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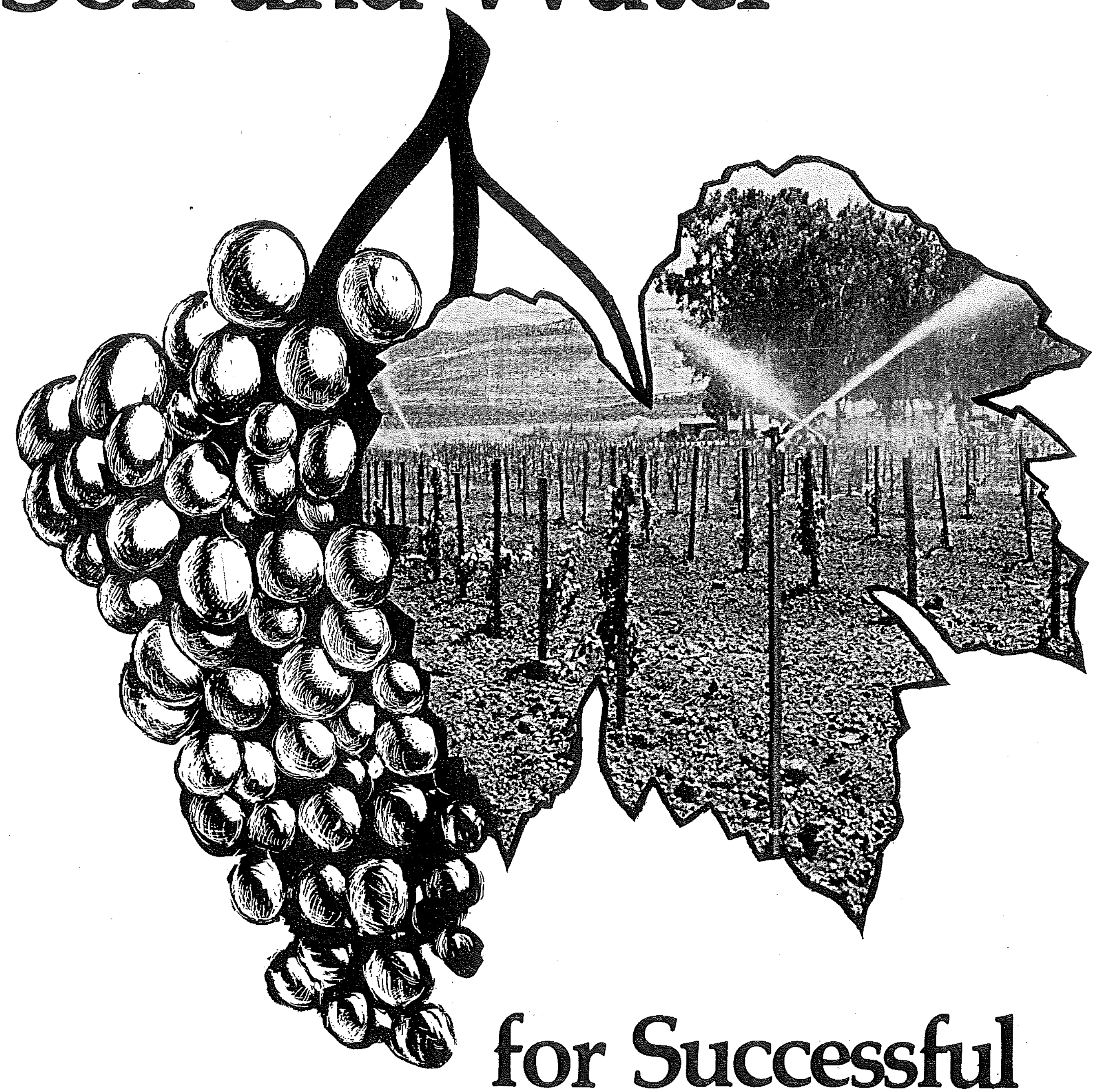
Salinity Appraisal of Soil and Water



for Successful Production of Grapes

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This publication attempts to answer the question, "What soil and water is best suited for successful grape production?" It is written for actual or potential grape growers, and for agriculturists in general. Subjects include:

...appraisal of soil and water in relation to salinity.
...problems related to soil and water chemistry.
...permeability, toxicity and other significant factors in soil and water.
...evaluating a vineyard site in view of the above considerations.

Solutions to problems normally encountered or expected are discussed in terms of practical vineyard management.

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Contents

SALINITY APPRAISAL OF SOIL AND WATER FOR SUCCESSFUL PRODUCTION OF GRAPES

Introduction

An on-the-spot evaluation for general site characteristics of a vineyard usually precedes an appraisal of physical soil characteristics (texture, profile, drainage), and of salinity or other chemical factors. A biological-factor evaluation to include nematodes, phylloxera, noxious weeds, and soil-borne diseases should also be made, and this completes the inventory for site suitability. Such a multiple appraisal before planting a new vineyard is perhaps of more importance to good production than is later diagnosing of problems encountered in the producing vineyard.

Chemical appraisal of soil and water from the standpoint of actual or potential problems usually includes an evaluation of: *salinity*, which reduces water availability to the vines; *soil permeability*, which influences ease of water entry into and through the soil and which may reduce the volume of water entering into storage for later use by the vines; *toxicity*, which results from vine uptake of certain soil constituents which may accumulate in vines to damaging amounts; and *miscellaneous*, which include effects caused by excess plant nutrients, by deposits on fruit or leaves, or those caused by other constituents in applied water which may be detrimental to production.

If a potential problem is indicated, suitable management practices can often prevent it. If a problem is present, proper management can often restore the vineyard to full production.

Soil Appraisal

Soils normally contain many soluble or slightly soluble substances which can be absorbed by vines and which can affect yield. In general, such solubles are called "salts" and soils contain various kinds of them. Small amounts of certain salts are essential for plant growth, but excessive amounts can decrease vine growth or reduce crop yield, or both. Therefore, salinity of soil or irrigation water is of prime importance.

Salts include all soil constituents which readily dissolve in water or which are applied in solution in irrigation water. Salts usually include chlorides, sulfates, and carbonates or bicarbonates, along with sodium, calcium, magnesium, and potassium. In some instances, ions other than those listed may occur in high enough concentration to cause a problem. Less frequently, ions causing problems include nitrates, ammonia, and boron.

Salinity

A soil is saline if there is some adverse affect on the crop or its management due directly or indirectly to the soil's high content of soluble salts. A saline soil causes problems which result either in reduced yields or increased costs due to management changes needed to maintain yields. Salinity is measured and reported in terms of electrical conductivity (EC) of a soil-saturation extract (ECe) or of water (ECw).

Table 1. Guidelines for Interpreting Laboratory Data on Soil Suitability for Grapes[a]

Possible problem and unit of measurement	No problem (less than 10% yield loss expected)	Increasing problems (10 to 25% yield loss expected)	Severe problems (25 to 50% yield loss expected)
Salinity			
ECe, mmhos/cm	1.5 to 2.5	2.5 to 4	4 to 7
Permeability			
ESP (est.)	Below 10	10 to 15	Above 15
Toxicity			
Chloride meq/l (mg/l or ppm)	Below 10 (350)	10 to 30 (350–1060)	Above 30 (1060)
Boron mg/l or ppm	Below 1	1 to 3	Above 3
Sodium (meq/l)	—	Above 30 (690 ppm)	—
Miscellaneous			
pH	5.5 to 8.5	—	—

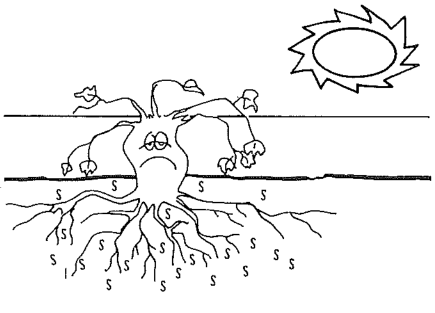
[a] Interpretations are based on chemical analyses of the soil saturation extracts from soil samples representing a major portion of the root zone—usually the top 2 to 3 feet of soil.

