THE EFFECT OF SALINE WATERS ON THE RATE OF TRANSPIRATION OF GERANIUMS (PELARGONIUM HORTORUM)

THE EFFECT OF SALINE WATERS ON THE RATE OF TRANSPIRATION OF GERANIUMS (PELARGONIUM HORTORUM)

By

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INTRODUCTION

In experiments[1] conducted at the Oklahoma Agricultural and Mechanical College in which geraniums and other plants were watered with saline waters, it was found that the saline waters had detrimental effects on the plants.

In order to collect some data that might help to solve the problem of the toxic effect of these saline waters on the plants, it was decided to study the effect of various saline waters on the transpiration rates of geraniums. Experiments were organized and conducted to determine the rate of water lost by transpiration from geranium plants watered with different salt solutions and with rainwater. So that the effect of the various salts could be determined, the salt solutions were applied individually rather than in combinations. The experiments were organized in such a manner that the effects produced by concentrations of 3000 parts per million and 6000 parts per million of the salt solutions could be compared.

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1. Unpublished data Okla. A. & M. College.

REVIEW OF LITERATURE

Variations in the Rate of Transpiration During the Day and on Succeeding days

Transpiration rates vary greatly from day to day and during various parts of the same day. Kiesselbach (15), in his studies of transpiration of the corn plant, found that the water requirement, occasionally, varied as much as 300-400 per cent on successive days. The maximum rate of transpiration occurred between 1:00 and 3:00 P.M. Briggs and Shantz (6) conducted transpiration experiments with various plants, in the region of Akron, Colorado. They found the maximum rate of transpiration for the plants studied, occurred between 12:00 M and 4:00 P.M. Transpiration was very low during the night being only, 3-5 per cent of that during the day. Darrow and Sherwood (9) found similar fluctuations when they studied the transpiration rates on the strawberry. In one of their experiments, conducted for 9 1/2 days, which contained 11 series of four plants each, the water lost by transpiration was as follows: 37 per cent from 9:00 A.M. to 1:00 P.M., 35 per cent from 1:00 to 5:00 P.M. and 28 per cent from 5:00 P.M. to 9:00 A.M. These results demonstrate that the transpiration rate fluctuates greatly throughout the day and on succeeding days.

Factors That Affect Transpiration

Many factors affect the rate and magnitude of transpiration. Some of the factors that affect the rate of transpiration are: fluctuations in air temperatures, fluctuations in the relative humidity of the atmosphere, windy or calm air conditions, kind, age and structure of plants, moisture content of the soil, and light intensity. Air temperature and relative humidity greatly influence the rate of transpiration.

Kiesselbach (14) conducted transpiration experiments with corn plants at the University of Nebraska. His results indicated that the relative humidity of the air was the chief controlling factor of transpiration. Whitfield (24) reported on certain projects conducted by the Carnegie Institution of Washington in the Pikes Peak Region. In those projects, the transpiration of some native and cultivated plants (corn, wheat and sunflowers) was measured. The transpiration curve showed a closer correlation to the curves of relative humidity and air temperature than to any of the other factors measured, such as, evaporation and saturation deficit.

Transpiration varies with the species, age and leaf area of plants. Darrow and Sherwood (9) in their transpiration studies with the strawberry, found marked variations between the transpiration rates of various varieties of strawberries. In the same variety, plants with young leaves transpired slightly faster than plants with old leaves and plants with larger leaf areas transpired at lower rates per unit than those plants with smaller leaf areas. The data presented by Brierley (7) indicates that the transpiration rates per square inch of leaf surface are about the same for leaves of old and new canes of the Latham Raspberry until late in the season when the transpiration rates of the leaves of new canes are slightly greater per square inch of leaf area. These results show that transpiration is affected differently by different plant species and by plants of different ages and leaf areas.

Transpiration is affected by the stomatal behavior. Loftfield (16) grouped plants into three classes according to stomatal behavior. (a) Plants such as cereals, in which night opening did not occur and the duration of day opening was regulated by factors such as, temperature and water content of the leaf. (b) Thin-leaved mesophytes which normally had closed stomata at night and open stomata during the day (could close part of day and open part of the night). (c) Plants like potatoes which, normally had stomata open day and night but closed during the day if the moisture content of the leaves became too low. Transpiration is regulated by environmental factors when the stomata are wide open or nearly so. As the stomata close, their effect in regulating transpiration increases until when nearly closed their effect is greater than the effect of environmental factors.

The effect of sprays on transpiration varies with the type of spray applied. Duggar and Cooley (10) found that a film of Bordeaux Mixture increased transpiration while dusts and other films did not affect the rate of transpiration to the same extent. In a later experiment, they (11) confirmed their earlier conclusion that a film of Bordeaux Mixture facilitated water loss by transpiration. This conclusion was later confirmed by Martin (19) and, also, by Wilson and Runnels (25).

Oil sprays appear to reduce transpiration. Kelley's (13) data showed that oil sprays reduced transpiration as much as 50 per cent in many cases and as much as 75 per cent in some instances. When the oil was sprayed upon the upper surface of the leaves there was, apparently, no reduction in transpiration. When the oil was sprayed upon the lower surface or upon both the upper and lower surfaces of the leaves, transpiration was markedly retarded.

Under certain conditions, root temperatures affect the rate of transpiration from the leaves of plants. Bialoglowski (1) conducted an experiment with lemon cuttings grown in nutrient solutions under such conditions that the tops were subjected to a temperature of 25°C, a relative humidity of 60 to 65 per cent, a light intensity of about 300 foot candles and an average air velocity of 130 feet per minute. The roots were subjected to constant temperatures which ranged from 0°-40°C, by 5° intervals.

Transpiration was not affected during the night by changes in root temperatures within the range 0°-$40^{\circ}C$. During the day, transpiration was markedly reduced by root temperatures below $25^{\circ}C$ and above $35^{\circ}C$ but was not significantly affected by root temperatures between those two limits. Probably, the extreme root temperatures interfered with water absorption during the day thus causing a retardation of transpiration.

The moisture content of different soils and of the same soil at different times varies greatly. The maximum available water is that amount between the wilting coefficient and the field capacity. In Magness' (18) opinion the most satisfactory orchard soil should have a wide range between the wilting coefficient and the field capacity. The wilting coefficient varies greatly with different soils but very slightly with different species of plants. Briggs and Shantz's (5) work on wilting coefficients of various plants indicated that the wilting coefficient varied so slightly with different species of plants as to be insignificant. Briggs and McLane (3) determined the moisture equivalent of 100 types of soils. It varied from 3.6 per cent for coaser soils to 46.5 per cent in heavy clay subsoil. The wilting coefficient of a soil may be so high that the available water in the soil is not sufficient to prevent retardation of transpiration.

Effect of Salts on Transpiration

The effects of chemicals on transpiration of plants are very complicated. The effects vary with such factors as: different combinations of cations and anions, different concentrations of the salts applied and different types of media in which the plants are grown. Bouyoucos (2) did some extensive work on the transpiration of wheat seedlings as affected by different chemical compounds and by different densities of nutrient solutions. To determine the effects of different chemicals on transpiration, he conducted experiments in both water and sand cultures. Glass bottles were used as containers for the water cultures and paraffined wire baskets were used as containers for the sand cultures. At intervals of three to four days, during the experiments, the bottles and baskets were weighed. The loss of weight was attributed to transpiration and this loss was replenished by adding solutions to the bottles and distilled water to the baskets. He used 0.02N solutions of the following salts: $NaNO_3$, KNO_3, Na_3HPO_4, K_2HPO_4, $MgSO_4$, $(NH_4)_2SO_4$, $MgCl_2$, $(NH_4)_2CO_3$, $CaCl_2$, $Ca(NO_3)_2$ and K_2CO_3, applied individually.

The effect of the salts on transpiration of plants grown in water cultures differed from the effects of the salts on transpiration of plants grown in sand cultures. In the water cultures the inhibiting effect on transpiration was as follows: $(NH_4)_2CO_3 > MgSO_4 > MgCl_2 > K_2CO_3 > (NH_4)SO_4 > KNO_3 > Ca(NO_3)_2 > NaNO_3 > CaCl_2 > Na_2HPO_4 > K_2HPO_4$. In the sand cultures the inhibiting effect was in this order: $(NH_4)_2SO_4 > (NH_4)_2CO_3 > MgSO_4 > Ca(NO_3)_2 > MgCl_2 > KNO_3 > CaCl_2 > K_2CO_3 > NaNO_3 > NaHPO_4 > K_2HPO_4$.

The effects of cations and anions were studied by comparing effects of two salts with a common cation or anion and assuming the difference to be due to the effect of the unlike cations or anions. The retarding effect on transpiration rate was as follows: Ca > Na (combined with NO_3), Ca > Mg, Cl > CO_3 (in sand culture), CO_3 > Cl (in solution culture) and SO_4 > Cl. The effect of the ions varied in the different cultures.

In experiments with complete nutrient solutions of different densities, the transpiration rate increased with a decrease in density of the solution until a certain point was reached and then the transpiration rate decreased with further decreases in density of the solution. The density at which the reduction in transpiration occurred varied with the different cultures. It is evident that different densities of the solution had a significant effect on the transpiration of the wheat seedlings.

Harter (12), likewise, found that the effects of salts on transpiration varied with the different concentrations of salts in the soil. In three experiments, he used soils containing 1.5 per cent of total soluble salts, calculated on a dry weight basis in which to grow wheat plants. The check plants were grown in nonsaline garden loam. When the plants were about 6 inches tall, the leaves were removed and the cut surfaces sealed by dipping into melted paraffin. They were weighed at various intervals and the loss of weight taken as the amount of water transpired. The per cent of original weight lost by the leaves was:

Experiment number	1	2	3
Period of Exposure (hours)	21	19	3 1/2
Leaves from plants grown in saline soils	13.6%	16%	5%
Leaves from plants grown in non-saline soils	24.8%	48%	21%

In another experiment wheat was grown in sealed pots of saline soils which had low concentrations of total soluble salts amounting to 0.09 and 0.12 per cent of the dry weight of the soil. The transpiration was determined by the weighing method. In this experiment the plants grown in saline soils transpired faster than the plants grown in nonsaline soils.

In the first experiment, the leaves of the plants grown in saline soils had a deposit of wax on them and thickened cuticles, at the end of the experiment. These conditions were not present in the second experiment. When the salts were present in the soil in sufficient quantities to cause modifications of the plant structure, transpiration was reduced. When the salts were present in the soil in quantities too small to modify the plant structure, transpiration was stimulated.

Reed's (23) experiments with wheat plants produced similar results. The plants were grown in paraffined wire baskets. $NaNO_3$, K_2SO_4 and $CaH_4(PO_4)_2$ were used at concentrations of 100 parts per million of soil. $CaCO_3$ was used at a concentration of 1000 parts per million of soil. The control plants were grown in soil to which no chemicals had been added.

Using the transpiration of the control plants as a basis for comparison and representing it by 100 per cent, the values for the transpiration of the plants subjected to the various treatments were: $NaNO_3$ 90.4 per cent, K_2SO_4 94.8 per cent, $CaH_4(PO_4)_2$ 100.8 per cent and $CaCO_3$ 97.9 per cent.

Meyer (21) found that salts affected the rate of transpiration of cotton plants. During the 4 days of the experiments, the plants were in earthenware pots sealed in Ganong aluminum shells. NaCl, $CaCl_2$, KCl, $NaNO_3$, $Ca(NO_3)_2$ and KNO_3 were applied to the soil in different pots. All salts were applied at concentrations of: 0.025, 0.05, 0.1, 0.2 and 0.4 per cent of the dry weight of the soil. The calcium salts were applied at an additional concentration of 0.8 per cent.

The results showed that all concentrations of all salts, with the exception of the two lowest concentrations of potassium nitrate caused reduction in transpiration as compared to the transpiration of the control plants. The two lowest concentrations of potassium nitrate slightly stimulated transpiration. The rate of transpiration decreased as the accumulation of the salts in the soil increased. The results were essentially the same whether calculated on the basis of leaf area, fresh weight of the tops or dry weight of the tops.

Procedure in Conducting Transpiration Experiments

Various investigators use different methods of studying transpiration. The common methods are: potometer, weighing, cobalt chloride and Freeman (22). Each method has certain advantages as well as certain disadvantages for particular conditions. Miller (22) considers the weighing method to be the most convenient and satisfactory for securing quantitative data. This method does not take account of the increase in weight of the plant due to growth. Maximov (20) maintains that the loss of water from a plant in unit time is hundreds of times as great as the increase in dry weight. Therefore, the error due to disregarding this increase in weight would be insignificant.

Briggs and Shantz (4) recommend sealing pots with wax as a method particularly adapted to the study of transpiration as the loss of water from the soil is practically eliminated except that which is lost through the plants by transpiration.

METHODS AND MATERIALS

This experiment deals with the effect of saline waters upon the rate of transpiration of geraniums (Pelargonium hortorum). Three series of plants: numbered 1, 2, and 3, were used.

In series 1, the following salts were used: NaCl, $NaHCO_3$, $MgCl_2$, $MgSO_4$, $CaCl_2$, and $CaSO_4$. All of these salts, except $CaSO_4$, were used at concentrations of 3000 parts per million. Since $CaSO_4$ formed a saturated solution with 1759 parts per million, it was used at that concentration. Rainwater was used as a check.

