THE INFLUENCE OF CERTAIN WATER SOURCES AND POT TREATMENTS ON THE GROWTH OF REPRESENTATIVE GREENHOUSE PLANTS

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Introduction

In recent years the problem of proper water supply for greenhouse crops has become increasingly important. The use of chlorinating and water softening processes by many Municipal water supply plants has tended to produce adverse soil conditons in greenhouses which depend on such sources for their water supply.

Since the relationship of clay pot containers to plant growth has received considerable attention recently, it seemed desirable to obtain more definite information concerning this relationship under greenhouse conditions. The clay pot has certain properties which apparently affect plant growth and these have not as yet been thoroughly investigated. A study of the relation of certain water sources and pot treatments to the growth of representative plants appeared, therefore, desirable.

Review of Literature

Recommendations as to the proper sources of water for potted plants have been given from time to time in English and American periodicals and books on gardening. The use of rain water is generally recommended as best for potted plants. No controlled experiments on water sources for greenhouse crops have been reported until recently, however.

The porous clay pot adopted by the American Florist's Association, in 1885, as a "standard" pot has been virtually unchanged since that time and is still used, almost to the exclusion of other pot containers. Pre-soaking of new clay pots and washing of used pots has been recommended by commercial growers and horticultural writers and the belief that plant roots are aerated through the wall of a porous clay pot has been generally accepted until the work of Jones (18, 21) cast some doubt on this matter.

Water source has long been regarded as an important factor in the growth of garden and house plants. As early as 1739, Bradley (4) recommended the use of a "natural" water and suggested that it be held in a cistern or earthen pit for several days before applying it to the plants. Loudon (23) advocated the use of rain water and cited certain experimental results to show that the temperature of the water used should be, as nearly as possible, that of the soil in which the plants are grown. Burbridge (7) stated that the best water for plants is "soft" water, under which heading he put rain and river water. Fish (11). editor of Cassel's Popular Gardening, advised the use of pond water, where rain water was not available. In this connection gardeners were warned against the use of water with a high lime content. Regel (24) recommended the use of "soft" river water for watering cuttings, or rain water if a lime-free source was not available. In Le Bon Jardinier (34) certain water sources are compared. Rain water was considered best because it was free of salts and saturated with air. Well water was considered poorest for watering flowering plants. River water, it was stated, has considerable salts in solution and their nature and amount varies with the character of the soil through which the stream passes. The testing of all water except rain water was advised.

Volz and Burk (30) carried on a series of experiments to determine the relation of water sources to the ultimate pH of greenhouse soils and the effect of those sources on the growth of representative plants. This study was carried out in a typical greenhouse environment. They reported that plants do not have a constant pH requirement but rather an optimum for each set of environmental conditions, that the final pH of a greenhouse soil is a direct factor of the water source utilized, and that rain water is apparently the best source of water supply while well water softened by the zeolite process appears to inhibit plant growth to some extent.

The nature of plant growth in relation to soil reaction is of primary importance in a study of the effect of water source on the growth of greenhouse crops, since the water affects plants indirectly through its influence on soil reaction. Arrhenius (1, 2, 3) discussed the relation of plant growth to soil reaction and stated that there is a direct correlation between soil reaction and plant growth. He suggested that, in view of wide variations in pH requirements among plants, further study should be made to determine the pH ranges of important plants. Wiggin and Gourley (31) found that no specific soil reaction was required by greenhouse plants used in their study but that a slight apparent depression in growth occurred at neutrality with best results in slightly acid or slightly alkaline soil. Chadwick and Gourley (9) found that certain ornamental plants (Iris germanica, Lupinus polyphyllus, L. hartwegi, Daphne Cneorum, and Delphinium ajacis) responded best to neutral or alkaline soil reactions.