Note: guidelines are flexible and should be modified when warranted by local practices, experience, special conditions, or method of irrigation.

Salts in soils come primarily from salts in irrigation water, or from salts accumulated in soils overlying a shallow, salty water table.

Salts get into water originally by the slow breaking down of rocks as water passes over them, or from dissolving of soil minerals as water percolates downward to a water table.

When vines, weeds, or cover crops use water from the soil, or when water evaporates from a water or soil surface, salts in soil or water become more concentrated and the soil or water becomes of lower quality. Continuous addition of salts from incoming water, and loss of pure water by evaporation and by transpiration through the crop concentrate these salts and can eventually result in serious salt problems, especially where drainage is impaired. In excessively saline soils, the vine is not able to take up water fast enough to meet its needs and this can decrease vine growth, yield, and quality.



Excessive accumulation of salts can cause moisture stress.

Natural drainage should be adequate for surface water to percolate and leach enough of the salts below the root zone to keep salinity below the salt tolerance of the vines. Artificial drainage (tile, underdrains, or open drains) may be required where dense, compact subsoil layers significantly impede downward water movement—such layers cause water to temporarily stack up (perch) above them or cause water tables to rise and restrict aeration and root development.

All chemical fertilizers are salts, and thus not all salts are bad—it is the excess of salts that is harmful. The solution to salinity problems usually is improved water management or, sometimes, artificial drainage.

Permeability and sodic soils

Low permeability is a different problem from salinity but it also affects water availability. Soil can become so impermeable that it will not allow enough water to enter to sustain the vines between irrigations.

Soils having a permeability problem because of excessive sodium in relation to calcium and magnesium are known as "sodic" soils (sometimes called "alkali" or "black alkali" soil). They are less common in California than are saline soils, but they do occur, are often difficult to correct, and are hazardous to grape production. Soil and water analyses can help determine whether or not a permeability problem is due to a sodic soil condition, or to some other cause such as soil texture, soil compaction, too steep a slope or chemical constituents in the irrigation water, or a combination of causes.

Permeability problems can occur at the soil surface or deeper. Surface sodic conditions decrease water penetration into soil and thus cause excessive surface run-off of applied water. Subsurface sodic conditions reduce water percolation through the soil and cause perched water tables and, occasionally, excessive surface run-off; shallow rooting and water-logging may also result. Thus, because less water enters and is stored in the soil between irrigations, the vines may run out of water too soon before the next irrigation. If vine growth is affected by this, a change in water management may be necessary. Continual use of high-sodium irrigation water will usually result in a sodic soil. (Effects of sodium in irrigation water are discussed in the water-quality appraisal section.)

For sodium-sensitive crops, a relatively low concentration of sodium (less than 10 meq/l) may cause toxicity. Grapes are not as sensitive to sodium as are many other woody perennial crops, but some toxicity is to be expected at high concentrations (sodium greater than 30 meq/l)—for example, the high concentration of sodium usually present when salinity is excessive (ECe greater than 4 mmho/cm [see table 1]) may cause some toxicity.

Where typical subsurface sodic problems exist, the poor soil structure can further restrict downward water movement and cause a temporary perched water table to form. This causes poor aeration and consequent water-logging for too long a period after an irrigation.

Subsoil sodic conditions resulting in perched water tables can be corrected by special practices, such as subsoiling or deep plowing, in combination with soil and water amendments which supply calcium to correct the sodium imbalance. Artificial drainage may be required if water tables are expected to persist.

Factors Preventing or Opposing Salt Accumulation

Low salt content in irrigation water and soil.

No water table.

Good water-management practices which meet the needs of the particular soil and crop conditions. This includes meeting the proper leaching requirement for the water and for the grape variety.

Well-drained moderately-deep to deep loamy uniform soils, which allow good downward percolation of water and salts to the lower root zone or below.

Sufficiently wet winters and mild summers, which require fewer irrigations.

Uniform topography and soil textures which allow relatively uniform infiltration of applied water and uniform depths of wetting and leaching.

Application of the correct type and amount of fertilizers and soil amendments.

Frequent but light applications of irrigation water if soil is shallow.

In general, frequent irrigation is advisable to maintain low salinity, good water availability, and to help prevent excessive dry-down and concentration of salts between irrigations.

Toxicity

Relatively low levels of chloride and boron as shown in table 1 often cause leaf burn, sometimes defoliation, and usually a reduced yield of grapes. However, similar leaf burn can be caused by potassium deficiency or by Pierce's disease, so soil, plant, and water analyses may be required to establish the probable cause of the toxicity symptoms.

Toxicity due to leaf absorption of either or both sodium and chloride ions from sprinkler-applied water occurs under certain conditions and will be discussed in the section on water-quality appraisal.

Factors Increasing Salt Accumulations

Too much salt in irrigation water, water table, or soil.

Poor drainage: claypan or dense subsoil layer; restricted downward water movement and root penetration; perched water tables.

Inadequate leaching; this allows too much salt to accumulate in the rooting area.

Low rainfall and high temperatures: low rainfall does not give adequate winter leaching; high temperatures increase water needs and thus the application of more water and salts.

Uneven topography and variable soil texture, which result in variable rates of water infiltration, variable depths of wetting, and uneven leaching.

Excessive applications of fertilizers and certain types of soil amendments. (Remember, all fertilizers are salts.)

Infrequent but heavy applications of water during the growing season which result in extremes of wet and dry periods. On shallow-lying claypan subsoils this may cause water to be stacked up, and may also cause rot-off of deeper roots—which in turn causes an already shallow root zone to become shallower.

Excessive soil dry-down and plant stress between irrigations may concentrate salts in the soil.

Choosing a Good Vineyard Site

The following steps are suggested

- Determine the physical characteristics and limitations of the soil.
- Have soil and irrigation water analyzed for usual quality constituents by an agricultural laboratory.
- If crops are growing and problems are apparent, take similar but separate soil and plant tissue samples from both problem and non-problem areas and have each analyzed by a competent agricultural laboratory using USDA Salinity Laboratory or University of California methods.
- Evaluate the above analyses to arrive at the probable cause of the problem(s). Evaluation of laboratory results should be made only by a qualified agriculturist or viticulturist.

Soil sampling and analysis

Soil depth, texture, permeability, and drainage are important components of a salt-affected soil situation and should be evaluated.

Soil samples should be carefully taken and should be representative of a specific area or problem.

- Select sampling sites on the basis of the particular problem or soil condition. Sample representative problem areas, and for comparison, sample nearby areas having no problems.
- Take soil samples at 1-foot intervals as far down as depth of rooting. Each sample should be labeled and analyzed separately. For layered soils, each sample should be limited to a single soil layer; do not mix several different layers into one sample.
- Each sample submitted should be at least 1 quart (1 to 2 pounds).
- Use a waterproof container for each sample. Be sure to label each according to location and depth, and include any other useful observations.
- Keep samples cool and get them to the laboratory immediately, or air-dry them before they are delivered to the laboratory. Caution: samples submitted for other than the usual chemical analyses may first need special treatment or handling. Check with the laboratory.

