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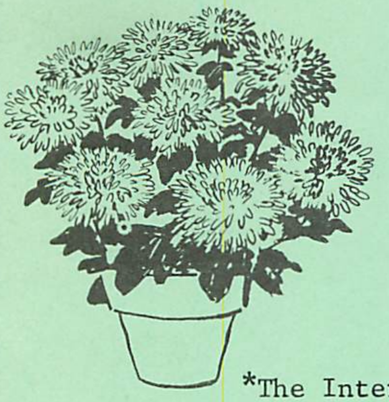

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*The Interpretation of Soluble Salt Tests and Soil Analysis by Different Procedures

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Controlling and accurately measuring the soluble salts in the soil solution is a continuous problem for most flower growers, especially where crops are grown in predominately sandy soils. Salts accumulate in the soil primarily from applied fertilizer and salty irrigation water, and small amounts are contributed by decaying organic matter. Soil soluble salts are composed predominantly of ammonium, calcium, magnesium, potassium, sodium, bicarbonate, chloride, nitrate and sulfate ions.

When soluble salt levels become too high, plant roots are damaged (burned), which reduces their ability to absorb water and nutrients. When salt concentration of the soil solution exceeds concentration inside plant roots, water moves out of the roots into the soil,causing partial or complete dehydration and death. Other symptoms include stunting, excessive wilting, marginal leaf burn, yellowing of new growth, and small flowers. In mild cases reduction in growth may occur without other visible symptoms.

Soil samples are normally analyzed for soluble salts by any of three different procedures in Florida; therefore, the producer and his advisor must recognize these different testing procedures and understand how to interpret the salt analysis. Extreme variations occur in parts per million soluble salts obtained on the same sample by the three testing procedures. These three salt procedures are (a) 1:2 soil to water dry weight procedure, (b) 1:2 soil to water volume procedure, and (c) the saturated paste procedure.

The objective of this report is to summarize existing knowledge and present rough guidelines on how to interpret salt analyses and soil tests from different procedures.

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Interpretation of soluble salts for 1:2 dry weight procedure

In the 1:2 dry weight procedure results are reported as ppm salts by weight of the air dry soil, which makes bulk density of media an important factor in interpretation. With the light weight media, much larger volumes are required to equal a given weight than with the heavier media, yet both are mixed in the same volume of water. Therefore, in establishing high and low salinity values as shown in Table 1 for light weight media by the dry weight method, values other than those recommended for sandy field soils must be used. Also, contrary to sandy field soils, light weight media frequently contain moderate quantities of moisture after air drying which skews results of dry weight procedure.

The mixture of one part soil by weight and two parts water are read on a Solu-Bridge at 25° C. The Solu-Bridge is calibrated to read specific conductance of the solution from 10 to 1,000 mhos x 10^{-5} or 0.1 to 10 mhos x 10^{-3} for the newer models.

The ppm salts for the dry-weight procedure are calculated by EC x 700 x 2 where EC equals electrical conductivity in mmhos/cm^3 or "solu-bridge reading" in mhos x 10^{-3}, 700 represents the average factor for converting conductivity readings to ppm salts, and 2 the water weight dilution factor.

EXAMPLE - Solu-Bridge reading was 0.48
.48 x 700 x 2 - 672 ppm salt

For Solu-Bridge designed to read in mhos x 10^{-5} use a factor of 7 instead of 700. For light weight mixes with high water holding capacity it may be necessary to use a 1:4 mixture of soil to water by weight. In which case a water dilution factor of 4 should be used instead of 2.

Table 1. Interpretation of soluble salt readings (ppm) of 1:2 mixture of dry soil to water by weight* for ornamental plants.

	ppm salts for three media**		
	Sandy soil	Sand:Peat (1:1 ratio)	Peat or light wt. mixes
Low	400	1,000	2,000
Medium	800	3,000	5,000
High	1,200	5,000	8,000
Very high	1,600	6,500	10,000
Excessive	1,600+	6,500+	10,000+

*This method of reporting soluble salts is used by Florida Agricultural Extension Service Laboratory and the Division of Plant Industry for Gainesville.

**Remember these readings are very rough guides only.

Interpretation of soluble salts for 1:2 volume procedure

In this procedure soluble salts are easily estimated by mixing one part air dry soil to two parts water and read on the Solu-Bridge at 25° C. The results are reported as ppm salts in a volume of water equivalent to the volume of soil sample. In the 1:2 volume procedure the same formula as for the dry weight method (EC x 700 x 2) is used for calculations where the EC and 700 representation are the same as for dry weight procedure and 2 represents water-volume dilution factor. Here again, where it is necessary to use 4 volumes of water for peat and light weight soil mixes, a water dilution factor of 4 must be used in the calculations.