The relation of the clay pot container to plant growth was mentioned by Loudon (23) who stated that the commonly used porous clay pot evaporates considerable moisture from its walls when placed in a dry room. This evaporation, under usual methods of periodic watering, would tend to produce alternate warming and cooling of the soil mass within the pot, which might prove harmful to the plant grown in it. He suggested glazing the outer walls of pots to control this condition but stated that such measures were unnecessary in the case of potted plants grown in the moist atmosphere of plant houses. Jones (16) reported similar findings and stated that the soil mass within a porous clay pot may be cooled as much as 20 F. by evaporation from its moist outer wall. Jones (16, 17, 18, 21) demonstrated that a clay pot, under conditions of low humidity such as are found in dwelling houses, may not be a satisfactory plant container. He recommended (17, 19, 20) the use of glazed or painted pots, or containers made of cement, glass, or metal for growing plants under such conditions.

The relation of porous clay pots to aeration was mentioned by Sutton (28) who recommended that used pots be thoroughly washed so that air may more easily enter through their walls. The pre-soaking of both used and new pots was likewise advocated. Goff (12) mentioned the value of water movement within a clay pot. Where drainage is good and water movement free, he considered that watering potted plants at the top forced exhausted air out of the soil mass and facilitated entry of fresh air from the soil surface.

The work of Jones (18) showed that appreciable aeration of plant roots through the walls of a porous clay pot is not probable or even possible. He presented experimental evidence showing that, although water passes out of the moist wall of a porous clay pot, no appreciable passage of air inward can take place under ordinary conditions.

Haber (13) found the porous clay pot superior to peat and composition pots for the growth of certain greenhouse crops. The reason given for inferior growth in peat and composition pots was nitrate deficiency caused by utilization of soil nitrates in the bacterial decomposition of the cellulose material of which such pots are constructed.

The comparison of new and used clay pots and their effect on plant growth was made by several investigators. Thorsrud (29) found that new clay pots seemed to inhibit the growth of plants within them. When compared with plants grown in used pots, there was a noticeable difference in total growth. This he attributed to the presence of toxic substances (probably bases) in the new pots and suggested washing these out with water or neutralizing them with dilute acid before putting new pots into use.

Knott and Jeffries (22) found a similar retardation of plant growth in new clay pots. Further investigation showed that this was apparently due to nitrate deficiency, since nitrate feeding of plants grown in new pots corrected the condition. The factor involved was apparently the absorption of nitrates into the walls of new pots. This absorption was much less in used pots, which already had considerable nitrate in their pot walls.

The present study was undertaken with the object of obtaining information concerning certain water sources and pot treatments which might be of value to commercial growers. In order that the results might be more readily applicable to the problems of the average greenhouse grower, this study was based on simple treatments such as might easily be applied by any grower. All trials were conducted in a typical greenhouse environment and water was applied by generally accepted methods.

Methods and Materials

This study was initiated on January 2, 1934 and terminated on July 4, 1934. All treatments applied, with the exception of distilled water as a water source, were such as might be used by the average commercial grower.

Six hundred potted plants were used in 80 sets involving 4 plant genera, 5 pot treatments, and 4 water sources. These were placed on a single, raised, greenhouse bench under conditions of temperature and humidity which may be considered typical for glasshouse crops. The external environment of all plants involved in this study was, therefore, the same. Since all plants were selected for uniformity at the time they were entered into the experiment, it appeared that such variations in growth as might be noted at the end of the experimental period should be due to the variable factors of water source, pot treatment, soil type, or genetic and physiological variations within the plant species.

Water was applied by hose in the manner of the commercial grower and watering was done when necessary rather than at definite intervals. The plants in the four water source treatments were separated by low board partitions which could not interfere with plant growth. Unavoidable drips introduced.

water from the greenhouse roof into several experimental sets but errors due to this source were of minor importance.

Chemically softened water was obtained by passing well water through a "Duro" domestic water softener which utilizes the Zeolite process. Since this source was not available before January 20, 1934, all plants to be included in this series were watered with river water until that date.

Distilled water was applied through rubber tubing in the same manner in which other waters were applied through lawn hose. Well water was taken from the pipes of the Michigan State College Campus water system which pumps its supply from five deep wells (250 to 350 feet in depth). River water was obtained from the greenhouse water supply which is pumped from the Red Cedar river, a tributary of Grand river. All water supplies except the distilled water were taken from pipes within the greenhouse. Outlets for each source were placed within a few feet of the bench on which the study was conducted. A comparison of the soluble contents of the various waters is given in Table IA.

