washed the 2,4-D down to the Rough lemon roots and resulted in severe damage and eventual death of the trees. The same weed in another grove nearby was treated in the same manner with the same spray and on the same day. This grove was on sour orange roots and in somewhat heavier soil. It escaped any visual damage. Presumably the difference in response can be attributed chiefly to the difference in rootstock,—the Rough lemon apparently being more sensitive than sour orange.

Acknowledgments

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THE CHEMICAL COMPOSITION OF IRRIGATION WATER USED IN FLORIDA CITRUS GROVES

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A knowledge of the chemical composition or mineral content of irrigation water is of great importance to growers because of the known detrimental effects to plants of highly mineralized water. Although water from various sources has been used for irrigating citrus in Florida for many years little is known of the actual chemical composition of much of the water which is used. A report made 50 years ago indicated damage to citrus when irrigated with artesian well water (9). A more recent report (14) indicated that many wells in several East Coast districts were increasing in salt content thus increasing the possibility of damage when used on groves. Similar increases in saltiness have been experienced with municipal water supplies for several coastal cities (8) (10).

In most areas where irrigation is required, the annual rainfall is generally low. Such conditions result in accumulations of salts in the soil, because there is little or no loss of the salts through leaching by rainfall. Since practically all of the citrus growing area of Florida receives annually 50 to 60 inches of rain (4) accumulations of salts are not likely to occur from year to year. Leaching of applied salts is also aided by the fact that most of the soils on which citrus is growing in Florida is of a very sandy porous nature and easily leached. Since these soils contain practically no clay which exhibits exchange capacity, additions of sodium from salt water does not destroy their structure thus impeding leaching as often happens in many regions using irrigation.

For these reasons the use of irrigation water on citrus in Florida presents a different problem than found in many other citrus growing areas. In fact,

water containing greater amounts of salts can be used under the climatic and soil conditions found in Florida than could be used if the climate were drier and the soils heavier. This was pointed out in work done by Young (15) using known concentrations of sodium chloride solutions on citrus seedlings growing in pots in the greenhouse. He concluded that relatively high concentrations of sodium chloride alone were not detrimental to growth.

Previous analysis of irrigation waters (14) involved only the determination of the chloride content and a calculation to the equivalent amount of sodium chloride. Some preliminary work with water samples taken in 1949 showed that the amounts of sodium found were not sufficient to account for all the chlorides present, thus indicating the presence of other minerals such as calcium and magnesium chlorides. This is to be expected because the mineral composition of the water will be determined by the minerals dissolved from the rock and mineral deposits through which it passes plus that contributed from any infiltration by sea water. Several reports (5) (10) have listed the chemical constituents found in waters from different Florida localities. Most of these analyses are for municipal water supplies and relatively less information is available giving data related to irrigation supplies.

Thus, for several reasons, a more complete picture of the composition of water used for irrigation was felt desirable in order to more correctly evaluate such water. It is the purpose of this report to list the composition of waters from widely different localities which are used for irrigating or for mixing sprays for citrus.

Collection of Samples

Clean quart mason jars fitted with a jar rubber and glass top were used to transport water samples to the laboratory for analysis. An effort was made to obtain samples from wells which were in use, since it is known that a lower mineral content is often found in wells which have not been used for several weeks or months. After the well has been in use for several hours the mineral content becomes relatively stable.

Methods of Analysis

The methods of analysis used were of a type primarily fitted to water analysis. Several of the methods are relatively recent developments and will be mentioned briefly.

pH measurements were made using a glass electrode.

Specific conductance was measured in mhos x 10^{-5} at 25°C. This measurement is directly related to total dissolved solids in the water.

Calcium was determined by titrating an aliquot of the water with versene (disodium dihydrogen ethylenediamine tetracetate dihydrate) using ammonium purpurate indicator (2) (6).

