Classification of Waters

The first of two articles on the quality of water and plant tolerance to salts.

quality is based on specific electrical conductance, boron and chloride concentration, and sodium percentage

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Classification of waters is based on the principle of salt accumulation.

Water sufficiently high in salts to be directly injurious to plants is seldom used for irrigation. The accumulation of these salts in the soil solution sometimes reaches a concentration that is detrimental to the plant or the soil structure.

The concentration of the salts in the soil is due principally to two factors: *1*, direct evaporation of the water from the soil surface, with the accumulation of salts in the surface few inches or on top of the soil; *2*, the water is lost from the soil through transpiration of the plant. Plants use the water but leave in the soil most of the salts which accumulate with each succeeding irrigation.

Certain types of irrigation water may be harmful eventually to plant growth. This detrimental effect may be broadly classified into two general types:

1. Certain salts—alkali—may accumulate in the soil and gradually become toxic to the plant. They may reduce—and with continued accumulation—prevent plant growth. This extreme is usually known as a saline or alkali soil, depending upon the type of salt involved.

2. An unfavorable sodium-calcium ratio may cause a sealing of the surface soil, preventing the water from penetrating into the lower root zone. This dry soil condition usually results in wilting of the plants between irrigations. Even if wilting is prevented by frequent irrigations, the growth of the plant is probably retarded due to the limited volume of soil available for plant nutrients.

In some cases, both of these effects may be involved.

Reporting Water Analyses

In reporting analyses of water, the most useful terms are milligram equivalents—m.e.—or milliequivalents per liter—m.e./L.—which are identical terms. Salts are made up of a combination of cations—positively charged atoms, such as sodium, calcium and magnesium—and anions—negatively charged atoms such as chloride, sulfate and bicarbonate.

Cations and anions combine in definite weight ratios. For example: in ordinary table salt, sodium chloride—NaCl—23 grams of sodium cation are in combination with 35.5 grams of the chloride anion; that is, one sodium cation will combine with one chloride anion to form the sodium chloride salt. Therefore, an equivalent of sodium is 23 grams, which will combine with its chemical equivalent, anion chloride, 35.5 grams; or possibly, with anion of sulfate—SO_4—48 grams; or bicarbonate—HCO_3—61 grams. A milligram equivalent—m.e.—is one thousandth of an equivalent, and in the case of sodium chloride, would be .023 gram of sodium and .0355 gram of chloride in one liter—approximately a quart—of water.

Recently the term—equivalent per million—has been used in reporting water analyses. The method of reporting is nearly the same as that for milligram equivalent, and for all practical purposes these terms can be interchanged.

In the past, and to some extent at present, water analyses are reported in parts per million—ppm. This is the concentration of one part of salt, or a single salt, or cation, or anion in a million parts of water. For sodium chloride, this would be one pound of the salt to a million pounds of water.

Milligram equivalents are changed to parts per million by multiplying the milligram equivalents by the equivalent weight of the cation or anion.

Three Classes

Because of diverse climatological conditions, crops, and soils in California, it has not been possible to establish rigid limits for all conditions involved.

Instead, irrigation waters have been divided into three broad classes based upon work done at the University of California, Rubidoux, and U. S. Regional Salinity laboratories of the U. S. Department of Agriculture.

Class I. *Excellent to Good*—

Regarded as safe and suitable for most plants under any condition of soil or climate.

Class II. *Good to Injurious*—

Regarded as possibly harmful for certain crops under certain conditions of soil or climate, particularly in the higher ranges of this class.

Class III. *Injurious to Unsatisfactory*—

Regarded as probably harmful to most crops and unsatisfactory for all but the most tolerant.

Tentative standards for irrigation waters have taken into account four factors or constituents: *1*, Specific electrical conductance—K x 10^5 at 25° C; *2*, Boron concentration, ppm; *3*, Sodium percentage; *4*, Chloride concentration, m.e.

Qualitative Classification of Irrigation Waters

	Class I Excellent to Good	Class II Good to Injurious	Class III Injurious to Unsatisfactory
Conductance (K$\times 10^5$ at 25° C)	Less than 100	100–300	More than 300
Boron, ppm	" 0.5	0.5–2.0	" 2.0
Sodium percentage	" 60	60–75	" 75
Chloride, m.e.	" 5	5–10	" 10

A chemical analysis of an irrigation water may include some or all of the following items:

1. Specific Electrical Conductance. Addition of salt to water increases its electrical conductance so its measure is an excellent and rapid determination for obtaining an estimation of the total salt content, but it does not give the individual salts that may predominate in a water.

2. Boron is expressed as parts per million of the element, and often is not determined unless in an area where boron is suspected.

3. Per Cent Sodium is the proportion of the element to the total bases—that is, sodium—Na—calcium—Ca—and magnesium—Mg—found in the water. These bases are listed as the cations. Sodium percentage is found by the formula $\frac{Na \times 100}{Na + Ca + Mg}$, when these bases are expressed as milligram equivalents per liter. For example, a water may contain five milligram equivalents of sodium, 3.5 milligram equivalents of calcium, and 1.5 milligram equivalents of magnesium, or a total of 10 milligram equivalents of cations; substituting for the letters in the formula, makes $\frac{5.0 \times 100}{5.0 + 3.5 + 1.5}$ or $\frac{500}{10}$ - 50% sodium water.

4. Chloride—Cl—is considered one of the most troublesome anions that normally occur in irrigation waters. Other anions which are usually determined in irrigation water are carbonate—CO_3—bicarbonate—HCO_3—and sulfate—SO_4. These last three anions usually are not

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NEMATODES

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sugar-beet nematode have been made in soils of the clay loam or clay series.