When interpreting soil analyses it should be remembered that factors other than those shown in table 1 may also affect grape production. These include soil characteristics, soil compaction, extent and distribution of the root system, water quality, method of irrigation, surface and subsurface drainage, climate, presence of plant pests and diseases, and quality of management. Each of these may have a bearing on interpretation of the analyses or on corrective action to be taken.

If the area has been irrigated, the effects of these soil factors affecting salinity can be judged by studying the site's soil-salinity profile to see where salts are accumulating.

Laboratory tests for the factors listed on top of next page are often used to help decide whether the land is suited to grapes (see Appendix for glossary of technical terms).

Electrical conductivity (ECe) of the soil-saturation extract as a measure of soil salinity.

Calcium, magnesium, and sodium in the saturation extract; used to estimate the exchangeable sodium percentage (ESP est.), and used to evaluate a permeability problem.

Gypsum requirement as determined by the Schoonover method; used as a check to confirm whether or not an indicated sodium problem actually exists. The gypsum requirement estimates the severity of the permeability problem, and can be used as a general guide to the amount of gypsum or other suitable amendment needed.

Boron and chloride in the soil-saturation extract; used to evaluate potential toxicity of the soil.

pH of a saturated soil paste; this is a measure of acidity or alkalinity. (A pH of 1 to 7 is acid, 7 is neutral, and pH above 7 to 14 is alkaline.)

Interpretation of the laboratory results can be made by using the guidelines of table 1.

Crop history

A site's previous crop history of symptoms or lack of symptoms is rarely a reliable guide in evaluating salinity problems in soils to be planted to grapes. This is because not all crops, or even varieties of the same crop, react as grapes do to saline, sodic, or toxic soil conditions.

In some sites, lack of symptoms in crops much more salt-tolerant than grapes may suggest no problems for grapes, when in fact salinity, sodium, or other factors related to soil would make it almost impossible to grow grapes competitively without costly changes in management practice or water supply. High-boron water, for example, may be detrimental to grapes but not to sugar beets or alfalfa, which can grow well in soils having a relatively high level of boron.

On the other hand, the absence of visual symptoms or problems on crops more sensitive than grapes might safely be used as a "green light" in evaluating the site for grapes. (See crop-tolerance tables in: Ayers, R. S. and D. W. Westcot, [1976] "Water Quality for Agriculture, Irrigation, and Drainage, Paper 29," FAO-Rome. Also see Ayers, R. S. [1977] "Water Quality for Agriculture, J. Irrigation, and Drainage," P-4, ASCE, Vol. 3, No. IR2.) Be sure to appraise soil depth also.

Water-Quality Appraisal

Quality of the water supply can also affect the suitability of a site for production of quality grapes. A grower is interested in the effect of the irrigation water on the crop—how salts in the water can directly or indirectly influence yield and quality of grapes.

Types and importance of salts in water

All irrigation waters contain varying amounts of soluble salts, such as the bicarbonate, chloride and sulfate salts of calcium,

The villain—too much total salt or too much of a certain kind of salt.

magnesium, and sodium. Water may also contain small amounts of nitrogen, boron, and other elements. Some water contains iron, bicarbonate, silt, organic matter, algae, or bacteria, any of which could cause plugging of the emitters and tubing used in drip irrigation.

Although irrigation water quality is one of the more important factors involved in grape production, its importance in general has been over-emphasized nearly as often as it has been neglected. Vines do not grow in the applied water—they grow in moist soil, and for the most part they take up irrigation or rain water after it has had time to come to equilibrium not only with the soil but also with water remaining from previous irrigations or rains. Actually, successful long-term use of irrigation water depends on a number of things other than its quality. These include on-farm water management, climate, soil, drainage characteristics, and salt tolerance of the vines. Of these, water management to apply adequate water for crop use and leaching may be the more important.

Relatively poor irrigation waters have been used successfully by good managers—and relatively good water has been misused by poor managers, with subsequent severe salinity problems. Such problems occur most often where a perched water table complicates water management.

Good-quality water has the potential for producing maximum crop yields. Poor-quality water can cause reduced yields unless special management practices are adopted.

Four types of grape-production problems related to water quality are recognized:

Salinity problems. Water brings in salts which may accumulate in the soil and reduce yield.

Soil permeability problems. Low-salt water or relatively high-sodium water may reduce soil permeability.

Toxicity problems. Chlorides or boron in irrigation water may accumulate in grape leaves. Sodium may also accumulate by way of foliar intake if vines are sprinkler irrigated.

Miscellaneous problems. Nutrients such as nitrogen may cause excessive vigor and lowered yields, or bicarbonate in sprinkler-applied water may result in an objectionable white deposit of lime on leaves or fruit.

Table 2 gives water-quality guidelines for each of the above types of problem. Even though these problems often occur in combination, they are more easily understood and evaluated on a one-problem-at-a-time basis.

Water salinity less than ECw = 1 mmhos/cm is considered excellent for grapes under average vineyard management. Water salinity in excess of ECw = 1 mmho/cm may still be satisfactory if special management practices are adopted.

Soil permeability problems caused by water

The first effects of water quality upon water penetration into soil should be apparent after several irrigations. The final effects, however, may not be known for several years for they will also depend upon irrigation management, cultural practices, soil, climate, and rainfall. High-salt content of irrigation water improves the rate of infiltration; low-salt content reduces it. Extremely low-salt water often results in poor water penetration. Relatively high sodium slows

Table 2. Guidelines for Interpreting Laboratory Data on Water Suitability for Grapes

Problem and related constituents	No problem	Increasing problem	Severe problem[a]
Salinity[b]—affects water availability to crop			
ECw (in millimhos/cm)	< 1**	1.0 to 2.7	> 2.7
Permeability—affects rate of water movement into and through soil			
ECw (in millimhos/cm)	> 0.5	0.5 to 0.2	< 0.2
adj.SAR[c]—(an estimation of the permeability hazard)	< 6	6 to 9	> 9
Toxicity—of specific ions which affect growth of crop			
Sodium (meq/l)*	< 20	—	—
Chloride (meq/l)*	< 4	4 to 15	> 15
Boron (ppm)	< 1	1 to 3	> 3
Miscellaneous			
Bicarbonate[d]	< 1.5	1.5 to 7.5	> 7.5
Nitrate-nitrogen (ppm)	< 5	to 30	> 30

The acceptable range for pH is between 6.5 and 8.4.

* With overhead sprinkler irrigation, sodium or chloride in excess of 3 meq/l under extreme drying conditions may result in excessive leaf absorption, leaf burn and crop damage. If overhead sprinklers are used for cooling by frequent on-off cycling, damage may occur even at lower concentrations.

** < means "less than"; > means "more than".

[a] Special management practices and favorable soil conditions required for successful production.

[b] Assumes that rainfall and extra water applied due to inefficiencies of normal irrigation will supply crop needs plus about 15% extra for salinity control.

[c] Adjusted Sodium Adsorption Ratio. Permeability problems are more likely to occur with low-salt water than with high.

