SOIL AND PLANT TISSUE TESTING IN CALIFORNIA

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FOREWORD

Soil, plant, and water analysis are the farmer's best guide to effective soil and water management and the production of top yields of high quality crops. This publication brings together the information essential to the most effective use of these analyses for determining the fertilizer needs of California's crops and the diagnosis of certain soil problems. Its objective is to increase the efficiency of fertilizer use and thereby increase yields and improve crop quality, to prevent the buildup of potentially harmful residues of nutrient elements in soils and ground-waters, and to conserve our soil, water, and mineral resources.

The topics presented include discussions of the basic philosophies of soil and plant tissue testing; listings of interpretative criteria; suggested rates of fertilization of our more important crops; the characterization and amelioration of saline, alkali, and acid soil conditions; and evaluation of the quality of water for irrigation. The advantages, limitations, and interpretation of soil and plant tissue analysis for diagnosing soil fertility and the nutritional status of plants are considered. Detailed instructions for sampling plants, soils, and waters are given; critical concentrations of nutrients in plant tissues are listed, and interpretive guides for soil and water analyses are outlined. Some of the diagnostic values given are tentative but represent the best information currently available.

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H. M. Reisenauer
Editor

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and with pH. While Mn and Al contents of soil extracts increase with decreasing pH, the Mn-Al ratio varied greatly between soils, with values ranging from 0.1 to 200 in the different extracts, probably because of different parent material.

Williams and Vlamis (1957) and Williams *et al.* (1971), working with soils and with culture solutions, have shown that for some crops, such as barley and mustard, high concentrations of Mn are toxic and reduce plant growth. A value of 400 ppm Mn in barley leaf-tissue is toxic, while approximately 2500 ppm Mn caused toxicity in lettuce and mustard. In examining saturation extracts of 17 northern California soils, Bradford, Blair and Hunsaker (1971) found high Mn in fields where "white strawberry" disease occurred with a Mn concentration in the leaves of 460 ppm and extracts having from 0.5 to 6.0 ppm Mn. These soils had been acidified by the use of amendments and fumigants which released Mn into the soil solution. Lingle *et al.* 1961 found that Brussels sprouts growing on acid San Mateo soils at a pH of 4.0 to 4.4 were deformed and chlorotic and contained 1,100 to 1,800 ppm Mn in their leaves. Normal growth was found in soils at pH values of 5.0 to 5 5 with leaf Mn of 300 to 550 ppm. Below pH 5.0 Mn toxicity is likely.

CORRECTIVE MEASURES

Soils are limed to eliminate toxicities due to Al and Mn and to increase the basic cation saturation of the exchange complex. The amount of lime required to eliminate these toxicities depends upon both the soil's initial pH and cation exchange capacity. Several rapid methods of determining the lime requirement of soils have been proposed. Pratt and Blair (1962b) have suggested using a buffered solution at pH 7 5 for this determination. Other rapid methods are listed by McLean (1973). Whether to apply lime, and the amount to be added, should be determined only after consideration of the crop to be grown, other soil characteristics, and the magnitude of likely benefits to the crop.

TABLE 21. CHEMICAL CHANGES IN SOIL EXTRACTS DUE TO LIMING AN ACID SOIL*

Item measured	Units	− Lime	+ Lime
pH	—	4.0 →	5.0
Calcium	meq per liter	1.0 →	6.0
Magnesium	meq per liter	1.4 ←	0.7
Potassium	meq per liter	0.4 ←	0.1
Iron	ppm	0.1	0.1
Aluminum	ppm	6.4 ←	0.2
Manganese	ppm	16.0 ←	7.8

* From Vlamis and Williams (1962)

IRRIGATION WATER QUALITY

Robert S. Ayers

Concentration and composition of dissolved salts in a water supply can affect the productivity of crops and soils and determine suitability of the water for irrigation use. The present system of assessing irrigation water quality is based on appraising the likelihood of a constituent of the water causing a significant crop or soils problem to develop over an extended period of use. If the possibility of a specific water-related problem developing is forseen, preventive management practices can then be adopted.

Following are four major areas of concern in determining the character and suitability of irrigation water. (Table 22 provides guidelines for specific determination of problems, and table 23 shows how to calculate adjusted sodium adsorption ratio of water.)

1. **Salinity:** Electrical conductivity (ECw).

2. **Permeability:** Low electrical conductivity (ECw <0.5); adjusted sodium adsorption ratio (Adj. SAR), modified to include carbonate plus bicarbonate (CO_3 + HCO_3).

3. **Specific ion toxicity:** Sodium (evaluated by Adj. SAR); chloride (Cl); Boron (B)

4. **Miscellaneous constitutents of interest:** Degree of acidity or alkalinity (pH), ammonia or nitrate nitro-

gen (NH_4-N or NO_3-N); *bicarbonate* (with use in overhead sprinklers).

