THE EFFECT OF THE TYPE OF WATER ON ZEA MAYS PROTOPLASM

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Introduction.

Within recent years, the use of water and soil cultures is increasing in studying many problems of plant physiology. Some workers advocate the need of distilled water (5) as a media for preparing nutrient solutions; while others (8), (9) think, that distilled water is toxic to higher plants and hence, it should be treated for physiological purity (9). Malhotra (10) has recently reviewed this subject.

In physiological literature the effect of other types of water has also appeared. Some conclusions drawn from these researches do not seem to agree with one another. It was, therefore, proposed to study the effect of various types of water on corn seedlings. It is hoped that, this study may yield some information to be utilized in preparing water or soil cultures.

Review of Literature.

Consouloff (1) germinated rice seeds in water distilled from a metal still as well as from glass apparatus. On comparing seedlings grown in these waters, he found, that the former positively stimulated them, while the latter showed adverse effects. Such oligodynamic activities of metallic ions on bacteria and lower fungi are already well known. If the stimulating effect of water distilled by metal still is due to ions, such an optimum must be very low, since it has been shown by many workers that copper and zinc even over 1.5 parts per million are toxic to plants.

Consouloff (3) studied the action of distilled and tap water. He found, that rice seedlings grown in distilled water were 12 per cent longer, while those grown in tap water did not grow well. He seems to think, that traces of metal dissolved from the still may be stimulative to higher plants. On the other hand, tap water may dissolve so much metal from the pipes, that it may be toxic to plants.

Consouloff (2) experimented with spring water also. He germinated rice in water taken from Vitosh mountain before enter-

ing and after passing through the Sofia water supply. He found a decreased growth for seedlings in the second case, due to the presence of metallic salts above their optimum, set by this author. His work seems to show that, an ordinary distilled water is better than any other type of water used in his experiments. Yet Livingston (9) and others seem to think, that distilled water is toxic to plants. Consouloff assumes length as a criteria of growth. Yet it is commonly accepted fact in growth studies, that dry weight is more reliable than length as reviewed by Van De Sande-Bakhuyzen and Alsberg (15).

River water contains a great deal of organic matter, which has a stimulating influence on plant growth. However, due to the presence of some salts as Sodium Chloride, it shows toxicity. For instance, Passerini's (12) experiments near Livorono, Italy, on the influence of Na Cl in river (irrigation) water are interesting. He found, that common cultivated plants should not be irrigated with water containing more than 1 p.p.m. of Cl. If Cl or other toxic salts are low, river water has a decided stimulating effect on plant growth.

Shibusawa, Motoji and Kita Shibata (13) have studied the effect of electric discharges on the rate of plant growth. They found, that water with high tension A.C. (50 cycles and 21,000 volts) several kinds of plants have shown accelerated growth, while with high frequency voltage (130,000 cycles and 13,000 volts) results were not uniform. In a recent experiment, they found yield of electrified buckwheat 12.6 per cent higher than that of the control.

There are many electro-culture experiments, which have given no consistent results. Some workers (7) have reported a considerable increase in crop production, while workers (11), (14) find no such effects. Marx (11) reports, that in none of his experiments did the current increase the rate of assimilation. He thinks that the effect of electric current of small densities of $1.15\text{-}6 \times 10^{-7}$ m per Cm^2 as passed through water has either negligible or depressing effect on Elodea Canadensis. Tamm's (14) extensive researches on the influence of electric currents through soil, seem to indicate that they have no direct favourable effect on the germination, vigor and early growth of Pisum sativum. He found slight adverse effects, which are explainable as secondary.

It may be concluded from the literature presented above, that experiments on the influence of various types of water have not yielded any uniform and definite results. Yet water being

the most important factor for germination, growth and life of a plant (6), more information in that respect is indispensable.

Material and Methods.

Two hundred uniform yellow corn seeds were selected from a single ear. Twenty of these seeds were germinated in each petri dish in such a way, that water could be renewed each day without disturbing the contents of these dishes following the method of Malhotra (10). A dish was allowed for one kind of water.

River water was obtained from the middle of the Kansas River as a representative sample. Spring water was obtained from a spring near the city of Saint Mary's. At no time was spring or river water allowed to touch any metal. Distilled and tap waters were secured from the laboratory metal still and St. Mary's College water supply respectively. In the last two kinds, the electric currents from dry cell battries were passed at 1½ to 2 volts for half an hour. All these waters were renewed once a day.

Six battery jars were cleaned, filled with each kind of water, covered with cheese cloth and labelled. As soon as germinating seeds showed root shoots (third day) they were transferred to their respective jars, which were kept in the laboratory light and temperature conditions for 10 days more. Plate A. shows battery jars and seedlings at the end of this period. Water was removed by means of a siphon without disturbing the seedlings.

Shoots were measured every day. At the end of the tenth day, both the shoots and the roots were first measured, then cut from the remaining seeds, dried in an oven, cooled in a desiccator for 12 hours and weighed up to four decimal places until a constant weight was obtained. The data was analyzed according to Fisher's (4) statistical methods.

Presentation of Data and Discussion.

A. *Effect of distilled water*:—Data presented in Table I, columns III–VI. show the growth made by an average root and shoot. Both roots and shoots made the least growth so far as length is concerned, with the exception of an electrified distilled water. The weight of the shoots, however, was greater with the exception of shoots grown in the river water. Roots did not show this behavior. Collectively root and shoot made better growth so far as weight is concerned with the exception of the seedlings grown in river and electrified tap water. In general appearance, plants were healthy, although on the eighth day, some spots were noticed on the shoots.

Table I. Data Showing the Length and Dry Weight of Corn Shoots and Roots Grown in Various Types of Water.