[d] Bicarbonate (HCO_3) in water applied by overhead sprinklers may cause white deposits on fruit and leaves (not toxic but reduces market acceptability).

Note: Guidelines are flexible and should be modified when warranted by local practices, experience, special conditions, or method of irrigation.

water infiltration; relatively high calcium improves it. Permeability problems due to water quality are particularly troublesome on sandy loam soils. Clay soils are affected to a lesser degree.

In predicting a potential permeability problem from a water-analysis, two determinations are helpful: water salinity (ECw) and the adjusted sodium adsorption ratio (adj.SAR).

- Extremely low-salinity water (ECw less than 0.2 mmho/cm) will usually cause some degree of reduced permeability.
- A high adjusted Sodium Adsorption Ratio (adj.SAR greater than 9) can be expected to cause a severe permeability problem and will be most severe on shrinking-swelling type soils.

These two problems rarely occur together.

Toxicity problems

Chloride or boron from applied water gradually accumulate in leaves as water taken up by the vines is transpired through them. If chloride, or boron accumulate in excess of the plant's tolerance, leaf burn occurs and crop yield may be reduced. Grapes are reported to be relatively insensitive to sodium in soil, but are sensitive to sodium in sprinkler-applied water.

Toxicity from overhead sprinkling. If overhead sprinkling is done with waters containing chloride, sodium, or boron, salt concentration increases on the leaves as water evaporates. Absorption through leaves may then cause toxicity. Such toxicity from sprinkling occurs primarily during periods of low humidity, high temperatures, or drying winds, all of which cause rapid evaporation of water and greater concentration of salts on the leaves between wettings. Sequencing of sprinklers for heat suppression (i.e., 3 minutes on, 15 minutes off) is another special case where dry-down between wettings can greatly increase salt concentration and toxicity effects. A typical toxicity symptom is burning or necrosis of leaf tissue at the tip and outer edge of the grape leaf.

Sprinkler-applied water containing as little as 3 meq/l (100 ppm) chloride, 3 meq/l (70 ppm) sodium or 1 ppm boron may cause injury, although the same levels would not be expected to cause significant leaf burn if applied by furrow, flood, basin, or drip irrigation. Damage from leaf absorption is believed to be much less probable if relative humidity remains above 30 to 40 percent.

Miscellaneous problems

Excessive nitrogen in irrigation water causes excessive vine growth and delayed fruit maturity. This is difficult to correct, but blending or changing to lower nitrate water sources should help. Reducing the amount of applied water and allowing soils to become somewhat drier between irrigations has also helped to slow excessive vegetative growth.

White deposits on berries resulting from overhead sprinkling with high bicarbonate water can greatly detract from the appearance of the grape cluster and will reduce fresh-market acceptability. Night irrigations can substantially reduce the amount of deposit. A procedure to reduce bicarbonate in sprinkler-applied water which has not been thoroughly evaluated (and thus needs more research) is the addition of sulfuric acid or sulfur dioxide to water at a controlled rate to reduce water pH to 6.5.

Problems associated with a water pH above 8.4 or below 6.5 are usually related to toxicity, nutritional imbalances, or soil permeability problems. Corrective procedures for abnormal pH are often possible, but vineyard management then may become much more complicated. Soil applications of lime for acidity control or gypsum for sodicity control are usual corrective actions.

Management

Good management often can restore salt-damaged soil to acceptable productivity. The usual solutions to the soil and water problems are as follows.

Irrigation

Certain irrigation practices can decrease the severity of problems related to soil or water, or delay their onset and in some cases may even prevent them. These practices include: changing scheduling and duration of irrigations; moving the water furrow closer to or under the vine row; winter leaching; getting rid of some or all of the weeds which compete for water; and land-grading for better distribution of water. Tensiometers, which measure the degree of soil wetness, are recommended as a guide to water needs and irrigation schedules; they are particularly well adapted to sandy and loamy soils. Tensiometers may be used somewhat as a thermostat is used to regulate temperature: if readings in the upper one-third of the root zone show that soil is too dry (60 to 80 centibars) for the "comfort" of vines, irrigate. If readings are in the comfort zone (10 to 30 centibars), don't irrigate. Tensiometer readings of 0 to less than 10 centibars at or near the bottom of the root zone indicate an excessively wet soil; if this persists for more than a day or two after an irrigation, a change in irrigation practices or improved drainage (tile under drains or deep ripping) is needed.

Vineyards with salinity problems should be irrigated at 20 to 40 centibars of suction during the early and main growth period instead of at the 30 to 50 centibars often recommended for non-saline soils (80 centibars of suction is approximately the maximum reading of the tensiometer, but such a reading does not mean all available moisture is gone). As harvest time approaches, the vineyard is usually allowed to become much drier in order to slow shoot growth and mature the crop.

Enough water should be applied to meet the vines needs for good production and quality and to help control salts through leaching below the root zone. Depending on climate, a water supply of 4 to 5 gallons per minute per acre usually is considered the minimum required in sprinkler irrigation. Under some soil conditions and methods of application, such as a sandy soil with furrow irrigation in a hot climate, 10 gallons per minute per acre would be desirable.

For best production and quality, irrigations should begin early enough in the growing season and should be frequent enough to produce an adequate vine leaf canopy. Once this is accomplished, irrigation should be reduced to discourage further tip growth, but be sure there is enough soil moisture to maintain a healthy canopy through harvest. After harvest, irrigate after tip growth has stopped but before vines become excessively dry and defoliated; otherwise, unwanted continued tip growth or regrowth is likely. Conversely, early and nearly-complete defoliation before harvest will likely result in regrowth whether or not you irrigate.

The preferred time for leaching is during winter dormancy. A post-harvest irrigation can replenish soil water and facilitate winter rainfall leaching. In dry years, winter irrigations in late December through early February may be necessary for replenishing deep soil moisture and for adequate leaching.

Fertilize for production and quality. Remember: grapes are not heavy users of nitrogen. Avoid excesses and luxury levels of fertilizers; these can cause overly vigorous vine growth, poor quality and reduced yields, and can also result in salinity and pollution problems. Any nitrogen in the water supply should be taken into account when fertilizing grapes.

Solutions to specific problems

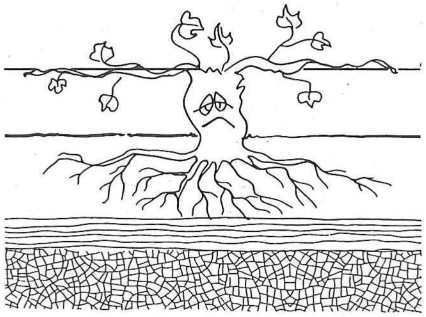
Salinity is the water-quality-related problem most often affecting vineyards in California. In a vineyard, almost all of the salts in applied water remain in the soil, with only a little going into the crop. However, each irrigation adds more salt. These added salts will accumulate and increase in concentrations, eventually causing a salinity problem unless they are removed by leaching.

Leaching. The amount of leaching water required to control salts is known as the leaching requirement. Leaching is the only practical way of removing soluble salts from the soil; there is no magic chemical that can neutralize or remove them. Soil or water amendments may increase the rate at which water enters or moves some ions through soil, but it is the water that does the job.

Enough leaching should be done to reduce the average salinity in the main portion of the root zone to at least an ECe of 1.5 to 2.5 mmho/cm at the beginning of the growing season. This should allow 90 percent maximum potential yield for grapes. After leaching, follow good water-management practices to meet growth requirement of the vines. If drainage is poor leaching may not be possible without artificial drainage, or if possible the effects may be only temporary. Artificial drains (tile, or underdrains) have been used in many areas, but they require a complementary off-farm collection, transport, and disposal system.