Magnesium was measured by titrating a portion of the water with versene using errochrome black T indicator which gives a value for the total magnesium and calcium present. By subtracting the amount of calcium previously found the magnesium concentration can be found (2).

Sodium was estimated through the use of a flame photometer (1) (12).

Chloride concentration was found by titration with mercuric nitrate using diphenylcarbazone bromophenol blue mixed indicator (3).

Sulfate content was measured by precipitation under controlled conditions with barium chloride and reading the resultant turbidity with a photoelectric colorimeter (11).

Carbonates and bicarbonates were estimated by titration with standard sulfuric acid using phenolphthalein indicator for

the carbonate endpoint and methyl purple for the bicarbonate endpoint (7).

A qualitative analysis of several of the wells containing the largest amounts of dissolved solids was made by a spectrographic procedure.

Relationship of Specific Conductance and Total Dissolved Solids

Twenty-four water samples representing the East Coast, West Coast and Central Florida were evaporated to dryness and the resulting salts weighed. The total dissolved solids in parts per million thus determined were compared to specific conductance values obtained with a conductivity meter. Fig. 1. The relationship was found to be directly proportional and if the specific conductance in mhos x 10^{-5} at 25°C. is multiplied by 7 the concentration of soluble salts is obtained directly in parts per million. This relationship is the same as found in other areas of the United States where water analyses are made (13). Since the specific conductance of a water sample is very easily obtained (comparable to the time required for a soil pH determination) it can be seen that such a measurement is of great value in rapidly evaluating a water source. It is probably the best single index for deciding the advisability of using water for irrigation in Florida.

Average Chemical Composition of Water from Nine Florida Counties

The maximum, minimum and average amounts of the various elements determined along with pH, total dissolved solids and calculated amount of sodium chloride in water from several localities is given in Table 1. The sodium chloride

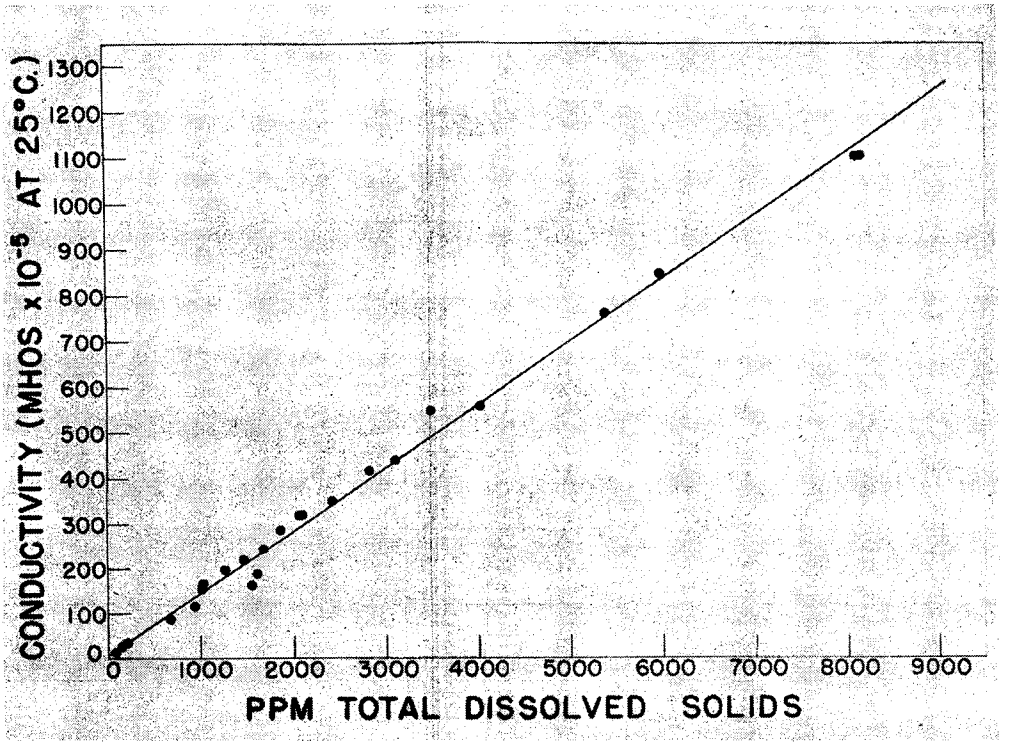

Fig. 1. Relationship between parts per million total dissolved solids and conductivity measurements of irrigation water.

