TEA AND SOIL ACIDITY.

Water Culture Experiments, II.

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The standard solution used for the water culture experiments described in the previous article (Tea Quarterly, Vol. 1, pp. 2-6) was made according to the following formula:—

Calcium nitrate	1·00 gm.
Potassium chloride	0·25 gm.
Magnesium sulphate	0·25 gm.
Potassium hydrogen phosphate	0·25 gm.
Ferric chloride	Trace
Water	1,000 c.c.

When freshly made this solution has a pH value of 5·1 (approx). The amounts (in c.c.) of N/10 sulphuric acid and N/10 sodium hydrate required to alter the pH of 1 litre of solution to any desired value are shown graphically in Fig. 1. It is apparent from this graph

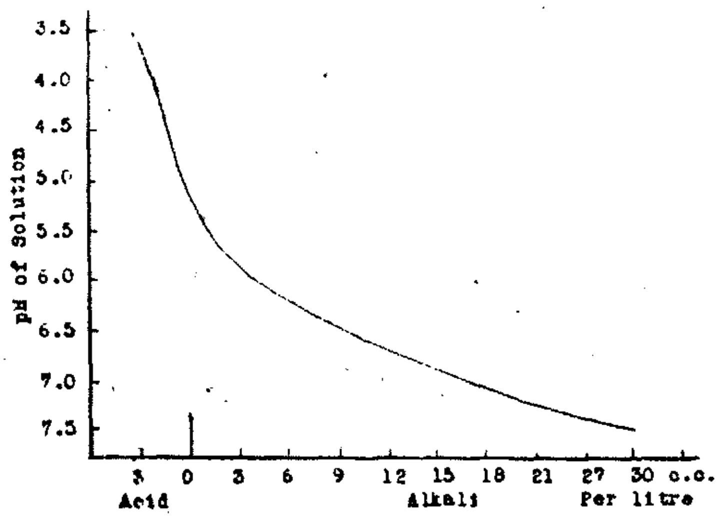

Fig. 1.—Titration curve of a standard water culture solution.

that equal quantities of alkali or acid do not bring about equal changes in the pH value of the solution. For example, about 3 c.c. of the alkali will change the reaction of a litre of this solution from pH 3·5 to pH 4·5, whereas 9 and 20 c.c. are required to change the pH value from 5·5 to 6·5 and 6·5 to 7·5 respectively. This is due to what is known as the " buffer action " of the solution. By buffer action is meant the resistance exhibited by a solution to change in pH through the addition or loss of acid or alkali; the substances which cause such resistance are termed " buffers." In this case, the buffer action is due, at least in part, to the presence of potassium phosphate in the solution.

When sufficient alkali is added to the standard solution to raise the pH value to 7·5, a white precipitate is formed. The precipitate begins to form when the pH of the solution reaches 7·0 approx., and it increases in volume as the pH value rises, up to pH 7·5. When acid is added to the solution containing the precipitate the latter disappears when the pH value again reaches 7·0. The solution, therefore, contains substances which are soluble when the pH value is less than 7·0 and which become insoluble when the solution becomes alkaline.

It will be evident that the tea seedlings grown in the culture solution at pH 7·5 had less available food material than had the plants grown in more acid solutions, because part of the food supplies was rendered insoluble by the alkalinity of the solution. This fact, however, cannot vitiate the conclusions drawn from the experiment, because the results obtained when the seedlings were grown in the solution at pH 7·5 were not materially different from those obtained when the seedlings were grown at pH 6·5. In the latter solution the whole of the nutrient substances were available to the plants, in so far as they were in complete solution.

The deposition of a part of the nutrient substances (phosphates) from this culture solution as a result of an alteration of its hydrogen-ion concentration illustrates what is known to occur in the soil, and offers some explanation why plant growth is to some extent dependent upon soil acidity. It is well known that the ordinary methods of estimation show low values for " available phosphate " in soils rich in lime. Conversely, the action of an acid soil is to increase the available phosphate.

Soil reaction regulates the solubility of iron salts as well as of the phosphates. When certain plants are cultivated on calcareous soils they become chlorotic as a rule; the leaves assume a yellowish colour owing to defective development of chlorophyll. The reason for this has been found to be a lack of available iron, and chlorotic individuals have been cured by repeated doses of solutions of ferric salts. The chlorosis exhibited by the tea seedlings grown in the solutions approximating neutrality may, at least in part, be due to this cause.

During the course of the experiments, frequent corrections had to be made to all solutions, because changes occurred in their pH value as a result of the activities of the growing plants. The acid solutions tended to become more alkaline, while the solutions at pH 6·5 and 7·5 became more acid, until a pH value of 6·1 approx. was reached, when no further alteration occurred. In order to maintain the culture solutions at a constant pH value, they were tested at intervals of 3 or 4 days and corrected to their proper value by the addition of requisite amounts of alkali or acid.

In order to trace the movement of the pH value of the solution when tea seedlings were grown in it, a growing seedling was placed in a solution at pH 3·5 and another in a solution having a pH value of 7·5. In these cases the pH values of the solutions were tested at frequent intervals, but no acid or alkali was added to bring the pH values back to the starting points. When the solutions were changed, the new solutions were adjusted to the pH values at which the old solutions reacted when the change was made. The results of this experiment are shown graphically in Fig. 2.