A leaching requirement can be calculated and is specific for the quality of water being used and the salinity tolerance of the crop being grown (see Appendix). Timing of leaching is usually not critical but leaching in winter is generally recommended. Leaching, however, can be done at each irrigation, after several irrigations, in the winter dormant period, or after several growing seasons as long as (a) salts do not approach damaging concentrations between leachings, and (b) the deeper part of the root zone does not become waterlogged.

Perched water tables at any time during the growing season may result in low oxygen supplies for roots, root rot, and shallower rooting depth. Because the shallower rooting depth means lesser amounts of water can be stored in the reduced rooting depth, good water management becomes more critical to prevent a shortage of water to the vines between irrigations.



A shallow, perched water table for more than a few days is a serious problem.

The amount of water needed to restore productivity of a too-salty soil depends primarily on the degree of soil salinity and the depth of soil to be leached. Roughly, 1 acre-foot of good-quality water passing through and below a 1-foot-depth of soil will remove about 80 percent of the salts in the top 1-foot of soil. But the 1 acre-foot of water leaches only about 50 percent of the salts from the 2nd-foot-depth of soil. It takes considerable water to reclaim soils!

The quality of water used for leaching will also influence final soil salinity—salinity of the soil surface after leaching will be about the same as the salinity of the water applied. The salinity of the deeper soil will be higher. The vines respond to average salinity of the root zone, so a systematic sampling of vineyards can serve to monitor the salinity status and need for, or effectiveness of, leaching.

Prevention of salinity problems through good water management, proper timing of irrigations, and monitoring for adequacy of control is not only easier but is generally less costly in the long run than are reduced yields or leaching to restore production. In short, good management pays even if soil, water, and climate are ideal.

Permeability. If soil-permeability problems are great enough to affect water supply to the vines, it may be necessary to increase the time water is on the land or to increase the rate of water entry into the soil.

Increasing the time water is on the land can be accomplished by lengthening the duration of each irrigation, or by irrigating more frequently. With sprinklers, however, extending the duration of an irrigation without having excessive surface runoff may require changing to smaller orifices in the sprinklers.

Increasing the rate of water entry into the soil can often be accomplished by cultivation, by cover crops, by soil-profile modification techniques, or by use of soil or water amendments such as gypsum, sulfuric acid, or sulfur dioxide.

Low-salinity waters. Low-salinity water has often been associated with surface-soil permeability problems. Friant-Kern canal water is an example of a low-salinity problem water. The reasons are not clearly understood, but such a low-salt water (ECw less than 0.2 mmho/cm) causes surface soil to seal and absorb less water, resulting in more surface runoff. Amendments such as gypsum applied directly to the soil, or in continuous applications in water, have long been used to correct the problem (gypsum at 100 to 500 pounds per acre-foot of water has been used). Where amendments are effective, infiltration rates have increased by as much as 50 to 300 percent. Return-flow systems for furrow-applied water can capture and utilize runoff water and greatly increase irrigation efficiency.

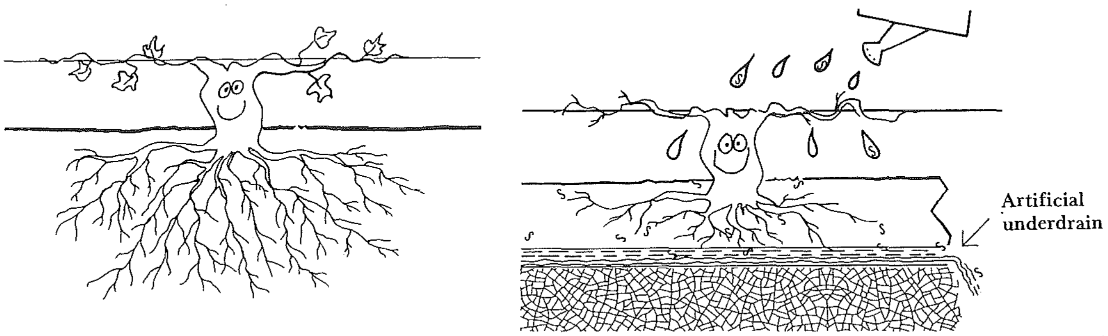
Toxicity. Leach and manage as for control of salinity (boron leaches about three times less readily than does chloride). If the problem is too severe, look for another water supply. Blending with a better supply is an acceptable alternative.

To minimize leaf burn and deposits from overhead sprinkler irrigation:

- Sprinkle only at night when humidity is higher and rate of drying is reduced.
- Use sprinkler heads that rotate at least once per minute.

- Avoid or minimize irrigating during periods of low humidity or drying winds. Start the hot, dry season with good soil moisture.
- If better water is available use it exclusively, or blend it with your poorer-quality water.

Wind-blow sprays or mists of high-salt water from sprinklers are particularly hazardous because salts are concentrated (through evaporation) in the spray as it drifts down-wind from the sprinklers. Such spray-drift falling on leaves of nearby vines can result in severe leaf burn. Thus sprinkler sets should be made downwind, rather than upwind, to wash off deposits.



Good soil + good water ... or fair soil or water + excellent management = happy vines, good yields, good profits, happy grower.

References

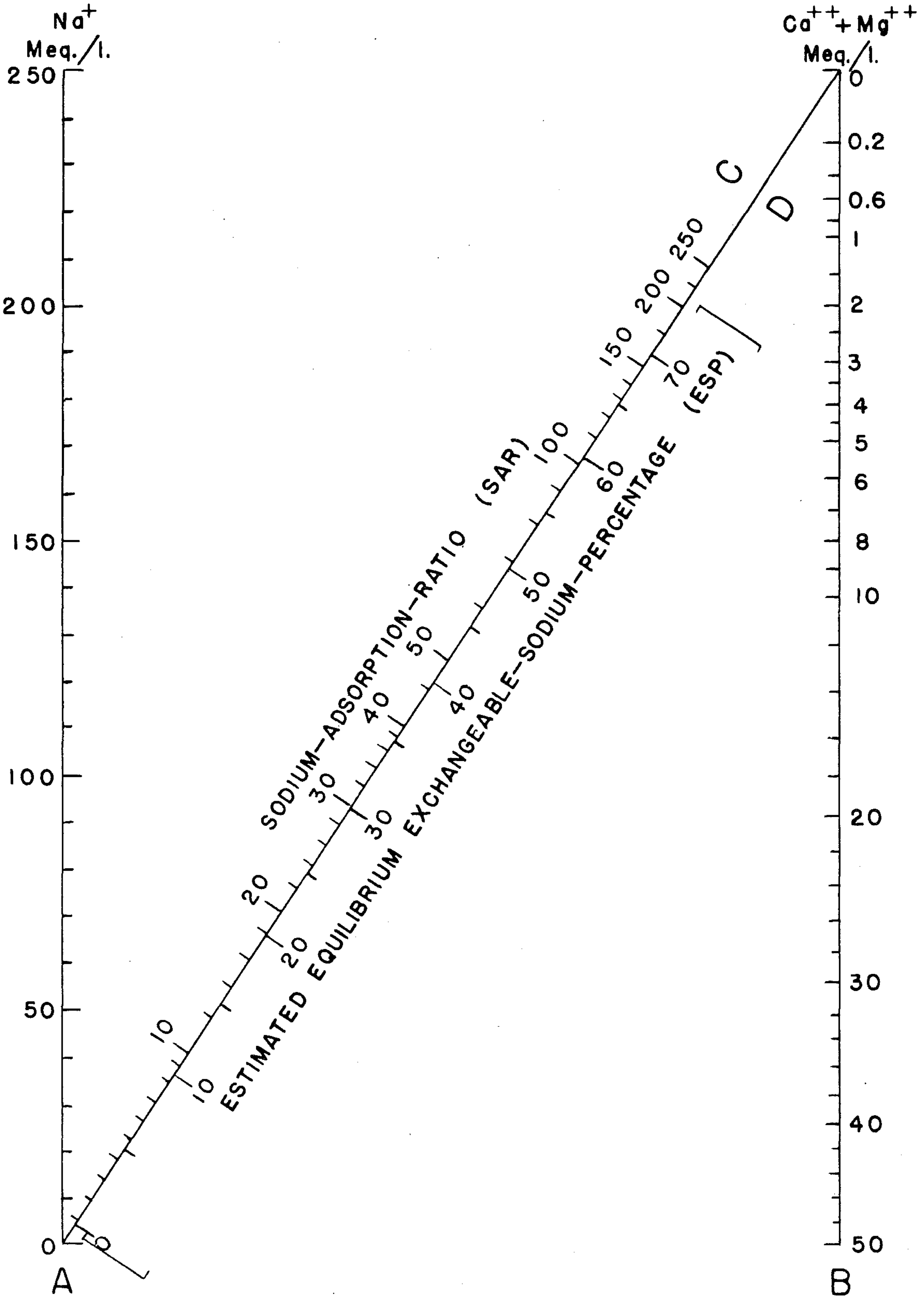
University of California Cooperative Extension Leaflet 2946 (1977) "How to Appraise Soil Physical Factors for Irrigated Vineyards," by R. A. Neja, W. E. Wildman, and L. P. Christensen (20 pages).

