5 a.m. - 7 a.m. Sundays).*	(818) 245-5438	78
Claremont Courier Claremont	(714) 621-4761	82
Marin County		
Marin Municipal Water District Corte Madera	(415) 924-1067	63
North Marin County Water District Novato	(415) 892-1418* Ext. 5	63
Merced County		
Dos Palos Star Dos Palos	(209) 392-2121	7,56
Gustine Standard Gustine	(209) 854-3787	56,70
Los Banos Enterprise Los Banos	(209) 826-3831	7,56

*Each phone number represented is a voice line unless marked with an *, which indicates a recording.

Agency/Media Outlet	Telephone	Station(s)
Modoc County		
KCNO 570 AM Alturas *ET information is presented during the agricultural broadcast (6 a.m., 12:30 p.m., and 2:30 p.m.)*	(916) 233-3570	43,90
Modoc Record Alturas, Cedarville	(916) 233-2632	43,90
Monterey County		
KCBA, TV Ch. 35 Salinas *Information aired during farm news report daily (5:30 a.m. and 6 a.m.)*	(408) 424-3500	19,89,113, 114,115,116
Monterey County Water Resources Agency Salinas	1-800-4U-CIMIS* *(within area)* (408) 755-5454* *(outside of area)*	19,89,113, 114,115,116
Riverside County		
KKIG 780 AM Coachella *The information is broadcasted during the weather forecast.*		50,129
National Weather Service Forecasting Coachella *ETo for Coachella Valley.*	(619) 398-7211*	50
Coachella Valley County Water District Coachella	(619) 398-7211*	50,129
Rancho California Water District Temecula	(909) 676-4435*	62
Riverside Corona Resource Cons. District Riverside	(909) 683-7691	44,62,78
Western Municipal Water District Riverside	(909) 780-2809*	44

*Each phone number represented is a voice line unless marked with an *, which indicates a recording.

Agency/Media Outlet	Telephone	Station(s)
Sacramento County		
KSTE 650 AM Sacramento *ET is presented during the Sunday morning garden show.*	(916) 858-1578	13
KRAK 1140 AM Sacramento *Information is presented on agricultural weather with ETo for Sacramento and San Joaquin Valley (7 p.m. Monday through Friday).*	(916) 923-9230	13
NOAA Weather Radio Station, 162.550 MHZ Sacramento *CIMIS ETo information can be heard weekdays, March through October, during the agricultural weather advisory report.*		
Citrus Heights Water District/Fair Oaks Water District/San Juan Water District/ Orangevale Water Company Citrus Heights	(916) 725-1713*	42,122
San Benito County		
San Benito County Water District Hollister	(408) 637-6200*	126
San Bernardino County		
Mojave Desert Resource Conservation District Hollister	(619) 261-3346* Victorville (619) 261-3326* Barstow	117 110
San Diego County		
Chula Vista Star News	(691) 427-3000	66
The Enterprise Fall Brook	(619) 728-6116	74
Mission Resource Conservation District Fallbrook	1-800-339-9954* *(within area)* (691) 945-2553* *(outside of area)*	49,62, 66,74,98
UC Cooperative Extension, San Diego San Diego	(619) 745-2215*	49,62, 66, 74
San Joaquin County		
Lodi News Sentinel Lodi	(209) 369-2761	42,70

*Each phone number represented is a voice line unless marked with an *, which indicates a recording.

Agency/Media Outlet	Telephone	Station(s)
Santa Barbara County		
KSNI 102 FM Santa Maria *Information aired during agricultural forecast (6 a.m., noon, and 5 p.m.)*	(805) 925-2582	38,64, 88,120
NOAA Weather Radio Station, 162.550 MHZ Santa Maria *CIMIS ETo information can be heard weekdays, March through October, during the agricultural weather advisory report*		
Santa Clara County		
Santa Clara Water District Santa Clara	(408) 267-3127*	69
Santa Cruz County		
Register Pajarian Watsonville	(408) 724-0611	16,19, 95,104
Shasta County		
NOAA Weather Radio Station, 162.550 MHZ Redding *CIMIS ETo information can be heard weekdays, March through October, during the agricultural weather advisory report.*		
Intermountain News Burney	(916) 335-4533	43
Solano County		
Solano Irrigation District/Maine Prairie Water District/Reclamation District 2068/ Natural Resources Conservation Service Fairfield	(800) 897-7666*	121,122, 123
Stanislaus County		
Turlock Journal Turlock	(209) 634-9141	71
Tehama County		
Corning Daily Observer Corning *Prints weekly ET for seven crops.*	(916) 824-5464	8
Red Bluff Daily News Red Bluff *Prints weekly ET for seven crops three times a week.*	(916) 527-2151	8
Tulare County		
NOAA Weather Radio Station, 162.500 Lindsay *CIMIS ETo information can be heard weekdays, March through October, during the agricultural weather advisory report.*		
Visalia Times Delta Visalia	(209) 734-5821	33,86

*Each phone number represented is a voice line unless marked with an *, which indicates a recording.

Agency/Media Outlet	Telephone	Station(s)
Ventura County		
Ventura County Resource Cons. District Ventura	(805) 644-4921*	97,101
Arizona		
NOAA Weather Radio Station, 162.550 Yuma *CIMIS ETo information can be heard weekdays, March through October, during the agricultural weather advisory report.*		

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AGENCIES THAT PROVIDE CIMIS RECORDINGS

Alameda County Water District
43885 South Grimmer Boulevard
Fremont, California 94537
(510) 659-1970, Ext. 212
Sue Modders

AgLine UC Cooperative Extension, Fresno
1720 Maple Avenue
Fresno, California, 93702
(209) 456-7285
Mark Freeman

Citrus Heights Water District/Fair Oaks Water District/San Juan Water District/Orangevale Water Company
6230 Sylvan Road
Citrus Heights, California 95610
(916) 725-6873
Joe Scherrer

Coachella Valley Water District
Post Office Box 1058
Coachella, California 92236
(619) 398-2651, Ext. 422
Dave Harbison

Contra Costa Water District
1331 Concord Avenue
Post Office Box H20
Concord, California 94524
(510) 603-8321
Chris Dundon