content is given simply for a basis of comparison with previously published figures. As previously mentioned it does not represent a true picture, however, since all the chlorides found cannot be assumed to be sodium chloride.

From this table it can be seen that individual wells within the same locality vary considerably in mineral content. This is to be expected because all wells are not at the same depth and consequently tap different water strata. This great variability stresses the need for careful consideration of local conditions and if a new well is to be drilled a geologist familiar with local conditions should be consulted. Further study of this table reveals the great variation between localities in water composition. For example on the mainland of Brevard County there was on the average 1283 p.p.m. of chloride ion and 107 p.p.m. of sulfate ion whereas in Sarasota County there was only 202 p.p.m. of chloride ion as compared to 836 p.p.m. of sulfate. In one case the water was primarily chloride

TABLE 1.

MAXIMUM, MINIMUM AND AVERAGE COMPOSITION OF WATER FROM INDEX WELLS IN NINE FLORIDA COUNTIES IN 1950.

Locality	No. Samples		pH	Parts Per Million T.D.S.[2]	Na	Ca	Mg	Cl	SO_4	CO_3	HCO_3	NaCl
Brevard Co.		Max.	8.40	15000	4800	514	635	7745	1200	14	135	12768
Islands		Min.	7.50	763	110	62	27	225	34	0	7	371
	57	Aver.	8.20[1]	3106	688	170	108	1432	203	8	105	2349
Brevard Co.		Max.	8.40	7217	2100	269	223	3872	230	16	156	6383
Mainland		Min.	7.65	1484	269	76	39	605	0	0	7	997
	10	Aver.	7.95	2580	624	132	87	1283	107	5	94	2116
Indian River Co.		Max.	8.40	1442	260	96	68	527	230	16	159	870
		Min.	7.30	833	124	47	46	225	38	6	99	371
	38	Aver.	7.79	1099	179	64	57	371	106	12	133	607
St. Lucie Co.		Max.	8.30	3570	869	116	110	1494	384	25	299	2463
		Min.	7.30	714	90	37	23	151	48	6	90	249
	55	Aver.	7.81	1528	295	72	59	538	138	13	137	887
Pinellas Co.		Max.	8.40	2280	590	246	67	1626	120	19	228	2681
		Min.	6.98	168	9	22	2	18	0	0	10	30
	21	Aver.	7.54	887	129	70	25	296	30	9	143	488
Manatee Co.		Max.	7.85	2430	360	289	116	822	590	19	164	1356
		Min.	7.35	441	0	60	28	18	137	0	35	30
	26	Aver.	7.60	1043	58	151	66	162	387	6	129	272
Sarasota Co.		Max.	8.20	2280	245	463	152	520	1526	16	170	857
		Min.	7.35	644	24	78	50	30	295	0	84	50
	14	Aver.	7.54	1314	60	255	96	202	836	5	121	333
Charlotte Co.		Max.	8.60	5240	1180	241	195	2109	771	16	145	3477
		Min.	7.20	1010	158	67	45	302	48	0	48	499
	11	Aver.	7.67	2485	468	150	93	975	302	6	100	1607
Lee Co.		Max.	7.80	2580	530	130	101	974	379	16	180	1605
		Min.	7.30	1554	270	71	61	457	240	0	96	754
	9	Aver.	7.59	2185	411	102	87	774	305	11	145	1276
Polk Co. Wells		Max.	7.65	221	8.1	37.2	7.1	9.6	2.4	0	144	16
		Min.	7.40	168	5.5	29.2	5.6	6.2	2.4	0	108	10
	2	Aver.	7.52	194	6.8	33.2	6.4	7.9	2.4	0	126	13
Polk Co. Lakes		Max.	7.20	98	9.0	6.4	5.3	18.8	31.2	0	22.6	31
		Min.	6.55	35	5.1	1.4	2.6	9.6	16.8	0	3.1	16
	9	Aver.	6.93	69	7	4	3	14	23	0	13	23

[1] Arithmetic mean of individual values.

