EFFECTS OF SOLUBLE SOIL SALTS ON VEGETABLE PRODUCTION AT SANFORD

PHILIP J. WESTGATE
Florida Agricultural Experiment Stations
Central Florida Experiment Station
Sanford

In a humid region of sandy soils, such as is found in the vicinity of Sanford, soluble soil salts are derived primarily from fertilizer and artesian well water residues.

In the production of winter vegetables, principally celery in the area, large amounts of commercial fertilizer are applied during the relatively dry winter growing season. It is not unusual for growers to apply from two to four tons of commercial fertilizer per acre to celery. In addition, two to four tons of soluble salts, over half of which are sodium chloride, may be added by each acre foot of artesian well water used for sub-irrigation through tile placed above a hardpan. Such large amounts of fertilizer and well water salts, if not washed out by frequent rains, may build up concentrations of soluble salts detrimental to plant growth.

The following three fields in the Winter Garden vegetable area will illustrate what excessive fertilizer buildup alone will do to vegetable production. The sampling date was May 9, 1950.

Field No. 1 was planted to, and produced one excellent crop of cucumbers each calendar year. Field No. 2 was planted to three crops, one of peppers and two of cucumbers, in one year, including a full fertilizer program for each crop, with successively poorer results. Fertilizer residues were the principal source of soluble soil salts in both fields since the irrigation water in both cases was very low in total dissolved salts i.e. less than 100. parts per million of Chlorides (Cl.)[2]

A virgin sand area east of Sanford near Lake Harney showed no plant growth, not even weeds or grasses. An analysis of this soil without the addition of fertilizer showed a total soluble salts reading of over 1000 MHOS x 10^{-5}, the upper limit of the scale, 9000 p.p.m. of Chlorides (Cl.), and 5700 p.p.m of sodium (Na.) This would amount to over twelve tons of sodium chloride per acre in six inches of soil.

[1] Throughout this paper "Total Soluble Salts" is given as the Specific Conductance expressed as MHOS X 10^{-5} at 25° C. as determined on a Solubridge, using a solution of one volume of soil plus two volumes of water. The higher the soluble salts, the higher the reading obtained.

[2] Chlorides were determined by titration with silver nitrate and expressed as parts per million of chlorine (p.p.m. Cl.) in the water or soil samples.

[3] pH determinations were made using a Quinhydrone electrode with one volume of soil plus two volumes of distilled water.

Soil Depth	Soil Profile	Total Soluble Salts Specific Conductance MHOS x 10^{-5} 1 Virgin Soil (No Crop)	Field No. 1 (Good Crop)	Field No. 2 (Poor Crops)
0-1"	Sand	0	55.	340.
0-6"	Sand	0	60.	130.
6-12"	Sand	0	23.	28.
12-18"	Sand	0	22.	15.
18-24"	Hardpan	0	10.	0.

The pH of this soil was 5.90[3]. Evaporation of saline underground waters probably accounted for the accumulation of soluble salts in this spot.

An adjoining corn field in the Lake Harney area showed uneven growth of corn. The poor spots in the corn showed stunting, "firing" of the lower leaves, and a chlorosis or yellowing of the plant as a whole. The surface soil from good and poor areas in this corn field analyzed as follows:

Soil 0-6"	Chlorides (p.p.m. Cl)	Total Soluble Salts (MHOS x 10^{-5})	pH
"Good corn"	133.	30.	5.88
"Poor corn"	466.	90.	5.87

The irrigation water for this corn field was pumped from Lake Harney, which showed a chlorine content of 541. p.p.m. Cl. The adjoining artesian well, approximately 125 feet deep with 8200. p.p.m. Cl. was capped and not used for irrigation because of the high salt content.

In pot tests, soil from the poor spots in the corn field grew good cowpeas after leaching with Lake Harney water, but not before. The following data was obtained from the leachates.

The two previous examples have illustrated troubles due to soluble soil salts, first from fertilizer at Winter Garden, and second from saline waters at Lake Harney. In the Sanford vegetable area we are confronted with both a wide range in salt content of artesian well waters used for irrigation, and a wide variation in the amounts of soluble commercial fertilizer used. Underlying these soils are hardpans of varying permeabilities at different depths from the surface.

The following well water samples analyzed in 1950 will illustrate the wide range in salt concentration of various wells in the Sanford area.