East Bay Municipal Utilities District
3189 Danville Boulevard
Alamo, California 94507
(510) 820-2760
Andrea Pook

Marin Municipal Water District
220 Nellen Avenue
Corte Madera, California 94925
(415) 924-4600, Ext. 322

Mission Resource Conservation District
1181 East Mission Road
Fallbrook, California 92028
(619) 728-1332
Judy Mitchell

Mohave Desert Resource Conservation District
18484 Highway 18, Suite 195
Apple Valley, California 92307
(619) 242-2906
Jakie Lindgren

Monterey County Water Resource Agency
855 East Laurel Drive Building G
Salinas, California 93905
(408) 755-4860
Danyal Kasapligil

North Marin Water District
999 Rush Creek Place
Post Office Box 146
Novato, California 94948
(415) 897-4133
John Nelson

Rancho California Water District
Post Office Box 9017
Temecula, California 92589-9017
(909) 676-4101
Don Peck

San Benito County Water District
Post Office Box 899
30 Mansfield Road
Hollister, California 95024
(408) 637-8218
Jeff Ray

Solano County
2000 West Texas Street
Fairfield, California 94533
(707) 421-6790 Larry Clement
(916) 678-1655 Sally Negroni

UC Cooperative Extension, San Diego
5555 Overland Avenue, Building 4
San Diego, California 92123
(619) 745-2845
Gary Bender

Western Municipal Water District
450 Alessandro Boulevard
Riverside, California 92508
(909) 780-4170
Steven Mains

REGIONAL ACCESS POINTS FOR CIMIS INFORMATION.

Newspapers

Ag Alert (weekly)	(916) 924-4140	5,7,30,38,
California Farm Bureau Federation		41,48,61,62,
1601 Exposition Boulevard		70,89
Sacramento, California 95815		

Graphical presentation of ETo information for Sacramento/San Joaquin Valley agricultural areas

University of California
Statewide IPM Project
University of California, Davis
Davis, California 95616
Mary Martino (916) 752-5361
Information on daily CIMIS data for all stations.

CIMIS Alert
CIMIS Alert is a program sponsored by DWR to help public and private agencies provide a useful, cost-effective service to water users.
The CIMIS Alert program helps public agencies to provide a daily telephone recording of local evapotranspiration (ETo). Contact your local water agency and/or cooperative extension office to see if CIMIS ETo information is available. For further information, call the CIMIS help line at 1-800-922-4647.

APPENDIX 3.

REFERENCE EVAPOTRANSPIRATION (ETo) IN INCHES PER DAY FOR MODESTO, CA

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.02	0.04	0.08	0.13	0.18	0.24	0.26	0.24	0.19	0.14	0.07	0.03
2	0.02	0.04	0.08	0.14	0.19	0.24	0.26	0.24	0.19	0.14	0.07	0.03
3	0.02	0.04	0.08	0.14	0.19	0.24	0.26	0.24	0.19	0.13	0.07	0.03
4	0.02	0.04	0.08	0.14	0.19	0.24	0.26	0.23	0.19	0.13	0.07	0.03
5	0.02	0.04	0.08	0.14	0.19	0.24	0.26	0.23	0.18	0.13	0.06	0.03
6	0.02	0.04	0.09	0.14	0.19	0.25	0.26	0.23	0.18	0.13	0.06	0.03
7	0.02	0.04	0.09	0.14	0.19	0.25	0.26	0.23	0.18	0.13	0.06	0.03
8	0.02	0.04	0.09	0.15	0.20	0.25	0.26	0.23	0.18	0.12	0.06	0.03
9	0.02	0.05	0.09	0.15	0.20	0.25	0.26	0.23	0.18	0.12	0.06	0.03
10	0.02	0.05	0.09	0.15	0.20	0.25	0.26	0.22	0.18	0.12	0.06	0.03
11	0.02	0.05	0.09	0.15	0.20	0.25	0.26	0.22	0.17	0.12	0.05	0.03
12	0.02	0.05	0.10	0.15	0.20	0.25	0.26	0.22	0.17	0.12	0.05	0.03
13	0.03	0.05	0.10	0.16	0.20	0.25	0.26	0.22	0.17	0.11	0.05	0.02
14	0.03	0.05	0.10	0.16	0.21	0.26	0.26	0.22	0.17	0.11	0.05	0.02
15	0.03	0.05	0.10	0.16	0.21	0.26	0.26	0.22	0.17	0.11	0.05	0.02
16	0.03	0.05	0.10	0.16	0.21	0.26	0.26	0.22	0.17	0.11	0.05	0.02
17	0.03	0.05	0.11	0.16	0.21	0.26	0.26	0.21	0.16	0.11	0.04	0.02
18	0.03	0.06	0.11	0.16	0.21	0.26	0.26	0.21	0.16	0.10	0.04	0.02
19	0.03	0.06	0.11	0.17	0.21	0.26	0.26	0.21	0.16	0.10	0.04	0.02
20	0.03	0.06	0.11	0.17	0.22	0.26	0.25	0.21	0.16	0.10	0.04	0.02
21	0.03	0.06	0.11	0.17	0.22	0.26	0.25	0.21	0.16	0.10	0.04	0.02
22	0.03	0.06	0.12	0.17	0.22	0.26	0.25	0.21	0.15	0.09	0.04	0.02
23	0.03	0.06	0.12	0.17	0.22	0.26	0.25	0.20	0.15	0.09	0.04	0.02
24	0.03	0.07	0.12	0.17	0.22	0.26	0.25	0.20	0.15	0.09	0.04	0.02
25	0.03	0.07	0.12	0.17	0.23	0.26	0.25	0.20	0.15	0.09	0.04	0.02
26	0.04	0.07	0.12	0.18	0.23	0.26	0.25	0.20	0.15	0.08	0.04	0.02
27	0.04	0.07	0.13	0.18	0.23	0.26	0.25	0.20	0.15	0.08	0.03	0.02
28	0.04	0.07	0.13	0.18	0.23	0.26	0.24	0.20	0.14	0.08	0.03	0.02
29	0.04	—	0.13	0.18	0.23	0.26	0.24	0.20	0.14	0.08	0.03	0.02
30	0.04	—	0.13	0.18	0.23	0.26	0.24	0.19	0.14	0.08	0.03	0.02
31	0.04	—	0.13	—	0.24	—	0.24	0.19	—	0.07	—	0.02

APPENDIX 4.