The geranium plants were grown in 6 inch glazed pots. The surface of the soil was covered with a wax composed of 7 parts of paraffin and 1 part of beeswax. There was a tendency for the wax to break away from the edges of some of the pots. When this occurred, an electric soldering iron was used to melt the wax around the edge of the pots and reseal them. Paper was wrapped around the plants before the wax was applied to prevent injury. It was wrapped loosely enough to provide room for growth expansion of the plants during the course of the experiment.

To provide for watering the plants, a 2 1/2 inch pot was submerged into the soil in each 6 inch pot. The top of the 2 1/2 inch pot was covered with a piece of cardboard which had been soaked in paraffin. A hole was punched into the center of this cardboard. A 6 inch test tube, the bottom of which had been removed with a resistance wire, was placed into this and permitted to extend upward through the wax. A small cork was placed into the upper end of the tube. See Fig. 1.

A piece of 5 millimeter glass tube 2 1/2 inches long was pushed into the soil and permitted to extend above the wax so that air could enter the soil.

By adding pieces of broken pots on top of the wax, each pot was adjusted to a definite weight of 3325 grams.

1700 grams of soil composed of 1 part clay loam, 1 part fine sandy loam, and 1 part of manure, were placed into each pot. The moisture content of the soil was 28.13 per cent on a dry weight basis.

There were eleven plants in each group (A-------G). Each group was watered with rainwater or a different salt solution. See Table 1 (page 25). The plants were weighed every 48 hours and the loss of weight was taken as a measure of transpiration during that time. In an effort to eliminate differences due to varying light intensity, the groups of plants were rotated each time they were watered and weighed.

The solutions were kept in 5 gallon glass bottles upon an elevated platform. When it was time to record data on the plants, each one was placed upon a small scale and the solutions were delivered through siphons, burettes and rubber tubing to each plant in turn, restoring it to normal weight. The amount of solution used by each plant was read directly from the burette and recorded. See Fig. 2.

Fig. 1. Plants as grown for these experiments. The test tubes were to provide a means of watering the plants.

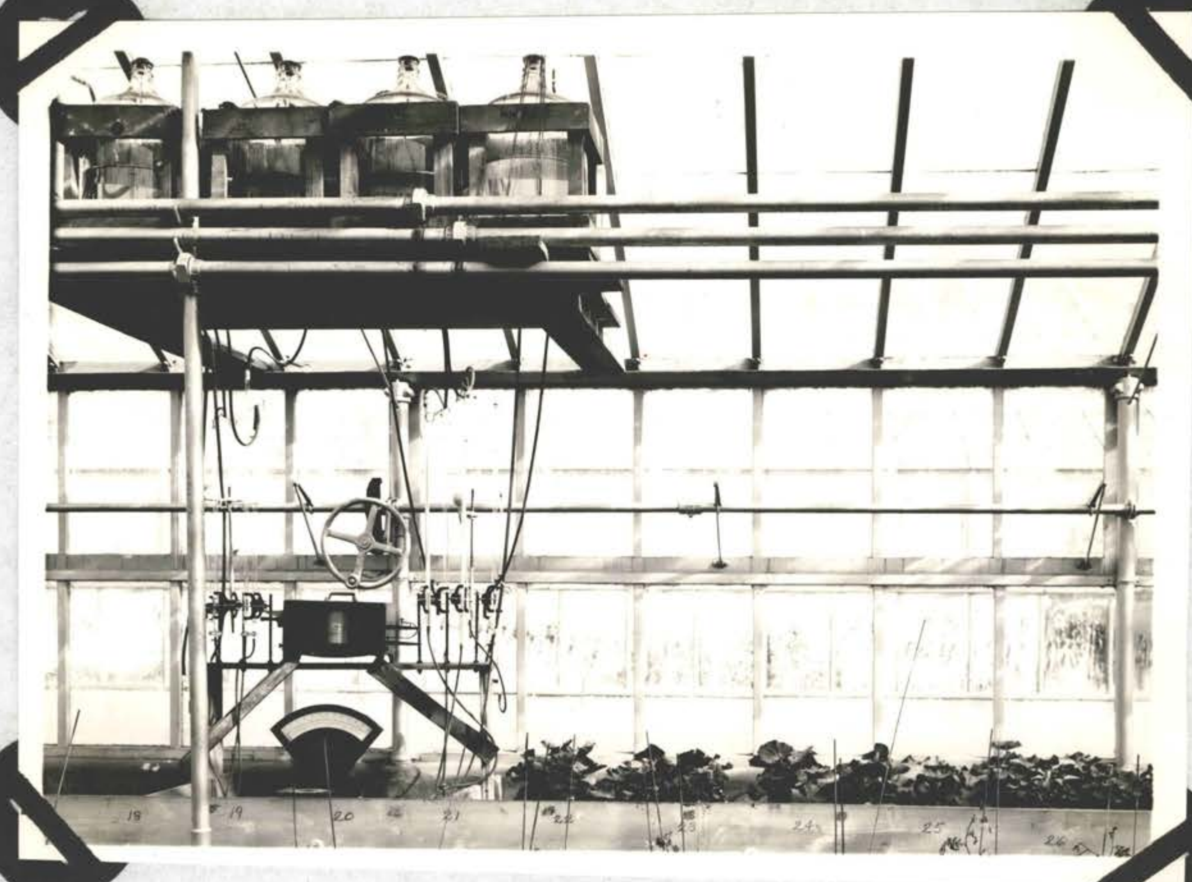


Fig. 2. A general view of the set-up for the experiment. The bottles on the platform were for the solutions. The burettes, tubes and scales were used to determine the proper amount of solutions to be added to the plants. The atmometer was used to measure the evaporating power of the air. The hydro-thermo-graph (above the scales) was usually located upon the bench behind the scales but for the purpose of taking this picture it was placed onto the support above the scales.

In an effort to keep the variation in leaf area as small as possible during the time of the experiment (28 days), new leaves were cut off as formed.

To determine the evaporating power of air, a Livingston atmometer was attached to a burette. To prevent there being too great a difference between the water levels in the burette and the atmometer, readings were made at 7:30 A.M., 10:00 A.M. and 4:30 P.M., the data recorded, and the water level in the burette adjusted to zero.

At the beginning of the experiment the pH of the soil and of each solution was determined. At the close of the experiment, the pH of the soil in each group, which was watered with a different solution, was determined. The pH determinations were made by using a Universal pH Potentiometer Assembly (quinhydrone). See Table 1V.

At the close of the experiment, one plant from each group (A-------G), was set aside and permitted to dry until the leaves began to wilt. The pots were then plunged into soil in a bench and the plants covered with a bell jar. The leaves were, thus, in an atmosphere which had a high relative humidity. When the permanent wilting point was reached, the moisture content of the soil was determined. See Table V.

A hydro-thermo-graph was used for recording temperature and relative humidity. The chart was changed at the end of each week. The mean temperature and relative humidity was determined for each 48 hour period by integrating curves by means of a planimeter. See Table 111 and Figs. 3-12 inc.

HYDRO-THERMO-GRAPH CHARTS FOR SERIES 1

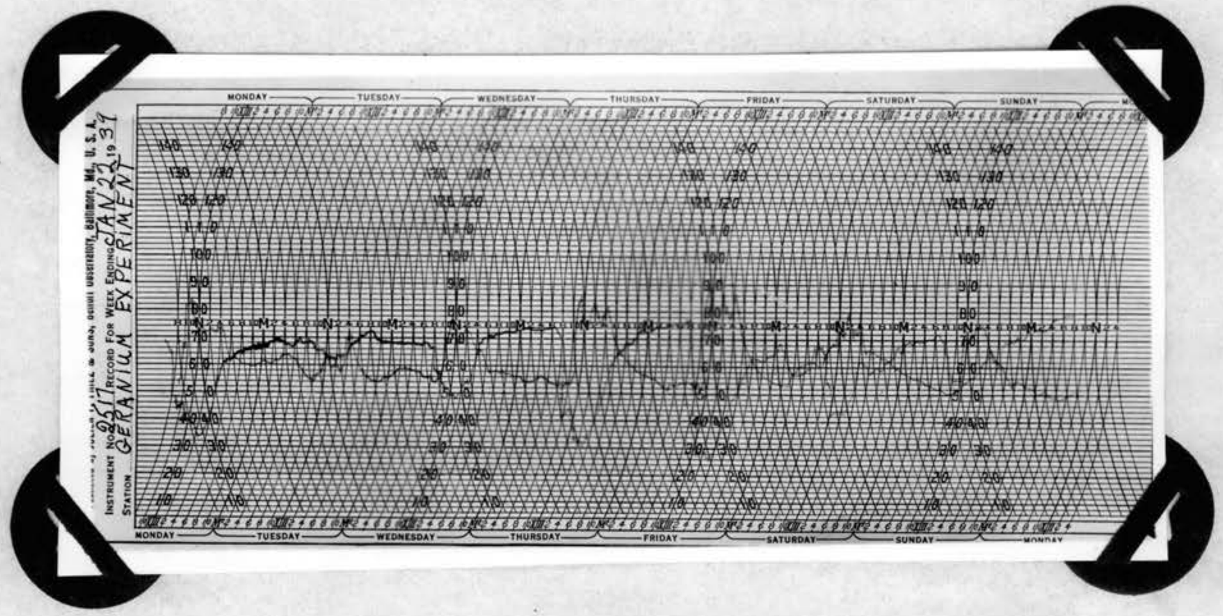


Fig. 3. Chart for week ending Jan. 22, 1939.

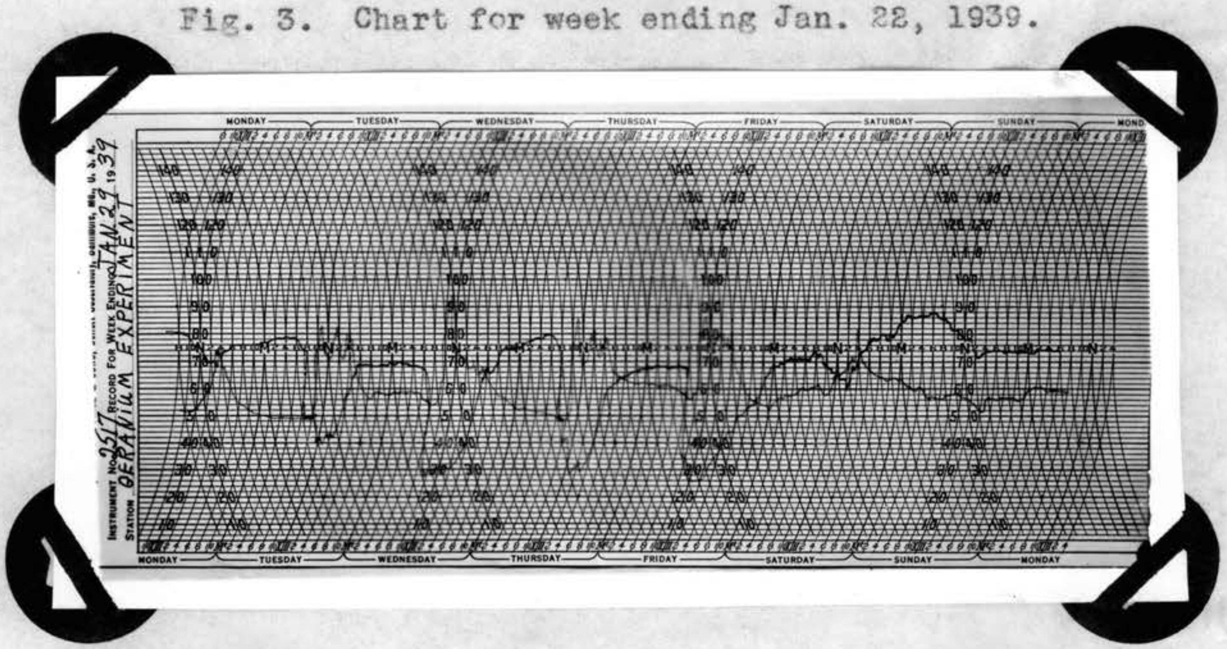


Fig. 4. Chart for week ending Jan. 29, 1939.