Five pot treatments were used as shown in Table I. These treatments were duplicated for each water source and plant material used. New and used porous clay pots, in standard sizes, were treated as follows. For the new pot treatments, 360 pots were divided into three groups of 120 each. One group was thoroughly impregnated with hot paraffin at a temperature of 85° to 95° C. Since paraffin is practically inert, pots treated in this way are non-porous and equivalent to glazed or painted clay pots. One group was soaked in water for 24 hours and used immediately. One group was left untreated.

For the used pot series, 240 pots were selected at random from a group of standard clay pots which had been in use from one to several times previously. One-half of this group was thoroughly cleaned with a pot brush and sterilized in a 1-50 solution of pyroligneous acid (10) and one-half was left untreated.

The potting soils used were of two types and may be designated as soils A and B. Soil A consisted of 6 parts composted soil, 1 part granulated peat, and 1 part sand. Soil B consisted of 2 parts composted soil, 2 parts granulated peat, and 4 parts sand. Since these parts were measured by volume, as is common greenhouse practice, the proportions by weight would be consiserably different. Soil A and soil B were nearly neutral in reaction with soil A slightly alkaline. Soil A was high in nitrate nitrogen and soil B rather low in nitrate nitrogen. All Antirrhinum, Coleus, and Hedera helix plants were potted in Soil A and the Begonias were potted in soil B. All plants were potted in 3-inch pots, excepting the Begonias which were potted in 2½-inch pots because of the small size of the plants at the beginning of the study period.

As soon as potted, each treatment was marked with a 6-inch wooden stake on which the treatment, the series, and the number of pots involved was printed. The groups of potted plants were arranged according to their treatments and each group watered with the appropriate water source. Care was taken that all potted plants should receive sufficient water throughout the experimental period without the soil at any time becoming "water-logged" from over watering. This condition could not be avoided, however, in several pots which were exposed to overhead drips.

The plant materials used were selected as representative: Antirrhinum majus as a cut flower annual; Coleus Blumei as a colored foliage plant; Hedera helix as a semi-woody trailing vine; and Begonia semperflorens var. Wurtemgergia as a flowering pot plant. The roots of all plants were shaken free of soil before potting so that no soil would be introduced on the plant roots. The Antirrhinum and Begonia were grown from seed and potted out of flats of transplants. The Coleus and Hedera helix plants were grown from cuttings, the former taken directly from the cutting bench and the latter taken from 2¼-inch pots. All plants in each group were selected for uniformity of growth.

As growth warranted it, the plants were shifted to the next larger size pot. These pots were given treatments identical with the original treatments. All plants were grown for a six months period, with the exception of the Antirrhinum group which matured at the end of four months. Since their retention through the remainder of the period would have made all records of their growth practically valueless, the Antirrhinums were removed at this time. At the time of their removal they were in 4-inch pots and, in order that the results on other plant materials should be comparable, all remaining plants were carried in 4-pots until the end of the experimental period. Some individual plants were pot bound at that time, but not seriously so.

All shifts were made, as nearly as possible, simultaneously within each series. The bench positions were interchanged each month in order that possible differences in light intensity due to bench position might not cause any growth variations. General notes on foliage color, growth, and habit of plants in each series were taken as observed.

Individual plants of Antirrhinum, Coleus, and Begonia varied to such an extent in their growth habits that it was evident that comparison of their dry weights was the only feasible method of measuring variations in their total growth. In Hedera helix, which developed single shoots, the dry weight comparison could be supplemented by individual shoot growth measurements. These measurements seemed closely related to the total plant growth.

At the termination of the study period, each set was treated as a unit sample, although either 5 or 10 plants were actually involved. The plants in each set were removed from the pots, roots shaken free of the soil, and placed in a large paper sack. This was marked with the treatment, series, and number of plants in the set and saved for dry weight determinations. All samples were air dried and then brought to a constant weight in an electric oven at 95° C. Twenty-four hours of drying in the electric oven was found to be sufficient.

Eighty composite soil samples, representing each pot in every set, were taken at the end of the experimental period. These samples were analyzed by the "Simplex" method of soil analysis as described in Mich. Agr. Exp. Sta. Tech. Bul. 132. On the advice of the originator of this system results are given on a comparative basis rather than in actual parts per million. The pH. values were determined electrometically by the use of a calomel cell and quin-hydrone electrode.