MONTHLY REFERENCE EVAPOTRANSPIRATION (ETo) AND CUMULATIVE EVAPOTRANSPIRATION (C ETo) FOR MODESTO, CA

Month	Monthly ETo (inches)	Cumulative ETo (inches)
January	0.85	0.85
February	1.43	2.28
March	3.17	5.45
April	4.76	10.21
May	6.41	16.62
June	7.68	24.73
July	8.06	32.36
August	6.83	39.19
September	5.02	44.21
October	3.42	47.63
November	1.42	49.05
December	0.73	49.78

APPENDIX 5.

AVERAGE ETo BY COUNTY AND CITY, IN TOTAL INCHES PER MONTH

County & City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
ALAMEDA												
Livermore	1.22	1.54	2.93	4.37	5.86	6.61	7.44	6.35	5.31	3.17	1.54	0.85
Oakland	1.46	1.54	2.81	3.98	5.13	5.31	5.98	5.49	4.84	3.05	1.42	0.85
ALPINE												
Markleeville	0.73	0.88	1.95	3.54	5.00	6.14	7.32	6.35	4.37	2.56	1.18	0.49
AMADOR												
Jackson	1.16	1.54	2.81	4.37	5.98	7.20	7.93	7.20	5.31	3.17	1.42	0.85
BUTTE												
Chico	1.22	1.76	2.93	4.72	6.10	7.38	8.54	7.32	5.43	3.66	1.65	0.98
Gridley	1.22	1.76	2.99	4.72	6.10	7.74	8.54	7.08	5.43	3.66	1.65	0.98
Oroville	1.22	1.65	2.81	4.72	6.10	7.56	8.54	7.32	5.31	3.66	1.65	0.98
CALAVERAS												
San Andreas	1.16	.54	2.81	4.37	5.98	7.32	7.93	7.02	5.31	3.17	1.42	0.73
COLUSA												
Colusa	1.10	1.65	2.81	4.84	6.59	7.44	8.18	6.96	5.67	3.54	1.65	0.98
Williams	1.22	1.65	2.93	4.49	6.10	7.20	8.54	7.32	5.31	3.42	1.59	1.04
CONTRA COSTA												
Brentwood	0.98	1.54	2.93	4.49	6.10	7.09	7.93	6.71	5.20	3.17	1.42	0.73
Concord	1.10	1.43	2.43	4.02	5.49	5.91	6.96	5.98	4.48	3.17	1.30	0.73
Martinez	1.22	1.43	2.43	3.90	5.25	5.55	6.71	5.61	4.72	3.05	1.18	0.73
Pittsburgh	0.98	1.54	2.81	4.13	5.61	6.38	7.44	6.35	4.96	3.17	1.30	0.73
DEL NORTE												
Crescent City	0.49	0.88	1.95	2.95	3.66	3.54	4.27	3.66	2.95	1.95	0.94	0.49
EL DORADO												
Camino	0.98	1.68	2.48	3.90	5.98	7.20	7.75	6.82	5.10	3.10	1.50	0.93

County & City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
FRESNO												
Clovis	0.98	1.54	3.17	4.84	6.35	7.74	8.54	7.32	5.31	3.42	1.42	0.73
Coalinga	1.22	1.65	3.11	4.61	6.22	7.20	8.54	7.32	5.31	3.42	1.59	0.73
Five Points	0.92	1.65	3.30	4.96	6.59	7.68	8.54	7.32	5.43	3.42	1.48	0.85
Fresno	0.85	1.65	3.30	4.84	6.71	7.80	8.42	7.08	5.20	3.17	1.42	0.61
Friant	1.22	1.54	3.05	4.72	6.35	7.68	8.54	7.32	5.31	3.42	1.42	0.73
Kerman	0.85	1.49	3.23	4.84	6.59	7.74	8.42	7.20	5.31	3.42	1.42	0.73
Kingsburg	0.98	1.54	3.36	4.84	6.59	7.74	8.42	7.20	5.31	3.42	1.42	0.73
Reedley	1.10	1.54	3.17	4.72	6.35	7.68	8.54	7.32	5.31	3.42	1.42	0.73
GLENN												
Orland	1.22	1.65	3.05	4.84	6.71	7.44	8.79	7.32	5.79	3.78	1.65	1.10
Willows	1.22	1.71	2.93	4.72	6.10	7.20	8.54	7.32	5.31	3.60	1.65	1.04
HUMBOLDT												
Eureka	0.49	1.10	1.95	2.95	3.66	3.66	3.66	3.66	2.95	1.95	0.94	0.49
Ferndale	0.49	1.10	1.95	2.95	3.66	3.66	3.66	3.66	2.95	1.95	0.94	0.49
Garberville	0.61	1.18	2.20	3.07	4.52	5.02	5.49	4.88	3.78	2.44	1.00	0.67
Hoopa	0.49	1.10	2.07	2.95	4.39	5.43	6.10	5.13	3.84	2.44	0.94	0.67
IMPERIAL												
Brawley	2.81	3.75	5.86	8.03	10.37	11.46	11.72	10.01	8.39	6.22	3.54	2.07
Calipatria	2.87	3.86	6.10	8.27	10.50	11.81	11.96	10.37	8.62	6.47	3.78	2.26
El Centro	2.69	3.53	5.61	7.91	10.13	11.10	11.59	9.52	8.27	6.10	3.31	1.95
Holtville	2.81	3.75	5.86	7.91	10.37	11.57	11.96	10.01	8.62	6.22	3.54	2.07
Yuma	3.05	4.08	6.59	8.74	10.98	12.40	12.69	10.98	8.86	6.59	3.96	2.56
INYO												
Bishop	1.71	2.65	4.76	6.73	8.18	10.87	9.76	9.64	7.44	4.76	2.48	1.59
Death Valley	2.20	3.31	5.37	7.68	9.76	11.10	11.35	10.13	8.27	5.37	2.89	1.71
Independence	1.71	2.65	3.42	6.61	8.54	9.45	9.76	8.54	7.09	3.91	2.01	1.46
Lower Haiwee Reservoir	1.83	2.65	4.39	7.09	8.54	9.45	9.76	8.54	7.09	4.15	2.60	1.46