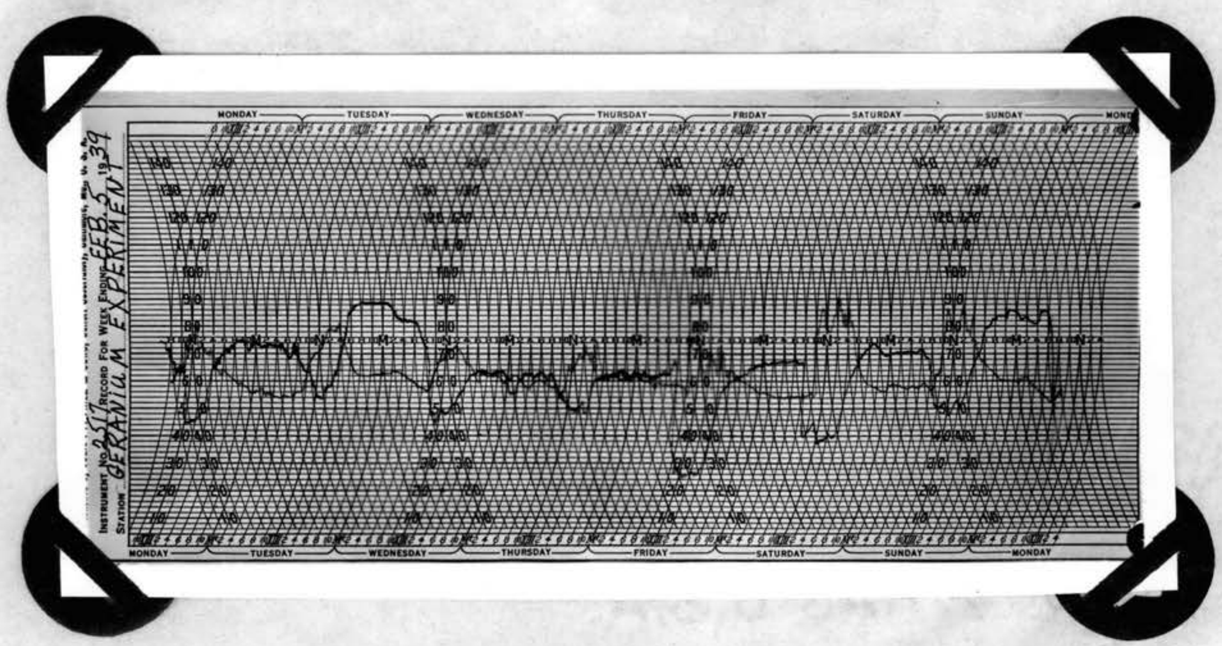


Fig. 5. Chart for week ending Feb. 5, 1939

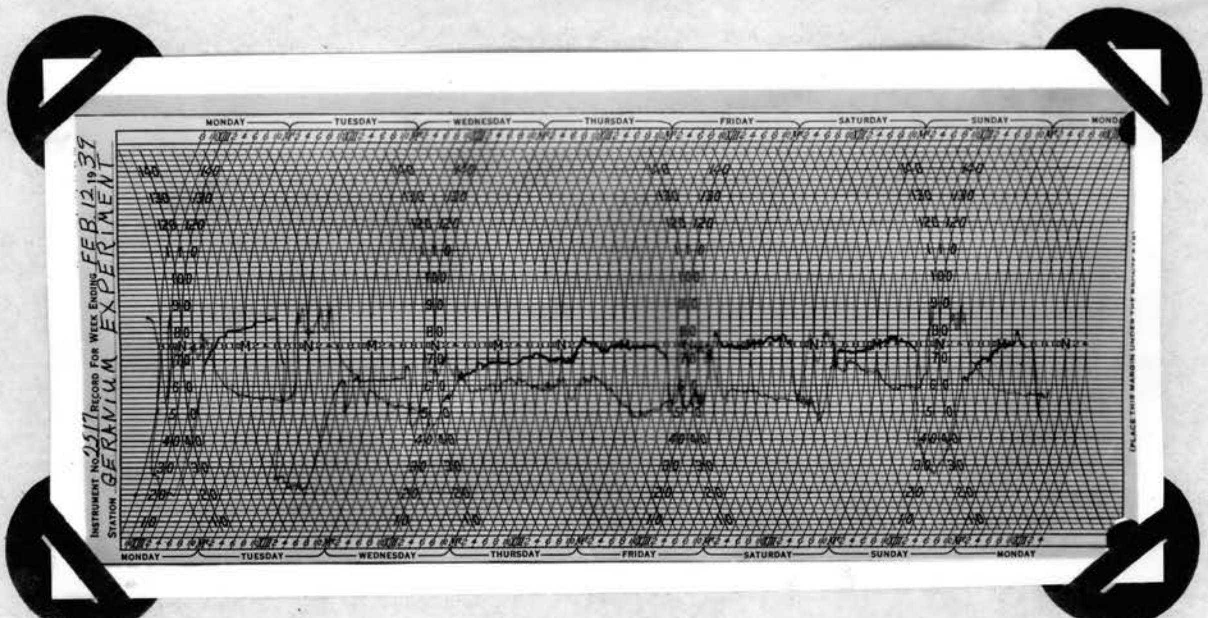


Fig. 6. Chart for week ending Feb. 12, 1939.

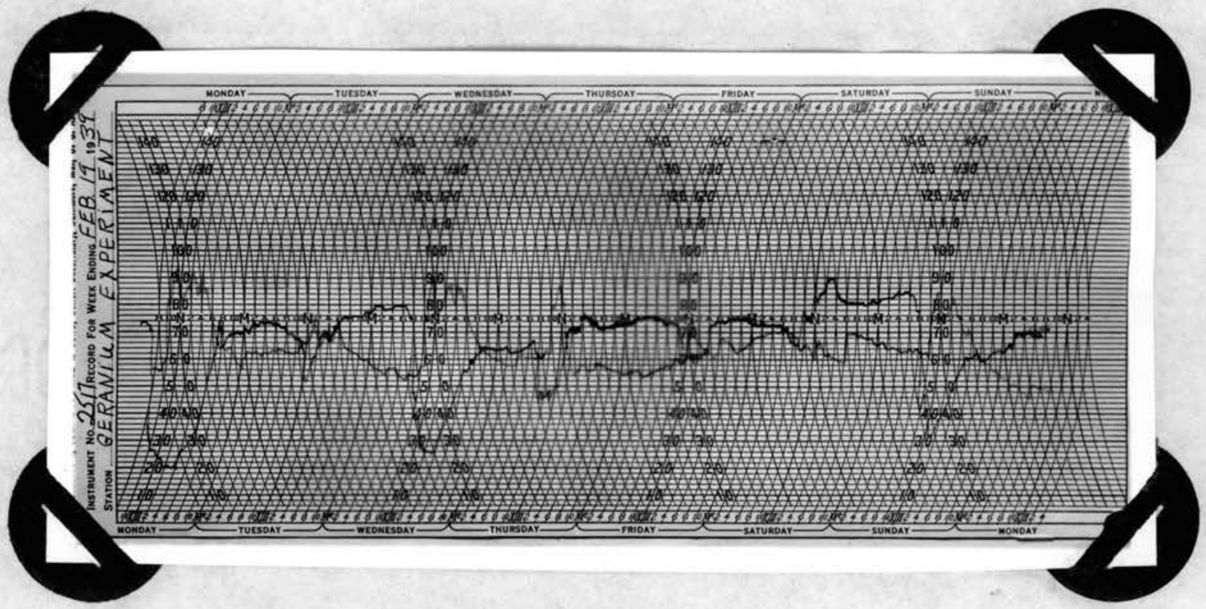


Fig. 7. Chart for week ending Feb. 19, 1939.

The mean temperature and relative humidity per 48 hour period is shown in Table 111.

HYDRO-THERMO-GRAPH CHARTS FOR SERIES 2 AND 3

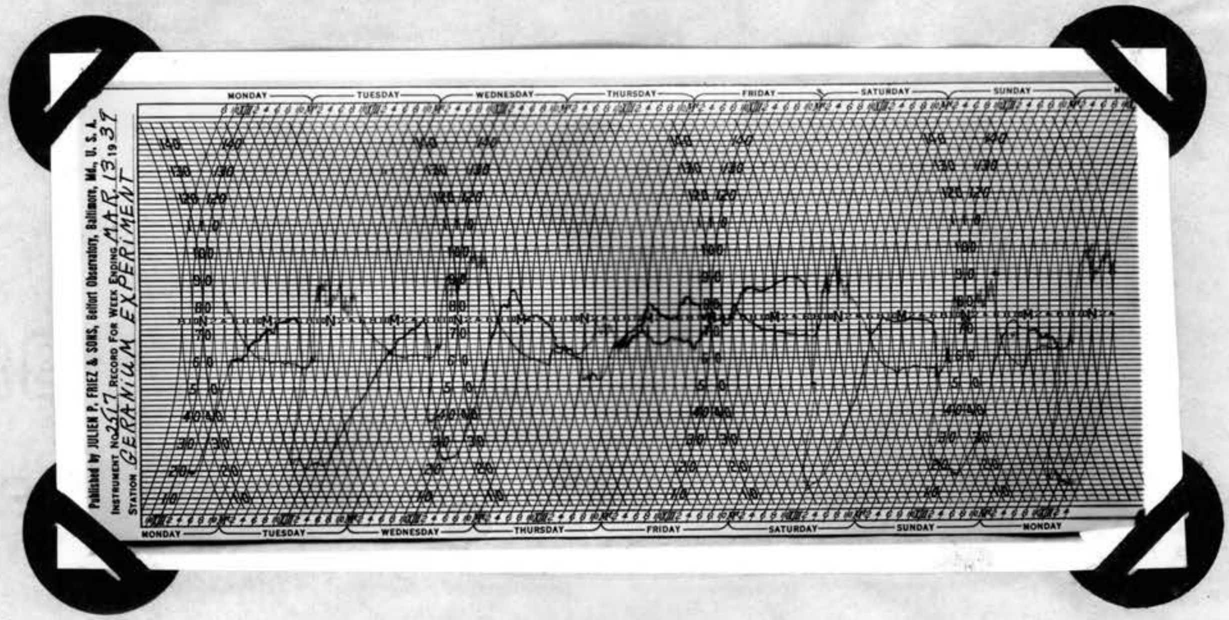


Fig. 8. Chart for week ending Mar. 13, 1939.

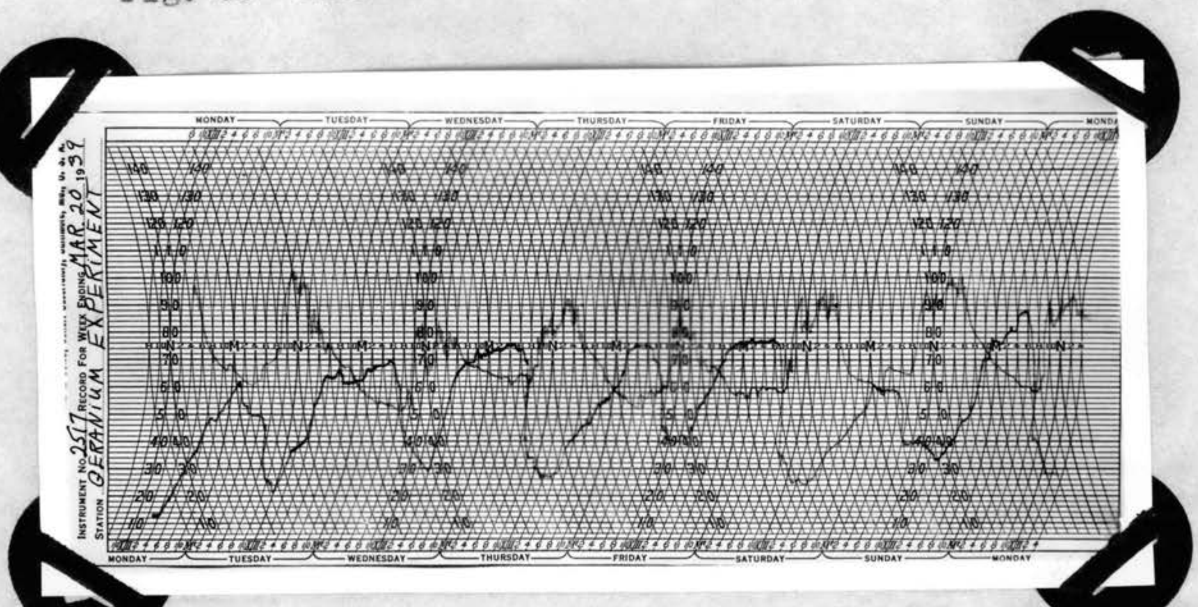


Fig. 9. Chart for week ending Mar. 20, 1939.

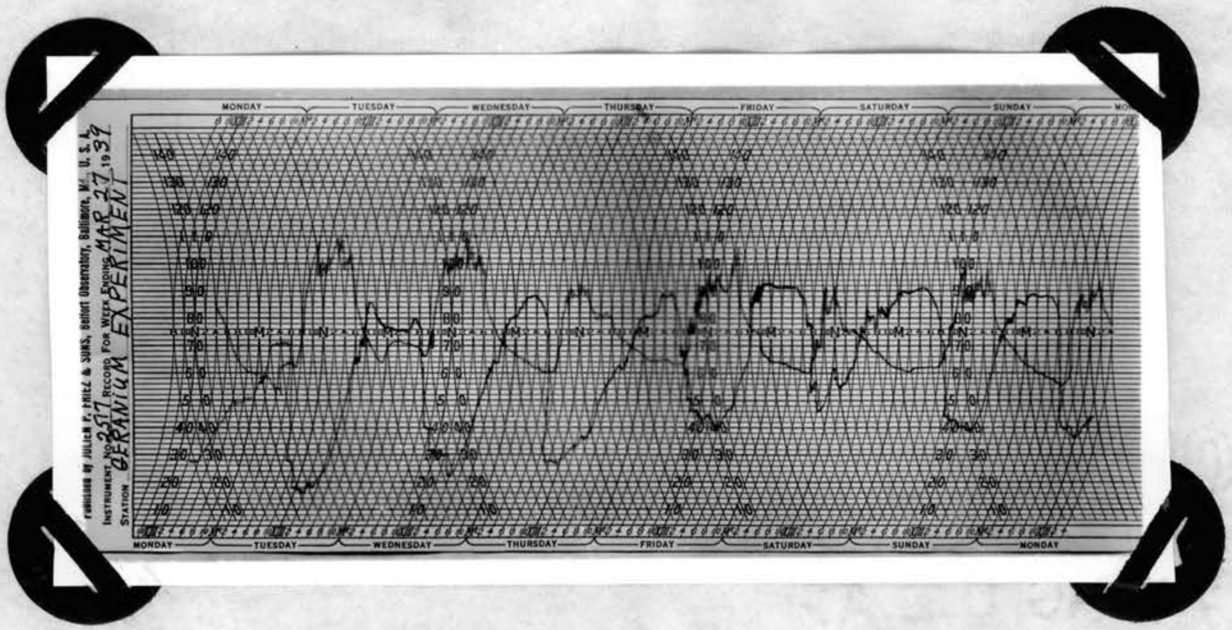


Fig. 10. Chart for week ending Mar. 27, 1939.