Explanation of Tabular Data

Tables I - V give in a condensed form the treatments used and the results obtained in this study. Table I gives the plant materials, pot treatments, and water sources, and their inter-relation. Table II gives individual shoot length measurements of the Hedera helix plants. These measurements and their averages supplement the dry weight figures given in Table III. Table II shows also that the variations in the growth of individual plants in the same experimental set were considerable. These variations in individual growth rates were observed in all plant materials used. Table III gives the results of dry weight determinations in terms of grams per plant. These figures represent an average of 5 plants in the softened water and distilled water series and 10 plants in the well water and river water series. The dry weights of Hedera helix are an exception. These were taken from averages of 5 plants in all the water source groups.

Table IV gives the results of analysis of composite soil samples by the "Simplex" method (27). This is given in the form of a general comparison of soil constituents rather than in parts per million. Observed variations in pH values and soil analyses within the same water source group make it evident that the results may be compared only on the basis of general trends.

Table V is in the form of a chart representing the value of each water source used. These comparative values are based on plant growth averages computed from the dry weights given in Table III. Relative desirability is indicated by numerals. Since this ranking varied with each plant material used, it was found necessary to make comparisons for each plant series.

TABLE I

SCHEDULE OF EXPERIMENTAL TREATMENTS

Water Source	No. of pots	Treatment of standard clay pots	Plant materials and potting soils*			
			Coleus Blumei Coleus Soil A	Antirrhinum majus "Suntan" Snapdragon Soil A	Hedera helix English Ivy Soil A	Begonia semperflorens Wurtembergia Begonia Soil B
I well water softened by the zeolite process pH 7.8	5	A. new pots paraffin impregnated				
	5	B. new pots soaked 24 hrs. in KOH				
	5	C. new pots not treated				
	5	D. used pots washed and sterilized				
	5 5	E. used pots not treated				
II distilled water pH 6.8	5 5 5 5 5	as above	as above	as above	as above	as above
III well water from deep wells pH 7.7	10 10 10 10 10	as above	as above	as above	as above	as above
IV river water Red Cedar river pH 7.7	10 10 10 10 10	as above	as above	as above	as above	as above

Note: Pot treatments were duplicated for each water source and plant material used.
* Nomenclature according to Bailey (Cy. Am. Hort.).

TABLE IA

COMPARISON OF SOLUBLE SUBSTANCES IN WATERS USED

Water Source	Cl.	Ca.	Mg.	Na.	K.	P.	Nitrate N.
Softened Water	xxx	xxxx	xxxx	xxx	0	0	0
Distilled Water	0	0	0	0	0	0	0
Well Water	0	xxxxx	xxxxx	0	0	0	0
River Water ø	0-x	xxxx	xxxx	0-x	x-xx	x-xx	xx-xxxx

ø The salt content of the river water was not constant but varied considerably during the experimental period