County & City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
KERN												
Arvin	1.16	1.76	3.48	4.72	6.59	7.44	8.06	7.32	5.31	3.42	1.65	0.98
Bakersfield	1.04	1.76	3.48	4.72	6.59	7.68	8.54	7.32	5.31	3.54	1.59	0.85
Buttonwillow	0.98	1.76	3.17	4.72	6.59	7.68	8.54	7.32	5.43	3.42	1.54	0.85
China Lake	2.07	3.20	5.25	7.68	9.15	10.04	10.98	9.76	7.32	4.88	2.72	1.71
Delano	0.92	1.76	3.42	4.72	6.59	7.68	8.54	7.32	5.43	3.42	1.42	0.73
Grapevine	1.34	1.76	3.05	4.37	5.61	6.79	7.57	6.83	5.91	3.36	1.89	0.98
Inyokern	1.95	3.09	4.88	7.32	8.54	9.69	10.98	9.40	7.09	5.13	2.60	1.71
Isabella Dam	1.16	1.43	2.75	4.37	5.80	7.32	7.93	6.96	4.96	3.23	1.65	0.85
Lost Hills	0.61	1.10	2.56	4.37	6.96	7.68	8.54	7.08	4.96	3.91	0.83	0.37
Shafter	0.98	1.65	3.42	4.96	6.59	7.68	8.30	7.32	5.43	3.42	1.54	0.85
Taft	1.28	1.76	3.11	4.25	6.22	7.32	8.54	7.32	5.37	3.42	1.65	0.98
Tehachapi	1.40	1.76	3.17	4.96	6.10	7.68	7.93	7.32	5.91	3.42	2.07	1.22
KINGS												
Corcoran	0.85	1.54	3.30	5.20	7.20	7.91	8.42	7.32	5.79	3.42	1.42	0.73
Hanford	0.85	1.54	3.42	4.96	6.59	7.68	8.30	7.20	5.43	3.42	1.42	0.73
Kettleman City	0.98	1.76	3.42	5.31	7.20	7.91	8.42	7.44	5.91	3.66	1.65	0.98
Lenmoore	0.85	1.54	3.42	4.96	6.59	7.68	8.30	7.32	5.43	3.42	1.42	0.73
LAKE												
Lakeport	1.10	1.32	2.56	3.54	5.13	6.02	7.32	6.10	4.72	2.93	1.24	0.85
Lower Lake	1.22	1.43	2.69	4.49	5.25	6.26	7.44	6.41	4.96	3.05	1.30	0.92
LASSEN												
Ravendale	0.61	1.05	2.32	4.13	5.61	6.73	7.93	7.32	4.72	2.81	1.18	0.49
Susanville	0.73	0.99	2.20	4.13	5.61	6.50	7.81	6.96	4.61	2.81	1.18	0.49

County & City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
LOS ANGELES												
Burbank	2.07	2.76	3.66	4.72	5.13	6.02	6.59	6.71	5.43	4.03	2.60	1.95
Glendora	1.95	2.54	3.60	4.49	5.37	6.14	7.32	6.83	5.67	4.15	2.60	1.95
Gorman	1.59	2.15	3.42	4.61	5.49	7.38	7.69	7.08	5.91	3.60	2.36	1.10
Lancaster	2.14	2.98	4.64	5.91	8.54	9.69	10.98	9.76	7.32	4.64	2.78	1.71
Long Beach	2.20	2.54	3.42	3.78	4.76	4.96	5.25	4.88	4.49	3.42	2.36	1.95
Los Angeles	2.20	2.65	3.66	4.72	5.49	5.79	6.22	5.86	5.02	3.91	2.60	1.95
Palmdale	1.95	2.65	4.15	5.08	7.57	8.54	9.89	9.76	6.73	4.15	2.60	1.71
Pasadena	2.07	2.65	3.66	4.72	5.13	6.02	7.08	6.71	5.55	4.15	2.60	1.95
Pearblossom	1.71	2.43	3.66	4.72	7.32	7.68	9.89	7.93	6.38	4.03	2.60	1.59
Redondo Beach	2.20	2.43	3.30	3.78	4.52	4.72	5.37	4.76	4.37	2.81	2.36	1.95
San Fernando	1.95	2.65	3.54	4.61	5.49	5.91	7.32	6.71	5.31	3.91	2.60	1.95
MADERA												
Chowchilla	0.98	1.43	3.17	4.72	6.59	7.80	8.54	7.32	5.31	3.42	1.42	0.67
Madera	0.92	1.43	3.17	4.84	6.59	7.80	8.54	7.32	5.31	3.42	1.42	0.73
Raymond	1.22	1.54	2.99	4.61	6.10	7.56	8.42	7.32	5.20	3.42	1.42	0.73
MARIN												
Novato	1.34	1.54	2.43	3.54	4.39	6.02	5.86	5.37	4.37	2.81	1.42	0.73
San Rafael	1.22	1.32	2.44	3.30	4.03	4.84	4.84	4.88	4.25	2.69	1.30	0.73
MARIPOSA												
Coulterville	1.10	1.54	2.81	4.37	5.86	7.32	8.06	6.96	5.31	3.36	1.42	0.73
Mariposa	1.10	1.54	2.81	4.43	5.86	7.38	8.24	7.08	5.02	3.42	1.42	0.73
Yosemite Village	0.73	0.99	2.32	3.66	5.13	6.50	7.08	6.10	4.43	2.87	1.06	0.55
MENDOCINO												
Fort Bragg	0.85	1.27	2.20	2.95	3.66	3.54	3.66	3.66	2.95	2.32	1.18	.073
Hopland	1.10	1.32	2.56	3.43	5.00	5.91	6.47	5.74	4.49	2.81	1.30	0.73
Point Arena	0.98	1.32	2.32	2.95	3.66	3.90	3.66	3.66	2.95	2.32	1.18	0.73
Ukiah	0.98	1.32	2.56	3.31	5.00	5.79	6.71	5.86	4.49	2.81	1.30	0.73