The question arises as to whether or

Water Sample	Remarks	Chlorides (p.p.m. Cl)	Total Soluble Salts (MHOS X 10^{-5})	pH
(1)	Lake Harney water (used for irrigation)	541.	200.	6.86
(2)	Lake Harney water after washing out good corn soil. Good peas	640.	260.	6.52
(3)	Lake Harney water after washing out poor corn soil. Grew good peas only after washing	4969.	1000.	7.00

Well Location	Remarks	No. of Wells Tested	Chlorides (p.p.m. Cl) Low Well	High Well	Average
Samsula	Shallow, Pumped	2	33	49	41
Zellwood	Shallow, Pumped	1	49	49	49
Winter Garden	Shallow, Pumped	2	33	66	49
West Sanford	Free flowing, artesian	2	82	98	95
South Sanford	Shallow, Pumped	1	96	96	96
West Sanford	Free flowing, artesian	9	91	733	435
East Sanford	Free flowing, artesian	4	525	558	533
East Sanford	Free flowing, artesian	8	525	623	549
S.E. Sanford	Free flowing, artesian	3	476	607	557
Oviedo	Free flowing, artesian	7	286	1098	595
East Sanford	Free flowing, artesian	4	590	607	603
East Sanford	Free flowing, artesian	24	333	932	613
S.E. Sanford	Free flowing, artesian	4	893	1140	977
West Sanford	Free flowing, artesian	2	1098	1115	1106
S.E. Sanford	Free flowing, artesian	1	1132	1132	1132
Oviedo	Free flowing, artesian	6	869	1509	1255
Iowa City	Free flowing, artesian	1	1714	1714	1714
Lake Harney	Free flowing, artesian	1	8200	8200	8200

not the salt content of the artesian wells in the Sanford area changes from season to season or from year to year. The following wells in this area have been analyzed for chlorides during the past fifteen years with these results:

Location	Depth (Ft.)	Chloride Content (p.p.m. Cl) 1935	1936	1938	1941	1950
West Sanford	151	35	50	Deepened		500
East Sanford	......	....	....	....	452	466
East Sanford	227	565	503	....	....	525
West Sanford	157	1225	1040	1188	....	1115
Lake Harney	125	8900	(Capped)		....	8200

Thus of the artesian wells tested fifteen years ago by the Central Florida Experiment Station, and retested in 1950, the only one which had any significant increase in chloride content was one which had been deepened in the intervening years because of loss in head. The other wells, of a wide range in salt concentrations, remained practically constant whenever checked during the fifteen year period. Geologists tell us that these artesian wells are merely washing out the salts in the layers of rocks laid down when central Florida was under the sea (2).

As the suggestion has been made that surface water might be substituted for our artesian well water as a source of irrigation water, several sources of surface waters were analyzed as follows:

Date Water Sampled	Location	Chlorides (p.p.m. Cl)
3/24/50	Elder Spring water, south of Sanford (analysis on label)	8.
5/24/50	Rock Springs (flows into Wekiva River)	16.
3/20/50	Black Lake, Winter Garden (citrus irrigation)	66.
5/19/50	Buck Lake, Geneva	66.
3/27/50	Lake Jessup	71.
6/12/50	Wekiva River (near St. John's River)	164.
12/14/35	Lake Harney	150.
1939	Lake Harney	1030.
3/15/50	Lake Harney	315.
3/19/50	Lake Monroe (16 samples, east and west, surface and bottom, maximum depth 12 feet)	
	Minimum sample	300.
	Maximum sample	333.
	Average for the day	316.
1926-1950	Lake Monroe	
	Minimum	62.
	Maximum	937.
5/2/50	St. John's River (Osteen Bridge)	377.
5/16/50	St. John's River (Osteen Bridge)	459.
5/27/50	St. John's River (Osteen Bridge) (Water very shallow at this date)	820.
11/3/50	St. John's River (Osteen Bridge) (Water very high at this date)	98.
3/24/50	Atlantic Ocean (East Coast, Canaveral)	21,520.

Thus there is a wide variation and fluctuation in the chloride content of surface waters in the Sanford area. These sources, such as the St. John's River, Lake Monroe, and Lake Harney, vary with the season of the year, depending upon the rainfall and evaporation.

One disadvantage of the St. John's River as a possible source of irrigation water is the fact that when irrigation water is not required the chloride content of the river water is low, but when irrigation water is most needed, the chloride content of the river water is even higher than most of the artesian wells in the area.

The fresh water springs, fresh water lakes, the Wekiva River, shallow pumped wells, and our fifty inches of rainfall per year are all potential sources of water low in chlorides.

On February 7, 1950, during an unusually warm, dry winter season, the following soil profile was analyzed from a poor spot of celery in an old tiled field along Celery Avenue, Sanford.

These poor spots in old celery fields are associated with a surface layer of white sand which compacts, especially after rains, thus interfering with aeration. Liming tends to keep such soil loose and friable thus improving leaching and aeration. Leaching also greatly improved root and plant growth in these poor spots of celery.