Key to symbols

0.......Negative to trace

x.......Low

xx......Medium

xxx.....Medium to high

xxxx....High

xxxxx...Extremely high

TABLE II

SHOOT LENGTHS OF HEDERA HELIX

Treat-ment	Shoot Lengths in Inches									Aver-ages In.
IA	25.5	21.0	25.5	29.0	24.0					
IB	20.0	21.0	18.0	24.0	17.5					
IC	16.0	18.0	17.0	14.0	26.0					
ID	18.0	26.5	23.5	18.0	19.0					
IE	23.5	21.0	16.0	27.5	22.0					
IIA	32.0	32.0	33.0	33.5	36.5					
IIB	29.0	37.0	39.0	32.0	31.0					
IIC	32.0	35.0	36.0	35.0	33.0					
IID	34.5	31.0	30.0	31.0	43.0					
IIE	37.0	29.0	37.0	36.0	39.5					
IIIA	36.5	41.5	34.5	45.0	23.0	32.5	32.0	34.0	36.0	39.0	35.4
IIIB	39.0	32.0	31.0	34.0	30.0	37.0	41.0	38.0	35.5	34.0	35.2
IIIC	35.0	37.0	21.5	35.0	31.0	25.0	33.0	32.0	37.0	26.0	31.1
IIID	36.0	30.5	37.0	36.0	31.0	32.0	30.0	33.0	30.0	42.0	33.8
IIIE	43.5	36.0	32.0	33.0	27.0	29.0	32.0	37.5	29.0	33.0	33.2
IVA	23.0	34.0	34.5	34.5	35.0	31.0	22.0	37.0	27.0	22.0	29.8
IVB	26.0	29.0	39.0	31.0	32.0	32.0	32.0	44.5			33.2
IVC	28.0	31.0	30.0	46.5	39.5	37.0	41.5	36.0	39.5	30.0	35.9
IVD	31.5	30.0	34.0	38.0	26.0	39.0	28.5	33.0	29.0	37.0	32.6
IVE	23.0	40.0	33.0	35.0	28.0	30.0	37.0	35.0	36.0	41.0	33.8

Legend

A New pots waxed
B New pots soaked 24 hours
C New pots untreated
D Used pots washed & sterilized
E Used pots untreated

I Zeolite softened well water
II Distilled water
III Well water
IV River water

TABLE III ∅ DRY WEIGHTS IN GRAMS PER PLANT

Coleus Blumei			Antirrhinum majus			Hedera helix			Begonia semperflorens		
treat-ment	pot no.	dry wts.	treat-ment	pot no.	dry wts.	treat-ment	pot no.	dry wts.	treat-ment	pot no.	dry wts.
IA	5	1.5	IA	5	3.1	IA	5	6.1	IA	5	0.4
IB	5	2.2	IB	5	5.7	IB	5	5.6	IB	5	0.9
IC	5	2.1	IC	5	4.9	IC	5	4.4	IC	5	0.6¢
ID	5	2.7	ID	5	7.2	ID	5	4.7	ID	5	1.5
IE	5	2.2	IE	5	7.1	IE	5	4.9	IE	4	1.3‡
IIA	5	2.7	IIA	5	5.0	IIA	5	6.2	IIA	5	1.5
IIB	5	4.2	IIB	5	8.0	IIB	5	7.8	IIB	5	2.3
IIC	5	4.0	IIC	5	7.2	IIC	5	8.2	IIC	5	2.4
IID	5	3.0¢	IID	5	8.1	IID	5	7.8	IID	5	2.4
IIE	5	4.2	IIE	5	7.8	IIE	5	7.4	IIE	5	2.4
IIIA	10	1.6	IIIA	10	5.8	IIIA	5	6.9	IIIA	10	0.9
IIIB	10	2.6	IIIB	10	7.9	IIIB	5	7.1	IIIB	10	2.2
IIIC	10	3.1	IIIC	10	9.2	IIIC	5	7.6	IIIC	10	2.7
IIID	10	3.5	IIID	10	6.5¢	IIID	5	7.3	IIID	10	3.0
IIIE	10	2.9	IIIE	10	8.2	IIIE	5	7.3	IIIE	10	2.7¢
IVA	10	1.5	IVA	10	6.7	IVA	5	4.9	IVA	10	1.0
IVB	10	2.5	IVB	10	9.2	IVB	5	6.0	IVB	10	2.5
IVC	10	2.8	IVC	10	7.3¢	IVC	5	6.0	IVC	10	3.0
IVD	10	2.8	IVD	10	8.5	IVD	5	7.5	IVD	10	2.9
IVE	10	2.8	IVE	10	6.9¢	IVE	5	6.7	IVE	10	3.0

∅ Dry weights per plant based on average weights of 5 or 10 plants as indicated.

¢ Growth retarded by unavoidable overhead drips.

‡ One plant dead. Average based on 4 plants.

† Legend the same as in Table II.