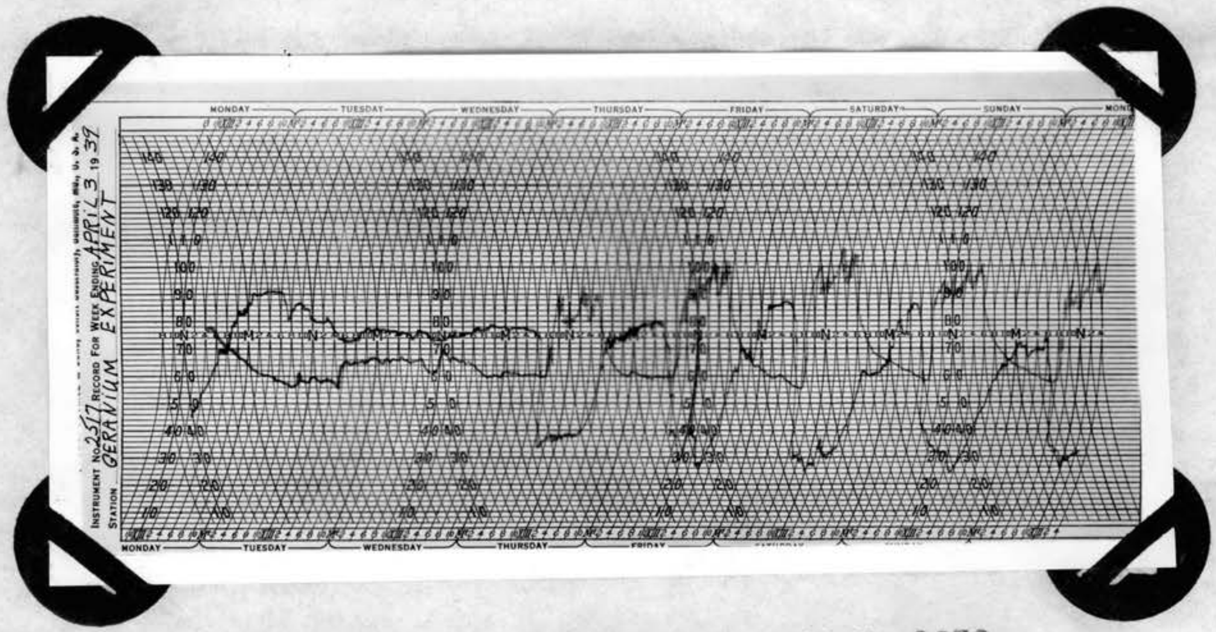


Fig. 11. Chart for week ending April 3, 1939.

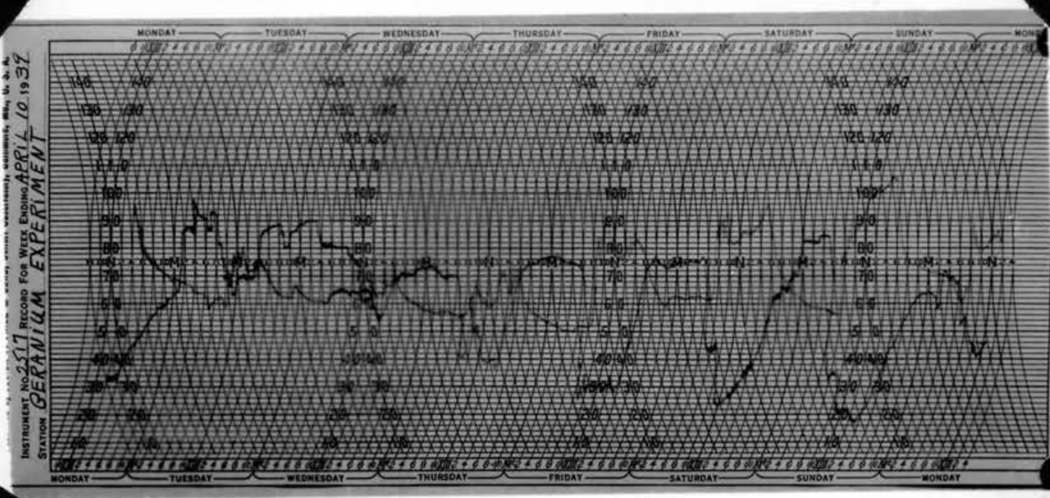


Fig. 12. Chart for week ending April 10, 1939.

The mean temperature and relative humidity per 48 hour period is shown in Tables V11l and X1l.

At the end of 28 days, the leaves were removed from the remaining ten plants in each group and blue printed. By means of a planimeter, the total leaf area of each plant was determined from these blue prints. See Table 1.

Series 2 and 3 were conducted concurrently. Although there were some small variations in method of conducting, it was in general the same as for series 1. Series 2 and 3 were conducted over a period of 22 days. Each pot contained 1700 grams of soil composed of 2 parts of fine sandy loam and 1 part of sewer sludge. The moisture content of the soil at the beginning of the experiment was 32.47 per cent on a dry weight basis.

There were 10 plants in each group (A-----M) in these series. The pots were sealed as in series 1 and adjusted to a definite weight of 3400 grams. The pH: of each solution applied, of the soil at the beginning of the experiment, and of the soil in each group (A-----M) at the end of the experiment (after being treated for 22 days) was determined. See Tables 1X and X111. The atmometer readings were taken and the water level in the burette adjusted to zero at 7:00 A.M., 12:00 M and 5:00 P.M. The leaf areas were determined as in series 1.

In series 2, the same salts and same concentrations were used as in series 1. In series 3, the salts were used at a concentration of 6000 parts per million. Since $CaSO_4$ forms a saturated solution with 1759 parts per million, it was omitted from this series.

With the exceptions noted above, the method of conducting series 2 and 3 was the same as the method of conducting series 1.

PRESENTATION OF DATA

Series 1

The transpiration per square inch of leaf area when the plants were subjected to various treatments is given in Table 1.

Table 1. The effect of various salts on the rate of transpiration per square inch of leaf surface during a period of 28 days.*

Plant number	Total leaf area (Sq. in.)	Grams of water lost per plant during 28 days	
		Total	Per Sq. in. of leaf surface
Group A. Treated with 3000 parts per million of NaCl			
1	87.71	1008.8	11.50
2	59.90	716.2	11.96
3	21.89	369.6	16.88
4	46.67	550.7	11.80
5	62.67	754.1	12.03
6	51.78	649.6	12.55
7	54.52	585.6	10.74
8	55.46	550.8	9.93
9	105.11	915.5	8.71
10	97.98	720.6	7.35
Group B. Treated with 3000 parts per million of $NaHCO_3$			
1	66.42	919.2	13.84
2	51.63	705.3	13.66
3	49.55	704.6	14.22
4	65.47	1046.4	15.98

5	111.37	1234.0	11.08
6	49.13	714.9	14.55
7	98.40	1106.2	11.24
8	154.48	1957.2	12.67
9	79.17	1346.3	17.01
10	110.41	1448.5	13.12
Group C.	Treated with 3000 parts per million of $MgCl_2$		
1	64.96	682.3	10.50
2	44.24	492.8	11.14
3	60.76	677.4	11.15
4	88.46	826.9	9.35
5	41.49	508.1	12.25
6	44.92	558.0	12.42
7	92.39	684.4	7.41
8	159.87	1212.9	7.59
9	99.90	1116.7	11.18
10	96.24	947.1	9.84
Group D.	Treated with 3000 parts per million of $MgSO_4$		
1	52.16	681.3	13.06
2	62.53	983.5	15.64
3	68.50	760.3	11.10
4	81.70	1008.0	12.34
5	97.88	1281.8	13.10
6	57.91	770.2	13.30
7	41.42	670.8	16.20
8	140.31	1568.1	11.32
9	123.35	1670.2	13.54

10	114.77	1448.0	12.62
Group E. Treated with 3000 parts per million of $CaCl_2$			
1	62.84	757.9	12.06
2	46.56	422.7	9.08
3	91.94	810.9	8.82
4	41.04	561.1	13.67
5	45.64	544.6	11.93
6	93.87	987.2	10.52
7	44.19	504.3	11.41
8	93.30	1045.6	11.21
9	140.11	1332.3	9.51
10	119.56	1133.9	9.48
Group F. Treated with 1759 parts per million of $CaSO_4$**			
1	36.99	505.0	13.65
2	45.16	629.8	13.95
3	56.83	728.5	12.82
4	77.75	1053.7	13.55
5	75.77	1021.7	13.48
6	105.26	1167.6	11.09
7	86.33	874.3	10.13
8	94.24	1336.1	14.18
9	145.32	1451.2	9.99
10	132.99	1666.6	12.53
Group G. Treated with rainwater			
1	58.27	773.6	13.28
2	36.41	650.7	17.87
3	71.60	1055.58	14.75

4	80.14	1006.2	12.56
5	82.75	1032.2	13.08
6	77.06	927.1	12.03
7	112.27	1403.9	12.50
8	137.79	1743.2	12.65
9	114.39	1649.0	14.42
10	159.97	1640.8	10.26

* Each pot contained 1700 grams of soil. Its moisture content was 28.13 per cent on a dry weight basis, at the beginning of the experiment.

** $CaSO_4$ forms a saturated solution at a concentration of 1759 parts per million.

Table 11. Grams of water lost per square inch of leaf surface from seven groups of plants, each group of plants watered with rainwater or a different salt solution, for 14 periods of 48 hours each.

48 hour period ending at 4:00 P.M. on:	Treatment								
	$NaCl$	$NaHCO_3$	$MgCl_2$	$MgSO_4$	$CaCl_2$	$CaSO_4$	rain water	Total	Mean
Jan. 18, 1930	0.8	0.8	0.7	0.7	0.8	0.6	0.7	5.1	0.73
Jan. 20, 1939	1.0	1.1	1.1	1.1	1.0	1.0	1.0	7.3	1.04
Jan. 22, 1939	0.7	0.8	0.7	0.8	0.7	0.7	0.7	5.1	0.73
Jan. 24, 1939	0.8	0.8	0.7	0.8	0.8	0.6	0.7	5.2	0.74
Jan. 26, 1939	1.1	1.2	0.9	1.0	1.0	1.0	1.2	7.4	1.06
Jan. 28, 1939	0.8	1.0	0.8	1.0	0.7	0.8	0.9	6.0	0.86
Jan. 30, 1939	0.5	0.5	0.4	0.5	0.4	0.5	0.6	3.4	0.49
Feb. 1, 1939	0.8	0.9	0.6	0.9	0.7	0.8	0.8	5.5	0.79
Feb. 3, 1939	0.8	1.0	0.7	0.9	0.8	0.9	0.9	6.0	0.86
Feb. 5, 1939	0.8	1.1	0.8	1.2	0.8	1.1	1.2	7.0	1.00
Feb. 7, 1939	1.0	1.4	0.9	1.5	0.8	1.2	1.3	7.9	1.13
Feb. 9, 1939	0.5	0.8	0.5	0.8	0.7	0.8	0.8	4.9	0.70
Feb. 11, 1939	0.3	0.9	0.4	0.8	0.4	0.7	0.8	4.3	0.61
Feb. 13, 1939	0.8	1.2	0.6	1.2	0.9	1.4	1.3	7.4	1.06
Total	10.7	13.5	9.8	13.0	10.5	12.1	12.9	82.5	
Mean	0.76	0.96	0.70	0.93	0.75	0.86	0.92		

Analysis of Variance[1]

Factors of Variance	d/f	Sum of Sq.	Mean sq. or variance	F value	Value required for: 5%	1%
Total	97	5.2785				
Treatment	6	0.8949	0.14915	11.2143	2.21	3.04
Replicates	13	3.3470	0.2575	19.3609	1.89	2.41
Tr. & Rep.	19	4.2419				
Remainder	78	1.0366	0.0133			

Difference necessary for significance $= \frac{\sigma}{\sqrt{N}} \times 2\sqrt{2}$

$\sigma = \sqrt{0.0133} = 0.1153$

$\frac{0.1153}{\sqrt{14}} \times 2\sqrt{2} = \frac{0.1153}{3.7417} \times 2.83 = 0.087204$

The analysis of variance showed that the salt treatments were highly significant in retarding transpiration. The chlorides retarded the transpiration enough to be significant but the bicarbonate and the sulphates did not.