Serial No.	Kind of Water	Length in mm. of a		Dry Weight in grs. of a			Remarks
		Shoot	Root	Shoot	Root	Root and Shoot	
I	II	III	IV	V	VI		VII
1.	River ...	308 ± 13	203 ± 10	0.0469	0.0209	0.0678	Seedlings showed healthy growth.
2.	Spring ...	212 ± 16	180 ± 13	0.0391	0.0141	0.0532	Seedlings were healthy.
3.	Electrified Distilled ...	8 ± 2	6 ± 2	0.0114	0.0051	0.0165	Most seedlings died on 7th day.
4.	Distilled ...	78 ± 6	115 ± 19	0.0420	0.0136	0.0556	Shoots showed some spots.
5.	Tap ...	132 ± 9	137 ± 11	0.0149	0.0264	0.0413	Roots made the best development.
6.	Electrified Tap	226 ± 21	142 ± 16	0.0415	0.0211	0.0626	

B. *Effect of electrified distilled water:*—Seedlings seem to show the least amount of growth both as to their length and weight. This holds true for shoots as well as for roots. On the fourth day, plants began to lose their turgidity and finally died on the seventh day. It seems, that even a small electric current when passed through distilled water shows adverse effect on the

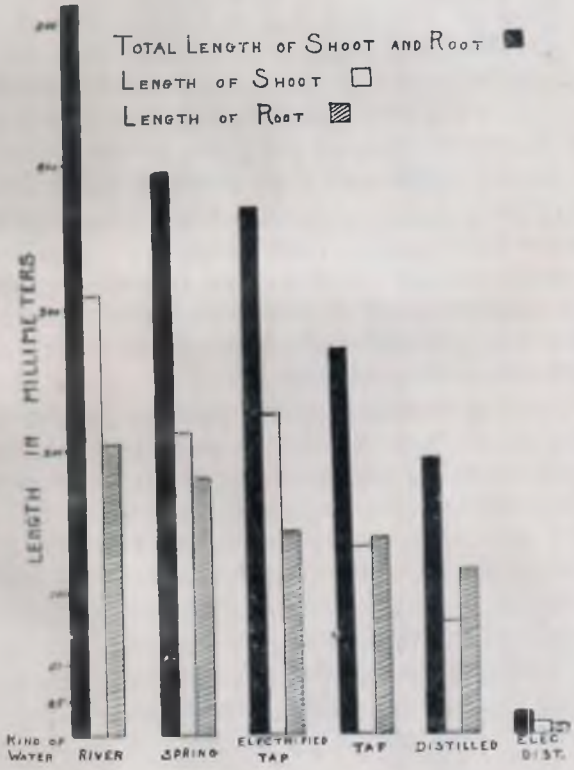

CHART NO. I

The effect of different kinds of water on root, shoot and total length of Corn Seedlings.

seedlings. It is interesting, on the other hand, to note that similar currents when passed through tap water, accelerated growth. Distilled water has comparatively less ionization than tap water. Electric current someway brings about such movement of ions in tap water, that either their permeability is effected or plants derive direct stimulation of some sort from the medium.

C. *Effect of tap water:*—Seedlings made a better growth than ordinary as well as electrified distilled water, so far as length of the roots and shoots is concerned. The weight of shoots was less than distilled water, although the weight of root was greatest of all. It seems as if tap water stimulates more root than shoot development at least in corn used in this study. The total weight, however, was less than the seedlings grown in any type of water (except electrified distilled water).

D. *Effect of electrified tap water:*—It showed stimulating effect on the length and weight of seedlings (both roots and shoots). With the exception of river water, the seedlings showed the maximum growth in this medium. It is interesting to note the adverse effect of electric currents on the plants grown in distilled water and favourable influence on those grown in tap water.

E. *Effect of spring water:*—As to the length, both roots and shoots made better growth, except electrified tap and river water. As to weight, besides the above two classes of water, seedlings grown in distilled water were also somewhat higher. However, the difference falls within the range of an experimental error. Seedlings were healthy looking.

F. *Effect of river water:*—The shoots and the roots made the maximum growth both in length and weight. This may in part be contributed to the organic matter present, besides minerals in this type of water. The chlorophyll development was also maximum and leaves were longer and wider. Plate No. 2 illustrates growth of seedlings grown in all types of water.

It may also be noted that results on the leaves of length and dry weight appear to show similar tendency, although they do not indicate the same quantitative relationship. Seedlings grown in tap and distilled water, seem to be exceptional in this respect. Chart No. 1 shows the length of seedlings at the end of the experiment.

Summary.

The effect of various kinds of water was studied during early growth of yellow corn seedlings. The data seems to indicate that the total length of the seedlings may be arranged from the maximum to the minimum in the following order: River water, spring water, electrified tap water, tap water, distilled water and electrified distilled water. On the basis of the total dry weight, seedlings grown in various waters show the same qualitative relationship, except that distilled water made more growth than tap water.

Length and dry weight of shoots and roots have also been presented. Some responses as caused by the type of water on shoots and roots have been noted.

The writer takes this opportunity to appreciate Mr. George Dernbach, St. Mary's College, for his co-operation in taking some measurements.

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Plate A.

A. Photograph of battery jars with Corn Seedlings grown in different waters. Reading from left to right: Electrolytic Distilled Water, Electrolytic Tap Water, Tap Water, River Water, Distilled Water and Spring Water.

Plate B.

B. Corn shoots and roots at the end of the tenth day's growth. Note the relative sizes. Reading from left to right: River Water, Spring Water, Distilled Water, Electrified Tap Water, Tap Water and Electrolytic Distilled Water.