Depth of Soil Sample	Remarks	Total Soluble Salts (MHOS X 1[5])	pH
0-1"	White sand crust	155.	5.65
4-8"	River "muck" and 2-year-old, undecomposed corn stalks	85.	5.48
8-12"	Dark Sand	38.	6.52
16-20"	White sand	33.	7.00
TILE	(For irrigation and drainage)	....	....
38-42"	White sand	52.	7.17
44"	Dark hardpan (Palmetto roots undecomposed after thirty years)	39.	7.30

On October 25, 1950, after the heavy summer and hurricane rains, the following profile from a farm on Geneva Avenue, Sanford, was analyzed.

Depth of Soil Sample	Soil Characteristics	Chlorides (p.p.m. Cl)	Total Soluble Salts (MHOS X 10^{-5})	pH
0-1"	White sand crust	66.	42.	5.74
0-6"	Dark sand	33.	12.	6.34
12"	White sand	33.	23.	6.52
Tile	(For irrigation and drainage)	....	....	....
18"	Dark hardpan	142.	30.	6.56
24"	Dark subsoil	165.	33.	5.83
30-36"	Dark subsoil	264.	55.	6.68
36-42"	Dark subsoil	297.	60.	6.81

This marked reduction in soluble salts above the tile, with a considerable hold over of soluble salts in the subsoil below the tile, was characteristic of profiles analyzed after the summer and hurricane rains of 1950. Soil profiles analyzed during the dry winter and spring seasons showed an accumulation of soluble salts at the surface as well as in the more dense layers below the tile.

This summer a squash field was spotty in growth with a large percentage of the plants stunted and yellow. Most of the crop was disked in without harvesting a crop. A few vines sent out new, dark green growth after the hurricane rains.

Surface soil from an old field on Celery Avenue, which has produced crop failures for at least the past five years was sent to the U. S. Regional Salinity Laboratory, Riverside, California, for analysis. Considerable work on saline soils of the West has been done at this Laboratory (1). The resulting soil analysis showed a "soluble sodium percentage" of 52, indicating that 52 percent of the total cation concentration was sodium. This report showed this soil from a poor pepper field to be "highly saline, and any crop would have difficulty." Leaching previous to planting was recommended.

Soil samples from poor spots in a celery field on Beardall Avenue averaged 74 p.p.m. of ammonia nitrogen, whereas adjacent good spots of celery in the same field showed only 5 p.p.m. of ammonia nitrogen. Soil samples from these poor spots failed to nitrify ammonia even when nitrifying bacteria were added unless lime was also added. Lumps of St. John's River "muck" and cover crop residues failed to decompose under the poor spots of celery in the field, indicating an inactivation of bacterial action in the soil.

Leaching of the poor celery soils in crocks in the greenhouse with distilled water produced normal celery plants, whereas unleached soils from the same area produced stunted, chlorotic plants. Poor, stunted celery plants in the field, when leached with distilled water or artesian well water, put out new roots and made good growth, while unleached adjoining plants remained stunted. Liming of the stunted plants in the field improved the texture of the soil and favored new root and top growth.

On February 8, 1950, a fall, celery seedbed area on Celery Avenue, planted to cabbage, was doing very poorly. The cabbage plants remained stunted, were all shades of yellow to purple, but would not respond to fertilizer. The cabbage was finally disked in without harvesting a single head. This grower, as he has often done in the past, then turned on his artesian wells, which have an average chloride (Cl) content of 613 p.p.m. Cl, and let them run through his tiled fields, including the seedbed area, for a solid month. At the end of this time, on June 2, 1950, this same seedbed area, which failed to grow cabbage, was again analyzed. The data obtained is as follows:

Depth of Soil Sample	Average Total Soluble Salts (MHOS X 10^{-5})		
	Feb. 8, 1950 Poor Cabbage Before Flooding	June 2, 1950 After Flooding	Sept. 25, 1950 New Seedbeds After summer Rains and Fertilizer
0-1"	502.	80.	60.
0-6"	153.	65.	32.

Thus a large part of the accumulated soluble salts, at least of those in the top six inches of soil, were washed out of the surface soil by the well water and about 1.50 inches of rain by June 2. Celery seedbeds were again planted on this same area on July 4, 1950, and have produced excellent celery plants for this fall's plantings.

On June 15, 1950, soil from seedbeds south of Sanford was analyzed when the plants were about three weeks old, with the following results:

Soil Samples, 0-½"	Average Chlorides, p.p.m. Cl.	Average Total Soluble Salts (MHOS X 10^{-5})	pH
Good celery germination	229.	21.	7.35
Poor celery germination. Bare	3695.	316.	6.92

Eight hundred parts per million of chlorides (Cl) have been reported by the Central Florida Experiment Station as the upper limit for growth of celery under greenhouse conditions.

Recent observations in numerous commercial celery fields in the Sanford area have shown poor growth of celery plants, probably due to malnutrition when the total soluble salts (including fertilizer salts) is below 20 MHOS X 10^{-5} in the top six inches of soil. Excellent crop yields of 1000 crates or more per acre have been observed where the total soluble salts readings have been between 20 and 50 MHOS X 10^{-5}. Readings of above 85 MHOS are usually associated with black hearting, stunting and even death of the plants at the higher readings.