County & City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
MERCED												
Los Banos	0.98	1.54	3.17	4.72	6.10	7.38	8.18	7.02	5.31	3.42	1.42	0.73
Merced	0.98	1.54	3.17	4.72	6.59	7.91	8.54	7.20	5.31	3.42	1.42	0.73
MONO												
Bridgeport	0.73	0.88	2.20	3.84	5.49	6.61	7.44	6.71	4.72	2.69	1.18	0.49
MONTEREY												
Castroville	1.59	1.76	2.69	3.54	4.39	4.37	4.52	4.15	3.78	2.81	1.77	1.34
King City	1.71	1.98	3.42	4.37	4.37	5.61	6.14	6.71	6.47	5.2	2.24	1.34
Long Valley	1.53	1.87	3.17	4.13	5.80	6.50	7.32	6.71	5.31	3.60	1.95	1.22
Monterey	1.71	1.76	2.69	3.54	4.03	4.13	4.27	4.15	3.54	2.81	1.89	1.46
Salinas	1.59	1.87	2.72	3.78	4.76	4.72	5.00	4.52	4.02	2.93	1.89	1.34
Soledad	1.71	1.98	3.42	4.37	5.49	5.43	6.47	6.22	5.20	3.66	2.24	1.46
NAPA												
St. Helena	1.22	1.54	2.81	3.90	5.13	6.14	6.96	6.22	4.84	3.05	1.42	0.85
Yountville	1.34	1.65	2.81	3.90	5.13	6.02	7.08	6.10	4.84	3.05	1.54	0.85
NEVADA												
Grass Valley	1.10	1.54	2.56	4.02	5.74	7.09	7.93	7.08	5.31	3.23	1.48	0.92
Nevada City	1.10	1.54	2.56	3.90	5.80	6.85	7.93	6.96	5.31	3.17	1.42	0.85
Soda Springs	0.73	0.66	1.77	2.95	4.27	5.31	6.20	5.49	4.13	2.50	0.71	0.67
Truckee	0.73	0.66	1.71	3.19	4.39	5.43	6.35	5.74	4.13	2.44	0.83	0.61
ORANGE												
Laguna Beach	2.20	2.65	3.42	3.78	4.64	4.61	4.88	4.88	4.37	3.42	2.36	1.95
Santa Ana	2.20	2.65	3.66	4.49	4.64	5.43	6.22	6.10	4.72	3.66	2.48	1.95

County & City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
PLACER												
Auburn	1.22	1.65	2.81	4.37	6.10	7.38	8.30	7.32	5.43	3.42	1.59	0.98
Blue Canyon	0.73	1.05	2.14	3.43	4.76	6.02	7.20	6.10	4.61	2.87	0.94	0.61
Colfax	1.10	1.54	2.56	4.02	5.80	7.09	7.93	7.02	5.31	3.17	1.42	0.92
Lincoln	1.22	1.65	2.81	4.72	6.10	7.44	8.42	7.32	5.43	3.66	1.89	1.22
Roseville	1.10	1.71	3.05	4.72	6.22	7.68	8.54	7.32	5.55	3.66	1.65	0.98
Tahoe City	0.73	0.66	1.71	2.95	4.27	5.43	6.10	5.61	4.13	2.44	0.83	0.61
PLUMAS												
Portola	0.73	0.88	1.95	3.54	4.88	5.91	7.32	5.86	4.25	2.69	0.94	0.49
Quincy	0.73	0.94	2.20	3.54	4.88	5.91	7.32	5.86	4.37	2.81	1.18	0.49
RIVERSIDE												
Beaumont	1.95	2.31	3.42	4.37	6.10	7.09	7.57	7.93	6.02	3.91	2.60	1.71
Blythe	3.17	4.19	6.71	8.86	11.11	12.40	12.81	11.11	9.09	6.71	4.02	2.69
Coachella	2.93	4.39	6.22	8.39	10.50	11.93	12.33	10.13	8.86	6.22	3.78	2.44
Desert Center	2.93	4.08	6.35	8.50	10.98	12.05	12.20	11.11	8.98	6.35	3.90	2.56
Elsinore	2.07	2.76	3.91	4.43	5.86	7.09	7.63	7.02	5.79	3.91	2.60	1.95
Indio	2.93	3.97	6.22	8.27	10.50	11.93	12.33	10.01	8.86	6.35	3.78	2.44
Oasis	2.69	2.75	5.86	8.03	10.37	11.69	11.59	10.01	8.39	6.22	3.43	2.07
Palm Desert	1.95	3.53	4.88	7.68	8.54	10.63	9.76	9.15	8.39	6.10	2.72	1.77
Palm Springs	1.95	2.87	4.88	7.20	8.30	8.50	11.59	8.30	7.20	5.86	2.72	1.71
Riverside	2.07	2.87	4.03	4.13	6.10	7.09	7.93	7.57	6.14	4.15	2.60	1.95
SACRAMENTO												
Courtland	0.92	1.54	2.93	4.43	6.10	6.85	7.93	6.71	5.31	3.17	1.36	0.73
Sacramento	0.98	1.76	3.17	4.72	6.35	7.68	8.36	7.20	5.43	3.66	1.65	0.92
SAN BENITO												
Hollister	1.46	1.76	3.05	4.25	5.49	5.67	6.35	5.86	4.96	3.54	1.65	1.10