Monterey County and San Joaquin County leaflet (July 1975) "How to Appraise and Correct Vineyard Biological Problems That Cause Decline," by J. J. Kissler and R. A. Neja (16 pages).

University of California Cooperative Extension Leaflet 2791 (1975) "Managing and Modifying Problem Soils," by W. E. Wildman, Jewell L. Meyer, and R. A. Neja (temporarily out-of-stock).

APPENDIX

Nomogram for determining the SAR value of a saturation extract and for estimating the corresponding ESP value of soil at equilibrium with the extract.



To use this nomogram, add the laboratory value for Ca and Mg in meq/l and locate the sum on right vertical line of the diagram. Then locate the Na value on the left vertical line. Now lay a ruler so as to connect both located values. The SAR is then read where the ruler intersects the diagonal line. Example: Ca = 4, Mg = 2; Ca + Mg = 6. Na = 8. Then SAR = 4.8 on the diagonal line.

Glossary of Terms and Symbols

meq/l = milliequivalents per liter

mg/l = milligrams per liter (mg/l *ppm)

ppm = parts per million (ppm mg/l)

ET = evapotranspiration demand of crop

LR = leaching requirement to control salinity

SP = saturation percentage (for soil); the weight of water required to completely saturate 100 grams of air-dry soil. A good reproducible value and equal to about two times the field-water holding capacity and four times the permanent wilting point.

Correlates well with soil texture —
SP less than 20 = sand to loamy sand
20 to 35 = sandy loam
35 to 50 = loam to silt loam
50 to 65 = clay loam
65 to 135 = clay
135+ = usually organic (peat, muck, or peaty muck).

EC = electrical conductivity of a solution and is a measure of the solution's salt content.

ECe = electrical conductivity of the saturation extract of soil.

ECw = electrical conductivity of water.

ECsw = electrical conductivity of soil and water.

ECdw = electrical conductivity of drainage water.

* ≈ means "is approximately equal to"

Salinity is reported in various terms:

EC = millimhos per centimeter (mmhos/cm or ECe x 10^3)
= micromhos per centimeter (μmhos/cm or ECe x 10^6)
EC in mmhos/cm x 640 ≈ ppm or mg/l

TDS = Total Dissolved Solids; reported in parts per million (ppm) or in milligrams per liter (mg/l)
1 ppm 1 mg/l
640 ppm 1 mmho/cm or .640 ppm 1 μ mho/cm
TDS in ppm ÷ 640 ≈ EC in mmhos/cm
1 grain/gallon = 17.12 mg/l

Percent = parts per hundred, usually reported on dry-weight basis
1% = 10,000 ppm
Soil surveys sometimes report soil salinity in terms of %.

For a rough conversion from % salinity in dry soil to equivalent ECe of a soil-saturation extract.

$$\text{ECe} \approx \frac{(\%\ \text{salt}) \times 10{,}000 \times \text{soil bulk density} \times 100}{\%\ \text{field water-holding capacity} \times 640 \times 2}$$

For example: if bulk density (estimated or measured) = 1.4

Field water-holding capacity (estimated from water-holding capacity = ½ SP; or from soil texture) = 35%

Salts, as reported = 0.25%

$$\text{ECe} \approx \frac{.25 \times 10{,}000 \times 1.4 \times 100}{35 \times 640 \times 2} \quad 7.8\ \text{mmho/cm}$$

Saturation extract. The soil is mixed with distilled water to a specified paste-consistency called "saturated paste" from which some water is vacuum-extracted. Extracted water is the saturation extract on which most of water-soluble soil constituents are determined. These include EC, Na, Ca+Mg, Cl, CO_3+HCO_3, SO_4, B, and NO_3-N. (Soil pH is determined on a soil paste prepared in a similar manner.)

Other constituents sometimes included in an analysis are nitrate, ammonia, and lithium.

SAR = Sodium Adsorption Ratio. The SAR of the soil saturation extract is used to estimate the ESP of the soil from the nomogram (see front of Appendix). SAR of an irrigation water is used to predict the long-term potential of the water to cause a soil permeability problem. SAR is a calculated ratio using the reported concentrations of sodium (Na), and calcium plus magnesium (Ca+Mg) in the SAR equation.

$$\text{SAR} = \frac{\text{Na}}{\sqrt{\frac{\text{Ca+Mg}}{2}}}$$

Na, Ca+Mg must be in terms of milliequivalents per liter (meq/l).

adj. SAR = adjusted Sodium Adsorption Ratio: This is the usual SAR calculated as previously shown but modified to include the tendency of the irrigation water to dissolve lime from the soil thereby increasing calcium, or the tendency for calcium to precipitate from the soil water thereby appreciably reducing calcium. The adj.SAR should be calculated and reported by the reporting laboratory.

ESP = Estimated Exchangeable Sodium Percentage of the soil. Determined from the calculated Sodium Adsorption Ratio (SAR) of the saturation extract (see nomogram at front of Appendix). If gypsum is present this estimation is not appropriate, and other procedures must be used.

Na = sodium: Reported in milliequivalents per liter (meq/l). If reported in other terms, convert as follows:

Na in ppm or mg/l ÷ 23 = Na in meq/l

Ca = calcium: Reported in milliequivalents per liter (meq/l). If reported in other terms, convert as follows:

Ca in ppm or mg/l ÷ 20 = Ca in meq/l

Mg = magnesium: Reported in milliequivalents per liter (meq/l). If reported in other terms, convert as follows:

Mg in ppm or mg/l ÷ 12.2 = Mg in meq/l

Ca+Mg = calcium plus magnesium: Reported in milliequivalents per liter (meq/l). If reported separately as mg/l, or ppm, each must first be converted to milliequivalents per liter and then combined to give Ca+Mg in meq/l.