1. Formulas taken from Love (17).

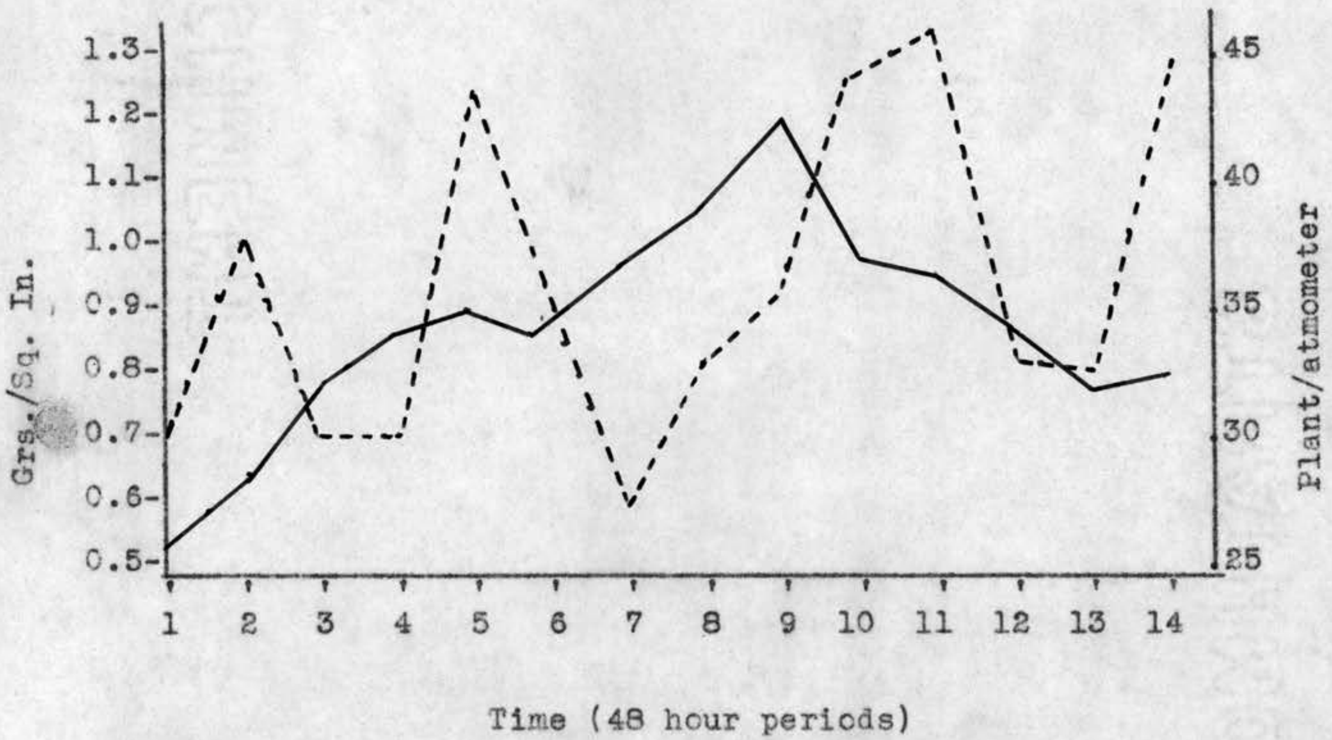
Table 111. Mean relative humidity and temperature and ratios of transpiration in grams per square inch of leaf surface to evaporation in grams per square inch of atmometer surface during 14, 48 hour periods.

48 hour period ending 4:00 P.M. on:	Treatment							Evap. from atm. Grs. per Sq.In.	Mean	
	$NaCl$	$NaHCO_3$	$MgCl_2$	$MgSO_4$	$CaCl_2$	$CaSO_4$	rain water		R. H. %	Temp. 0 F
Jan. 18, 1939	0.296	0.296	0.259	0.259	0.296	0.222	0.259	2.7	64.30	60.92
Jan. 20, 1939	0.333	0.367	0.367	0.367	0.333	0.333	0.333	3.0	60.74	62.87
Jan. 22, 1939	0.269	0.308	0.269	0.308	0.269	0.269	0.269	2.6	59.36	62.99
Jan. 24, 1939	0.421	0.421	0.368	0.421	0.421	0.316	0.368	1.9	57.98	56.18
Jan. 26, 1939	0.344	0.375	0.281	0.313	0.313	0.313	0.375	3.2	58.68	61.49
Jan. 28, 1939	0.276	0.345	0.276	0.345	0.241	0.276	0.310	2.9	60.05	65.29
Jan. 30, 1939	0.278	0.278	0.222	0.278	0.222	0.278	0.333	1.8	74.85	61.04
Feb. 1, 1939	0.471	0.529	0.353	0.529	0.412	0.471	0.471	1.7	71.41	63.45
Feb. 3, 1939	0.286	0.357	0.250	0.321	0.286	0.321	0.321	2.8	59.02	62.30
Feb. 5, 1939	0.286	0.393	0.286	0.429	0.286	0.393	0.429	2.8	59.47	67.35
Feb. 7, 1939	0.286	0.400	0.257	0.371	0.229	0.343	0.371	3.5	59.94	59.54
Feb. 9, 1939	0.192	0.308	0.192	0.308	0.269	0.308	0.308	2.6	62.23	60.46
Feb. 11, 1939	0.120	0.360	0.160	0.320	0.160	0.280	0.320	2.5	67.05	61.95
Feb. 13, 1939	0.200	0.300	0.150	0.300	0.225	0.350	0.325	4.0	56.83	67.82

Table 111 indicates that the ratios of transpiration from plants treated with NaCl, $MgCl_2$, and $CaCl_2$, to the evaporation from an atmometer are less than the ratios of transpiration from plants treated with $NaHCO_3$, $MgSO_4$ and $CaSO_4$ to the evaporation from the atmometer.

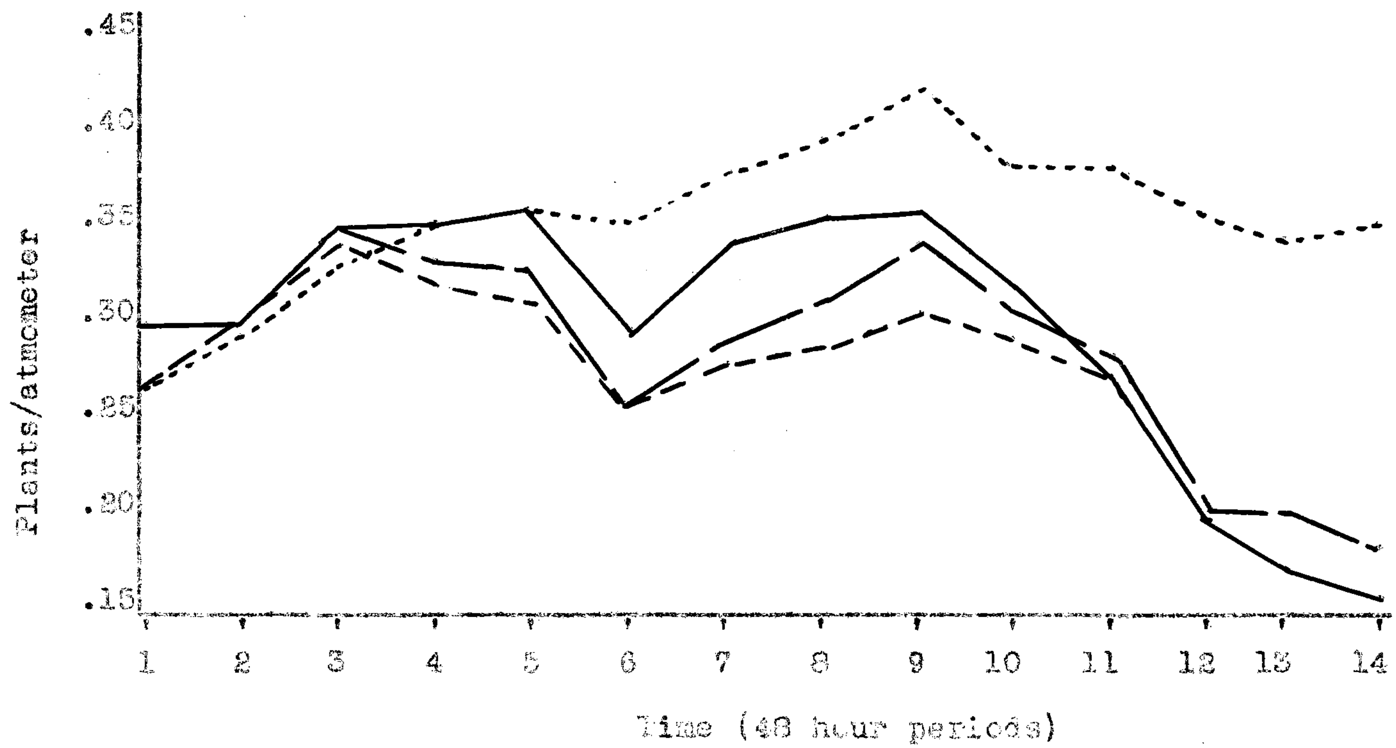
It was felt that the moving average would give a better picture of the general trend of results than the actual transpiration per square inch, since the moving average tends to smooth the effects of fluctuations from period to period. See Fig. 13.

Figs. 14 and 14A picture graphically the retarding effect of NaCl, $MgCl_2$, and $CaCl_2$ as contrasted to the lack of retardation of transpiration from plants treated with $CaSO_4$, $MgSO_4$, $NaHCO_3$ and rainwater.



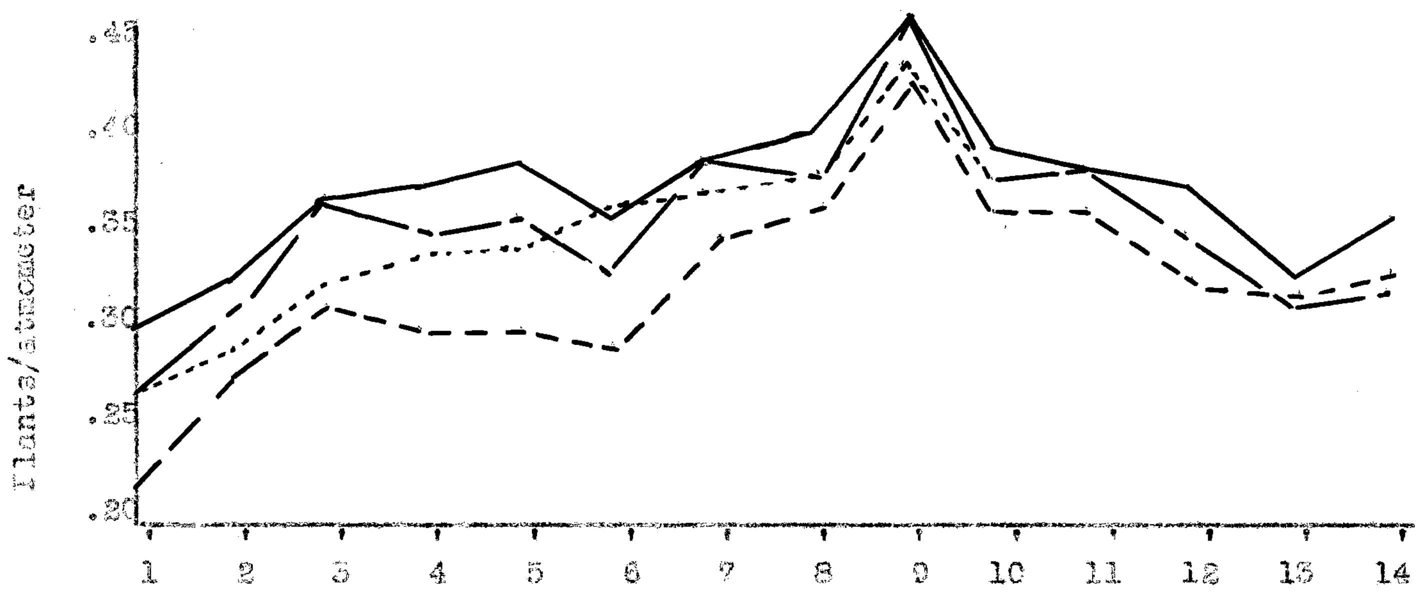
Key: ______________Moving average (ratio)_ _ _ _Transpiration

Fig. 13. Transpiration in grams per square inch of leaf area of ten plants watered with rainwater and the ratio, expressed by means of a moving average, of transpiration to evaporation from an atmometer for 28 days.



Key: ________ NaCl, ______ _ $CaCl_2$, _ _ _ _ _ _ $MgCl_2$, -------- rainwater

Fig. 14. A comparison of the ratios of transpiration, of plants treated with different solutions, to the evaporation from an atmometer, by means of a moving average, for 28 days.



Key: ________ $NaHCO_3$, ________ _ $MgSO_4$, _ _ _ _ _ _ $CaCl_2$, ----- rainwater

Fig. 14A. A comparison of the ratios of transpiration, of plants treated with various salt solutions, to the evaporation from an atmometer, by means of a moving average, during 28 days.

Table 1V. * The pH of the salt solutions applied, and of the soil after the solutions had been applied during 28 days.

Materials	pH of the solutions applied	pH of soil after solutions were applied 28 days
NaCl	6.80	6.78
$NaHCO_3$	9.55	7.98
$MgCl_2$	8.70	7.14
$MgSO_4$	8.28	6.55
$CaCl_2$	7.70	7.28
$CaSO_4$	7.70	7.86
Rainwater	7.90	7.55

* The pH of the soil at the beginning of the experiment was 7.40.

The results given in Table 1V indicate that the pH of the soil at the end of the experiment was affected by the pH of the solutions applied.

Table V. The moisture content of the soil at the beginning of the experiment and the wilting coefficients after the plants had been treated with various salts during 28 days.*

Treatment	Moisture content of soil at the beginning of exp.	Wilting coefficient at end of exp.
No treatment	28.13%	3.90%
NaCl 3000 PPM	28.13	7.41
$NaHCO_3$ 3000 PPM	28.13	4.97
$MgCl_2$ 3000 PPM	28.13	6.11
$MgSO_4$ 3000 PPM	28.13	4.83
$CaCl_2$ 3000 PPM	28.13	6.61
$CaSO_4$ 3000 PPM	28.13	6.59
Rainwater	28.13	4.43

* The moisture content was determined on a dry weight basis at the beginning of the experiment and the wilting coefficient was determined on a dry weight basis at the end of the experiment.