SAMPLING

1. Sample must be representative. Take well-water samples after well has been pumped for at least 30 minutes.

2. Collect samples in clean, plastic bottles. Wash or rinse at least three times with the water to be sampled.

3. If nitrate or special "pollution" analyses are required, and these analyses cannot be completed within 3 hours, the sample should be frozen or held below 40°F (4.4°C) until analyzed.

METHODS AND FOLLOW-UP RECOMMENDATIONS

Methods of analysis are based on those given in USDA Agriculture Handbook 60 (U.S. Salinity Laboratory Staff, 1954)

The trend in interpreting water quality is away from "classes" of water and toward "appraisal" systems. Waters are evaluated for hazards when used under general crop, soil, and climatic conditions, and an assessment of needed corrective action is included. For example, when ECw indicates a possible salinity hazard, the corrective action indicated is intended to satisfy water need for both the crop and the leaching requirements. Reference is given to crop tolerance tables and leaching requirement (LR). Similarly, if a probable permeability hazard is indicated by the Adj. SAR, use of gypsum is suggested and typical rates needed are given as a guide to corrective action and better water management. If the indicated correction cannot be made, alternative courses of action such as changing water supply or growing a more tolerant crop may be necessary

Interpretation of water analysis as related to crop growth should be made only after consideration of specific plant and soil conditions. The guidelines given in table 22 are based on possible effects on crops and soils. Soil analysis and leaf analysis, in addition to the water analysis, will be helpful.

TABLE 22. GUIDELINES FOR INTERPRETATION OF QUALITY OF IRRIGATION WATER

Item	Range of water-quality		
	No problems	Increasing problems	Severe problems
*Salinity**			
ECw of irrigation water, in mmhos/cm	<0.75	0.75-3.0	>3.0
Permeability			
ECw of irrigation water, in mmho/cm	>0.5	<0.5	>0.2
Adj. SAR of irrigation water†	<6.0	6.0-9.0	>9.0
Specific ion toxicity‡			
from ROOT absorption			
Sodium (evaluate by Adj. SAR)	<3	3.0-9.0	>9.0
Chloride (meq/liter)	<4	4.0-10	>10
(mg/liter)	<142	142-355	>355
Boron (mg/liter)	<0.5	0.5-2.0	2.0-10.0
from FOLIAR absorption§ (sprinklers)			
Sodium (meq/liter)	<3.0	>3.0	—
(mg/liter)	<69	>69	—
Chloride (meq/liter)	<3.0	>3.0	—
(mg/liter	<106	>106	—
Miscellaneous¶			
NH_4 -N (mg/liter) for sensitive crops	<5	5-30	>30
NO_3 -N	<5	5-30	>30
HCO_3 (meq/liter) only with overhead sprinklers	<1.5	1.5-8.5	>8.5
(mg/liter)	<90	90-520	>520
pH		normal range = 6.5-8.4	

Assumes water for crop plus needed water for leaching requirement (LR) will be applied. Crops vary in tolerance to salinity. Refer to tables for crop tolerance and LR in *Soluble Salts, Exchangeable Sodium, and Boron in Soils,* this publication, and in Handbook 60 (U.S. Salinity Laboratory Staff, 1954). (mmho/cm X 640 = approximate total dissolved solids (TDS) in mg/liter or ppm; mmho X 1000 - micromhos).

† Adj. SAR is calculated from the following equation which allows for precipitation and dissolution of $CaCO_3$ in soils:

$$Na \Big/ \sqrt{\frac{Ca + Mg}{2}} \quad [1 + (8.4 - pHc)]$$

Where pHc is a calculated value based on Na + Ca + Mg, Ca + Mg, CO_3 + HCO_3—See table 23. Permeability problems, related to *low ECw or high* Adj. SAR of water, can be reduced if necessary by adding gypsum. Usual application rate per acre-foot of applied water is from 200 to 1000 lbs. (234 lb. of 100 percent gypsum added to 1 acre-foot of water will supply 1 meq/liter of Ca and raise the ECw about 0.1 mmho). In many cases a soil application may be needed.

‡ Most tree crops and woody ornamentals are sensitive to Na and Cl (use values shown). Most annual crops are not sensitive (use salinity tolerance tables). For B sensitivity, refer to "Boron tolerance Tables" (U.S. Salinity Laboratory Staff, 1954).

§ Leaf areas wet by sprinklers (rotating heads) may show a leaf burn due to Na or Cl absoption under low-humidity, high-evaporation conditions. (Evaporation increases ion concentration in water films on leaves between rotations of sprinkler heads.) Night irrigation may greatly reduce problem.

¶ Excess N may affect production or quality of certain crops, e.g. sugar beets, citrus, avocados, apricots, grapes, etc.; (1 mg/liter NO_3-N = 2.72 lb. N/acre-foot of applied water). Bicarbonate in waters applied with overhead sprinklers may leave a white carbonate deposit on fruit and leaves.