Cl = chloride: Reported in milliequivalents per liter (meq/l). If reported in other terms, convert as follows:

Cl in ppm or mg/l ÷ 35.5 = Cl in meq/l

B = boron: Reported in milligrams per liter (mg/l) or parts per million (ppm) of soil saturation extract or of water.

CO_3 = carbonate: Reported in milliequivalents per liter (meq/l). If reported in other terms, convert as follows:

CO_3 in ppm or mg/l ÷ 30 = CO_3 in meq/l

HCO_3 = bicarbonate: Reported in milliequivalents per liter (meq/l). If reported in other terms, convert as follows:

HCO_3 in ppm or mg/l ÷ 61 = HCO_3 in meq/l

CO_3+HCO_3 = carbonate plus bicarbonate: Each should be determined separately and then combined. Each must first be converted into meq/l as shown above before they can be combined as CO_3+HCO_3.

SO_4 = sulfate: May be required for special evaluations and reported in milliequivalents per liter (meq/l). If reported in other terms, convert as follows:

SO_4 in ppm or mg/l ÷ 48 = SO_4 in meq/l

NO_3-N = nitrate-nitrogen: Useful in fertility evaluations. Determined as nitrate but usually reported as nitrate-nitrogen (NO_3-N) in ppm or mg/l. Results probably are more meaningful if converted to pounds of nitrogen per acre-foot of applied water or pounds of nitrogen per acre-foot of soil.

For water: NO_3-N in ppm or mg/l x 2.72 = pounds of N per acre-foot of water

For soil: Determine the soil saturation percent (SP and the NO_3-N in saturation extract.

$$NO_3\text{-N in ppm or mg/l} \times \frac{SP}{100} \times 1.4 \times 4 \approx \text{pounds N/Ac. ft. of soil.}$$

If NO_3-N is reported in terms other than mg/l, convert as follows:

NO_3 in ppm or mg/l x .226 = NO_3-N in ppm or mg/l

NO_3-N in meq/l x 14 = NO_3-N in ppm or mg/l

Vineyard Water Demand

A vine's need for water (ET) is usually based on climate, solar radiation, wind, and growth characteristic of the vine. It can be calculated from various equations or can be estimated from evaporation pan data. An evaporation pan is a pan of standard size, containing water, and placed in a suitable location. Depth of water evaporating daily is measured. These pan data, multiplied by a factor suitable for grapes, will give the ET for grapes grown in the vicinity of the pan.

If the ET of vines, weeds, and cover crop in a field is known, along with the leaching requirement (LR) and volume of available water stored in the root zone at start of spring growth, the applied seasonal water needed to supply ET + LR can be determined from the following:

$$\text{Water needed} = \frac{ET}{1-LR} - \text{available soil water in storage} - \text{rainfall during growth period}$$

For example:

ET = 30 inches

LR = 9 percent

Soil water in storage = 2 inches

Rainfall = 6 inches

$$\text{Water needed} = \frac{30}{1-.09} - 2 - 6$$

$$= 33 - 2 - 6$$

$$= 25 \text{ inches}$$

This says that available soil-water stored in soil at start of vine growth, plus rainfall and properly-timed irrigations, will need to supply 30 inches of water per acre to meet the crop demand plus 3 inches per acre to control salts. The total of 33 inches needed would come from irrigation (25 inches), available water in storage (2 inches), and rainfall (6 inches). Winter rainfall the following winter would be relied upon to refill the soil to its normal water-holding-capacity of 6 inches for the next year's crop use.

Leaching requirement

Salts accumulating in the root zone can be reduced only by being dissolved and removed in water percolating downward from the soil surface to well below the crop roots. Each bit of water percolating through the root zone will remove a portion of the salts, and the amount of salts removed is proportional to the total depth of drainage water.

The depth (or amount) of drainage water that must percolate below the root zone annually to control salts and maintain root zones relatively free of salts for acceptable production of a desired crop is called the leaching requirement (LR). LR depends on the depth of applied water and its salinity and the depth of percolating drainage water required to remove enough salinity to keep the root zone below the salt tolerance of the crop.

For grapes, average soil salinity tolerated in the root zone is

ECe = 1.5 mmho/cm for 100% yield,

ECe = 2.5 mmho/cm for 90% yield,

ECe = 4.0 mmho/cm for 75% yield, and

ECe = 7.0 mmho/cm for 50% yield.

Vine growth should stop when average ECe = 12 mmho/cm.

If salinity of applied water and the average soil salinity tolerated by grapes are known, a good estimate of the LR can be obtained from the equation of Rhoades (U.S. Salinity Laboratory, Riverside):

$$LR = \frac{ECw}{5ECe\text{-}ECw}$$

Where ECw = salinity of irrigation water in millimhos per centimeter.

ECe = average soil salinity of the root zone taken from table 1, using the tolerance value for an indicated acceptable yield loss. (ECe = 2.5 if a 10 percent loss in yield is acceptable; ECe = 1.5 if 0 percent yield loss is acceptable.)

For example:

If the salinity of irrigation water is ECw = 1.0 mmho/cm, and if a 10 percent yield loss is acceptable, ECe = 2.5 mmho/cm. Thus,

$$LR = \frac{1.0}{5(2.5)\text{-}1.0} = .09 \text{ or } 9 \text{ percent}$$

This means at least 9 percent more water than required to meet the crop ET demand must percolate through and below the root zone to remove enough of the salts added in the applied water to insure at least a 90 percent yield potential. A little more leaching than this will probably be needed because of application inefficiencies and distribution variability. A 15 percent leaching fraction is suggested as being more or less normal in irrigated agriculture; however, the higher the salinity of the water, the higher will be the necessary leaching requirement and the more difficult will it be to control salinity.

LR is reported as a percent of applied water. The amount of applied water (in inches) needed to supply ET demands plus necessary leaching can be calculated by using the equation

$$\text{Applied water} = \frac{ET}{1\text{-}LR}$$

where ET = evapotranspiration demand of the crop

LR = leaching requirement.

For example:

ET = 30 inches

LR = 9 percent

$$\text{applied water} = \frac{ET}{1\text{-}LR}$$

$$= \frac{30}{1-.09} = 33 \text{ inches.}$$

Long-term Salinity Effects

The possible effects of irrigation-water salinity can be illustrated by the following example. Assume several years of irrigation with water with salinity (ECw) of 1 mmho/cm, and further assume this is applied to a 4-foot-deep, uniform, well-drained loam soil (SP 40 percent; bulk density 1.4) which holds in each foot-depth about 3.2 inches of water at field capacity. Good water management will be followed to supply vines and cover crop with all their water needs plus about 15 percent extra water for leaching. With good irrigation practices, the resulting soil salinity (ECe) in the upper half of the root zone should not exceed 1.5 mmho/cm. For grapes, at least an ECe of 1.5 to 2.5 mmho/cm (table 1) must be reached before an appreciable (10 percent) reduction in yield is expected. Therefore, for the example in which the soil salinity was (ECe = 1.5) resulting from use of water with salinity ECw = 1, no loss in yield is to be expected. However, even this 4-foot-depth of low-salinity loam soil (ECe = 1.5) would still contain as much as 6,000 pounds of salts; this shows that an appreciable quantity of salt can be tolerated by grapes.