[2] Total dissolved solids calculated from conductivity.

TABLE 2

POUNDS OF SALTS CONTAINED IN ONE ACRE INCH OF WATER FROM AVERAGE WELLS IN SEVERAL FLORIDA LOCALITIES.

Locality	Source	Pounds per Acre Inch									
		$NaCl$	Na_2SO_4	$MgCl_2$	$CaCl_2$	$MgSO_4$	$CaSO_4$	$CaCO_3$	$Mg(HCO_3)_2$	$Ca(HCO_3)_2$	Total
Brevard County Islands	Wells	395.6		95.9	28.9		66.7	2.9		29.5	619.5
Brevard County Mainland	Wells	358.5		77.1	24.5		34.4	1.8		28.3	524.6
Indian River County	Wells	103.1		29.2		27.0	3.5	4.5		40.0	207.3
St. Lucie County	Wells	169.3		27.0		32.0	8.2	4.5		41.1	282.1
Pinellas County	Wells	74.1		22.2	9.0		9.6	3.4		34.1	152.4
Sarasota County	Wells	34.5		33.3		65.5	194.1	1.6			329.0
Manatee County	Wells	33.3		22.2		45.9	72.1	2.3		38.5	214.3
Charlotte County	Wells	269.9		78.7		4.8	91.7	2.3		24.8	472.2
Lee County	Wells	236.8		42.0		44.5	47.6	4.1		30.1	405.3
Polk County	Wells	2.9	0.8						8.5	28.3	40.5
Polk County	Lakes	4.0		1.1		2.1				3.7	10.7

and in the other primarily sulfate. Further inspection shows the much greater mineral concentration in water from both coastal regions as compared to deep wells in the inland district of Polk County. As might be expected the lowest concentration of salts is found in the lakes of Polk County.

Another perhaps more easily understandable way of expressing the mineral content of water and resultant addition of salts when added to the soil as irrigation is given in Table 2. This table gives the pounds of various salts added to an acre of soil when that acre is irrigated with one inch of water containing the average mineral composition for the particular locality in question. If for example you applied an irrigation of two acre inches using the maximum water found in Sarasota County you would have added to that acre 414 pounds of sodium chloride, 162.8 pounds of magnesium chloride, 50.6 pounds of magnesium sulfate, 307.4 pounds of calcium sulfate, 14.1 pounds of calcium carbonate and 62 pounds of calcium bicarbonate or a total of 1021 pounds of these various salts. When it is realized how much material can be added through irrigation the importance of not letting a grove get dry after irrigation is readily understood. If 1000 pounds of soluble salts were evenly distributed through the first 2 feet of an acre of the average sandy soil by an irrigation, the soil would contain 125 p.p.m. of soluble salts. However, the average sandy soil will hold only 5 percent water so that the soil solution at field capacity will contain 2500 p.p.m. soluble salts. If the soil moisture drops to 1 percent the soil solution will contain 12,500 p.p.m. soluble salts which is high enough to injure most plants. Once irrigation is started with water containing considerable soluble salts the soil should never be permitted to become low in moisture at least until after a good leaching rain.

Trend in Salt Concentration of East Coast Wells

Table 3 records the changes found in wells from several East Coast areas from the period 1942 to 1950. More wells were sampled from 1944 to 1950 and that data is included separately. In eight out of eleven areas sampled from 1942 to 1950 there was an increase in salt concentration. With more samples taken from 1944 to 1950 six areas out of 12 showed an increase while the other six areas decreased. In all cases the increase or decrease was slight and the trend either way was related to a definite region. For these wells it would appear that changes take place rather slowly.