County & City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
SAN BERNARDINO												
Baker	2.69	3.86	6.10	8.27	10.37	11.81	12.20	10.98	8.86	6.10	3.31	2.07
Barstow	2.56	3.64	5.74	7.91	10.13	11.57	11.96	10.37	8.62	5.74	3.31	2.07
Chino	2.07	2.87	3.91	4.49	5.74	6.50	7.32	7.08	5.91	4.15	2.60	1.95
Crestline	1.46	1.87	3.30	4.37	5.49	6.61	7.81	7.08	5.43	3.54	2.24	1.59
Lucerne Valley	2.20	2.87	5.13	6.50	9.15	10.98	11.35	9.89	7.44	5.00	2.95	1.83
Needles	3.17	4.19	6.59	8.86	10.98	12.40	12.81	10.98	8.86	6.59	4.02	2.69
San Bernardino	1.95	2.65	3.78	4.61	5.74	6.85	7.93	7.44	5.91	4.15	2.60	1.95
Twentynine Palms	2.56	3.64	5.86	7.91	10.13	11.22	11.23	10.25	8.62	5.86	3.43	2.20
Victorville	2.32	3.09	4.88	6.73	9.28	10.04	11.23	9.76	7.44	5.13	2.83	1.83
SAN DIEGO												
Chula Vista	2.20	2.65	3.42	3.78	4.88	4.72	5.49	4.88	4.49	3.42	2.36	1.95
Escondido	2.07	2.76	3.78	4.72	5.49	6.14	6.71	6.47	5.43	3.78	2.48	1.95
Fallbrook	2.07	2.65	3.78	4.72	5.49	6.14	6.84	6.47	5.43	3.78	2.48	1.95
Oceanside	2.20	2.65	3.42	3.78	4.88	4.72	4.88	5.13	4.13	3.30	2.36	1.95
Pine Valley	1.46	1.76	2.93	4.13	5.49	6.85	7.93	7.32	5.91	4.03	2.24	1.47
Ramona	2.07	2.54	3.91	4.72	5.49	6.50	7.32	6.96	5.55	3.91	2.60	1.71
San Diego	2.20	2.65	3.42	3.78	4.88	4.88	5.13	4.88	4.49	3.42	2.36	1.95
Santee	2.07	2.65	3.66	4.49	5.49	6.14	6.84	6.22	5.43	3.78	2.60	1.95
Warner Springs	1.59	2.20	3.66	4.72	5.74	7.56	8.30	7.69	6.26	4.03	2.48	1.47
SAN FRANCISCO												
San Francisco	1.46	1.32	2.44	2.95	3.66	4.61	4.88	4.76	4.13	2.81	1.30	0.73
SAN JOAQUIN												
Farmington	1.46	1.49	2.93	4.72	6.22	7.56	8.06	6.83	5.31	3.30	1.42	0.73
Lodi	0.85	1.54	2.93	5.08	6.47	6.97	7.69	7.69	5.20	3.05	1.30	0.73
Manteca	1.46	1.49	2.99	4.72	6.35	7.56	8.06	6.83	5.31	3.30	1.42	0.61
Stockton	0.79	1.54	2.93	4.72	6.22	7.44	8.06	6.83	5.31	3.23	1.42	0.61
Tracy	0.98	1.54	2.93	4.49	6.10	7.32	7.93	6.71	5.31	3.17	1.30	0.73

County & City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
SAN LUIS OBISPO												
Arroyo Grande	1.95	2.20	3.17	3.78	4.27	4.72	4.27	4.64	3.78	3.17	2.36	1.71
Atascadero	1.22	1.54	2.81	3.90	4.52	6.02	6.71	6.22	4.96	3.17	1.65	0.98
Morro Bay	1.95	2.20	3.11	3.54	4.27	4.49	4.64	4.58	3.84	3.48	2.13	1.71
Paso Robles	1.59	1.98	3.17	4.25	5.49	6.26	7.32	6.71	5.08	3.66	2.13	1.40
San Luis Obispo	1.95	2.20	3.17	4.13	4.88	5.31	4.64	5.49	4.37	3.54	2.36	1.71
San Miguel	1.59	1.98	3.23	4.25	5.00	6.38	7.44	6.83	5.08	3.66	2.13	1.40
San Simeon	1.95	1.98	2.93	3.54	4.15	4.43	4.58	4.27	3.54	3.05	2.01	1.71
SAN MATEO												
Half Moon Bay	1.46	1.65	2.44	2.95	3.91	4.25	4.27	4.15	3.54	2.81	1.30	0.98
Redwood City	1.46	1.76	2.87	3.84	5.19	5.31	6.22	5.61	4.84	3.11	1.65	0.98
SANTA BARBARA												
Carpenteria	1.95	2.43	3.17	3.90	4.76	5.20	5.49	5.74	4.49	3.42	2.36	1.95
Guadalupe	1.95	2.20	3.17	3.66	4.88	4.61	4.52	4.58	4.13	3.30	2.36	1.71
Lompoc	1.95	2.20	3.17	3.66	4.76	4.61	4.88	4.76	3.90	3.17	2.36	1.71
Los Alamos	1.83	1.98	3.17	4.13	4.88	5.31	5.74	5.49	4.43	3.66	2.36	1.59
Santa Barbara	1.95	2.54	3.17	3.78	4.64	5.08	5.49	4.49	3.42	2.36	1.83	1.83
Santa Maria	1.83	2.20	3.17	4.02	5.00	5.08	5.13	5.13	4.49	3.54	2.36	1.71
Solvang	1.95	1.98	3.30	4.25	5.00	5.55	6.10	5.61	4.37	3.66	2.24	1.59
SANTA CLARA												
Gilroy	1.34	1.76	3.05	4.13	5.25	5.55	6.10	5.49	4.72	3.42	1.65	1.10
Los Gatos	1.46	1.76	2.81	3.90	5.00	5.61	6.22	5.49	4.72	3.17	1.65	1.10
Palo Alto	1.46	1.76	2.81	3.84	5.19	5.31	6.22	5.61	4.96	3.17	1.65	0.98
San Jose	1.46	1.76	3.05	4.13	5.49	5.79	6.47	5.86	5.20	3.30	1.77	0.98
SANTA CRUZ												
Santa Cruz	1.46	1.76	2.56	3.54	4.27	4.37	4.76	4.39	3.78	2.81	1.65	1.22
Watsonville	1.46	1.76	2.69	3.66	4.64	4.49	4.88	4.15	4.02	2.93	1.77	1.22