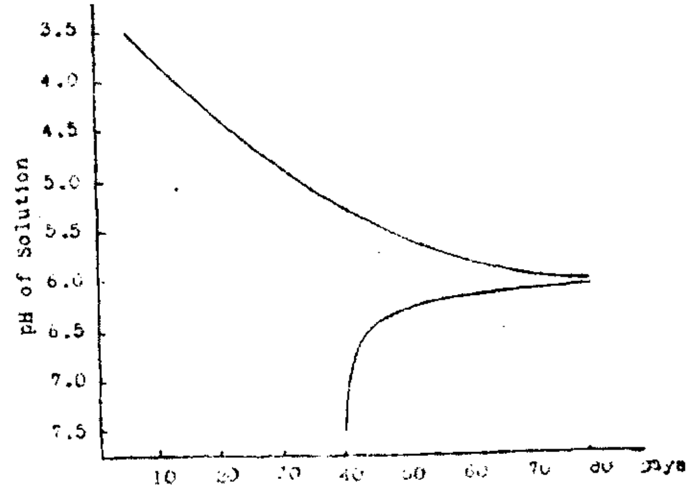

Fig. 2.—Graphs showing pH values of a culture solution in contact with living tea roots, when plotted against time.

It will be understood that Fig. 2 also represents the changes which were occurring in the culture solutions of the main experiment, except that the alterations were corrected at frequent intervals. It will be noticed that the solution at pH 7·5 altered very rapidly to 6·5 and therefore required more frequent attention than the others. The solutions at pH 5·5 and 6·5 became less and more acid respectively, until a pH value of 6·1 (approx.) was reached, while the more acid solutions gradually became less acid.

In the past, it has been incorrectly assumed that the pH value of the solution is altered to a value which meets the plant's requirements. It was apparent from the results of this experiment that 6·1 was *not* a pH value favourable for normal healthy growth of tea seedlings, and this value had nothing to do with the optimum requirements of tea.

It was suspected that the liberation of carbon dioxide by the roots was partly responsible for the alteration of the acidity of the solution. In order to test this hypothesis, carbon dioxide was bubbled through the culture solution after adjustment to pH 7·5. The precipitate present in this solution gradually dissolved, and the solution became clear, indicating that the solution was becoming more acid. The lowest pH value obtained as a result of bubbling carbon dioxide through this solution was 5·2, and the solution remained at this value after standing in an open vessel for 24 hours. When, however, the solution was boiled in order to drive off the carbon dioxide from the solution the pH value increased to 6·0.

When carbon dioxide was bubbled through an acid culture solution (pH 3·8), no alteration occurred, even when the operation was continued for several hours.

It was evident, therefore, that although carbon dioxide had no effect on the pH value of the acid solution, it had a marked effect on the alkaline one. The rapid alteration of the pH value of the 7·5 culture solution, when tea seedlings were grown in it, was due primarily to the liberation of carbon dioxide from the roots. This experiment also suggests that the point of equilibrium (pH 6·1 approx.) reached in the experiments with growing plants is controlled by the carbon dioxide excreted by the roots, and not by the plant's requirements. The presence of carbon dioxide in the solution prevents the pH value from rising above 6·1.

Another culture solution was prepared, the formula of which was identical with that used in the above experiments, except that the calcium nitrate was replaced by an equal amount of ammonium nitrate. A third nutrient medium was made by adding 0·25 gms. of ammonium chloride per litre to the one containing ammonium nitrate. Both solutions had a pH value of 5·2. When tea seedlings were grown in these solutions, the solutions became more acid. This effect was directly opposite to that which occurred in the solution containing calcium nitrate. After one month, the solution containing ammonium nitrate had a pH value of 4·7, while the one containing ammonium chloride had reached a value of 3·7. After 2 months, the pH values were 3·6 and 3·3 respectively.

The change in reaction of a nutrient medium in contact with the roots of a living plant is dependent more upon the composition of the solution than upon the requirements of the plant. Solutions containing ammonium nitrate and ammonium chloride are physiologically acid, i.e., they tend to develop acidity when in contact with living roots, while solutions containing calcium nitrate are physiologically alkaline. It would appear from the investigations of other workers on this point, that, in general, ammonium salts are physiologically acid, while nitrates (except ammonium nitrate) tend to develop alkalinity.

These observations indicate that unintentional alterations in reaction may occur in soil as a result of manuring. Prolonged experiments at Rothamsted and elsewhere have shown that certain manures, e.g., ammonium sulphate, tend to increase the acidity of the soil, while others tend to decrease it. In other words, the application of different manurial substances to the soil will cause changes similar to those seen to occur in culture solutions.

Coincident with the change in reaction of the culture solution, a corresponding but smaller change occurs in the acidity of the root sap. The following determinations of the acidity of the root sap of tea plants grown in culture solutions of fairly constant pH values were made at the end of the first period of the experiment.

pH of culture solution.	*pH of root sap.*
3·5	5·4
4·5	5·4
5·5	5·5
6·5	5·6
7·5	5·6—5·7

From these figures it is evident that marked differences in the pH of the solutions caused only small differences in the acidity of the root juices. This indicates that the plant possesses considerable power to regulate internal acidity. The importance to the plant of a constant hydrogen-ion concentration is not clearly understood, but it is probable that it is very necessary for the proper performance of the synthetic processes which take place within the plant. A marked alteration of the acidity of the plant juices is likely to affect adversely many of the vital processes essential to healthy growth.

The necessity for a suitable degree of acidity (hydrogen-ion concentration) of the medium surrounding the roots of a tea plant is demonstrated by these experiments. The pathological symptoms induced by an unsuitable reaction may be explained partly by the effect of the reaction on the solubility (and consequently their availability to the plant) of various nutrient substances, and partly by its direct effect upon the internal juices of the plant.