TABLE IV

COMPARISON OF ANALYSES OF SOIL SAMPLES AT THE TERMINATION OF THE EXPERIMENTAL PERIOD

Water source	pH of soil	soil	Cl	Ca	Mg	Na	K	P	Nitrate N.
I softened water	7.5-7.8-	A	0-x	x	x	xxxx	xxxxx	xxxxx	x
	7.5-8.0	B							#
II distilled water	6.7-7.0	A	0	xx	xx	0	xx	xxx	xx
	6.7-7.1	B							
III well water	7.1-7.6	A	0	xxxxx	xxxxx	0	xx	xxx	xx
	7.1-7.6	B							
IV river water	7.1-7.5	A	0-x	xxxx	xxxx	0-x	xxxx	xxxx	xxxx
	7.1-7.5	B							

In soil B, treatment IA was an exception. This gave a xxxx test for nitrate nitrogen.

Key to Symbols

0......Negative to trace
0-x....Trace to low
x......Low
xx.....Medium
xxx....Medium high
xxxx...High
xxxxx..Extremely high

TABLE V

RELATIVE PLANT GROWTH IN RELATION TO WATER SOURCE

Plants	Softened Water	Distilled Water	Well Water	River Water
Begonia semperflorens	∅ 4	3	2	1
Antirrhinum majus	4	3	2	1
Coleus Blumei	4	1	2	3
Hedera helix	4	1	2	3

∅ Numerals represent ranking of water source values as indicated by plant growth (Ranking computed from averages of dry weights in Table III).

Presentation of Data and Discussion of Results

It is apparent from the results obtained (Tables II, III, V) that the use of tap water softened by the Zeolite process was harmful to the growth of plants used in this study. The more succulent plants appeared to suffer the greatest degree of injury since the coleus and begonia plants were most affected by water from this source. With distilled water taken as the standard for comparison, the average growth of Begonia plants watered with softened water was 41 per cent of normal and that of Coleus watered with the same source, 53 per cent of normal. On the same basis of comparison, average growths of Hedera helix and Antirrhinum in the softened water series were 68 and 78 per cent of normal, respectively. These percentages ate based on averages computed from the dry weights given in Table III.

Analysis of soil samples indicated that the relation of certain soil constituents to each other and to the soil complex as a whole was responsible for variations in plant growth in the four water source groups. It seems necessary to discuss these relationships in order that the results obtained in this study may be better understood.

Spurway (26) showed the effect of certain soluble salts on the solubility of phosphate and (27) gave a practical method of soil analysis. Scofield (25) stated that high alkali content of soils is injurious due to its effect in lowering soil permeability as well as to the toxicity of high ion concentration in the plant. Breazeale (5) found that the presence of sodium in carbonate form inhibited the normal absorption of potassium and phosphates by the plant. In a later paper (6) he stated that the observed toxicity of black alkali soils is not due to direct toxicity of sodium salts but rather to the indirect effect of sodium in dispersing the soil to such an extent that the proper intake of water is prevented. Harris (14) observed that soil permeability decreases in proportion to its sodium content. Zobell and Stewart (33) found that the addition of organic matter to soils containing large amounts of sodium carbonate tended to increase plant growth and partially correct the toxic effect of the sodium.

From soil analyses (Table IV) it is apparent that several factors may be concerned in the sub-normal growth of plants watered with zeolite-softened water. The following conditions were indicated by analysis of samples from soils watered with this source, through a six months period.

Low concentration of H ions (pH 7.5 to 8.0).
High concentration of Na in the soil solution.
High concentration of K in the soil solution.
Low permeability of the soil, a physical condition attributed to the dispersion effect of Na and K.

Since the pH values of the soil samples are within the general range of the plants involved (32) it is not probable that such concentrations of H ions would prove markedly toxic to the plants. The absence of chlorides in the samples shows that the sodium present is apparently in the form of carbonates or bicarbonates, which are not highly toxic (6). Therefore, we may assume that apparent toxicity due to this water source is the result of indirect action of Na on the solubility of K and the combined effect of high concentrations of Na and K on the physical condition of the soil. The factors of high pH and high concentrations of Na may, however, have considerable effect in combination with the other factors involved. It may be noted in support of the foregoing statements that plants in the softened water series displayed symptoms of poor aeration such as weak root development (8) foliage changes, and leaf drop (15) and that soil solutions from samples in this series were extremely dark.