From the wilting coefficients given in Table V., it appears that the plants can reduce the moisture content of the soil to a lower level when treated with $CaSO_4$, $MgSO_4$, $NaHCO_3$ and rainwater than they can when treated with NaCl, $MgCl_2$ and $CaCl_2$.

Series 2

Series 2 was conducted to see if it were possible to duplicate the results obtained in series 1. In Table V1 is given the treatment of the various plants together with: their total leaf area, the total transpiration and the rate of transpiration per square inch of leaf area during a period of 22 days.

Table V1. The effect of various salts upon the rate of transpiration per square inch of leaf surface when applied during 22 days.

Plant number	Total leaf area (Sq. in.)	Grams of water lost per plant during 22 days	
		Total	Per Sq. in. of leaf surface
Group A. Treated with 3000 parts per million of NaCl			
1	29.72	469.6	15.80
2	31.12	609.2	19.58
3	17.48	302.3	17.29
4	10.82	262.8	24.29
5	13.07	193.4	14.80
6	14.82	234.4	15.82
7	23.37	378.0	16.17
8	32.25	500.3	15.51
9	14.20	280.6	19.76
10	18.87	471.9	25.01
Group B. Treated with 3000 parts per million of $NaHCO_3$			
1	7.42	265.5	35.78
2	27.64	518.3	18.75
3	16.25	482.0	29.66

4	36.86	748.7	20.31
5	12.68	339.0	26.74
6	10.44	341.5	32.71
7	32.31	641.0	19.84
8	14.12	369.8	26.19
9	24.65	531.8	21.57
10	25.36	668.1	26.34
Group C.	Treated with 3000 parts per million of $MgCl_2$		
1	15.41	340.5	22.10
2	7.77	171.0	22.01
3	23.35	437.0	18.72
4	10.47	154.3	14.74
5	17.85	400.7	22.45
6	18.95	383.8	20.25
7	13.16	348.2	26.46
8	21.94	451.2	20.57
9	20.02	491.4	24.55
10	28.42	506.8	17.83
Group D.	Treated with 3000 parts per million of $MgSO_4$		
1	44.10	896.5	20.33
2	16.30	390.5	23.96
3	32.16	713.0	22.17
4	9.23	323.6	35.06
5	29.32	416.8	14.22
6	26.02	663.4	25.50
7	25.95	537.4	20.71
8	8.62	228.0	26.45

9	15.32	313.8	20.48
10	21.93	577.4	26.33
Group E.	Treated with 3000 parts per million of $CaCl_2$		
1	28.22	555.6	19.69
2	66.93	714.8	10.68
3	29.42	524.0	17.81
4	25.02	451.7	18.05
5	11.17	235.8	21.11
6	76.82	945.9	12.31
7	13.73	303.4	22.10
8	14.14	288.3	20.39
9	46.96	764.0	16.27
10	49.10	730.5	14.88
Group F.	Treated with 1759 parts per million of $CaSO_4$*		
1	20.15	349.7	17.35
2	20.28	558.8	27.55
3	11.98	356.0	29.72
4	20.06	521.3	25.99
5	16.73	365.7	21.86
6	29.58	703.7	23.79
7	30.06	704.9	23.45
8	17.90	339.4	18.96
9	62.33	1083.2	17.38
10	18.31	430.2	23.50
Group G.	Treated with rainwater		
1	25.14	805.1	32.02
2	40.89	988.9	24.18

3	26.26	610.4	23.24
4	25.88	731.6	28.27
5	20.59	581.9	28.26
6	26.25	657.1	25.03
7	16.58	310.7	18.74
8	38.64	909.5	23.54
9	11.79	249.9	21.20
10	27.76	735.4	26.49

* $CaSO_4$ forms a saturated solution at that concentration.

Table V11. Grams of water lost per square inch of leaf surface from seven groups of plants, each group watered with rainwater or a different salt solution, during 11 periods of 48 hours each.

48 hour period ending at 6:00 P.M. on:	Treatment							Total	Mean
	$NaCl$	$NaHCO_3$	$MgCl_2$	$MgSO_4$	$CaCl_2$	$CaSO_4$	rain water		
Mar. 15, 1939	0.9	1.2	1.3	1.3	1.2	1.3	1.1	8.3	1.19
Mar. 17, 1939	3.5	4.0	4.2	3.7	2.3	2.9	3.2	23.8	3.40
Mar. 19, 1939	1.4	1.8	1.4	1.7	1.5	1.8	1.9	11.5	1.64
Mar. 21, 1939	1.7	2.1	1.9	2.0	1.7	2.0	2.7	14.1	2.01
Mar. 23, 1939	2.2	2.8	2.5	2.8	1.4	2.3	2.7	16.7	2.39
Mar. 25, 1939	1.1	1.7	1.2	1.3	0.9	1.3	1.6	9.1	1.30
Mar. 27, 1939	1.4	1.8	1.5	1.8	1.3	2.0	2.1	11.9	1.70
Mar. 29, 1939	0.8	0.9	0.8	1.1	0.6	0.8	1.0	6.0	0.86
Mar. 31, 1939	1.8	2.6	2.2	2.3	1.4	2.4	3.3	16.0	2.29
Apr. 2, 1939	2.0	3.1	2.5	2.9	1.7	3.1	3.6	18.9	2.70
Apr. 4, 1939	1.3	1.5	1.2	1.2	1.0	2.0	2.3	10.5	1.50
Total	18.1	23.5	20.7	22.1	15.0	21.9	25.5	146.8	
Mean	1.65	2.14	1.88	2.01	1.36	1.99	2.32		

Analysis of Variance[1]

Factors of Variance	d/f	Sum of Sq.	Mean sq. or variance	F value	Value required for: 5%	1%
Total	76	51.127				
Treatment	6	6.638	1.106	11.228	2.25	3.12
Replicates	10	38.578	3.858	39.168	1.01	2.66
Tr. & Rep.	16	45.216				
Remainder	60	5.911		0.0985		

Difference necessary to be significant $= \frac{\sigma}{\sqrt{N}} \times 2\sqrt{2}$

$\sigma = \sqrt{0.0985} = 0.3138$

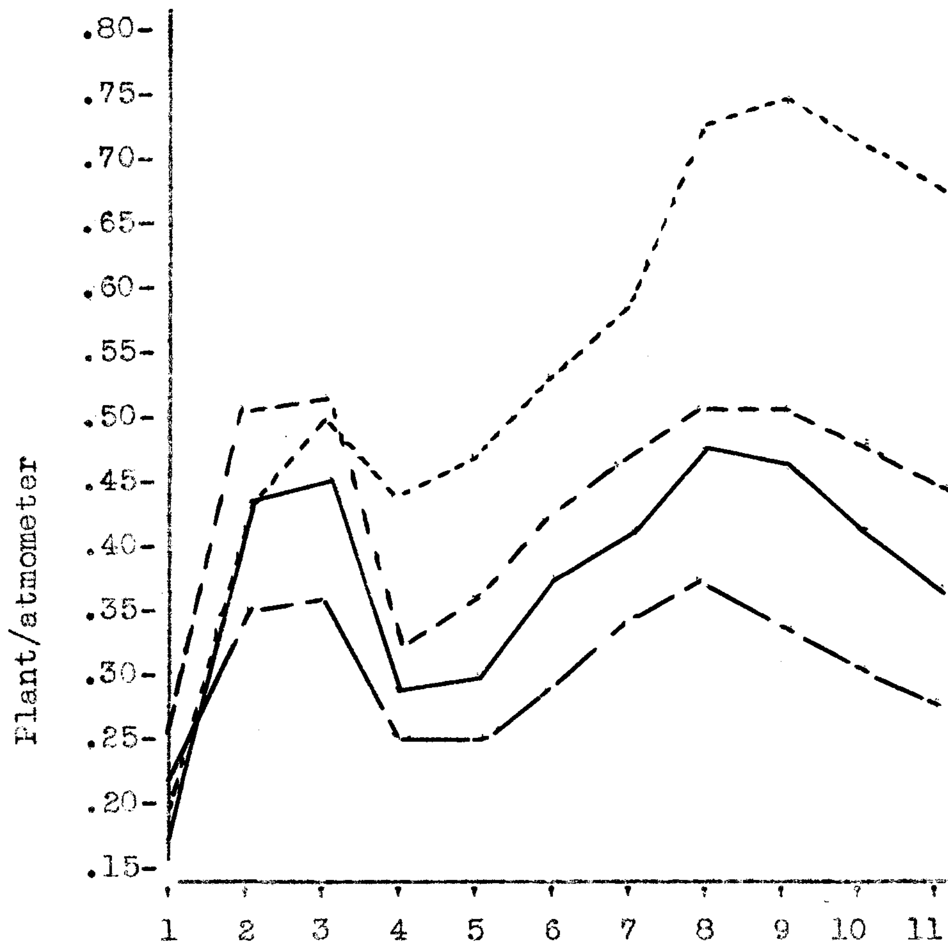
$\frac{0.3138}{\sqrt{11}} \times 2\sqrt{2} = \frac{0.3138}{3.3166} \times 2.83 = 0.26776$

An analysis of variance, calculated from the data of Table V11, showed similar results to those obtained when an analysis of variance was calculated from the data in Table 11. Again the treatments were highly significant. The chlorides retarded transpiration more than the other salts did. In this series, $MgSO_4$ and $CaSO_4$ retarded the rate of transpiration enough to be significant.

1. Formulas taken from Love (17).

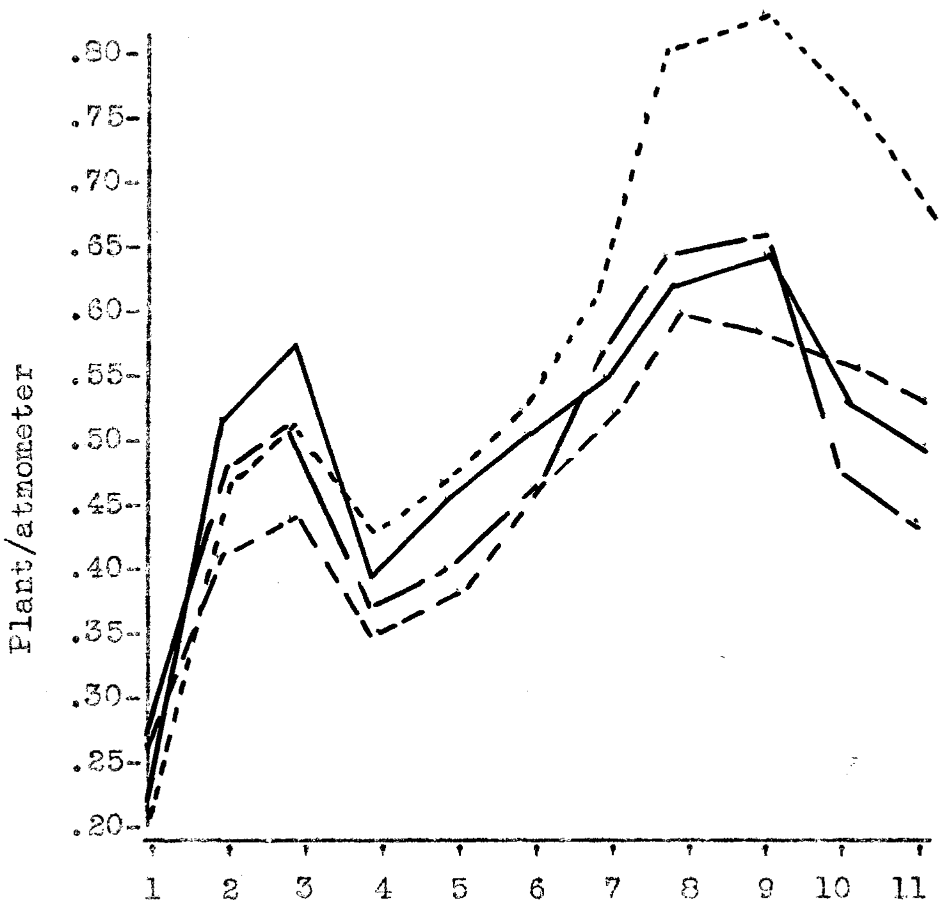
Table V111. Mean relative humidity and temperature and ratios of transpiration in grams per square inch of leaf surface to evaporation in grams per square inch of atmometer surface for 11 periods of 48 hours each.

48 hour period ending 6:00 P.M. on:	Treatment							Evap. from atm. Grs. per Sq.In.	Mean	
	NaCl	$NaHCO_3$	$MgCl_2$	$MgSO_4$	$CaCl_2$	$CaSO_4$	rain water		R. H. %	Temp. ° F
Mar. 15, 1939	0.164	0.218	0.236	0.236	0.218	0.236	0.200	5.5	54.10	71.29
Mar. 17, 1939	0.881	1.007	1.057	0.951	0.579	0.730	0.805	4.0	61.75	69.09
Mar. 19, 1939	0.236	0.303	0.236	0.286	0.253	0.303	0.320	5.9	56.04	73.59
Mar. 21, 1939	0.276	0.341	0.308	0.325	0.276	0.325	0.438	6.2	49.04	77.10
Mar. 23, 1939	0.337	0.493	0.440	0.493	0.247	0.405	0.476	5.7	57.45	78.30
Mar. 25, 1939	0.306	0.471	0.333	0.330	0.249	0.380	0.443	3.6	70.00	75.05
Mar. 27, 1939	0.444	0.571	0.476	0.571	0.412	0.635	0.666	3.2	70.30	85.70
Mar. 29, 1939	0.578	0.651	0.579	0.795	0.434	0.578	0.723	1.4	79.90	64.00
Mar. 31, 1939	0.471	0.680	0.575	0.601	0.366	0.627	0.863	3.8	60.00	67.25
Apr. 2, 1939	0.380	0.590	0.476	0.552	0.323	0.590	0.685	5.3	54.50	76.70
Apr. 4, 1939	0.316	0.364	0.291	0.291	0.243	0.485	0.558	4.1	61.95	71.50



Key: ___NaCl, ___ _$CaCl_2$, _ _ $MgCl_2$---Rainwater

Fig. 15. A comparison of the ratios of transpiration of plants watered with various salt solutions, to the evaporation from an atmometer, by means of a moving average, extending over 11 periods of 48 hours each.