Other Elements Found in Water

One of the objectives of this investigation was to determine what other elements might be present in addition to the usual constituents. Examination by spectrographic means of residues from 16 wells showing the highest concentration of soluble salts revealed considerable amounts of strontium present in all samples. A quantitative analysis of one sample showed approximately 30 p.p.m. strontium present. The effects of strontium on citrus are not known but it is known to be toxic to some plants. Experiments have been started to estimate its effect on citrus. No barium, potassium, or lithium was present in the samples examined although these elements are often present in natural waters.

Summary

1. The total soluble salts present in an irrigation water is probably the best single index to use in evaluating the water.

2. The climatic conditions and soil types in Florida permit the use of water containing greater amounts of soluble salts than is ordinarily considered safe.

3. It is essential that, when irrigating with a high mineral content water, the soil moisture is maintained as high as practical.

4. Individual wells in the same area vary considerably in soluble salt concentration and different areas vary as to the type of soluble salts present.

5. Strontium was found in the water

TABLE 3

CHANGES IN SALT CONCENTRATION (CALCULATED AS P.P.M. NaCl FROM Cl CONTENT) IN INDEX WELLS IN THE INDIAN RIVER AREA

Locality	57 Wells Sampled from 1942 to 1950					88 Wells Sampled from 1944 to 1950			
	No. Wells	1942	1944	1947	1950	No. Wells	1944	1947	1950
Brevard Mainland	1	1235	1320	1360	1587	3	1263	1250	1370
Courtenay						3	5712	6227	6080
Merritt-Indianola	12	2123	2105	2120	2162	19	2134	2155	2170
Georgiania-Footman	6	1668	1765	1657	1771	6	1765	1657	1771
Lotus	6	1331	1472	1540	1533	10	1481	1527	1494
Tropic	2	875	1138	1080	1058	3	1068	1047	1029
Oslo	4	465	486	488	502	4	486	488	502
N. W. Vero Beach	7	539	614	641	592	11	611	625	609
S. W. Vero Beach	10	598	646	655	592	13	630	650	604
Ft. Pierce Farms	4	683	750	720	673	8	703	669	658
Ft. Pierce Vicinity	3	576	627	613	629	6	633	632	620
White City	2	1003	1015	1010	967	2	1015	1010	967

from wells on both the East and West Coasts of Florida and may or may not present a hazard to citrus.

6. The increase in saltiness of wells on the East Coast is slow and confined to certain districts.

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GROUND WATER RESOURCES OF FLORIDA

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Introduction

All life depends upon water for its very existence. As an essential to human life water is second only to the air we breathe. It is therefore the more deplorable that this commodity on which our existence depends continues to be wastefully and unwisely used with either complacent disregard for, or no thought of, the consequences of such practices. Periodic deficiencies brought about by droughts, by local overdevelopment or by occasional breakdown of the water supply system may tend to impress upon us the importance of an adequate water supply, but as soon as our temporary inconveniences are removed we again fail to exercise discretion in protecting our water resources. Water is the most valuable and priceless resource that any community, county or state possesses. The shortage recently experienced by New York City has quite forcefully focused attention upon the necessity of an ample water supply, and this has had a stimulating influence on Nation-wide thinking about water resources.

In regions like Florida blessed with generous rainfall and with formations adapted to storing it, there is at least more reason for the prevailing general idea—and often firm conviction—that water supplies are inexhaustible and may be used or cast away without concern as to the effect on future supplies. Yet even in these regions where provident Nature has been extremely generous, there is evidence of an increasing concern about the adequacy and permanence of water supplies. This awakening has come about gradually the hard way—by actual experience. With rapid increase both in population and in industry greater and greater demands for water are