The 1:2 soil to water volume method is the procedure most commonly used by growers with their own Solu-Bridges. With this method variations in salinity readings of media with different bulk densities at a given fertilization rate are much less than with the 1:2 dry weight procedure. The volume measure offers partial compensation for the great variation in bulk density. However, as with the dry weight method, excessive soil moisture in the sample at the time of analysis, especially with light weight media, will reduce the salinity readings; therefore the initial soil sample should be air dried.

Table 2. Interpretation of soluble salt readings (ppm) for 1:2 air dry soil to water mixture by volume.

Media	Solu-Bridge reading mhos x 10^{-5}* on 1:2 volume	ppm salt**	Salt rating	Remarks
Sandy soils	Below 25	0-325	Low	Need fertilizer
1:1 peat: sand	Below 33	0-460		
Peat or light wt. mixes	Below 50	0-700		
Sandy soils	25 to 50	350-700	Low to medium	Satisfactory for growth in upper range.
1:1 peat:sand	33 to 66	460-925		
Peat or light wt. mixes	50 to 100	700-1400		
Sandy soils	50 to 100	700-1400	Medium to high	Desirable salt range no fert. needed, but light applications can be made.
1:1 peat:sand	66 to 130	925-1820		
Peat or light wt. mixes	100 to 175	1400-2450		
Sandy soils	100 to 150	1400-2100	High to very high	Do not fert. or allow soil to become dry. Leach media if readings are near top of these ranges.
1:1 peat:sand	130 to 200	1820-2800		
Peat or light wt. mixes	175 to 275	2450-3850		

*These readings are based on medium salt tolerant plants such as chrysanthemums and gladiolus. For salt sensitive plants these scales should be decreased by approximately 25%.

**EC (Solu-Bridge reading in mhos x 10^{-5}) x 7 x 2 = ppm salt.

Interpretation of the saturated past procedure for soluble salts and specific nutrients

The saturated paste extract procedure of testing salinity was initially developed by the U. S. Salinity Laboratory in Riverside, California (10) for saline and alkali soils and later was expanded by C. M. Geraldson at Agricultural Research and Education Center, Bradenton, Florida (3,4) to evaluate not only intensity (total salts) but also the balance of the various ions in the salt extract, hence, the intensity and balance or I & B concept of soil testing presently in use in Florida.

With this procedure sufficient water is added to any type of soil media to bring the soil sampling to a glistening saturated paste and then the moisture extracted from the soil under slight vacuum.

In the saturated paste procedure results are reported in Florida as ppm salts in the soil solution at maximum soil moisture holding capacity after drainage. These readings are calculated by EC_e x 700 x moisture factor (MF), where EC_e represents electrical conductivity in mmhos/cm^3 (Solu-Bridge reading) of the saturation extract, 700 represents standard conversion factor and MF represents ratio of moisture percentage at saturation (by dry weight) to moisture holding capacity percentage (by dry weight). The moisture factor changes with soil or media composition as well as with the pot size for container grown ornamentals. The moisture factor for any soil or media can be computed by:

$$\text{M. F.} = \frac{\text{\% soil moisture on weight basis at saturation}}{\text{\% soil moisture on weight basis at field moisture capacity}}$$

For field soils and ground beds the moisture factors normally used are 2.0 for sandy soils, 1.2 for organic soils and 1.5 for 1/2 sand to 1/2 peat mixtures (4).

In recent years it has been demonstrated that the moisture holding capacity of soils in containers is affected not only by the soil mixture but also by the container size and height (6,7,8,9,11). Moisture retention properties of media in containers are affected by a media-container interface phenomenon which acts as a barrier to free drainage and media water retention is also a function of container depth (11,13).

Since these phenomenon affect the moisture factors we have determined the moisture factors for several soil media in different containers (Table 3) for use when determining soluble salts by the saturated paste technique for container grown crops (11).

Since the media sample is brought to a saturated paste prior to salt determination, initial soil moisture, sample volume, bulk density, water holding capacity, or media composition are not critical factors in accuracy of determinations (1,2,3,4,5,11). Our conclusions are that in dealing with media with wide ranges of bulk density and water holding capacity, the saturated paste technique is superior and where it is not practicable the <u>air dry</u> volume based technique appears superior from a convenience viewpoint to the dry weight method. However, for sandy soils, the 1:2 dry weight method has advantages over the volume technique but both are inferior to the saturated paste procedure.