County & City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
SHASTA												
Burney	0.73	0.99	2.14	3.54	4.88	5.91	7.44	6.41	4.37	2.93	0.94	0.61
Fall River Mills	0.61	0.99	2.07	3.66	5.00	6.14	7.81	6.71	4.61	2.81	0.94	0.49
Glenburn	0.61	0.99	2.07	3.66	5.00	6.26	7.81	6.71	4.72	2.81	0.94	0.55
Redding	1.22	1.43	2.62	4.13	5.61	7.09	8.54	7.32	5.31	3.23	1.42	0.85
SIERRA												
Downieville	0.73	0.99	2.26	3.54	5.00	6.02	7.44	6.22	4.72	2.81	0.94	0.61
Sierraville	0.73	1.10	2.20	3.19	4.52	5.91	7.32	6.35	4.25	2.62	0.94	0.49
SISKIYOU												
Happy Camp	0.49	0.88	1.95	2.95	4.27	5.20	6.10	5.25	4.13	2.44	0.94	0.49
Mt. Shasta	0.49	0.88	1.95	2.95	4.52	5.31	6.71	5.74	4.02	2.20	0.71	0.49
Tulelake	0.49	0.88	2.07	3.43	5.25	5.91	7.93	6.71	4.37	2.69	0.94	0.49
Weed	0.49	0.88	1.95	2.48	4.52	5.31	6.71	5.49	3.66	1.95	0.94	0.49
Yreka	0.61	0.88	2.14	2.95	4.88	5.79	7.32	6.47	4.25	2.50	0.94	0.49
SOLANO												
Benecia	1.34	1.43	2.69	3.78	4.88	5.02	6.35	5.49	4.43	2.93	1.18	0.73
Fairfield	1.10	1.65	2.81	4.02	5.49	6.14	7.81	5.98	4.84	3.05	1.42	0.85
Rio Vista	0.85	1.65	2.81	4.37	5.86	6.73	7.93	6.47	5.08	3.17	1.30	0.73
SONOMA												
Cloverdale	1.10	1.43	2.56	3.43	5.00	5.91	6.22	5.61	4.49	2.81	1.42	0.73
Fort Ross	1.22	1.43	2.20	2.95	3.66	4.49	4.15	4.27	3.43	2.44	1.18	0.49
Healdsburg	1.22	1.54	2.43	3.54	5.00	5.91	6.10	5.61	4.49	2.81	1.42	0.73
Petaluma	1.22	1.54	2.81	3.66	4.64	5.61	4.64	5.74	4.49	2.93	1.42	0.85
Santa Rosa	1.22	1.65	2.81	3.66	5.00	6.02	6.10	5.86	4.49	2.93	1.54	0.73
STANISLAUS												
La Grange	1.22	1.54	3.11	4.72	6.22	7.68	8.54	7.32	5.31	3.42	1.42	0.73
Modesto	0.85	1.43	3.17	4.72	6.41	7.68	8.06	6.83	5.02	3.42	1.42	0.73
Newman	0.98	1.54	3.17	4.61	6.22	7.44	8.06	6.71	4.96	3.42	1.42	0.73
Oakdale	1.22	1.49	3.17	4.72	6.22	7.68	8.06	7.08	5.08	3.42	1.42	0.73
Turlock	0.85	1.49	3.17	4.72	6.47	7.68	8.18	7.02	5.08	3.42	1.42	0.73

County & City	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
SUTTER												
Yuba City	1.34	2.09	2.81	4.37	5.74	7.20	7.08	6.10	4.72	3.17	1.18	0.85
TEHAMA												
Corning	1.22	1.76	2.93	4.49	6.10	7.26	8.06	7.20	5.31	3.66	1.65	1.10
Red Bluff	1.22	1.76	2.93	4.37	5.86	7.44	8.54	7.32	5.43	3.54	1.65	1.04
TRINITY												
Hayfork	0.49	1.10	2.32	3.54	4.88	5.91	6.96	5.98	4.49	2.75	0.94	0.73
Weaverville	0.61	1.10	2.20	3.31	4.88	5.91	7.32	5.98	4.37	2.69	0.94	0.73
TUOLUMNE												
Groveland	1.10	1.54	2.75	4.13	5.74	7.20	7.93	6.59	5.08	3.30	1.42	0.73
Sonora	1.10	1.54	2.75	4.13	5.80	7.20	7.93	6.71	5.08	3.23	1.42	0.73
TULARE												
Alpaugh	0.85	1.71	3.42	4.84	6.59	7.68	8.18	7.32	5.43	3.42	1.42	0.73
Badger	0.98	1.32	2.69	4.13	5.98	7.32	7.69	6.96	4.84	3.30	1.36	0.73
Dinuba	1.10	1.54	3.17	4.72	6.22	7.68	8.54	7.32	5.31	3.42	1.42	0.73
Porterville	1.22	1.76	3.42	4.72	6.59	7.68	8.54	7.32	5.31	3.42	1.42	0.73
Visalia	0.98	1.76	3.42	5.43	6.96	8.15	8.42	7.20	5.67	3.78	1.65	0.85
VENTURA												
Oxnard	2.20	2.54	3.17	3.66	4.39	4.61	5.37	4.76	4.02	3.30	2.36	1.95
Thousand Oaks	2.20	2.65	3.42	4.49	5.37	5.91	6.71	6.35	5.43	3.91	2.60	1.95
Ventura	2.20	2.65	3.17	3.78	4.64	4.72	5.49	4.88	4.13	3.42	2.48	1.95
YOLO												
Davis	0.98	1.87	3.30	4.96	6.35	7.56	8.18	7.08	5.43	4.03	1.77	0.98
Winters	1.71	1.65	2.93	4.37	5.80	7.09	7.93	6.71	5.31	3.30	1.59	0.98
Woodland	1.04	1.76	3.17	4.72	6.10	7.68	8.18	7.20	5.43	3.66	1.65	1.04
YUBA												
Brownsville	1.10	1.43	2.56	4.02	5.74	6.79	7.93	6.83	5.31	3.36	1.48	0.85

APPENDIX 6.

TREE CROP COEFFICIENTS FOR DECIDUOUS ORCHARDS IN THE SAN JOAQUIN AND SACRAMENTO VALLEYS.

Date	K_c
Mar. 16-31	0.53
Apr. 1-15	0.60
Apr. 16-30	0.66
May 1-15	0.72
May 16-31	0.78
June 1-15	0.83
June 16-30	0.86
July 1-15	0.92
July 16-31	0.93
Aug. 1-15	0.93
Aug. 16-31	0.93
Sept. 1-15	0.93
Sept. 16-30	0.91
Oct. 1-15	0.84
Oct 16-31	0.78
Nov. 1-15	0.69

For more information see Goldhammer, D. A. and R. L. Snyder. 1989. Irrigation Scheduling: A Guide for Efficient On-Farm Water Management. University of California Publication No. 21454.