To help visualize the amount of salt represented by an electrical conductivity of 1 millimho per centimeter in a typical saturation extract of soil (ECe = 1 mmho/cm), consider this example: A 50-gallon (189-liter) barrel of pure water in which 4¼ ounces (120.5 grams) of table salt is mixed until dissolved will have a concentration equal to about 640 parts per million, or an electrical conductivity of approximately 1 mmho/cm. If an acre of land were irrigated with an acre-foot of this water (EC = 1 mmho/cm), it would receive about 1,700 pounds (0.85 tons) of salt. No problem for grapes is to be expected from long-term use of such water if good management practices are followed.

For comparison, let's now assume the applied water plus rainfall over a several-year period was too little, adequate leaching did not take place, and salts accumulated. Further, assume approximately 2½ acre feet of irrigation water is being applied to each acre each year to satisfy vine and cover-crop water requirements but no extra water is applied for leaching for salt control. This application of 2½ acre feet of irrigation water per acre (ECw = 1 mmho/cm) would apply over 2 tons of salt per acre per season (640 ppm x 2.71 million pounds in each acre-foot of water x 2.5 feet = 4,336 pounds of salts). Because leaching did not take place, the 4,336 pounds of salt applied via irrigation water would accumulate and increase the average salt content of the soil water in the 4-foot-deep root zone by about 1,400 ppm (4,336 pounds added to the 14 inches of soil water [from 3.5 inches/foot x 4 feet of soil] which weighs 3.16 million pounds [14 inches of soil water = 1.17 feet; 1.17 x 2.71 million pounds/foot = 3.16 million pounds] will raise salinity of the soil water by 1,372 parts per million). This is equal to a rise in soil-water salinity (ECsw) of about 2.1 mmhos/cm (1,372 ÷ 640 ≈ 2.1 mmhos/cm) in one season or in terms of the salinity of the saturation extract, a rise in soil salinity of about 1 ECe unit. If, at the beginning of the first season, the ECe had been ECe = 1.5 mmho/cm, by the end of that same first season of irrigation with no leaching, the average soil salinity (ECe) in the 4-foot-deep soil would rise to about ECe = 2.5 mmhos/cm and by the end of the second season to about 3.5 mmhos/cm.

It can be concluded that by the end of this second year of no leaching, or the third year at the latest, a noticeable reduction in yield in the range of 10 to 25 percent would be expected due to salinity.

Here are three other examples that require special management:

Case I. *If salinity of irrigation water is the problem, winter leaching is essential.*

If winter leaching is done, the growing season can be started at a low salinity level and subsequent efficient use of water during the usual irrigation season, even without leaching would not result in sufficient salt accumulation to harm the vineyard. Then one or more post-harvest irrigations to re-wet the soil, followed by normal winter rainfall, should replenish soil moisture and accomplish needed leaching. It is essential that the vines have adequate moisture of low salinity at the start of spring growth.

A 4-foot-deep loamy soil should be able to hold at least 6 inches of usable water. This will remain in the soil following the fall irrigations and winter rains; then, during the growing season, instead of having to supply the entire 2½ acre-feet of seasonally required water per acre, irrigations would need to supply just 2 acre-feet. This in itself will reduce the salt problem because less water applied means less salts applied.

In deeper soils, vine roots are often growing down to 8 feet. Salts applied in the irrigation water to the 8-foot-depth of soil without leaching losses would still accumulate, but at a much slower rate. In such deep root zones as much as 12 inches of usable water will remain in storage after fall irrigations and winter rains. This might reduce in-season water use to about 18 inches, and further reduce the salinity problem resulting from salts in applied water.

During excessively long periods between irrigations, vines may deplete the available water in the upper root zone and then will have to take water from the lower root zone where salt concentrations are usually much higher. However, if salts have been leached through and below the entire root zone, even these lower depths would be low in salts and the vines could use almost all the low-salinity stored water. These deeper soil depths, however, require considerably more leaching water and leaching the lower depths may not be possible or necessary as long as the upper half of the root zone is maintained at low salinity.

Post-harvest, late fall, or winter irrigations are good insurance against salts becoming a problem. Dormant-season irrigations can be extended long enough to get adequate water through the soil to accomplish needed leaching, with little chance of root damage due to poor aeration or temporary perched water tables. Leaching irrigations should be made in early winter. Allow enough time between leaching irrigations and budbreak for drainage to become complete.

Case II. *Shallow depth of rooting because of restricted drainage can complicate salinity management.*

If soil depth were only 2 feet instead of 4 feet and no leaching occurred, the salt concentration would increase about twice as fast as in the 4-foot root zone and four times as fast as in an 8-foot root zone, assuming the same total water demand by the crop (2½ acre-feet per acre). Seldom are irrigations so efficient that no leaching occurs. Actual salt accumulation will depend on how much applied water enters the soil and drains through the subsoil (the leaching fraction) to move salts beyond the reach of roots.

If the root zone is restricted by a hard pan or very poor drainage at 2 feet, the yearly rate of salt accumulation with no leaching would be expected to be in the range of ECe = 2 mmhos/cm as compared to the previously discussed 1 mmho/cm in 4-foot-deep soil. By the end of the first season the shallow soil would have a salinity equal to about ECe = 3.5 (starting with initial ECe = 1.5 mmho/cm). If this rate of accumulation were to continue, a decline in yield of 10 percent or more in the second year would be expected. However, with good water management and drainage to insure leaching, it should be possible to control salts and maintain vines in good production. Unlike the 4-foot soil depth in which as much as 6 inches of available water could be stored, the 2-foot soil depth could store no more than about 3 inches of usable water, making irrigation management much more difficult and exacting. Where water tables and poor drainage saturate the root zones for too long a period, underdrains may be needed.

Case III. *With better water quality few salinity problems are to be expected.*

If available water contained half the soluble salts of the earlier example (ECw = 0.5 mmhos/cm instead of 1.0), salts would accumulate only half as fast. As for the example used earlier, 2½ acre-feet of water with ECw = 0.5 mmho/cm applied on the 4-foot-deep soil would add about 1 ton of salts per acre per year and raise soil salinity 0.5 mmho/cm per year. Assuming a normal beginning salt concentration of ECe = 0.75 instead of ECe = 1.5, three to four seasons might go by without leaching before salts would accumulate enough to exceed crop tolerance and begin to reduce yield.

Under good irrigation and water management the average salt concentration of the soil water taken up by the crop is about three times greater than that of the irrigation water applied. Thus for an irrigation water of ECw = 0.5 mmho/cm, the average salt concentration of the soil water might be ECsw = 1.5 mmho/cm (ECw x 3 = ECsw); this is equal to a soil salinity of ECe = 0.75 mmhos/cm, (from ECe = 3 ECw/2). Starting the season with a soil salinity well below tolerance of the crop is much safer than starting the season with a border line or high salinity.

Winter rainfall should be considered an aid in controlling salinity as rainfall contains no appreciable salts. A late-fall irrigation prior to winter rains partially or completely refills the soil with water so that winter rains are then very effective in leaching. Fall irrigation thus helps assure that soil salinity will be reduced and salts will not become a problem—that they will be reduced more, and to a greater depth, than if there were no fall irrigation. Even limited winter rainfall entering into moist soils will help to dilute and leach salts.

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