Key: ____ $NaHCO_3$, ____ _ $MgSO_4$, _ _ $CaSO_4$ ----Rainwater

Fig. 15A. A comparison of the ratios of transpiration of plants watered with various salt solutions. to the evaporation from an atmometer, by means of a moving average, extending over 11 periods of 48 hours each.

In Table V111 is given the ratios of transpiration, from plants treated with the various salts, to the evaporation from an atmometer. These ratios were treated by means of a moving average and the results shown graphically in Figs. 15 and 15A. It will be noted that there is a close similarity between these results and those obtained in Figs. 14 and 14A.

Table 1X.* The pH of the solutions applied and of the soil after the various solutions had been applied during 22 days.

Materials	pH of the solutions applied	pH of the soil after the solutions were applied
NaCl	7.00	7.33
$NaHCO_3$	9.38	7.55
$MgCl_2$	7.57	7.13
$MgSO_4$	7.66	7.30
$CaCl_2$	7.75	7.28
$CaSO_4$	7.66	7.32
Rainwater	7.72	7.43

* The pH of the soil at the beginning of the experiment was 7.80.

The pH values given in Table 1X indicate that the final pH of the soil was affected by the pH of the solutions applied.

Series 3

In series 3, the salt solutions were used at a concentration of 6000 parts per million. In Table X, the transpiration per square inch of leaf area is given.

Table X. The effect of various salts on the rate of transpiration per square inch of leaf area when applied during 22 days.

Plant number	Total leaf area (Sq. in.)	Grams of water lost per plant during 22 days	
		Total	Per Sq. in. of leaf surface
Group H. Watered with 6000 parts per million of NaCl			
1	12.11	263.9	21.79
2	15.72	287.0	18.26
3	28.97	534.2	18.44
4	19.37	249.6	12.89
5	27.34	356.2	13.03
6	11.34	241.7	21.31
7	20.41	214.2	10.49
8	28.30	277.1	9.79
9	19.16	252.0	13.15
10	19.59	323.5	16.51
Group I. Watered with 6000 parts per million $NaHCO_3$			
1	12.50	267.8	21.42
2	16.83	300.2	17.84
3	14.99	364.2	24.30
4	22.13	539.0	24.36
5	24.07	514.7	21.38

6	17.88	158.5	8.86
7	12.69	268.9	21.19
8	10.12	325.9	32.20
9	23.26	561.4	24.14
10	49.73	806.0	16.21
Group J.	Watered with 6000 parts per million $MgCl_2$		
1	21.20	309.7	14.61
2	26.27	291.1	11.08
3	18.90	227.7	12.05
4	27.52	431.3	15.67
5	14.58	197.9	13.57
6	7.46	206.3	27.65
7	25.93	272.4	10.51
8	24.23	399.9	16.50
9	16.46	191.5	11.63
10	12.09	223.1	18.45
Group K.	Watered with 6000 parts per million $MgSO_4$		
1	14.75	329.2	22.32
2	30.77	516.3	16.78
3	15.13	258.7	17.10
4	24.34	702.5	28.86
5	12.46	362.0	29.05
6	12.15	329.7	27.14
7	Plant died		
8	26.52	545.4	20.57
9	18.07	416.7	23.06
10	21.41	580.4	27.11

Group L.	Watered with 6000 parts per million $CaCl_2$		
1	25.32	442.1	17.46
2	7.94	187.9	23.66
3	26.20	279.6	10.67
4	26.35	253.9	9.63
5	25.24	444.3	17.60
6	17.24	263.5	15.28
7	27.80	503.1	18.10
8	30.82	532.4	17.27
9	21.03	255.5	12.15
10	17.41	283.1	16.26
Group M.	Watered with rainwater		
1	18.28	373.2	20.42
2	7.17	246.7	34.41
3	43.63	1021.8	23.42
4	23.52	523.6	22.26
5	18.74	497.5	26.55
6	17.20	385.4	22.41
7	22.63	772.3	34.13
8	31.05	878.6	28.30
9	29.38	657.7	22.39
10	22.56	645.5	28.61

The results indicate that all five of the salts have retarded the rate of transpiration as compared to the rate of transpiration from those plants watered with rainwater.

Table XI. Grams of water lost per square inch of leaf surface from 6 groups of plants, each group watered with rainwater or a different salt solution during 22 days.

48 hour period ending at 6:00 P.M. on:	Treatment						Total	Mean
	$NaCl$	$NaHCO_3$	$MgCl_2$	$MgSO_4$	$CaCl_2$	rain water		
Mar. 14, 1939	2.5	1.6	2.0	2.0	2.0	2.1	12.2	2.03
Mar. 16, 1939	3.0	3.3	3.3	3.4	2.8	2.6	18.4	3.07
Mar. 18, 1939	1.7	1.7	1.1	1.5	1.7	1.8	9.5	1.58
Mar. 20, 1939	1.4	2.0	1.5	2.0	1.3	2.0	10.2	1.70
Mar. 22, 1939	2.0	2.7	1.8	3.2	2.1	2.9	14.7	2.45
Mar. 24, 1939	0.6	1.5	0.6	2.0	1.0	2.0	7.7	1.28
Mar. 26, 1939	0.6	1.2	0.9	1.5	0.8	1.7	6.7	1.12
Mar. 28, 1939	0.8	1.0	0.5	1.1	0.7	1.5	5.6	0.93
Mar. 30, 1939	0.5	1.1	0.7	1.1	0.7	2.0	6.1	1.02
Apr. 1, 1939	1.0	2.3	1.1	2.8	1.2	3.6	12.0	2.00
Apr. 3, 1939	0.6	1.7	0.7	2.5	0.9	3.5	0.9	1.65
Total	14.7	20.1	14.2	23.1	15.2	25.7	113.0	
Mean	1.34	1.83	1.29	1.92	1.38	2.34		

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Analysis of Variance[1]

Factors of Variance	d/f	Sum of Sq.	Mean Sq. or variance	F value	Value required for: 5%	1%
Total	65	46.1904				
Treatment	5	10.7922	2.1584	12.8095	2.37	3.34
Replicates	10	25.2871	2.5287	15.0071	1.01	2.66
Tr. & Rep.	15	36.0793				
Remainder	60	10.1111	0.1685			

Difference necessary to be significant $= \frac{C'}{\sqrt{N}} \times 2\sqrt{2}$

$C' = \sqrt{0.1685} = 0.410$

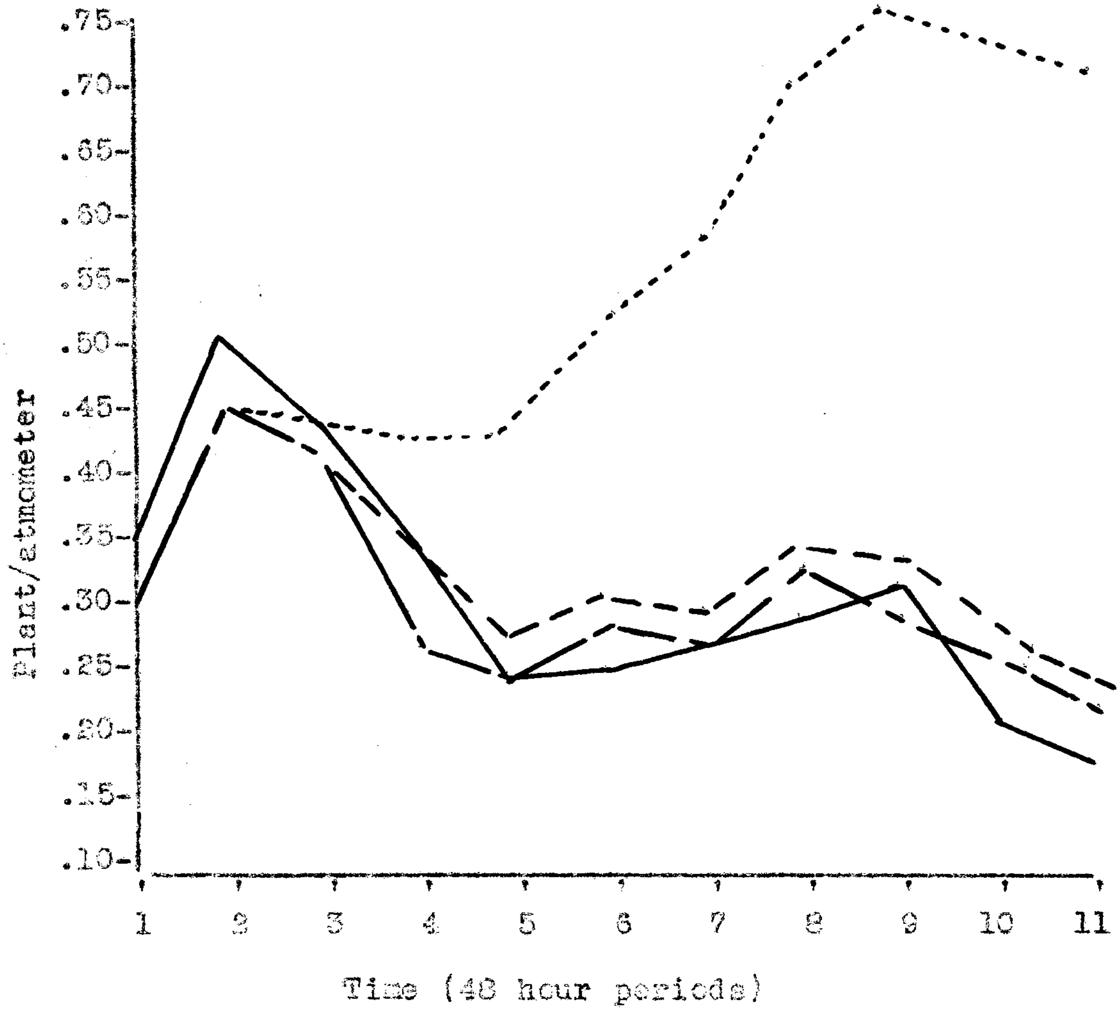
$\frac{0.41}{\sqrt{11}} \times 2\sqrt{2} = \frac{0.41}{3.3166} \times 2.83 = 0.3498$

The analysis of variance, calculated from the data in Table Xl, showed that treatments were highly significant. All salts retarded transpiration enough to be significant. No doubt, the higher concentration caused a larger accumulation of salts in the soil and they had more effect than they did in series 1 and 2.

1. Formulas taken from Love (17).

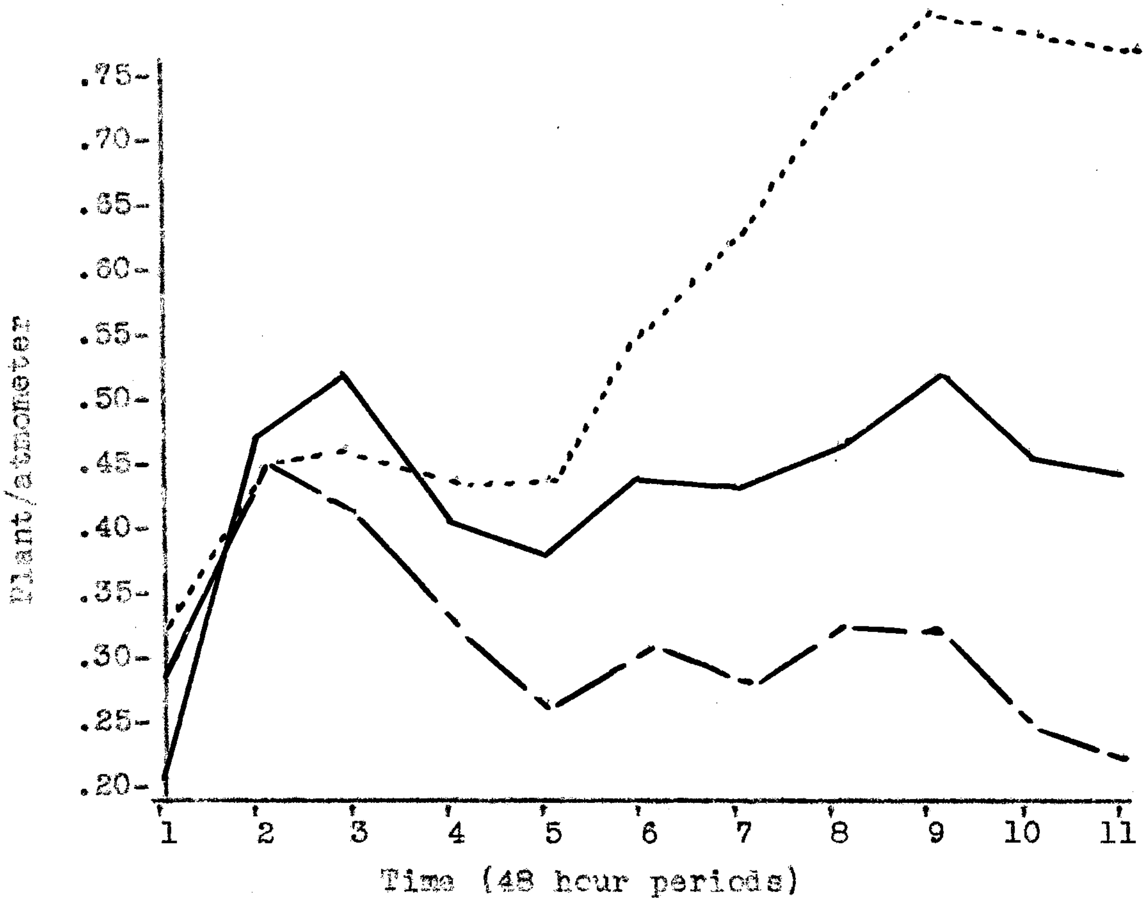
Table XII. Mean relative humidity and temperature and ratios of transpiration in grams per square inch of leaf surface to evaporation in grams per square inch of atmometer surface during 22 days.