Table 3. Factors to convert electrical conductivity of saturated paste extract (EC_e) to ppm soluble salts at field moisture capacity for several soil media mixtures.

Media Mixtures	Factors for various size plastic pots					
	2 1/4" sq. pot		5" round pot		7" round pot	
	Moisture Factor(MF)	MF x 7	Moisture Factor	MF x 7	Moisture Factor	MF x 7
Muck	1.1	7.7	1.3	9.1	1.8	12.6
European or native peat	1.14	8.0	1.37	9.6	1.8	12.6
Wood shavings	1.39	9.7	1.43	10.0	2.1	14.7
Shavings and peat comb.	1.2	8.4	1.43	10.0	1.7	11.9
Perlite and peat (not over 66% of either)	1.3	9.1	1.43	10.0	1.8	12.6
Shavings, peat and perlite mixture	1.3	9.1	1.43	10.0	1.9	13.3
Sand* peat 1:1	1.3	9.1	1.43	10.0	1.8	12.6
Sand:peat: perlite at 1:1:1 volume	1.2	8.4	1.43	10.0	1.7	11.9
Sand:peat: shavings at 1:1:1 volume	1.3	9.1	1.43	10.0	1.7	11.9
Perlite and shavings 1:1 volume	1.5	10.5	1.65	11.5	2.4	16.8
Builders sand alone	1.6	11.2	1.8	12.6	2.2	15.4
Sand:shavings: perlite at 1:1:1 volume	1.5	10.5	2.2	15.4	2.4	16.8

*Builders sand was used in these media.

Temporary low, medium, and high levels of soluble salts (ppm) as determined be saturated paste technique for ornamentals are given in Table 4. It should be emphasized that these are only first approximations and will be changed as information is gained.

Table 4. Interpretation of low, medium, and high soluble salt levels for ornamental crops as determined by saturated paste technique.

Crop Response	Low	Optimum	High
Salt sensitive crops	900	1800	2700
Range	up to 1400	1400 - 2300	2300 - 3000
Medium salt tolerant crops	1500	3000	4500
Range	up to 2200	2200 - 3800	3900 - 5200
High salt tolerant crops	3500	4500	5500
Range	up to 4000	4000 - 5000	5000 - 6000

These figures refer to ppm total soluble salts in the soil solution at field moisture capacity.

Interpretation of the intensity and balance of specific ions in the saturation extract

Rough guide lines (Table 5) have been established for use on gladiolus and chrysanthemum plantings and are subject to change as additional information is developed.

Table 5. Suggested ionic concentrations expressed as % of the total soluble salts from the saturated paste extract procedure.

Elements*	Desirable range (% of total salts)	Remarks
Ca	10 - 15	Below 10% - low
Mg	3 - 6	Below 2% - low
K	8 - 12	Below 5% - low
Na	0 - 5	Above 10% - high
NO_3	5 - 10	Above 15% - excessive
NH_4	1 - 3	Should be less than NO_3
P	0.5 - 1.5	Levels not firmly established
Cl	1 - 5	Above 10% - high

*Micro elements usually run 1-2 ppm each in the extract and 4 ppm or above for any given micro element should be considered excessive.

Interpretation of soluble salts in irrigation system

Quality of irrigation water is very important in plant production because of undesirable effects of total soluble salts as well as certain specific chemicals found in some waters. When a new well or growing operation is being planned, a complete water analysis should be made.

Concentration of soluble salts in Florida well waters ranges from very few to several thousand parts per million (ppm) (12). Generally wells can be classified as low, medium and high according to salt content. Wells containing less than 700 ppm total soluble salts are considered in the low class and usually do not cause trouble (Table 6). Wells containing from 700 to 1500 ppm salt are in the medium salt range and may cause trouble, especially during dry seasons or where frequent but light overhead irrigation is practiced. Wells containing over 2,000 ppm salt should be avoided as far as possible for ornamental plant production.

In order to convert Solu-Bridge Model RD-15 reading on well water or other irrigation water, multiply the reading of the water in mhos x 10^{-5} by 7. This will approximate the ppm total soluble salts in the water.

EXAMPLE: Solu-Bridge reading was 48
48 x 7 = 336 ppm total soluble salts in the water
(If the Solu-Bridge reads in mhos x 10^{-3} then
multiply the 0.48 by 700 instead of 7.)