From the pH values of the water sources as given in Table I, it is clearly demonstrated that water from streams may be as alkaline as well water and that softening of well water by the zeolite process increases its alkalinity. The final pH values of the soils watered with water from different sources were closely related to the pH values of the waters applied and varied only slightly from them. Since the growth of plants in soil has some effect on its ultimate pH value (30) it is possible that some variation is due to the plant materials used.

Distilled water produced better growth in Coleus and

Hedera helix plants and appeared to give slightly better results in general than tap water or river water (Table V). Although river water proved best in the case of Antirrhinum and Begonia plants, it was not noticeably superior to tap water, except in the case of the Begonia group, which was grown in soil B. Since soil B was relatively low in organic matter, this effect may have been produced by the increase in available nutrients through addition of nitrates and other soluble salts dissolved in the river water. The amount of nitrate nitrogen brought in by this water source was variable but always appreciable (Table IA).

The results obtained from growing plants in wax-impregnated non-porous pots were generally unsatisfactory when compared with other pot treatments (Table III). With one exception, growth was inferior and plants grown in pots of this type displayed symptoms generally associated with poor aeration (8), (15). Weak root systems and abnormal foliage colors were found in this series, particularly among the Begonias. With new pots, untreated, taken as a standard for comparison of the pot treatments, it was found that the growth of Begonias in wax-impregnated pots was 41 per cent of normal while that of Coleus and Antirrhinum was 61 and 72 per cent of normal, respectively. Hedera helix was least affected by this pot treatment, its growth being 94 per cent of normal. These percentages are computed from averages based on the dry weights given in Table III.

Jones (18,21) stated that air can not pass through the moist wall of a porous clay pot. The results obtained in this study seem to point to better aeration of plants in porous than in paraffin-impregnated pots. The studies of Jones, mentioned above, indicate that plant roots are not aerated through the walls of porous clay pots. Taking this into consideration, the superior growth of plants in porous pots may be explained by the following hypothesis: That the lateral and downward movement of water in a porous pot, produced by the strong attraction for water exerted by the pot wall and the pull of evaporation from the outer surface of that wall, creates a system of forced aeration through the soil surface which can not be set up in a non-porous pot.

The comparison of used and new pots in all cases where soil A was used as the potting medium shows that there is no apparent advantage of any one of the four porous pot series over another. Where soil B was used as a potting medium the two used pot treatments, D and E, have a definite advantage over the new pot treatments, B and C. This advantage is probably due to the fact that soil B had less available nitrate nitrogen and a physiological condition such as noted by Knott and Jeffries (22) may have been brought about. That is, there may have been partial nitrate starvation in the plants grown in new pots due to absorption of nitrates by the pot wall. This absorption is apparently less pronounced in used pots. In the Begonia group, soil from pot treatment A, water source

I, gave a high test for nitrate nitrogen whereas all other pot treatments in that group gave extremely low nitrate tests. This may have been due to the fact that such pots are not porous and, therefore, no nitrates could be absorbed into their pot walls. The soaking of new pots and the washing and sterilizing of used pots has no apparent value. Plants growing in these pots often made poorer growth than those in untreated pots of the same group.

Since the number of plants involved in each experimental set was small, the results obtained in this study should be corrorborated by further studies on a wider range of greenhouse crops. The growth relationships observed point to certain conclusions which appear logical, but should be confirmed by further investigations.

Summary and Conclusion

Data collected in this study points to the following conclusions.

1. The use of well water softened by the zeolite process is deleterious to plant growth and the observed toxicity of this water source is probably the resultant of several factors caused, directly or indirectly, by the substitution of sodium for calcium and magnesium.

2. Plants vary in their response to such toxicity and the more succulent plants are apparently most susceptible to

injury from zeolite softened water.

3. The substitution of river for well water may not reduce alkalinity or prove in any way advantageous to greenhouse crops, except when dealing with soil low in nitrate nitrogen.

4. The use of non-porous clay pots (as exemplified by paraffin impregnated clay pots) may be disadvantageous to the growth of plants in a typical greenhouse environment.

5. Plants grown in used pots are not superior to those grown in new pots unless the nitrate nitrogen content of the potting soil used is low.

6. Plant growth in new pots is not appreciably affected by pre-soaking of the pots and washing and sterilizing of used pots has no apparent value.

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