48 hour period ending 6:00 P.M. on:	Treatment						Evap. from atm. Grs. per Sq. in.	Mean	
	$NaCl$	$NaHCO_3$	$MgCl_2$	$MgSO_4$	$CaCl_2$	rain water		R. H. %	Temp. O F
Mar. 14, 1939	0.355	0.227	0.284	0.284	0.284	0.298	7.0	49.42	74.31
Mar. 16, 1939	0.704	0.774	0.774	0.798	0.657	0.610	4.3	60.72	69.76
Mar. 18, 1939	0.409	0.409	0.265	0.361	0.409	0.433	4.2	62.11	68.64
Mar. 20, 1939	0.211	0.301	0.226	0.301	0.196	0.301	6.6	53.32	75.87
Mar. 22, 1939	0.341	0.460	0.307	0.545	0.358	0.494	5.9	49.40	80.10
Mar. 24, 1939	0.118	0.295	0.118	0.393	0.197	0.393	5.1	61.15	76.35
Mar. 26, 1939	0.207	0.414	0.310	0.517	0.276	0.586	2.9	73.65	72.95
Mar. 28, 1939	0.356	0.445	0.223	0.490	0.312	0.668	2.2	76.90	79.85
Mar. 30, 1939	0.198	0.435	0.277	0.435	0.277	0.791	2.5	68.40	62.30
Apr. 1, 1939	0.221	0.508	0.243	0.619	0.265	0.795	4.5	57.35	76.45
Apr. 3, 1939	0.107	0.303	0.125	0.445	0.160	0.628	5.6	50.80	76.35



Key: ____NaCl, ____ _$MgCl_2$, _ _ _$CaCl_2$, ----Rainwater

Fig. 13. A comparison of the ratios of transpiration of plants treated with various salt solutions to the evaporation from an atmometer, by means of a moving average, extending over a period of 22 days.



Key: ______$NaHCO_3$,____ _$MgSO_4$,-----Rainwater

Fig. 16A. A comparison of the ratios of transpiration of plants treated with various salt solutions to the evaporation from an atmometer, by means of a moving average, extending over a period of 22 days.

When the ratios in Table X11 were treated by means of a moving average, and the results were shown graphically in Figs. 16 and 16A, the retarding effect of all of the salts was quite noticeable. Whereas, in series 1, the plants watered with bicarbonate or sulphates, transpired at a rate comparable to the rate of transpiration from the plants watered with rainwater, in series 3, the plants watered with these solutions were much retarded in their rate of transpiration as compared to the rate of transpiration of the plants watered with rainwater.

Table X111.* The pH of the solutions applied and of the soil after the various solutions had been applied during 22 days.

Material	pH of the solutions applied	pH of the soil after the solutions were applied
NaCl	7.35	7.34
$NaHCO_3$	9.33	7.80
$MgCl_2$	7.54	7.12
$MgSO_4$	7.70	7.33
$CaCl_2$	7.86	7.22
Rainwater	7.95	7.47

* At the beginning of the experiment, the pH of the soil was 7.80.

Although the soil in all of the pots in series 3 had a pH value of 7.80 at the beginning of the experiment, at the end of the experiment, the pH of the soil in the various groups varied somewhat indicating that the pH of the solutions applied had affected the pH of the soil.

DISCUSSION OF RESULTS

An analysis of the data presented in Tables 11, V11 and X1 showed that the plants watered with solutions of NaCl, $MgCl_2$ and $CaCl_2$ had significantly lower transpiration rates per square inch of leaf area than those plants watered with rainwater, when the salt solutions were applied at concentrations of 3000 parts per million and 6000 parts per million. The plants watered with a solution of $CaSO_4$* which had a concentration of 1759 parts per million, transpired at rates per square inch of leaf area somewhat lower than those plants watered with rainwater in series 1 and significantly lower in series 2. The plants watered with a $MgSO_4$ solution transpired at approximately the same rates as the plants watered with rainwater in series 1 but had significantly lower rates in series 2 and 3. The plants watered with a $NaHCO_3$ solution transpired slightly faster than the plants watered with rainwater in series 1. Their rates were somewhat lower in series 2 and significantly lower in series 3.

The higher mean air temperature (the mean air temperature was 62.4°F during series 1 and 73.8°F during series 2 and 3) and the lower mean relative humidity (the mean relative humidity was 62.3 per cent during series 1 and 60.9 per cent during series 2 and 3) of the air in the greenhouse during the time series 2 and 3 were being conducted, induced

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* $CaSO_4$ forms a saturated solution at a concentration of 1759 parts per million.

higher transpiration rates. Apparently, the accumulations of $CaSO_4$, $MgSO_4$ and $NaHCO_3$ in the soil in series 1 were not sufficient to significantly retard transpiration of the plants watered with solutions of those salts. It seems that the accumulations of $CaSO_4$ and $MgSO_4$ in the soil in series 2 and the accumulation of $MgSO_4$ and $NaHCO_3$ in the soil in series 3, were sufficient to significantly retard transpiration of the plants watered with solutions of those salts when the atmospheric conditions were favorable for higher rates of transpiration as in series 2 and 3.

The data obtained from series 2 and 3, which were conducted concurrently, indicate that in general, the plants watered with salt solutions of 6000 parts per million concentration had lower transpiration rates per square inch of leaf area than those plants watered with salt solutions of 3000 parts per million concentration. $CaCl_2$ was the only exception to this, having approximately the same rates of transpiration at both concentrations.

These results are similar to those obtained by others. Whitfield (24) found a closer correlation between the transpiration curve and the curves of air temperature and relative humidity than between the transpiration curve and the curves of any other factors measured, such as, evaporation and saturation deficit.

Reed (23) found that wheat plants transpired at different rates when treated with different salts. He used $NaNO_3$,

K_2SO_4, $CaH_4(PO_4)_2$ and $CaCO_3$. Using the transpiration rate of the control plants as a basis for comparison and representing it as 100 per cent, the transpiration rates of the plants treated with the various salts had the following relative values: $NaNO_3$ 90.4 per cent, K_2SO_4 94.8 per cent, $CaH_4(PO_4)_2$ 100.8 per cent and $CaCO_3$ 97.9 per cent.

Harter (12) conducted three experiments in which some wheat was germinated and grown in nonsaline soils and some in saline soils containing total soluble salts amounting to 1.5 per cent of the dry weight of the soil. When the plants were about 6 inches tall, the leaves were cut off and weighed at various intervals. The leaves lost the following per cents of their original weights.

Experiment number	1	2	3
Period of exposure (hours)	21	19	3½
Leaves from plants grown in saline soils	13.6	16%	5%
Leaves from plants grown in nonsaline soils	24.8%	48%	21%

The above results demonstrate that leaves of wheat plants grown in soils containing 1.5 per cent of salts, lost considerable less water than leaves of wheat plants grown in nonsaline soils. The transpiration rates of wheat plants grown in soil containing 0.09 and 0.12 per cent of soluble salts increased, the increase being greater with the smaller concentrations.

The plant/atmometer ratios of series 1 shown in Fig. 14, show there was a progressive reduction in the transpiration rates of plants watered with solutions of NaCl, $MgCl_2$ and

$CaCl_2$ of 3000 parts per million concentration, compared to the transpiration rates of plants watered with rainwater, as the accumulation of salts in the soil increased. The plant/atmometer ratios of series 1, shown in Fig. 14A, show no significant difference between the transpiration rates of those plants watered with solutions of $CaSO_4$, $MgSO_4$ and $NaHCO_3$ of 3000 parts per million concentration and the transpiration rates of those plants watered with rainwater.

So far as known, the only variable factor between series 2 and 3 was the difference in concentration of the salt solutions applied. The concentrations being 3000 parts per million in series 2 and 6000 parts per million in series 3. When the plant/atmometer ratios of series 2, shown in Fig. 15, were compared to the plant/atmometer ratios of series 3, shown in Fig. 16, two points were noted. The retarding effect on transpiration of salt solutions which had a concentration of 6000 parts per million was greater than the retarding effect on transpiration of salt solutions which had a concentration of 3000 parts per million, the only exception being the plants watered with solutions of $CaCl_2$. Those plants transpired at approximately the same rates in both series. In both series, there was a progressive decrease in transpiration rates of those plants watered with salt solutions, compared to the transpiration rates of those plants watered with rainwater, as the accumulation of the salts in the soil increased.

These results are similar to those obtained by Meyer (21). He conducted transpiration experiments at the Desert Laboratory, Tucson, Arizona. Cotton plants were treated with NaCl, $NaNO_3$, KCl, KNO_3, $CaCl_2$, and $Ca(NO_3)_2$. All salts were applied to the soil at concentrations equivalent to 0.025, 0.05, 0.1, 0.2 and 0.4 per cent of the dry weight of the soil. With the calcium salts, an additional concentration equivalent to 0.8 per cent of the dry weight of the soil was used. The experiments were conducted for four day periods. All concentrations of all salts, except the two lowest concentrations of KNO_3, caused a reduction in transpiration rates. Those two caused slight increases in transpiration rates.

A comparison of the mean rates of transpiration per square inch of leaf area of the plants watered with different salt solutions, as given in Tables 11, Vll and Xl, indicated the effect of different ions varied. If the effects of two salts having a common cation or anion are different, it would seem logical to attribute the difference to the effect of the unlike cations or anions. The inhibiting effect of the various ions was as follows: Cl $>$ CO_3 when combined with Na, Cl $>$ SO_4 when combined with Ca or Mg and Ca $>$ Mg when combined with SO_4. There were some variations in the magnitude of retardation caused by Na, Ca and Mg when combined with Cl. The inhibiting effect was Mg $>$ Ca $>$ Na in series 1. The inhibiting effect was Ca $>$ Na $>$ Mg in series 2. The inhibiting effect was Mg $>$ Na $>$ Ca in series 3.

These results do not agree entirely with those found by Bouyoucos (2). He used 0.02 N solutions of $NaNO_3$, KNO_3, Na_2HPO_4, K_2HPO_4, $MgSO_4$, $(NH_4)_2SO_4$, $MgCl_2$, $(NH_4)CO_3$, $CaCl_2$, $Ca(NO_3)_2$ and K_2CO_3 in both water and sand cultures. The inhibiting effect was as follows: Ca $>$ Mg, Ca $>$ Na, Cl $>$ CO_3 (in sand culture), CO_3 $>$ Cl (in water culture) and SO_4 Cl. The few differences in results could be due to differences in the conditions under which the experiments were conducted, such as, different concentrations of the salt solutions and different media for growing the plants.

The pH values given in Tables 1V, 1X and X111 indicate that the final pH of the soil was influenced by the pH of the solutions applied. This thought was substantiated by the findings of Burk (8). In his work with various plants under greenhouse conditions, he found that the final pH of the soil was influenced by the pH of the water applied.

Table V gives the wilting coefficients of the soil after the various salt solutions had been applied for 28 days. The wilting coefficients of the soil where solutions of NaCl, $MgCl_2$, $CaCl_2$ and $CaSO_4$ had been applied were higher than the wilting coefficients of the soil where solutions of $MgSO_4$ and $NaHCO_3$ had been applied. The plants watered with the first four of these salt solutions had lower rates of transpiration than the plants watered with rainwater. It would seem, therefore, that an accumulation of NaCl, $MgCl_2$, $CaCl_2$ and $CaSO_4$ in the soil interfered with the absorption of water from the soil by plants and retarded their rates of transpiration. If there had been a greater accumulation of $MgSO_4$ and $NaHCO_3$ in the soil, the wilting coefficients of the soil where these solutions were applied may have been higher.

The rates of transpiration, per square inch of leaf area, of the plants in the three series are given in Tables I, VI and X. The plants with larger total leaf areas tend to have lower transpiration rates per square inch of leaf area than the plants with smaller total leaf areas. These results agree with the results obtained by Darrow and Sherwood (9) in their transpiration studies on the strawberry.

SUMMARY

1. Saline waters when used in concentrations of 3000 parts per million and 6000 parts per million to water geranium plants retarded the transpiration rates of those plants.
2. The retarding effect progressively increased with an increasing accumulation of the salts in the soil.
3. The effects of the various ions differed.
4. The wilting coefficient of the soil was higher when there was an accumulation of salts present in it.
5. The final pH of the soil was influenced by the pH of the solutions applied.
6. In general, the larger the total leaf area of the plants, the lower the transpiration rates per unit area.

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