APPENDIX 7.

APPROXIMATE AMOUNTS OF AVAILABLE WATER HELD BY SOILS OF DIFFERENT TEXTURE.

Soil Texture	Inches of Water Held per Foot of Soil[a]
Sand	0.5 - 0.7
Fine sand	0.7 - 0.9
Loamy sand	0.7 - 1.1
Loamy fine sand	0.8 - 1.2
Loam	1.0 - 1.8
Silt loam	1.2 - 1.8
Clay loam	1.3 - 2.1
Silty clay	1.4 - 2.5
Clay	1.4 - 2.4

[a] From the Western Fertilizer Handbook, Eighth Edition, 1995. Table 2 -1, p. 24.

APPENDIX 8.

SAMPLE CALCULATIONS OF IRRIGATION WATER AMOUNTS.

The usual approach for calculating irrigation water amounts involves the following two equations:

Crop water need = CIMIS ET_0 X Crop Coefficient

Irrigation amount = Crop Water Need/Irrigation Efficiency

The historical ET_0 values for many locations in California are listed in Appendices 3 - 5 and crop coefficients for deciduous orchards are found in Appendix 6. Near real-time ET_0 data can be obtained from the CIMIS network as explained in Appendix 2.

EXAMPLE: Grower A has a mature almond orchard on a deep sandy loam soil near Modesto. The available soil water holding capacity is 1.2 inches per foot (see Appendix 7). Microsprinkler irrigation is used with an irrigation efficiency of 85% (0.85). No cover crop is present. Assume a root zone depth of 4 feet.

Calculation 1. Leaf Out

On March 16 the Grower wants to apply all of the water needed to adequately supply the crop for two months. a) How much water is needed? and b) Can this amount be efficiently applied in a single irrigation event?

a) Irrigation Amount = (ET_0 X Crop Coefficient)/Irrigation Efficiency

Dates	ET_0 Appendix 3 (inches)	Crop Coefficient Appendix 6 (%)	Irrigation efficiency (%)	Irrigation Amount (inches)
March 16-31	1.77	0.53	0.85	1.10
April 1-15	2.20	0.60	0.85	1.55
April 15-30	2.57	0.66	0.85	2.00
May 1-15	2.94	0.72	0.85	2.49
			TOTAL	7.14 inches

Note: Under most conditions in California it is unlikely that the soil profile would be without water in March. For a more comprehensive discussion and example calculations on using ET_0 for irrigation scheduling please refer to: Goldhammer, D.A. and R.L. Snyder. 1989. Irrigation Scheduling: A Guide for Efficient On-farm Water Management. University of California Publication No. 21454.

b) Maximum Soil Water Storage = Soil Depth X Soil Water Holding Capacity
= 4 feet X 1.2 inches/foot
= 4.8 inches

No, an application of about 7.14 inches of water exceeds the water holding capacity of this soil. About 2.4 inches of water would be leached below the root zone depth of 4 feet.

Calculation 2 . Peak Canopy Development

July is the peak water use month at this location with a monthly ET_0 of 8.06 inches (from Appendix 4). If each irrigation is 4.0 inches, what irrigation interval is required?

Irrigation Amount = (ET_0 X Crop Coefficient)/Irrigation Efficiency
= (8.06 in./mo. X 0.925)/0.85
= 8.77 inches per month

$$\text{Irrigation Interval} = \frac{4.0 \text{ inches}}{8.77 \text{ inches}} \times 31 \text{ days} = 14.1 \text{ days}$$

Grower will need to irrigate about every two weeks during July.

APPENDIX 9.

ADDITIONAL REFERENCES ON NITROGEN MANAGEMENT IN ORCHARD CROPS AVAILABLE THROUGH THE CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE (CDFA) AND OTHER SOURCES.

Source	Title
CDFA[a]	Best Management Practices for Nitrogen and Water Use in Irrigated Agriculture, 30 min. video
CDFA	Influence of Irrigation Management on Nitrogen Use Efficiency, Nitrate Movement and Groundwater Quality in a Peach Orchard, 36 pp
CDFA	The Effects of Various Cultural and Environmental Factors on Nitrogen Use Efficiency and Nitrate Leaching in Stone Fruit Orchards: A Literature Review, 20 pp
CDFA	Nitrogen Fertilizer Management to Reduce Groundwater Degradation, 8 pp
CDFA	Potential Nitrate Movement Below the Root Zone in Drip Irrigated Almonds, 10 pp
CDFA	Development of Diagnostic Measures of Tree Nitrogen Status to Optimize Nitrogen Fertilizer Use, 5 pp
CDFA	Nitrogen Efficiency in Drip Irrigated Almonds, 12 pp
CDFA	Effects of Four Levels of Applied Nitrogen on Three Fungal Diseases of Almond Trees
CDFA	Compost Production and Utilization: A Grower's Guide, 17 pp
Cal Poly[b]	Drip and Micro-Irrigation for Trees, Vines and Row Crops, 260 pp
Cal Poly	Fertigation, 295 pp
SAREP-UC Davis[c]	Organic Soil Amendments and Fertilizers, 36 pp
CFA[d]	Western Fertilizer Handbook, Eight Edition, 338 pp
Univ. Calif.[e]	Soil and Plant-Tissue Testing in California, Bulletin 1879, 54 pp

[a]CDFA publications are listed in: "A Resource Guide: Fertilizer Research and Education Program." Contact the CDFA-FREP at 1220 N Street, Sacramento, CA 95814, (916) 653-5340, FAX (916) 653-2407.
[b]Cal Poly publications can be ordered from: Irrigation Training and Research Center, Cal Poly State University, San Luis Obispo, CA 93407, (805) 756-2434.
[c]Available from: SAREP-UC Davis, Davis, CA 95616, (916) 757-3277.
[d]To order contact: Interstate Publishers, Inc., 510 North Vermilion Street, P.O. Box 50, Danville, IL 61834-0050, (800) 843-4774.
[e]To order contact: UC ANR Publications, Bulletin 1879, H.M. Reisenauer, Editor, 1978, 6701 San Pablo Ave., Oakland, CA 94608-1239, (501) 642-2431.

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