Investigations were undertaken to ascertain the effect of soil type upon the root-knot and sugar-beet nematode kills obtained in various soils with volatile soil fumigants.

Several soil types having moisture equivalents ranging from seven to more than 150% were collected in the field. These soils were placed in 32-gallon metal cans. Duplicate samples of root-knot nematode inoculum contained in cheesecloth bags were placed two, four, six, and eight inches from the center of the can at three, six, 12 and 18 inches below the soil surface. A measured amount of D-D mixture—2.15 ml.—was injected in the center of the soil contained in the can to a depth of six inches below the surface. After seven days exposure the samples were removed and the number of root-knot larvae per sample surviving the treatment was recorded for each soil type. During fumigation the soil temperature was maintained at 68° F. An attempt was made to fumigate all soils at a moisture content of about 75% of the moisture equivalent. The relative effectiveness of the fumigant in several soil types is indicated by the total number of root-knot larvae surviving the treatment in 32 samples exposed in each soil type.

Total Number of Root-knot Nematode Larvae Surviving a Single Injection of 2.15 ml. of D-D Mixture in Six California Soils

Soil type	Moisture equivalent	Moisture percentage at treatment	Root-knot larvae surviving
Fresno sandy loam	**7.0**	**5.1**	**20**
Yolo fine sandy loam	**10.4**	**9.2**	**88**
Yolo silt loam	**18.6**	**15.5**	**1,507**
Yolo clay loam	**30.1**	**23.9**	**1,155**
Bowers clay	**30.7**	**23.2**	**2,417**
Organic loam (Delta peat)	**150 (plus)**	**112.5**	**2,247**

The data obtained indicate that a given dosage of D-D mixture is about 100 times more effective in killing root-knot nematode larvae in Fresno sandy loam than in Bowers clay or organic loam.

Sugar-beet nematode kills in the various soils were found to follow the same trend as those indicated for root-knot nematode.

The diffusion patterns of the fumigant were also obtained in these tests. They indicate that the reason for the lowered effectiveness of D-D mixture in heavy soils is due to the reduced diffusion of the nematicide in the heavier type soils. In Fresno sandy loam the fumigant was toxic eight inches laterally and 12 inches vertically from the point of injection. In Bowers clay the fumigant failed to kill larvae in samples located four inches laterally and six inches downward from the point of injection. Typical diffusion patterns obtained against sugar-beet nematode in Yolo fine sandy loam and Egbert organic loam when 2.15 ml. of D-D mixture was applied in a single injection point are shown in the table in columns two and three.

These laboratory toxicity and diffusion experiments as well as field observations indicate that soil type may directly influence the success or failure of applications of volatile soil fumigants applied for sugar-beet nematode control. Also, it is suggested that root-knot nematode control might be influenced by soil type. Ethylene dibromide mixtures should not be used against sugar-beet nematode but can be used successfully against root-knot nematode larvae. Also since larvae of the root-knot nematode are among the most susceptible of the plant parasitic species to the action of soil fumigants, it appears probable that the soil type may frequently prove to be the most important limiting factor in securing satisfactory nematode control with volatile soil fumigants.

Lateral and Vertical Diffusion of 2.15 ml. of D-D Mixture in Yolo Fine Sandy Loam and Egbert Organic Loam as Indicated by Sugar-Beet Nematodes Surviving in 100 ml. Sample of Inoculum Located Varying Distances from the Point of Injection

Depth (inches)	Yolo fine sandy loam								Egbert organic loam							
	Lateral distance (inches)								Lateral distance (inches)							
	8	6	4	2	2	4	6	8	8	6	4	2	2	4	6	8
3	0	0	0	0	0	0	0	0	100	100	43	10	6	26	20	100
6	0	1	0	0*	0	0	0	0	89	38	21	0*	0	2	100	100
12	0	0	0	0	0	0	0	0	100	100	41	18	68	100	42	63
18	3	11	8	1	2	7	1	3	21	100	41	100	100	10	15	100

* Injection point of fumigant.

The effectiveness of D-D mixture in controlling sugar-beet nematode in the Utah-Idaho area is probably correlated with soil type. Beet soils in that area are in general lighter and have lower moisture equivalents than the average California beet soils.

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The above progress report is based on Research Project No. 1354.

WATERS

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considered extremely toxic to most plants unless in exceptionally high concentrations.

The analyses for these are important in determining the type of salt occurring in the water. The sulfate anion is generally considered about half as toxic as the chloride; therefore, plants tolerate about twice the concentration of sulfates as chlorides. If the total salts occur largely in the form of calcium sulfate—gypsum—the total salt value can be raised about 50%.

Most well waters in California contain appreciable quantities of salts. An estimate of the salt content in parts per million, or tons per acre-foot of water from conductance—K × 10^5—is given in the accompanying table.

Salt Content of Irrigation Waters

Water class	Conductance K x 10^5 at 25° C	Salt content	
		Total	Per acre-ft. of water
Class I		**Ppm**	**Tons**
(Excellent to Good)	**100**	**700**	**1**
Class II			
(Good to Injurious)	**100–300**	**700–2,100**	**1–3**
Class III			
(Injurious to Unsatisfactory)	**300**	**2,100**	**3**

A water may be in Class I and still contain approximately a ton of salts per acre-foot of water. If three acre-feet are used per season, about three tons of salt will be added to the soil. Many of the well waters of the state have a conductance in the neighborhood of 50 to 100. This is equal to about one half to one ton of salt per acre-foot of water.

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A second article on this subject by Dr. L. D. Doneen will report analyses of six river and nine well waters of California.