Table 6. Classes of irrigation water and permissible limits of constituents.

Class of water	Electrical conductance E.C. x 10^{-5} at 25° C	Total dissolved solids (salts) ppm	Sodium percent of total solids	Boron ppm
1. Excellent	less than 25	175	20	.33
2. Good	25-75	175-525	20-40	.33-.67
3. Permissible	75-200	525-1400	40-60	.67-1.00
4. Doubtful	200-300	1400-2100	60-80	1.00-1.25
5. Unsuitable	more than 300	2100	80	1.25

Source: L. V. Wilcox. 1948. The Quality of Water for Irrigation Use. USDA Tech. Bull. 962:p. 27, adapted for Florida conditions by Waters and Conover (12).

Interpretation of soil test utilizing ammonium acetate pH 4.8 extraction solution

This is the standard soil test procedure utilized by the Extension Service Soil Testing Laboratory, University of Florida, Gainesville, Florida and the results are reported as pounds per acre of the oxides. A guide to interpreting these tests for two soil or media types is listed in Table 7 below.

In the production of commercial flower crops in Florida, a soil analysis by the ammonium acetate method has the most application during the land preparation or media formulation process. The use of this method as a guide to fertilizing during the crop cycle has serious limitations.

Table 7. Suggested pH and nutrient levels as determined by NH_4Oac 4.8 method for ornamentals on two media types

Level	Sandy soils or sandy type media (lbs/acre)				
	pH	CaO	MgO	P_2O_5	K_2O
High	7.0	1700	300+	185	380
Medium	5.8	1100	200	95	240
Low	5.0	500	150	40	120
	Organic or light weight type media (lbs/acre)				
High	7.0	2600	400	200	400
Medium	5.8	1600	300	100	300
Low	5.0	750	200	50	200

Source: Dr. James NeSmith, Extension Service Soil Testing Laboratory, University of Florida, Gainesville, Florida.

Avoiding High Salt Problems

In addition to reducing water uptake as previously mentioned, salts from irrigation water may produce nutritional imbalance and toxicities, and may adversely affect the physical condition of soils (14). Sodium tends to make soils "run together", to be wet, non-aggregating and subject to poor drainage and aeration. Light, sandy soils are not so much affected. Sodium also interferes with the uptake of other positively charged ions that are nutritionally important. These include potassium, magnesium and especially calcium. Excess sodium may induce calcium deficiency or poor quality of plant products due to low calcium availability. Potential toxic elements in irrigation water include boron, fluoride, lithium, and bicarbonate. In the case of boron, there seems to be a need to learn how to fertilizer properly according to the amounts of boron present in the irrigation water. Analyses of water and leaf samples will aid in clarifying this situation.

Large amounts of the negatively charged ion, bicarbonate, are undesirable. If bicarbonate is present much in excess of the chloride plus sulfate content, the bicarbonate can result in the precipitation of calcium and magnesium and in the production of sodium-saturated soils that have poor physical condition. The bicarbonate ion also increases the incidence of iron deficiency.

To reduce or eliminate the effects of high soluble salts the following procedures are helpful:

1. Avoid excess use of chloride, sodium, and sulfate in fertilizer to reduce the salt-input of unnecessary elements.
2. Test irrigation water and soils regularly.

3. Select sources of water of the best quality available.
4. Provide good drainage to remove salts.
5. Double-row beds that are not thrown up too high are less subject to salt damage for seeded crops. Salts move to the highest place in the bed or to the top center of a double-row bed. Sloped beds may sometimes be used with seeding on the downward side.
6. Be careful to avoid letting very light soils dry out since a 50% loss of available soil moisture approximately doubles the salt concentration.
7. When possible, leach salts out of soil - even with slightly salty water. With seep irrigation one may raise the water level and then drain to remove dissolved salts. Overhead irrigation is the ideal way to remove salts by leaching. The saltier the water is, the more leaching is required.
8. Salts accumulate in hardpan sub-soil pockets or depressions in the hardpan profile. These small areas that will damage a planting should be corrected by breaking the hardpan somehow at the center of the affected area and leaching out the salts. Surprisingly, these areas will persist with heavy rains or heavy irrigation, unless the hardpan is broken.

A physiological character of root growth that has not been discussed is the failure of roots to grow into a zone of high soluble salts because of water limitations to the root. If fertilizer is placed too close to roots, they will probably be burned, but roots will not grow into excessively salty soil because of the water deficit. If soluble salts build up too high in soil, the plants will make little growth and leaves may be burned.

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