On June 13, 1950, fourteen soil samples (0-6") were analyzed from an East Celery Avenue corn field soon after the corn crop had been harvested. This sweet corn was grown on old tiled celery fields which analyzed as follows:

Crates of Corn Per Acre	Average Chlorides (p.p.m. Cl)	Average Total Soluble Salts (MHOS X 10^{-5})	pH
125.	254.	120.	6.23
25.	758.	203.	6.20
0.	1410	425.	6.49

Thus the corn yields were markedly reduced where the total soluble salts and chlorides were high in the soil. Even the lowest reading of 120 MHOS was probably too high for maximum growth of corn. Excellent corn has been observed along Celery Avenue with readings between 20 and 40 MHOS.

On June 14, 1950, surface soil samples were obtained from good and poor spots of a hairy indigo cover crop following celery in a field along Celery Avenue. This field was irrigated with artesian well water containing 549 p.p.m. Cl.

Hairy Indigo, Cover Crop	Soil Sample Depth	Chlorides (p.p.m. Cl)	Total Soluble Salts (MHOS X 10^{-5})	pH
Good germination and growth	0-1"	230.	52.	6.39
Poor Germination. Dead and dying	0-1"	885.	200.	6.52

On July 14, 1950, surface soil samples were collected from a west Sanford celery field which had been planted to Crotalaria as a cover crop following celery and corn. Where the celery and corn had been stunted from high soluble salts the cover crop failed to germinate. On the edge of the field the cover crop showed very good germination and growth.

After the summer rains set in, the cover crops responded nicely, and eventually covered even the bare spots formerly high in soluble salts.

To date leaching by rain or well water, and the addition of liming materials have been the two treatments which have shown marked response in overcoming the effects of soluble soil salts in the tiled, sandy, celery fields underlain by hardpans in the Sanford area. The sandy soil above the tile and hardpans is relatively easy to leach, but the more

Crotalaria, Cover Crop Following Celery and Corn	Soil Sample Depth	Average Chlorides (p.p.m. Cl)	Average Total Soluble Salts (MHOS X 10^{-5})	pH
Good germination and growth	0-6"	147.	0.	6.61
Poor germination and growth	0-6"	525.	110.	6.54

impermeable and retentive layers below the tile are much more difficult to wash out. This reserve supply of salts which remains in the lower layers of soil, even after summer and hurricane rains, is then available to be brought back to the surface layers by capillarity and evaporation during the comparatively warm, dry winter growing seasons.

Saline Spot in Celery Field, Sanford, Florida.

Acknowledgments

The author wishes to take this opportunity to thank Dr. Nathan Gammon, Soils Chemist, Gainesville, for the sodium determinations, Dr. George Thornton, Professor of Soils, Gainesville, for his work on nitrification, and Dr. A. D. Ayers, U. S. Regional Salinity Laboratory, Riverside, California, for his advice and suggestions regarding saline soils.

LITERATURE CITED

1. Richards, L. A. Diagnosis and Improvement of Saline and Alkali Soils. *U. S. Regional Salinity Laboratory*, Riverside, California. 1-157. 1947.
2. Stubbs, Sidney A. Study of the Artesian Water Supply of Seminole County, Florida. *Proceedings of the Florida Academy of Sciences.* Vol. II: 24-36. 1937.

A NEMATODE ATTACKING STRAWBERRY ROOTS

A. N. Brooks, *Plant Pathologist*
Strawberry Laboratory
Plant City

J. R. Christie, *Senior Nematologist*
U. S. Department of Agriculture
Sanford

This disease was first noticed in strawberry fields during the fruiting season 1946-47. Affected areas in a field were small at first but gradually increased in size in a somewhat circular pattern until large areas became involved. In a few cases all the plants in a field were affected.

The affected plants became semi-dormant, no new growth being apparent. Edges of leaflets became dark brown, a typical plant symptom of root injury. There was a gradual dying of leaf tissue from edges to midribs. Plants thus declined gradually, sometimes lingering for several weeks before death finally took place. The root systems of affected plants were lacking in fine feeder roots. The cortex of the remaining larger roots was dead but in most cases the steles or central cylinders remained alive for some time subsequent to destruction of cortex. Later studies showed that root tips were killed then lateral roots developed and their tips in turn were killed. This resulted in the production of root systems consisting of coarse roots with knobby tips.

Roots of affected plants were examined for nematodes but none were found in or on the roots. Isolations made from such roots gave the usual display of various soil fungi but none appeared consistently. Affected plants were collected for future use. The roots were carefully washed under running water and the plants then set either in treated soil in